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An Analysis of Tax Forecasting Errors in Ireland

Andrew Hannon, Eimear Leahy and Róisín
O'Sullivan*

* The authors are: Research Assistant, Irish Fiscal Advisory Council (IFAC); former Economist, IFAC; and Council member, IFAC and Associate Professor of Economics, Smith College, Massachusetts, respectively. The authors can be contacted at Andrew.Hannon@fiscalcouncil.ie. We would like to acknowledge helpful comments from Keith Walsh (Revenue Commissioners) and Niall Feerick (Department of Finance) as well as from members of the Council and Secretariat of IFAC. Any remaining errors are the authors'.

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ABSTRACT

This paper examines the tax revenue forecasting performance of the Department of Finance over the period 1997-2014. While the general forecasting framework used reflects standard international practice, forecasting errors are relatively large by international standards. In almost all cases, we find no evidence of bias in the forecasts when considering the major tax heads over various forecast horizons. Moreover, an innovative exercise examining the routine use of judgement by the Department to adjust the outcome of forecasting equations indicates that this judgement has not been used to systematically bias the forecasts in a particular direction and it often reduced the forecast error. A decomposition of the forecast errors reveals substantial contributions from sources other than errors in forecasting the macroeconomic environment or in estimating the previous year's revenue outturn. This suggests that a formal review of specific procedures and assumptions by the Department could yield further improvements in forecasting performance.

SECTION 1: INTRODUCTION

The central role played by numerical targets in meeting fiscal rules has underscored the importance of high quality forecasts of government revenue and expenditure streams. This is particularly key in the case of tax forecasts, as taxes are usually the main source of government revenue, accounting for around seventy percent of General Government revenue in Ireland over the past decade.

Forecasting tax revenues relatively accurately is a difficult task, however, encompassing predictions about macroeconomic growth¹ and about the responsiveness of the economy to any tax policy changes, among other factors. Moreover, Government commitments to meet certain targets for deficit measures may create incentives to produce *ex ante* revenue forecasts that are either overly optimistic (to create room for additional spending) or deliberately prudent (to ensure targets are met or exceeded).² In Ireland, the Department of Finance is responsible for forecasting tax revenues twice a year: in the Stability Programme; and in the budget.³ When judging the quality of these official forecasts, both the size and the direction of forecast errors are of interest to assess accuracy and un-biasedness.

Some previous work that looked at Irish revenue forecasts in an international context found that the Irish official forecasting performance was on the weaker end of the spectrum. For example, IMF (2005) assessed total revenue forecasting accuracy in Ireland as relatively weak when compared to a group of 11 other countries.⁴ That study attributed a dominant role to macroeconomic forecasting errors while also noting evidence of prudence in revenue forecasts. Buettner and Kauder (2010) found that the accuracy of Irish revenue forecasts ranked tenth among 12 OECD countries examined (Figure 1.1).⁵ They also highlighted the potentially important contribution of macroeconomic forecasting errors and noted that Irish GDP Root Mean Square Errors (RMSEs) were by far the largest in the sample (2.5 compared with an average of 1.4 for the 12 countries.) In a recent study of the European Commission's revenue forecasts, Afonso and Carvalho (2013) reported that the accuracy of the EC's total revenue forecasts scaled by GDP for Ireland ranked 11th of the EU-15, with an absolute

¹ The EC (2012) analysed growth forecast errors in the European Union and found that macroeconomic forecast errors were highest in small economies such as Ireland and Luxembourg in which growth is volatile and GDP forecasts are heavily reliant on external assumptions.

² Frankel and Schreger (2012) finds the optimism bias in forecasts for the European countries used in their sample was greater than for others and questions whether this finding is despite or because of those countries being subject to the SGP. (p. 2).

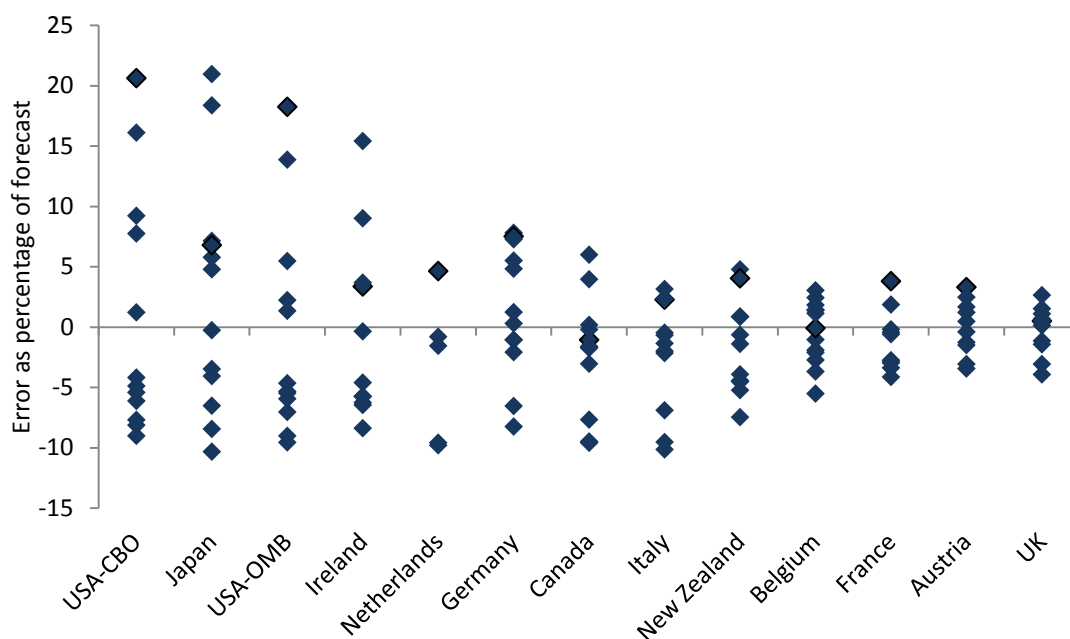
³ Monthly tax revenue profiles for each tax head are also published by the Department of Finance and are usually made available in February each year. The Department of Finance is also dependent on inputs from other agencies, the Revenue Commissioners in particular.

⁴ Other countries included in this analysis were the US, Germany, UK, France, Italy, Canada, Australia, New Zealand, Netherlands, Sweden, and Switzerland. Ireland was placed 10th out of 12 in terms of the root mean square error of its fiscal balance (1991-2003), with revenues accounting for most of the deviation.

⁵ Eight of the eleven countries included with Ireland in the IMF study were also part of Buettner and Kauder's work. The additional three countries in Buettner and Kauder (2010) were Japan, Austria and Belgium that replaced Australia, Sweden and Switzerland. Measures of accuracy included standard deviation of the forecast errors and root mean squared forecast errors. Data for Ireland spanned 1998-2008.

mean error across 3 years of 0.532 for Ireland compared with 0.142 for the EU-15.⁶ As these results compared forecasts across countries that were made by the same institution, the relatively poor performance for Ireland indicates that forecasting Irish revenues may be particularly challenging. In addition to difficulties in forecasting the macroeconomic drivers of the revenue, other factors, such as a small number of dominant firms contributing to corporation taxes, may complicate the task. This underscores the importance of assessing the forecasting methods used in addition to the forecasting accuracy when evaluating the performance of the Department of Finance.

FIGURE 1.1: FORECASTING PERFORMANCE IN AN INTERNATIONAL CONTEXT



Source: Buettner and Kauder (2010).

Note: CBO: US Congressional Budget Office. OMB: US Office of Management and Budget.

The figure displays the forecast errors for total tax revenues in percentage for up to thirteen years in each country, each point representing one forecast. A positive (negative) value denotes overestimation (underestimation). The forecasts are arranged in descending order of the standard deviation of the respective forecast errors. The two US forecasts only refer to federal taxes.

The most comprehensive study focussing exclusively on official tax forecasting errors in Ireland is the analysis of the Tax Forecasting Methodology Review Group (TFMRG) published in 2008.⁷ That study outlined the forecasting methodology used by the Department of Finance and analysed the size of forecast errors over the 1999 - 2006 period. The report found that, even when macroeconomic forecast errors were controlled for, overall forecast errors remained significant. VAT forecasts were most accurate while the largest forecast errors were observed for capital gains tax, stamp duty and

⁶ This is based on the average mean error for total revenue as a percentage of GDP for forecasts for t, t+1 and t+2 based on the ESA95 definition of total revenue for 1999-2012.

⁷ The TFMRG was given the task of reviewing tax forecasting performance and methodologies and was required to make methodological recommendations where appropriate. The working group consisted of 11 members: 5 from the Department of Finance; 2 from the Revenue Commissioners; 2 from the Economic and Social Research Institute; 1 from the Central Bank of Ireland; and 1 from the European Commission.

corporation tax. The influence of property market developments on tax revenues over that period was highlighted and recommendations were made to incorporate such developments into forecasts for VAT and stamp duty. The report also called for more regular analysis of tax forecasting performance, including analyses of one-off factors affecting tax revenue, and for the annual publication of such analyses by the Department of Finance. Since the publication of the 2008 report, some of the recommendations have been implemented but there has not been another review of that kind in the meantime.

TABLE 1.1: TFMRG RECOMMENDATIONS

Recommendation	Implemented?
Maintain aggregate tax-to-GDP elasticity of 1.0 as a "top-down" check on the "bottom-up" forecasting approach.	Yes
Complement VAT forecasting with approach which projects VAT receipts from new housing separately.	No published evidence (but reportedly used internally by the Department to inform judgement)
Forecast corporation tax using Gross Operating Surplus in conjunction with nominal GDP.	Yes
Continue using new housing output and prices to project stamp duty from residential property while using investment in building and construction for stamp duty from non-residential property.	Yes
Continue the cautious approach to forecasting property related tax revenue.	Yes
Investigate the possibility of providing a more detailed breakdown of VAT.	No published evidence
Undertake more regular analysis of the tax forecasting performance.	No major subsequent review published

Source: Report of the Tax Forecasting Methodology Review Group (2008).

This paper undertakes a comprehensive analysis of official tax forecast errors for the period 1997 – 2014. Some of the analysis builds upon material from the TFMRG report. Section 2 contains a brief description of the structure of the Irish tax system and outlines the general forecasting approach employed by the Department of Finance. The remainder of the paper evaluates the Department of Finance's tax forecasting performance over the past 18 years. Of interest is both the overall accuracy of the forecasts and whether there is any evidence of bias in the forecasting process. Section 3 looks at the size and direction of forecast errors, discussing whether forecasts are persistently optimistic or pessimistic, as well as examining the relative contributions of different tax categories to the overall

error. In Section 4, the errors for each major tax category are decomposed to determine whether they primarily arise from errors in macroeconomic forecasts or other sources. Section 5 analyses the degree to which forecasts generated by the relevant forecasting equations are subjected to discretionary upward or downward adjustments by the Department of Finance while Section 6 provides some conclusions.

SECTION 2: TAX REVENUE IN IRELAND

2.1 Structure of the Irish Tax System

Tax revenue (including direct and indirect taxes but not social security contributions) amounted to 21.8 percent of GDP (25.3 percent of GNP) in 2014. While this ratio has been slightly below the Euro Area average in recent years, Ireland relies relatively more on direct and indirect taxes than on social security contributions compared with the average in the Euro Area (European Commission, 2014).

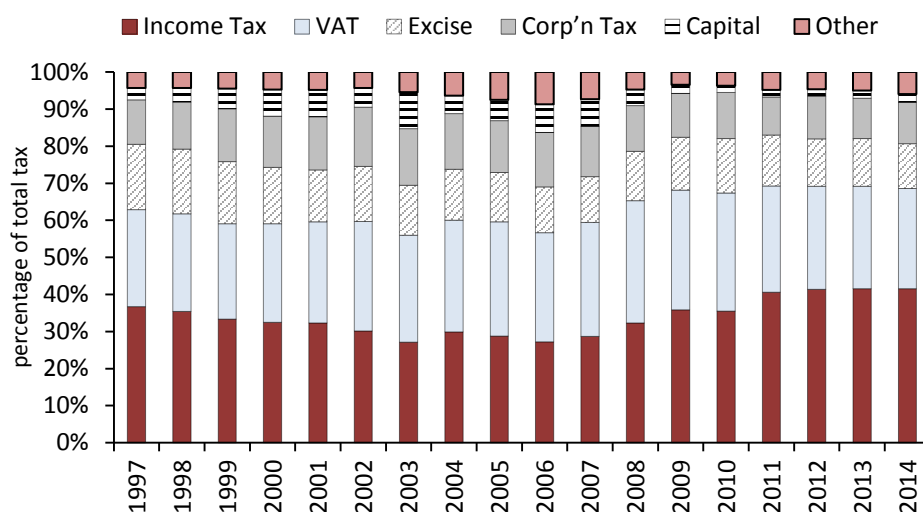
The relative contribution of the main tax heads towards overall tax revenue in Ireland between 1997 and 2014 is shown in Figure 2.1. Income tax is the largest tax head, on average accounting for about a third of all tax revenue. Despite a reduction in the number of people at work from 2008 - 2013, the contribution of income tax has risen in recent years, reaching over 40 percent in 2011 (due to changes in tax credits, standard rate bands as well as the phasing out and abolition of certain reliefs) and in subsequent years (due to the introduction of the Universal Social Charge).

VAT is the second biggest tax category, contributing 29 percent of total tax revenue on average between 1997 and 2014. Its contribution peaked at 33 percent in 2008 (and overtook income tax as the largest category) driven by very high levels of consumer spending and VAT related property transactions. Since then, its contribution has fallen and is now back below the period average.

Excise and corporation tax each account for about 14 percent of total tax revenue. Although revenue from excise increased in absolute terms, its contribution towards total tax revenue decreased during the boom period. The contribution of corporation tax peaked at 16.4 percent in 2002 (and peaked in absolute terms at €6.7 billion in 2006). Its contribution towards total tax revenue has decreased in recent years.

The remaining two categories are capital taxes, comprising capital gains tax and capital acquisitions tax (5 percent of total) and “other”, which includes stamp duties and customs duties (5 percent of total). Revenue from both of these categories increased steadily during the “celtic tiger” era, with the contributions of capital and other taxes reaching 8 and 9 percent of total tax revenue respectively in 2006. With the collapse in the property market, revenue from these categories has fallen sharply in recent years. This is especially true for capital taxes which have accounted for just 2 percent of revenue since 2009.

FIGURE 2.1: STRUCTURE OF TAX REVENUE



Sources: Department of Finance and internal calculations.

Note: Income tax includes the Universal Social Charge (USC) from 2012 onward. Other includes Local Property Tax (LPT) from 2013 on.

2.2 Department of Finance Tax Forecasting Methodology

The forecasting procedure employed by the Department of Finance is described in the 2008 TFMRG report and can be summarised using the following equation:

$$Rev_{t+1} = (Rev_t - T_t)(1 + (B_{t+1}^G E)) + T_{t+1} + M_{t+1} + J_{t+1} \quad (1)$$

where Rev_{t+1} is the one year ahead forecast for a particular tax head, Rev_t is an estimate of the yield for that tax head in the current year, i.e. the year in which the forecast is made, T_t are one-off (temporary) items affecting the yield in the current year, B_{t+1}^G is the projected growth rate in the appropriate macroeconomic driver (i.e. the main economic variable that drives receipts) for a particular tax for the year ahead, E is the elasticity measuring the responsiveness of tax revenue to the tax base, T_{t+1} are one-off items affecting the yield in the coming year, M_{t+1} is the estimated static yield from any changes in policy affecting receipts for a particular tax in the coming year and J_{t+1} is a judgement factor applied by the Department of Finance. The relevant macro driver for each tax head is shown in Table 1.1.⁸

⁸ Table 2.1 excludes DIRT, self-assessed income tax, USC and local property tax.

TABLE 2.1: MACRO DRIVER BY TAX HEAD

Tax Head	Macro driver
VAT	Nominal personal consumption adjusted for tourist spending.
Corporation Tax	Nominal GDP until 2008, since then Gross Operating Surplus.
Excise Duties excl Vehicle Registration Tax (VRT)	Adjusted personal consumption excluding cars.
VRT	Projected change in the price of new cars and the volume of new car sales.
PAYE ⁹	Non-agricultural employment and non-agricultural wages.
Capital Gains Tax	Nominal GNP.
Capital Acquisitions Tax	Nominal GNP.
Stamp Duties	Volume and price of new housing activity; Investment in non-residential construction.

The elasticity factor, E , in equation (1) measures the response of tax revenue to changes in the macro driver. An elasticity of 1 is used¹⁰ except in the case of PAYE, which uses time specific earnings and employment elasticities. Most recently, the Department of Finance assume that the elasticity of PAYE is 2.15 with respect to growth in earnings per head and 0.9 with respect to growth in employment. The 2008 TFMRG Report stated that “over the 1996-2006 period, the implied aggregate tax-to-GDP elasticity was found to average 1.1”.¹¹ Analysis by the ESRI (published in TFMRG, 2008) suggests that the Department of Finance’s assumption of an aggregate tax elasticity of 1 is reasonable. However, the application of an aggregate elasticity to specific tax heads may not always be appropriate. It is also the case that elasticities vary over time, with aggregate annual measures sometimes deviating far from the long-run average, making this a worthy topic for further investigation.

In addition to the responsiveness of tax revenue to the macro driver captured by E , revenue forecasts also need to take account of the impact of policy changes, such as the effect of changes in tax rates on the appropriate macro driver. For example, while nominal personal consumption growth will impact VAT revenue (with E capturing this relationship) a change in the VAT rate will also affect the growth in nominal personal consumption. The tax forecasting equation does not specify this effect explicitly but captures it by taking account of the impact of tax rate changes in the forecast for the macro driver.

⁹ Pay as you earn (PAYE) is the largest component of income tax. Non-PAYE components of income tax are not considered in this paper due to data limitations.

¹⁰ The TFMRG (2008) report specifies the elasticity used in the case of each tax head.

¹¹ At the time of this study the Department of Finance confirmed that their estimate of the elasticity has not changed.

SECTION 3. SIZE AND DIRECTION OF FORECAST ERRORS

3.1 Errors by Forecast Horizon

First we measure the size and direction of forecast errors for various tax categories by comparing tax forecasts published in the annual budgets with outcomes from end-year exchequer statements. We consider forecast horizons of one, two and three years ahead over the period 1999-2014.^{12,13} For example, for 2013, tax outturns published in the end-year exchequer statement for 2013 are compared with forecasts made one year earlier in *Budget 2013* (published in December 2012), two years earlier in *Budget 2012* (published in December 2011) and three years earlier in *Budget 2011* (published in December 2010). Six tax categories are examined: income tax; VAT; excise; corporation tax; capital taxes; and “other” (defined in section 2.1).

The Mean Error (ME) shown in Figure 3.1 is calculated as the average of the yearly differences between tax outturns and the corresponding one/two/three year ahead Budget forecasts (as a percentage of the outturn):

$$ME_t = \frac{1}{T} \sum_{t=1}^T e_t \quad (2)$$

A positive error indicates that the outturn was greater than the forecast and implies that the Department of Finance underestimated the actual outturn in a particular year. Negative errors imply that the Department of Finance overestimated actual outturns. This measure is a useful indicator of the average direction of the forecast errors and can be informative about possible bias in the forecasting process.

Results show that, on average, forecasts have overestimated actual outturns with the ME being negative for each tax category considered. For each tax head, the errors increase as the forecast horizon lengthens, with the ME for overall tax revenue increasing in absolute size from -1.8 percent for one year ahead forecasts to -7.3 percent for two year ahead forecasts and to -13.1 percent for forecasts made three years ahead. However, average errors are distorted by very large overestimations in 2008 and 2009. Excluding these two years, the MEs are greatly reduced and even turn positive in some instances. For example, the MEs for total tax revenue for one, two and three year - ahead forecasts, excluding the 2008-2009 period, are 1.5, -0.3 and -5.9 percent, respectively. The largest errors have consistently been in capital taxes – the tax category that was most volatile in the boom and subsequent bust periods – with the ME reaching -73 percent for 3 year ahead forecasts.¹⁴ The very large forecast errors that occurred in the 2008-2009 period are discussed in more detail in Section 3.2.

The pattern of consistently negative average errors may give the initial impression that the forecasts are biased towards an overestimation of tax revenues, in contrast with the IMF’s (2005) view that

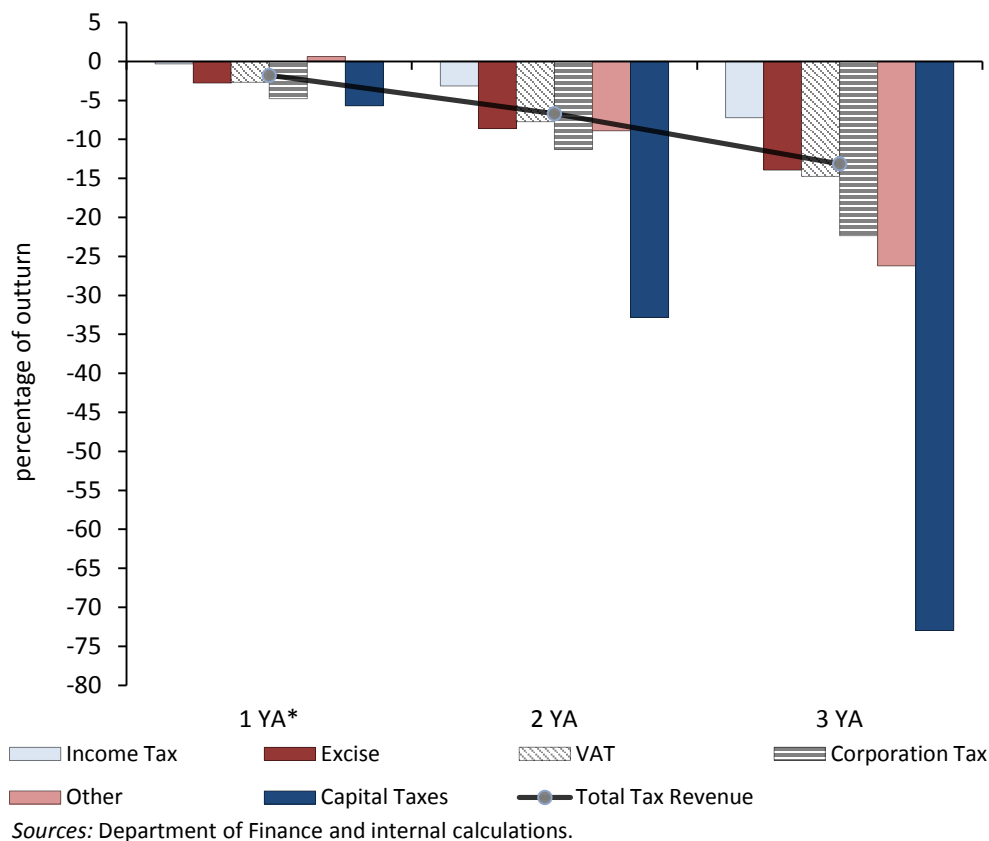
¹² We begin the analysis with forecasts published in December 1998 (Budget 1999) because forecasts beyond a one year horizon were not provided in Budget 1997 (published in December 1996) or Budget 1998 (published in December 1997). The one year ahead sample contains 16 observations, the last of which reflects forecasts made in 2013 for 2014. There are 15 and 14 observations in the two and three year ahead samples respectively.

¹³ In 2014, the Budget moved from December to October.

¹⁴ This figure is reduced to -19.4 percent when 2008 and 2009 errors are excluded.

between 1991 and 2003 “budget forecasts relied on a prudent assumption”, i.e., tended to be biased in the direction of underestimation. Upon closer examination, it appears that there are no clear signs of bias in the forecasts over the 1999-2014 period as a whole. For the 14-16 years for which forecasts across the various horizons are examined, there are close to equal numbers of positive and negative errors observed for total tax revenue. This is also evident for most of the individual tax heads.¹⁵ More formal statistical tests fail to reject the null hypothesis of unbiasedness in most cases (see Appendix D). Interestingly, looking at the direction of year-by-year errors does indicate that for many tax heads, revenues tended to be underestimated during periods of strong economic activity and overestimated when economic conditions were weak, including during the exceptional period of economic weakness in 2008-09. In subsequent sections, a closer look is taken at the pattern of errors in specific sub-periods and the role of errors in the forecasts of the relevant macroeconomic drivers for tax revenue is examined.

FIGURE 3.1: ME BY TAX HEAD AND FORECAST HORIZON (1999-2014)



*Year Ahead

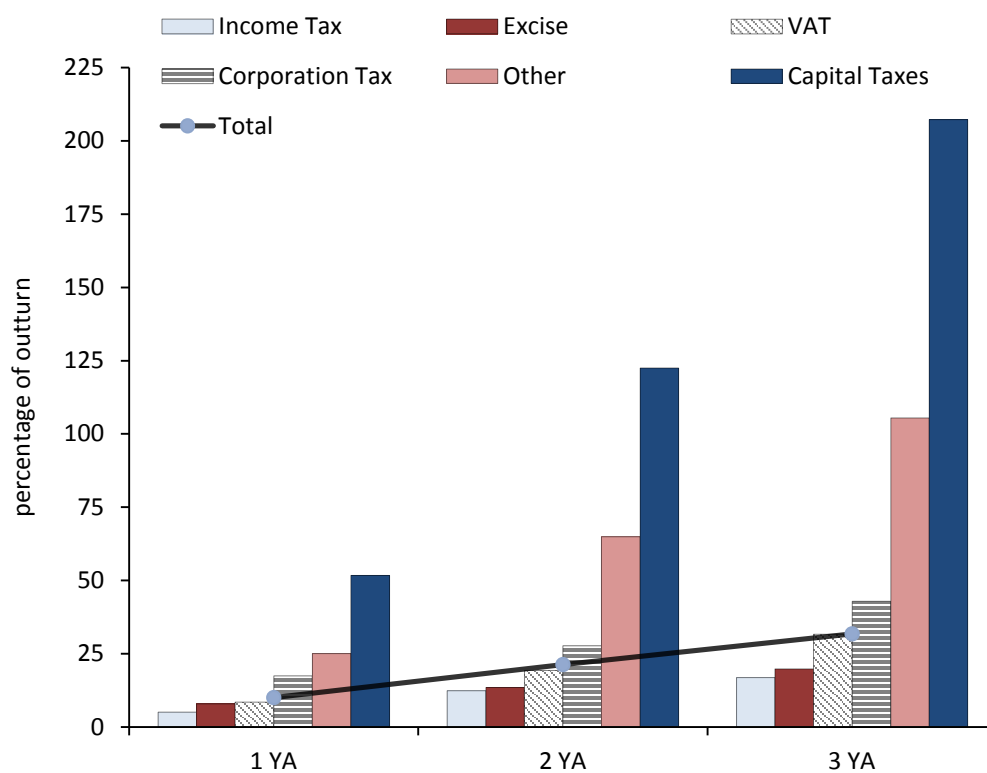
The root mean square error (RMSE) measure shown in Figure 3.2 gives a better sense of the magnitude of the errors, as it is not differentially affected by positive and negative errors. The RMSE is calculated as the square root of the mean of the errors squared, where the error is defined in the same way as for the ME:

¹⁵ There are indications that t+1 and t+2 Excise tax forecasts may be systematically overestimated.

$$RMSE_t = \left(\frac{1}{T} \sum_{t=1}^T e_t^2 \right)^{1/2} \quad (3)$$

As was the case with the ME, the RMSE increases as the forecast horizon lengthens. The RMSEs are largest across all forecast horizons for capital taxes followed by “other” and corporation tax. In the case of corporation tax, a large part of the volatility is likely the result of a few very large corporations being responsible for the majority of corporation tax receipts, meaning that idiosyncrasies relating to a small number of firms can have a significant impact on the forecast error. Excluding the 2008-2009 period makes a significant difference, about halving the RMSE for the one- and two-year ahead forecasts for total tax revenue and reducing it by about a third for forecasts made three years ahead. Income tax forecasts have consistently been the most accurate.

FIGURE 3.2: RMSE BY TAX HEAD AND FORECAST HORIZON (1999-2014)



Sources: Department of Finance and internal calculations.

3.2 One Year Ahead Errors Before, During and After the Crisis¹⁶

Focussing on one-year ahead forecasting errors, we next break the sample into three sub-periods to represent the periods before, during and after the crisis.¹⁷ Table 3.1 shows that for the period as a whole, the ME for total tax revenue was slightly negative (-0.9 percent). It is evident, however, that this average was influenced heavily by large negative errors in the 2008-2009 sub-period, as the Department of Finance (and forecasting agencies generally) failed to predict the sharp economic

¹⁶ Much of the material in this section was previously presented in a box using data to 2012 in the April 2013 *Fiscal Assessment Report* (IFAC, 2013 pp. 30-31).

¹⁷ We can use a slightly longer time period here: 1997 –2014, as only the one-year forecast horizon is examined.

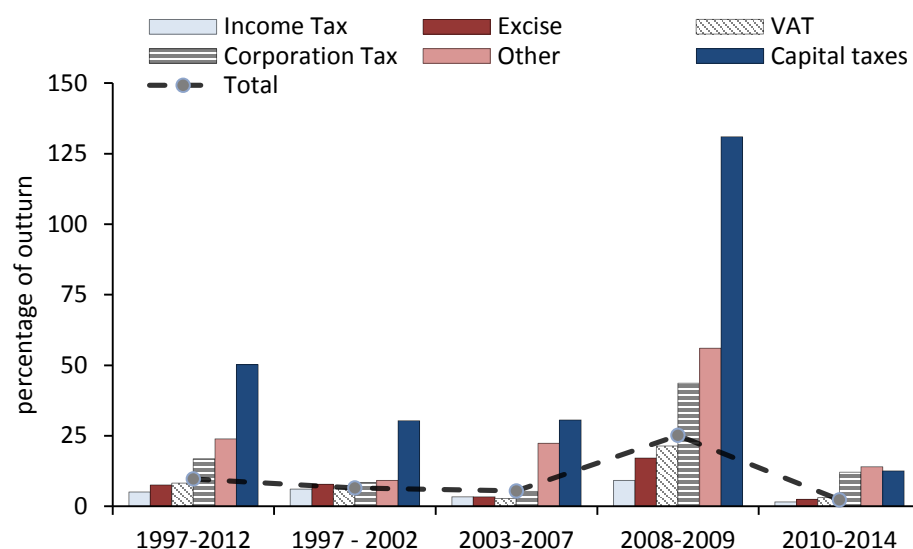
downturn. Over-predictions were mostly evident during periods of economic weakness, with errors also negative during the previous economic downturn in 2001 and 2002. In most of the remaining years in the sample, forecast errors for overall tax revenue were positive, peaking at 8.5 percent in 2006 (Figure 3.4). Similarities are evident across the individual tax heads, with large over-predictions in each of the categories in the 2008-2009 sub-period and almost exclusively negative errors for both 2001 and 2002. Differences are also apparent, however, indicating that factors other than macroeconomic conditions were at play in determining the forecast errors.

TABLE 3.1: ONE YEAR AHEAD MEAN ERRORS BY TAX HEAD

ME	1997-2014	1997-2007	2008-2009	2010-2014
Income Tax	0.2	2.3	-8.6	-0.7
Excise	-2.1	-0.9	-16.0	0.8
Capital Taxes	-1.0	21.8	-128.8	0.0
VAT	-1.7	1.2	-20.7	-0.3
Corporation Tax	-3.0	0.6	-42.4	4.8
Other	1.8	7.9	-54.9	10.9
Total	-0.9	2.7	-24.7	0.9

Figure 3.3 shows that the largest RMSEs have been consistently in capital taxes and the “other” category, with the latter including stamp duties. The major influence of property market developments on these tax categories is reflected in the large positive MEs during the boom years, as revenues from this source were underestimated, followed by even larger negative errors (overestimates) during the subsequent correction.

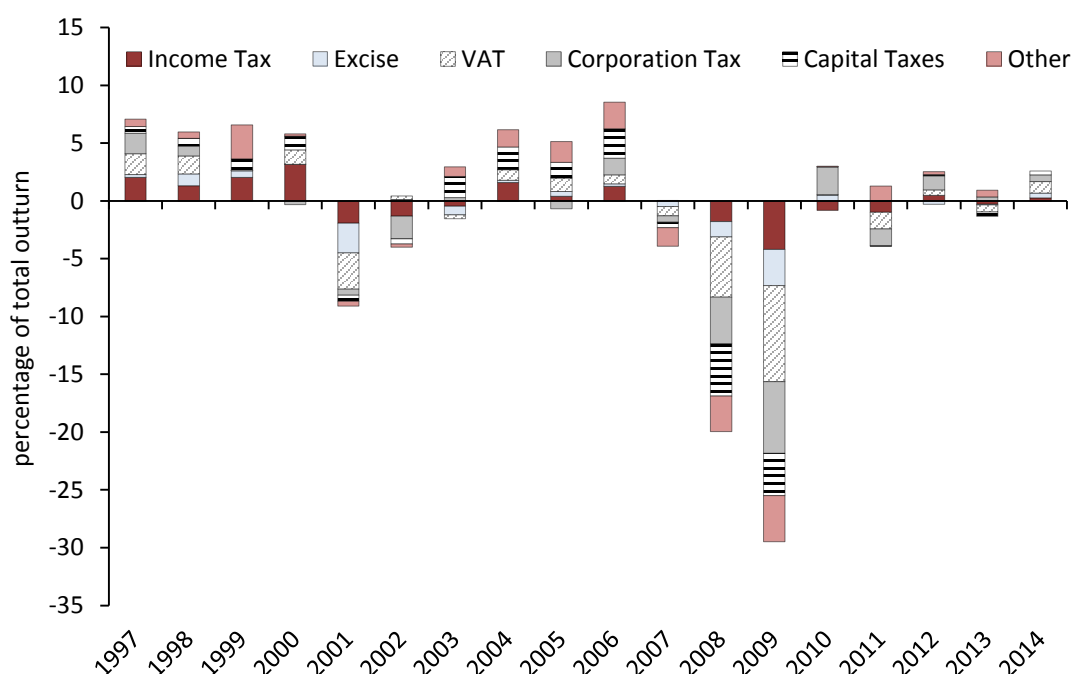
FIGURE 3.3: ONE YEAR AHEAD RMSE BY TAX HEAD



Sources: Department of Finance and internal calculations.

Figure 3.4 shows the contributions of each tax head towards overall errors. It has generally been the case that the largest tax categories have made the greatest contributions to forecasting errors over the 1997 – 2014 period. VAT accounted for the greatest proportion of the forecasting errors in both 2008 and 2009, due mainly to the unforeseen collapse in property related and consumption expenditure.¹⁸ A decomposition of the errors, presented in Section 4, suggests that effects of VAT policy changes¹⁹ and one-off items were also overestimated in these years. Corporation tax made the second largest contribution to the error during this period, as yields fell by over 20 percent in both 2008 and 2009 against the background of a broad deterioration in the international economic environment. Although capital and “other” taxes contribute only a small proportion of the total tax take, the contribution of these taxes toward the overall error became quite significant between 2003 and 2009. For example, in 2005, capital and “other” taxes contributed 13 percent to total tax revenue but accounted for over two thirds of the forecasting error.

FIGURE 3.4: CONTRIBUTION OF EACH TAX HEAD TO THE OVERALL ERROR



Sources: Department of Finance and internal calculations.

Note: Forecast error = Outturn – forecast, where forecast includes adjustment for judgement.

*2009 contained a Supplementary Budget.

¹⁸ The Department of Finance forecast that real consumption would grow by 3.8 percent and 0.5 percent in 2008 and 2009 respectively. Data from the CSO’s National Income and Expenditure Accounts 2014 shows that the actual growth rates were 0.3 percent in 2008 and -5.3 percent in 2009.

¹⁹ Changes in VAT charged on supplies in the construction sector were expected to yield €49 million in 2008. Also, the standard rate of VAT was increased from 21 to 21.5 percent in December 2008. This measure was expected to yield €227 million in a full year.

SECTION 4: ERROR DECOMPOSITION²⁰

4.1 Data and Methodology

To gain further insight into the sources of the errors, we decompose one year-ahead errors for four of the main tax heads (VAT, corporation tax, excise and the “pay as you earn” (PAYE) component of income tax). Three types of errors are identified: starting point errors, i.e. errors that are caused by using an incorrect estimate of the yield for a particular tax in the current year (Rev_t in equation 1); macro driver errors, i.e. errors that are caused by using an incorrect projected growth rate in the macro driver (B_{t+1}^G in equation 1); and other errors which are caused by using incorrect estimates of any other component of the forecast, i.e. one-off items in the current year and the next year (T_t and T_{t+1}), the static yield from any changes in policy for the coming year (M_{t+1}), the judgement factor for the coming year (J_{t+1}) and the elasticity, E , which the Department of Finance assumes is 1 for most tax heads (an exception is the PAYE component of income tax).²¹

First, the Department of Finance forecasts are replicated. This is done by collecting the data that were used at the time the forecast was made: in the case of VAT and corporation tax, data for Rev_t are taken from annual budget publications while the Department of Finance supplied these data for the PAYE component of income tax and for sub components of excise duty; data for M_{t+1} for each tax head are taken from Budget publications; information about B_{t+1}^G , T_t , T_{t+1} and E was provided to us by the Department of Finance for the years 2004 – 2014. We identify the judgement term, J_{t+1} , as the difference between the published forecast and the forecast that is generated using the information that was provided by the Department of Finance.

The forecast equations for VAT and corporation tax mirror equation (1) presented earlier. The forecast for excise duty consists of two parts: the first part involves predicting the expected yield from Vehicle Registration Tax (VRT) (in which case the macro driver is the expected increase in the demand for new cars multiplied by the expected increase in the price of new cars); the second part consists of forecasting excise duty minus VRT (in which case the macro driver is the projected growth rate in nominal personal consumption excluding cars).²² In the case of PAYE, equation (1) is adapted to include two macro drivers – the expected growth in non-agricultural wages and non-agricultural employment – each of which is multiplied by an elasticity factor. The elasticities used to forecast PAYE are estimated by the Department of Finance and can vary over time. The employment elasticity has been close to one in recent years while the earnings elasticity has been between 2.1 and 2.2. In the case of other tax heads the elasticity, E , is assumed to be one.

²⁰ Some of the results in this section for data up to 2012 have been previously presented in Analytical Note 3 as part of the June 2014 Fiscal Assessment Report.

²¹ This approach ignores possible interactions between different sources of errors. It is likely that any interaction terms would be small and this approach greatly simplifies the analysis.

²² In the case of excise, the measure of personal consumption expenditure is adjusted to include expenditure by Irish residents abroad and exclude expenditure of non- Irish residents in Ireland.

Starting point errors can be identified by estimating equation (1) using actual outturn data for Rev_t which is published in the end year exchequer statement.²³ All other values in the equation are those that were used by the Department of Finance at the time the forecast was made. By comparing the number that is generated using this equation to the budget forecast we isolate the degree to which Rev_{t+1} is inaccurate due to the use of an incorrect estimate of the tax yield in the current year – that is – at the start of the forecast period. For example, in the case of VAT, the total forecast error in 2012 was €176 million. This error falls to €166 million when the actual yield for 2011 (Rev_t) is used in place of the estimated yield. Thus, the starting point error in this case is €10 million. Similarly, we identify the macro driver error by estimating equation (1) using the correct value for B_{t+1}^G , published in the National Income and Expenditure Accounts (NIE).²⁴ The “other” forecast error is calculated as a residual, i.e. the overall forecast error for a particular tax head minus the starting point error and the macro driver error. All errors are calculated in Euros to facilitate aggregation and comparison. In the case of excise, the various types of errors are calculated for each subcomponent separately and are then combined in order to get the total excise starting point, macro driver and “other” errors.

The specific equations for each tax head are described in more detail in Appendix A. Due to data limitations, we cannot decompose the forecast errors for other components of income tax, capital taxes, customs duties or stamp duties, or for the period before 2004.

4.2 Error Decomposition Results

Figure 4.1 shows the absolute size of VAT errors as well as the source of the error between 2004 and 2014. Results show that both positive and negative errors were prevalent over the period. The error peaked in absolute terms in 2009 when the error relating to the macro driver estimate (i.e. expected levels of consumption expenditure) accounted for 70 percent of the gross error.²⁵ On average, however, the contribution of the macro driver error to the gross VAT error was lower, accounting for approximately one third of the total. The starting point errors were negative (the outturns were overestimated) in eight of the eleven years considered and accounted for the smallest proportion (around 8 percent) of the gross VAT forecasting error on average. The direction and size of the “other” error has fluctuated over time. It peaked in absolute terms in 2008, when it amounted to €1.2 billion and accounted for 59 per cent of the gross error. We cannot tell, however, the extent to which the estimated cost of these measures (which should be captured by M_{t+1}) contributed towards the “other” error. It could be the case that the majority of the “other” error was caused by the level of judgement imposed on the forecast (i.e. the J_{t+1} component) or that the effect of one-off items (T_{t+1}) was overestimated. “Other” errors accounted for almost 60 percent of VAT forecast

²³ Outturn data for PAYE, VRT and excise excluding VRT are provided by the Department of Finance.

²⁴ In the case of a forecast made for the year 2011, outturn data for B_{t+1}^G are taken from the National Income and Expenditure Accounts (2014). Outturns for non-agricultural employment, which feeds into the PAYE forecast, are taken from the Quarterly National Household Survey (Q1 2015). In the case of VRT, outturn data for new car sales and prices were provided by the CSO.

²⁵ Because positive and negative errors from different sources can cancel each other out, we convert all errors to positive values and generate a “gross” error in absolute terms. We can then identify the contribution of each source of error to the overall error.

errors on average. Since 2009, the absolute size of VAT forecast errors has generally decreased. However, in some years (e.g. 2010) it has been the case that substantial positive and negative errors from different sources have offset each other, resulting in an overall forecast error that appears small.

The total PAYE error peaked in 2009, having been overestimated by some €1.6 billion (19 percent of the outturn for that year). The macro driver accounted for 89 per cent of the gross error that year. On average, however, “other” errors made the largest contributions (49 percent) towards the gross PAYE forecasting error over the 2004-2014 period. PAYE errors are small compared to the other tax heads with the only large error coming in 2009 due to the size of the macro error. The contribution of starting point errors to the gross error has been small (11 percent on average) due to the fact that PAYE receipts do not fluctuate largely from month to month.

Corporation tax forecasts errors have also been well distributed above and below zero since 2004. Figure 4.3 shows that they peaked in 2009, with contributions from all three types of errors. The biggest contributor was the starting point error (45 percent of the gross error), reflecting, in part, the unexpected decline in company profits in 2008. In most years considered, however, the “other” errors accounted for the greatest proportion of the forecasting error (59 percent of the gross error on average) reflecting the difficulty in predicting the effects of Irish policy changes²⁶ and the external environment on already volatile levels of corporation tax revenue²⁷. Until 2008, the macro driver used for corporation tax was the predicted change in the level of nominal GDP. In an effort to improve forecasting performance following the TFMRG 2008 report, the macro driver has been Gross Operating Surplus (GOS) (i.e. GDP less taxes and compensation of employees, plus subsidies) since 2009. An analysis of the forecast errors for both of these variables indicates that on average the move to GOS had only a small positive effect on the accuracy of the forecasts.²⁸ Unlike VAT, starting point errors made a bigger contribution (23 percent on average) to the gross error in the case of corporation tax than macro driver errors (18 percent on average) over the 2004 – 2014 period. This likely reflects the somewhat lumpy nature of corporate tax revenues often received towards the end of the year.

In absolute terms, excise duty forecast errors are smaller than those of other taxes analysed in this paper (in percentage terms, however, excise duty errors are greater than those of income tax, as was shown in Section 3). “Other” errors, accounted for the highest proportion of the gross excise duty errors (43 percent) on average over the 2004-2014 period, peaking at 83 percent in 2007. The starting point error’s average contribution was smallest at 13 percent. Macro driver errors, on the other hand, accounted for approximately 44 percent of the error on average over the relevant period

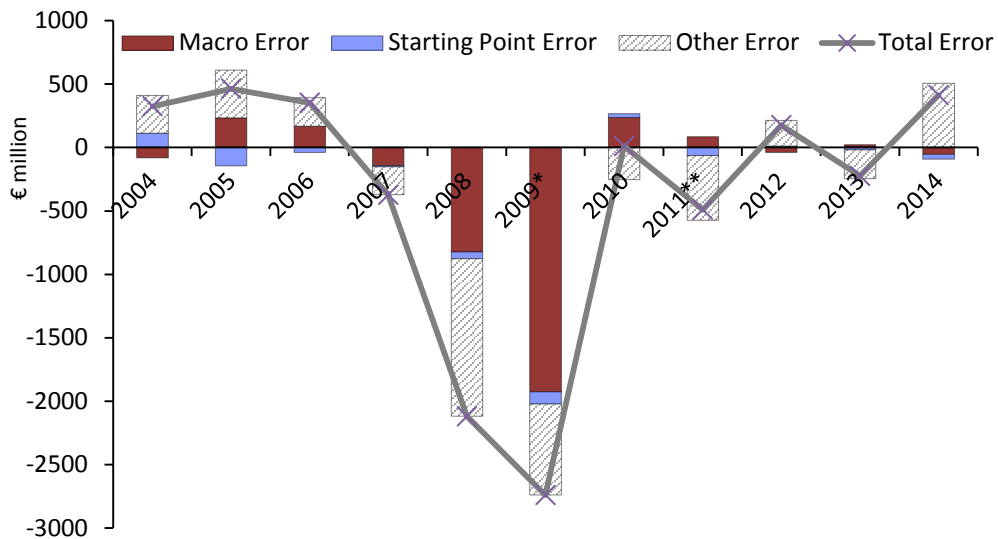
²⁶ Although the rate of corporation tax has not changed since 2003, various policy changes have been introduced, for example, incentives for expenditure on research and development, changes in liability depending on accounting periods, or alternative thresholds for start-up/small companies.

²⁷ As noted above, corporation tax receipts are highly concentrated among several large corporations in the external sector.

²⁸ Over the four year period (2009 – 2013 inclusive), the RMSE for nominal GDP was 25 per cent whereas for GOS it was 21 per cent. Nominal GDP forecasts performed better than GOS forecasts in 2011 and 2012 whereas GOS performed better in all other years.

and made the largest contribution on six of the eleven occasions considered. Separate decompositions of the forecasts for excise excluding VRT and VRT itself are shown in Appendix B. Results indicate that the large excise duty errors in 2008-2009 were largely driven by poorer than expected levels of VRT.²⁹ Appendix B also shows that VRT errors are driven by macro errors while starting point errors tend to be particularly small. As very few cars are sold in the month of December, it may be easier to predict Rev_t for VRT than is the case for other tax heads.

FIGURE 4.1: VAT



Sources: Department of Finance and internal calculations.

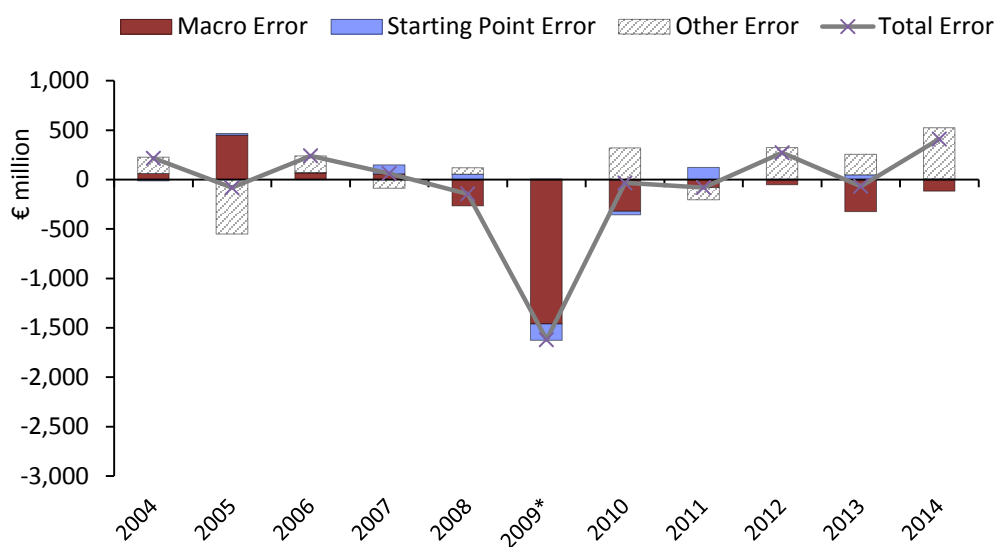
Note: Forecast error = Outturn – forecast, where forecast includes adjustment for judgement.

* 2009 Contained a Supplementary Budget.

**The Action Plan For Jobs 2011 levied a reduced 9% VAT rate on the tourism sector.

²⁹ According to the Department of Finance (2010), car sales declined by 19 percent in 2008 and by 63 percent in 2009. These declines, combined with an increase in car price competition, and the tendency towards buying cheaper and cleaner cars (where the VRT rates are lower), significantly reduced the VRT yield.

FIGURE 4.2: PAYE

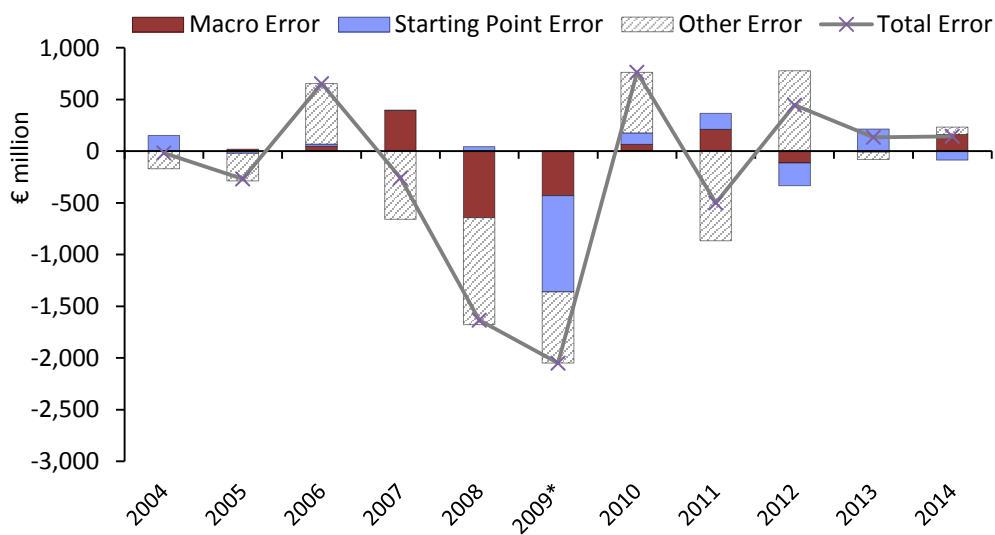


Sources: Department of Finance and internal calculations.

Note: Forecast error = Outturn – forecast, where forecast includes adjustment for judgement.

*2009 contained a Supplementary Budget.

FIGURE 4.3: CORPORATION TAX

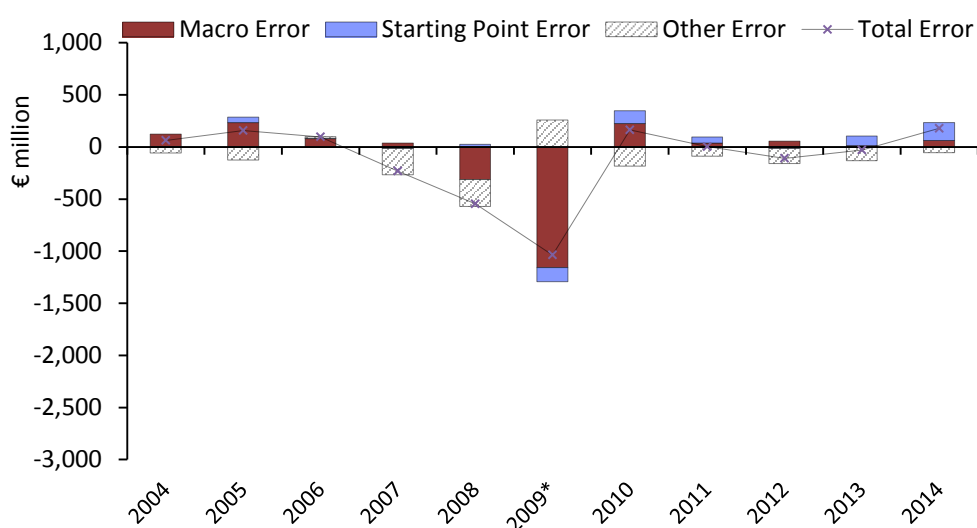


Sources: Department of Finance and internal calculations.

Note: Forecast error = Outturn – forecast, where forecast includes adjustment for judgement.

*2009 contained a Supplementary Budget.

FIGURE 4.4 EXCISE



Sources: Department of Finance and internal calculations.

Note: Forecast error = Outturn – forecast, where forecast includes adjustment for judgement.

*2009 contained a Supplementary Budget.

In general, these decompositions suggest that the relative contribution of different error sources towards the overall error varies over time and by tax head. The exercise reveals that, on occasion, relatively small overall forecast errors mask larger offsetting component errors. A brief analysis of the correlations between the errors from the various sources did not reveal any discernible pattern, however. The IMF (2005) stated that “revenue forecast errors can be largely explained by errors in the outlook for growth” for the 1991-2003 period. The analysis presented here indicates that, while macro driver errors accounted for substantial portions of the errors in many cases, the “other” component had at least an equal if not more significant impact on forecasting accuracy over the 2004-2014 period. This finding was consistent across the four key tax heads. Thus, it is clear that tax revenue errors are not simply reflecting errors in the macro forecasts. While it is difficult to disentangle the driving forces behind the residual “other” error category, the consistently large contributions of these errors would suggest that there is room for improvement in the forecasting methodology.

SECTION 5: ADJUSTMENTS TO THE FORECASTS

In some cases forecasters may seek to make adjustments to the forecast beyond those made to account for one-offs or policy changes. This may be due to the forecasting procedure persistently over- or underestimating the tax yield in the past, or due to a belief that some part of agents' behaviour with regard to the tax may change in a way that cannot accurately be picked up by the macro driver.³⁰ In this section, we take a more in-depth look at this judgement term, given the obvious potential for bias to enter into the forecasting process through this avenue. Specifically, we estimate the degree to which one year ahead forecasts for VAT, corporation tax, excise and PAYE were subjected to discretionary upward or downward adjustments by policy makers. We do this by estimating the forecast equations described in Section 2.2 (and Appendix A) for the years 2004 – 2014 using the same data as was used by the Department of Finance at the time the forecast was made. The judgement term (J_{t+1}) is omitted from the estimation (we refer to these forecasts as “unadjusted” forecasts). We then compare the resulting values to the forecasts that are published in the annual budgets (we refer to these forecasts as “adjusted” forecasts because they are altered by the judgement term J_{t+1}). We also analyse the effect of such adjustments on overall forecast errors.

Figures 5.1 – 5.4 show the size and direction of adjustments (i.e. the size of J_{t+1} as a percentage of the overall forecast) that were applied to VAT, PAYE, corporation tax, and excise forecasts respectively between 2004 and 2014. The absolute size of the adjustments as well as the size of the adjustment as a percentage of the yield for the relevant tax head is shown in Appendix C. As a percentage of overall forecasts, adjustments appear relatively small: the biggest adjustments were applied to corporation tax (the absolute value of the adjustment amounted to 7.7 percent of the forecast on average), followed by PAYE (6.2 percent of the forecast on average). The average adjustments applied to excise and VAT forecasts were much smaller (1.6 percent and 1.4 percent respectively). In the case of corporation tax, the biggest adjustment was applied in 2010 where forecasts were adjusted downwards by over €800 million (26 percent of the forecast for that year). The biggest excise adjustment occurred in 2009 when the forecast was adjusted downwards by €196 million (3.4 percent of the forecast).³¹ The largest adjustment to the VAT forecast occurred in 2009 – a downward adjustment of almost €800 million (5.8 percent of the forecast for that year) – despite an increase of 0.5 percent in the standard VAT rate that year.³² The biggest adjustments to PAYE forecasts occurred before the crisis where forecasts were adjusted upwards by 12 percent in 2004, 2005 and 2006. (This followed three years of income tax underestimations of 6, 4 and 2 percent respectively.)

³⁰ For example, the Department of Finance may believe that growth in consumption could be more tax rich in future years and wish to adjust for that.

³¹ This adjustment coincided with a measure to reduce excise on alcohol which was expected to cost approximately €90 million in 2010. This measure, however, should be captured in the term M_{t+1} rather than J_{t+1} .

³² The standard rate was increased from 21 percent to 21.5 percent and was expected to yield €208 million in 2009.

For VAT, corporation tax and PAYE, the majority of adjustments were in an upward direction. In the case of excise, however, downward adjustments were consistently applied between 2004 and 2011. This pattern was reversed in 2012 when a small upward adjustment (less than 1 percent of the excise forecast) was imposed. Although forecasts are routinely adjusted by the Department of Finance, in general, the adjustments are relatively small.³³

Also shown in Figures 5.1 – 5.4 are the forecast errors that resulted after adjustments had been applied to the forecasts (i.e. the difference between the actual outturn and the forecast published by the Department of Finance). Where the adjustment and the error are in the same direction, it indicates that the judgement improved the forecast accuracy. For example, in the case of a positive forecast error, the actual outturn was underestimated. If this forecast included a positive adjustment, this use of judgement to bring up the forecast resulted in the underestimation being smaller than it would otherwise have been. Where the adjustment and the error are in opposite directions, whether the accuracy was improved by the judgement depends on the absolute size of the judgement relative to the error. When the absolute value of the adjustment is less than twice that of the error, then removing the adjustment would reduce the absolute value of the error. In other words, the inclusion of an adjustment based on judgement worsens the forecast.

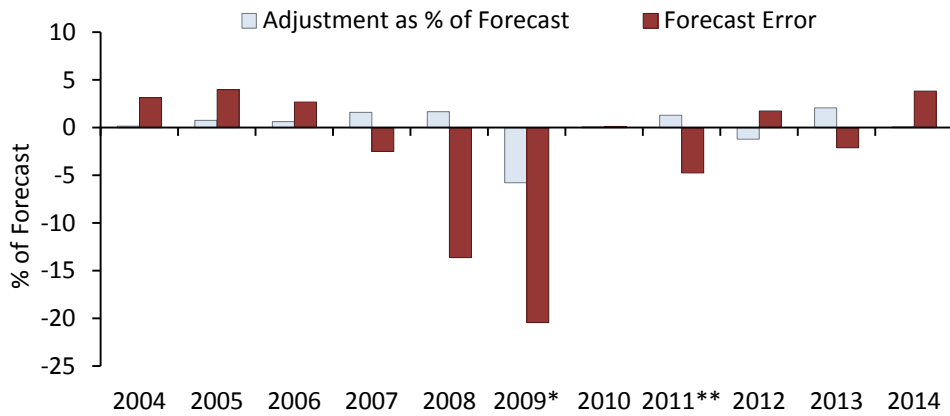
Adjustments made by the Department of Finance improved the accuracy of the VAT forecasts in six of the eleven years considered. With regard to corporation tax and excise, adjusted forecasts exhibited smaller forecast errors than non-adjusted forecasts on four and six, respectively of the eleven occasions considered. With regard to PAYE, adjustments improved the accuracy of the forecasts in all years considered and by a significant amount in each year.

The ME and RMSE for forecasts with and without adjustments are shown in Tables 5.1 and 5.2. For each tax head, the RMSE and ME are calculated over the period 2004 – 2014 and for three sub periods: 2004-2007; 2008-2009; 2010-2014. Results confirm that, on average, the errors for adjusted forecasts were smaller than those for unadjusted forecasts. In the case of PAYE, adjustments greatly reduced the MEs and RMSEs in all sub-periods considered. VAT and excise adjusted forecasts performed better than non-adjusted forecasts in all periods with the exception of 2010-2014 (as measured by the RMSE). The adjustments to corporation tax reduced the ME and RMSE in the 2004-2007 period only.

As can be seen in Tables 5.1 and 5.2, the application of judgement to the outcome of the forecasting equation to form the final tax forecasts has improved the forecasts in most cases. The fact that the adjustments have mostly had the effect of reducing RMSEs across tax heads suggests that they reflect an attempt to improve the accuracy of the forecasts, rather than an attempt to unjustifiably move the forecasts to what is considered a 'better' outcome based on bias.

³³ An exception is the VRT component of excise duty. Between 2004 and 2012, the VRT forecast was adjusted on only one occasion: a downward adjustment of €67 million in 2010.

FIGURE 5.1: ADJUSTMENTS TO VAT FORECASTS AND THE FORECAST ERROR



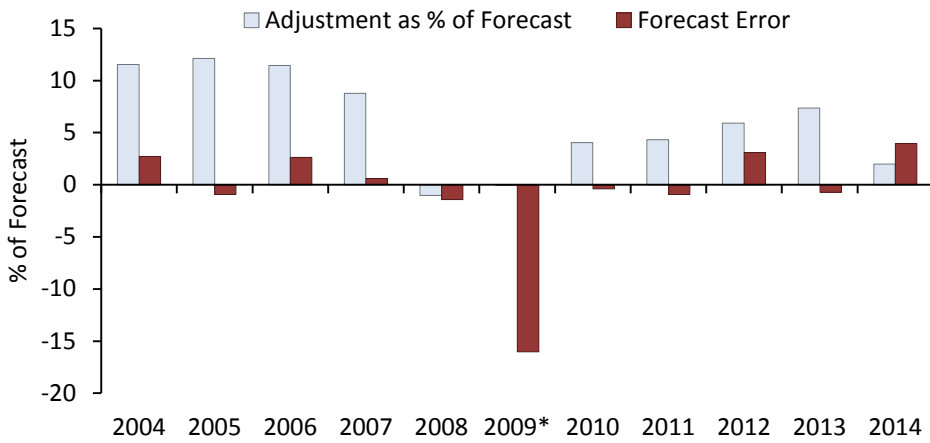
Sources: Department of Finance and internal calculations.

Note: Forecast error = Outturn – forecast, where forecast includes adjustment for judgement.

* 2009 Contained a Supplementary Budget

**The Action Plan For Jobs 2011 contained some small VAT policy changes.

FIGURE 5.2: ADJUSTMENTS TO PAYE FORECASTS AND THE FORECAST ERROR

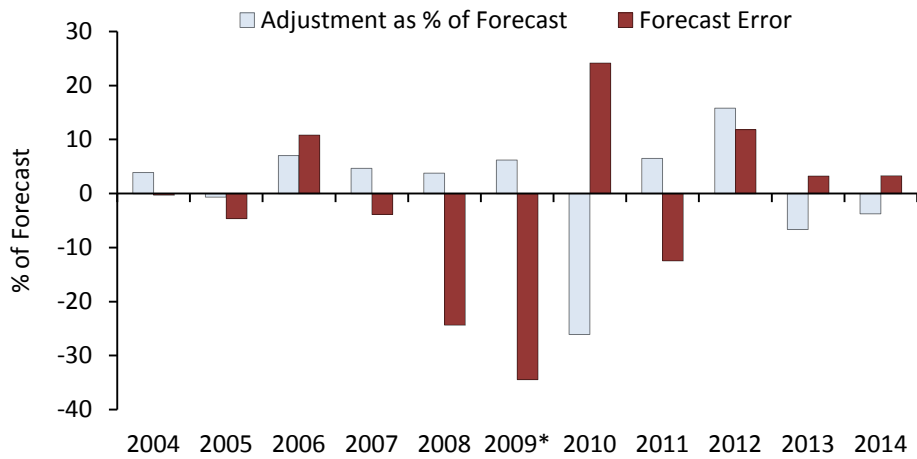


Source: Department of Finance and internal calculations.

Note: Forecast error = outturn – forecast, where forecast includes adjustment for judgement.

*2009 contained a Supplementary Budget

FIGURE 5.3: ADJUSTMENTS TO CORPORATION TAX FORECASTS AND THE FORECAST ERROR

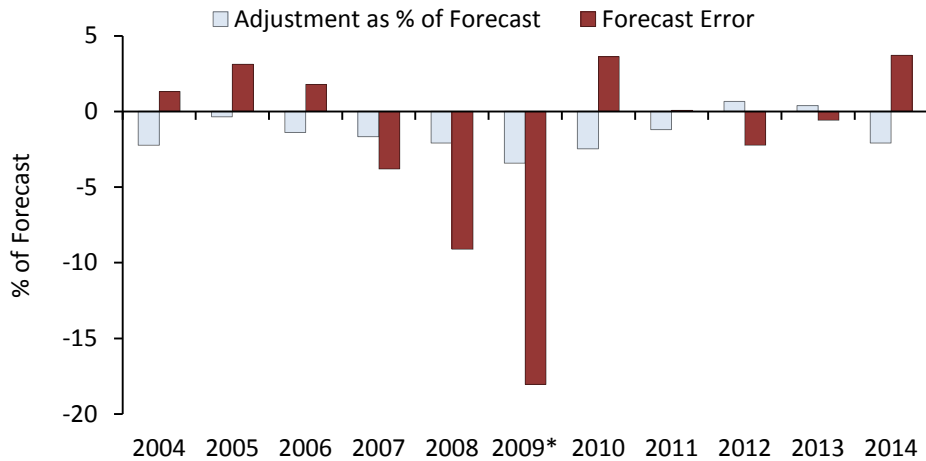


Source: Department of Finance and internal calculations.

Note: Forecast error = Outturn – forecast, where forecast includes adjustment for judgement.

*2009 contained a Supplementary Budget

FIGURE 5.4: ADJUSTMENTS TO EXCISE FORECASTS AND THE FORECAST ERROR



Source: Department of Finance and internal calculations.

Note: Forecast error = Outturn – forecast, where forecast includes adjustment for judgement.

*2009 contained a Supplementary Budget

TABLE 5.1: MEAN ERROR FOR UNADJUSTED³⁴ AND ADJUSTED FORECASTS

Mean Error	2004-2014		2004-2007		2008-2009		2010-2014	
	Unadj	Adjusted	Unadj	Adjusted	Unadj	Adjusted	Unadj	Adjusted
VAT	-4	-4	2.5	1.7	-23.4	-20.7	0.2	-0.3
Corporation Tax	-4.2	-6.5	3.7	0.1	-35.2	-42.4	2.5	4.4
Excise	-4.8	-3.2	-0.9	0.5	-19.3	-16	0	0.9
PAYE	4.9	-1.5	12.1	1.2	-10.8	-10.3	5.7	0.9

TABLE 5.2: RMSE FOR UNADJUSTED AND ADJUSTED FORECASTS

RMSE	2004-2014		2004-2007		2008-2009		2010-2014	
	Unadj	Adjusted	Unadj	Adjusted	Unadj	Adjusted	Unadj	Adjusted
VAT	11.5	9.9	3.2	3.1	25.3	21.3	2.4	3.1
Corporation Tax	18.9	21.5	8.7	5.8	36.1	43.6	11.6	11.9
Excise	9.4	8	3.2	2.7	20.5	17.1	1.2	2.5
PAYE	10.6	6.3	12.2	1.9	13.7	13.5	6	2.2

³⁴ We refer to unadjusted forecasts as forecasts that do not include the judgement term, J_{t+1} . The adjusted forecast is that which includes the judgement term and was published in the annual Budget.

SECTION 6: CONCLUSIONS

From the analysis conducted in this paper, we conclude that the general approach to forecasting tax revenues by the Department of Finance reflects standard international practice but that forecasting errors are relatively large by international standards. With regard to bias, while judgement is routinely applied to the outcome of the tax forecasting equations, the adjustments usually improved the accuracy of the forecast and we find no evidence that this judgement is exercised in a systematic way with a view to biasing the forecasts in a particular direction. An examination of the pattern of forecasting errors and more formal statistical tests also support a lack of bias in the forecasts.

It has generally been the case that the largest tax categories have made the greatest contributions to forecasting errors over the 1997 – 2014 period. As this incorporated the recent economic crisis, however, there were unusually large errors observed in certain years, leading to significant contributions from some of the smaller tax heads to the forecast errors for overall tax revenue. A decomposition of the overall errors into errors arising from macro driver errors, starting point errors and ‘other’ sources, reveals an important contribution from errors associated with the macro driver for the tax head in question. This is in line to some extent with the finding on the role of macroeconomic forecast errors in IMF (2005) for an earlier time period. However, we also find that the “other” category routinely accounts for a very significant portion of the errors. This residual category by definition is a ‘catch-all’ and includes errors arising from estimates of the static impact of policy changes, of one-off items, of elasticities and an element of judgement applied by the Department of Finance.

The dominant role played by this “other” source of forecasting error suggests that the relatively weak forecasting record for Ireland is not simply an inevitable consequence of the macroeconomic uncertainty associated with a small open economy and that careful review of the forecasting process may yield improvement. However, it appears that no formal review of the tax forecasting methodology has been undertaken since the 2008 TFMRG study. While internal reviews may occur periodically within the Department of Finance, the additional benefits of a more formal and public review, with inputs from a broader group of experts and users, would suggest another review is overdue. Indeed, a more regular analysis of the tax forecasting performance was a key recommendation of the 2008 review. In addition, the periodic publication of more detailed information, such as on the role of judgement, on how the static impact of tax changes are calculated, on the impact of one-off factors and the evolution of elasticities over time, for example, would facilitate greater understanding of the forecasts generally and allow for more detailed investigations by outside analysts. It is noteworthy that much of the data used to conduct the decompositions in this paper were not publicly available. This greater transparency would likely bolster confidence in the official forecasts, as it would enable more rigorous independent assessment of whether the forecasts suffered from bias. Given the recent change in the timing of the Budget from December to October, forecasts now need to be made based on less information than before, underscoring the importance of having the best possible forecasting procedures in place.

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APPENDIX A

The following equation can be used to summarise the VAT forecasting process:

$$VAT_{t+1} = (VAT_t - T_t)((1 + (dPCN_{t+1})E) + T_{t+1} + M_{t+1} + J_{t+1})$$

where VAT_{t+1} is the forecast for VAT in the coming year, VAT_t is an estimate of the yield in the current year, T_t are one-off items affecting the yield in the current year and $dPCN_{t+1}$ is the projected growth rate in nominal personal consumption expenditure for the coming year, E is the elasticity between VAT revenue and the tax base, assumed to be 1, T_{t+1} are one-off items affecting the yield in the coming year, M_{t+1} is the estimated static yield from any changes in policy and J_{t+1} is a judgement factor applied by the Department of Finance.

The procedure for forecasting corporation tax can be summarised using the following equation:

$$Cor_{t+1} = (Cor_t - T_t)((1 + (dGDP_{t+1})E) + T_{t+1} + M_{t+1} + J_{t+1})$$

where Cor_{t+1} is the forecast for corporation tax in the coming year, Cor_t is an estimate of the yield in the current year and $dGDP_{t+1}$ is the projected growth rate in nominal GDP for the coming year. Nominal GDP was used as the macro driver until 2008. From 2009 onwards, gross operating surplus was used. T_t, E, T_{t+1}, M_{t+1} and J_{t+1} are defined above.

The forecasting procedure for excise involves two strands, the first of which is to estimate excise that is collected from Vehicle Registration Tax (VRT). The second strand forecasts excise that is collected from all other sources.³⁵ The procedure can be summarised using the following equations:

$$VRT_{t+1} = VRT_t((1 + dPNC_{t+1})(1 + dVNC_{t+1})) + T_{t+1} + M_{t+1} + J_{t+1}$$

VRT_{t+1} is the forecast for Vehicle Registration Tax in the coming year, VRT_t is an estimate of the VRT yield in current year, $dPNC_{t+1}$ is the projected increase in the price of new cars while $dVNC_{t+1}$ is the projected increase in the volume of new car sales. All other variables are defined above. The second equation can be summarised as follows:

$$Exc_{t+1} = (Exc_t - T_t)((1 + (dPCA_{t+1})E) + T_{t+1} + M_{t+1} + J_{t+1})$$

Exc_{t+1} is the forecast for excise excluding VRT in the coming year, Exc_t is an estimate of the excise excluding VRT yield in current year, and $dPCA_{t+1}$ is the projected growth rate in adjusted nominal personal consumption excluding cars. It is called an adjusted measure because it excludes the expenditure of non-Irish residents in Ireland but includes expenditure of Irish residents abroad.

³⁵ There are three main categories of excisable products: mineral oils; alcohol and alcoholic beverages; and manufactured tobacco. Excise duties are also chargeable on certain premises and activities (e.g. on betting and licenses for retailing of liquor). In Ireland, carbon tax, VRT and air travel tax are also collected as part of excise duty. The rates that apply to each excisable item can be found at <http://www.revenue.ie/en/tax/excise/duties/excise-duty-rates.html>.

PAYE accounted for approximately 73 percent of total income tax revenue in 2012. The PAYE forecasting process can be summarised as follows:

$$PAYE_{t+1} = (PAYE_t - T)_t \left((1 + (dY_{t+1})E_{t+1}^Y)(1 + (dM_{t+1})E_{t+1}^M) \right) + T_{t+1} + M_{t+1} + J_{t+1}$$

where $PAYE_{t+1}$ is the forecast for PAYE in the coming year and $PAYE_t$ is an estimate of the yield in the current year. dY_{t+1} , the projected growth in non-agricultural wages, is multiplied by an earnings elasticity E_{t+1}^Y and dM_{t+1} , the projected growth in non-agricultural employment, is multiplied by an employment elasticity E_{t+1}^M . All other variables are defined above.

APPENDIX B

FIGURE B.1: EXCISE EXCLUDING VRT

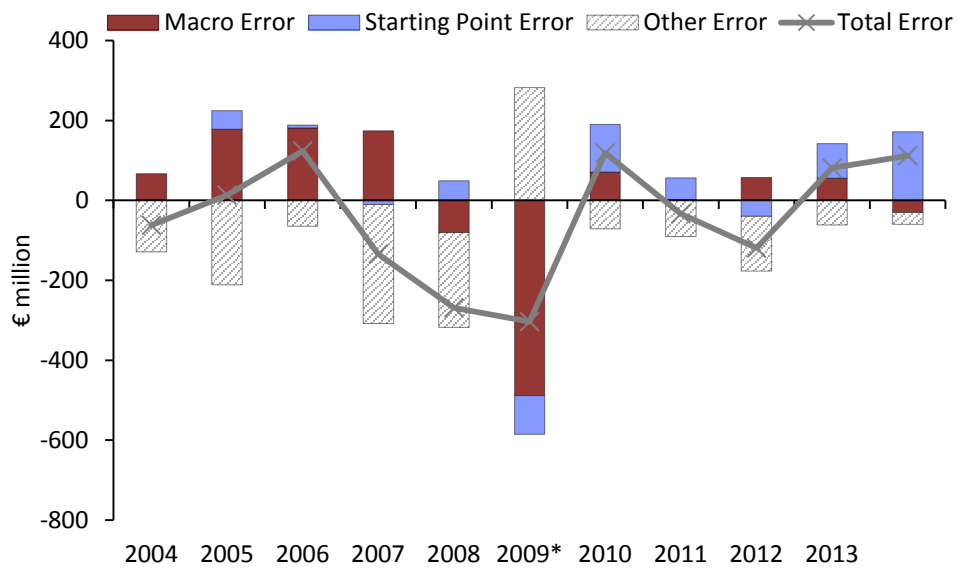
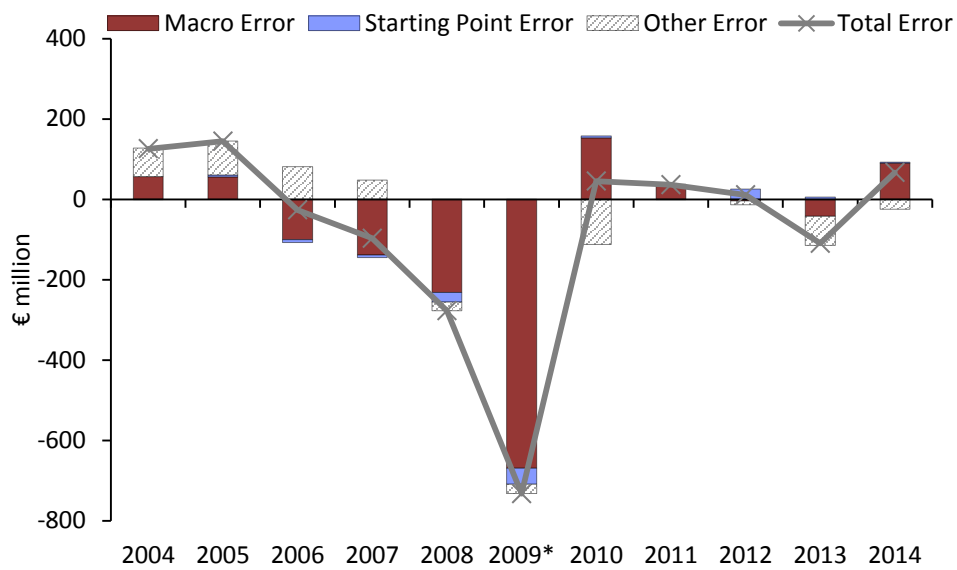
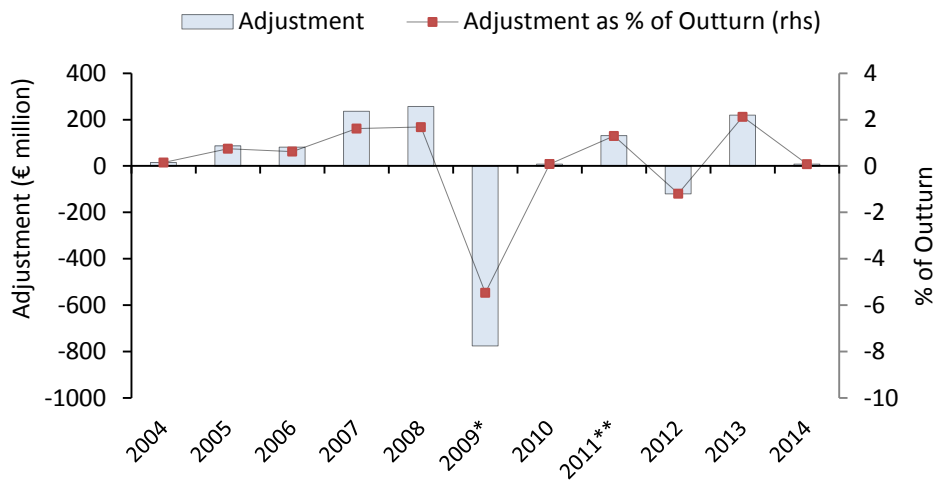


FIGURE B.2: VRT



APPENDIX C

FIGURE C.1: ADJUSTMENT TO VAT FORECASTS



Note: The size of the adjustment is shown on the left axis whereas the adjustment as a percentage of the outturn is shown on the right axis.

FIGURE C.2: ADJUSTMENT TO PAYE

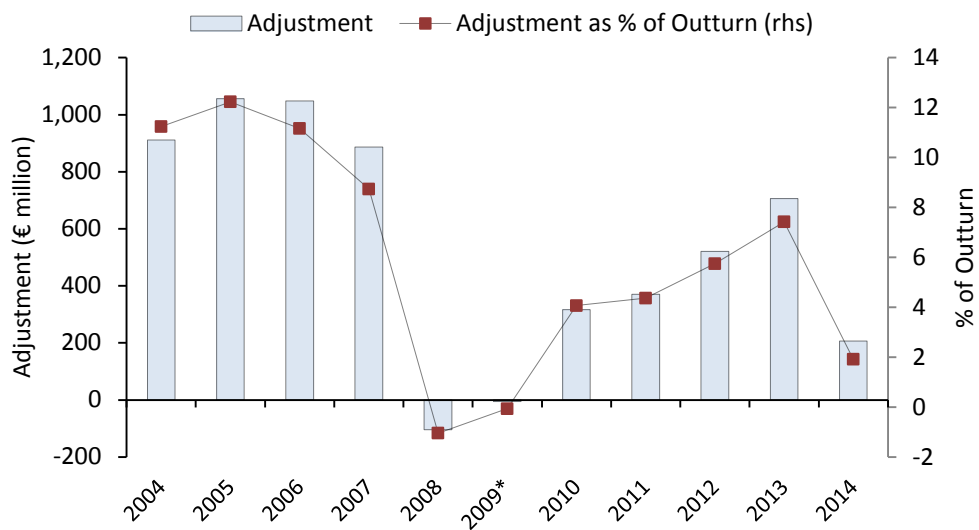


FIGURE C.3: ADJUSTMENT TO CORPORATION TAX FORECASTS

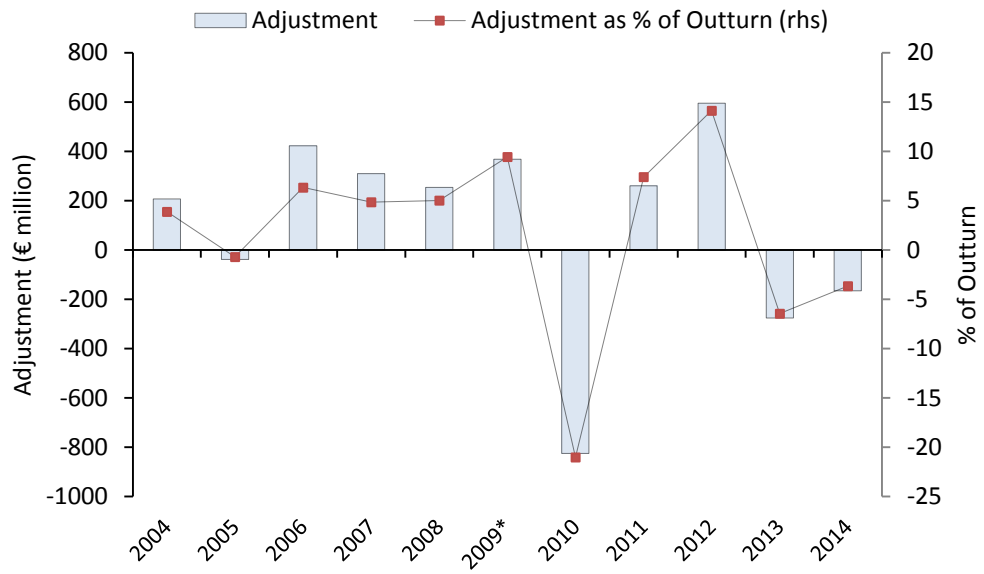
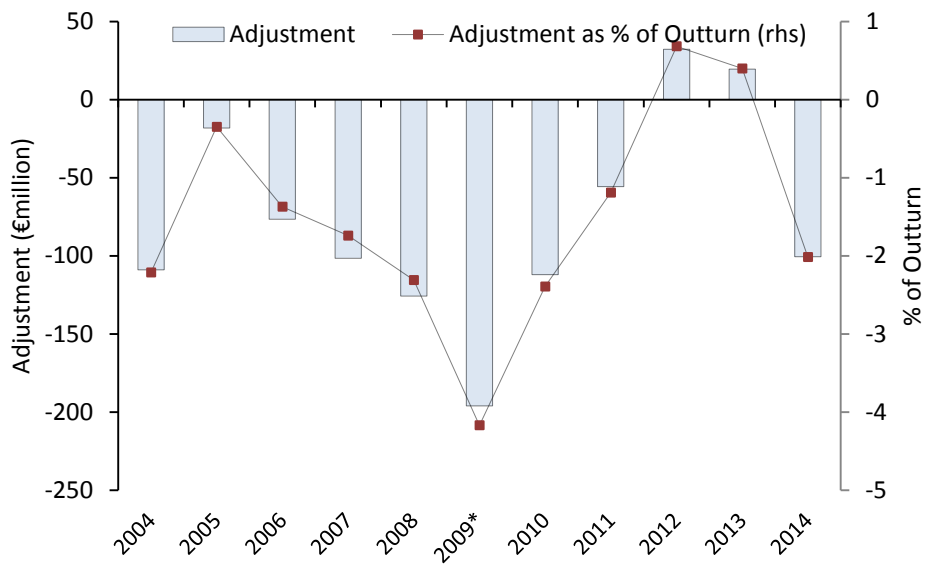


FIGURE C.4: ADJUSTMENT TO EXCISE FORECASTS



APPENDIX D

The fact that the ME is positive or negative over the period should not of itself lead to a conclusion that the forecasts are biased. To examine this, we attempt to determine whether the average error is statistically significantly different from zero. If the errors are normally distributed, a simple t-test that the average equals zero will tell us if the forecasts are biased. If the errors are a result of a series of miscellaneous factors, we would (by the central limit theorem) expect them to approximate a normal distribution. One of the limitations of the analysis below is the relatively low power as a result of the small sample sizes. Thus, a failure to reject a null hypothesis cannot be considered conclusive evidence that the null is true, but is rather an indication that within our sample, we cannot find enough evidence to support the null's rejection.

We test for normality using the Shapiro-Wilk normality test and then cross-check this by employing four other common normality tests.³⁶ Given the relatively low power of these tests when the number of observations is low, we conclude that a p-value of under 10% in any one of these tests should be taken as sufficient reason for rejecting the null hypothesis of normality.

Where we find evidence that the errors are not normally distributed, we can employ a non-parametric test (the Wilcoxon signed rank test) of whether the median is zero.

Another method of checking for bias and efficiency in forecasts is the Mincer-Zarnowitz (1969) test which runs the regression:

$$A_t = \alpha + \beta F_t + \epsilon_t$$

where A_t is the actual value at time t and F_t is the forecast value. From this regression, we can test whether $\alpha=0$ and $\beta = 1$, in which case the forecasts are unbiased. However, as Mankiw and Shapiro (1986) show, the Mincer-Zarnowitz test can be inaccurate in small samples. Since we are using small samples, we follow the method used in Croushore (2012) and run the following, simpler regression:

$$e_t = \alpha + \epsilon_t$$

where e_t is the forecast error ($A_t - F_t$). It is possible that the errors exhibit serial correlation and when we test for this using a simple Breush-Godfrey test, we find evidence for this for some tax heads. We attempt to correct for this using Newey-West standard errors.

³⁶ Lilliefors, Cramer-von Mises, Watson and Anderson-Darling normality tests.

TABLE D.1A: TESTS FOR NORMALITY AND BIAS

Full Sample Tests for Normality and Bias		Shapiro-Wilk Probability	Bias t-test	Bias Wilcoxon	Regression Constant
VAT	+1 yr	0.002***	0.409	0.862	0.493
	+2 yrs	0.002***	0.124	0.201	0.253
	+3 yrs	0.003***	0.08*	0.187	0.203
Income	+1 yr	0.924	0.851	0.794	0.879
	+2 yrs	0.518	0.339	0.478	0.325
	+3 yrs	0.533	0.113	0.167	0.122
CT	+1 yr	0.010**	0.461	0.887	0.474
	+2 yrs	0.002***	0.116	0.244	0.205
	+3 yrs	0.003***	0.047**	0.052*	0.128
Excise	+1 yr	0.001***	0.259	0.896	0.276
	+2 yrs	0.045**	0.008***	0.004***	0.023**
	+3 yrs	0.049**	0.003***	0.002***	0.017**
Stamp	+1 yr	0.003***	0.688	0.191	0.757
	+2 yrs	0.000***	0.602	0.443	0.684
	+3 yrs	0.000***	0.427	0.530	0.541
CAT	+1 yr	0.073*	0.210	0.223	0.339
	+2 yrs	0.000***	0.390	0.755	0.303
	+3 yrs	0.000***	0.176	0.349	0.202
CGT	+1 yr	0.000***	0.818	0.177	0.855
	+2 yrs	0.000***	0.255	0.842	0.375
	+3 yrs	0.000***	0.163	0.900	0.284
Total	+1 yr	0.001***	0.713	0.571	0.767
	+2 yrs	0.012**	0.211	0.616	0.333
	+3 yrs	0.006***	0.111	0.286	0.231

Table 3.1a summarises the results for 1, 2 and 3 year ahead forecasts for all tax heads and total taxes. We show the p-values for the Shapiro-Wilk test, the simple t-test and the Wilcoxon signed rank test; we also show the p-value for α from the regression above. We find that we must reject the null hypothesis of normality for all tax heads except income tax. Therefore, the use of t-tests is in question and we also report the results from the Wilcoxon signed rank test. The results broadly agree with each other and with the results of the simple regression. We find evidence of bias only for excise for forecasts of 2 and 3 years ahead and mixed evidence for corporation tax over the same horizons. However, for total taxes, our regression suggests bias may be present.

Given the scale of forecasting errors in 2008 and 2009, it is possible that these outliers are biasing our results. Therefore, we also perform the above tests excluding these years. The results are reported in Table 3.1b. The Shapiro-Wilk test still rejects the null hypothesis of normally distributed

errors for most tax heads, although it now fails to reject for VAT over 1 and 2 year ahead forecasts. Excise, is still found to be biased under the normal t-test and Wilcoxon signed rank test but in our simple regression we fail to reject the null hypothesis that $\alpha = 0$.

TABLE D.1B: TESTS FOR NORMALITY AND BIAS WITH RESTRICTED SAMPLE

Restricted Sample Tests for Normality and Bias		Shapiro- Wilk Probability	Bias t-test	Bias Wilcoxon	Regression Constant
VAT	+1 yr	0.250	0.535	0.293	0.527
	+2 yrs	0.169	0.509	0.552	0.557
	+3 yrs	0.001***	0.312	0.556	0.361
Income	+1 yr	0.925	0.218	0.289	0.267
	+2 yrs	0.982	0.952	0.917	0.943
	+3 yrs	0.382	0.324	0.410	0.256
CT	+1 yr	0.989	0.416	0.478	0.354
	+2 yrs	0.024**	0.436	0.675	0.347
	+3 yrs	0.001***	0.189	0.170	0.220
Excise	+1 yr	0.001***	0.813	0.485	0.474
	+2 yrs	0.098*	0.018**	0.012**	0.205
	+3 yrs	0.007***	0.015**	0.005***	0.128
Stamp	+1 yr	0.534	0.010***	0.014**	0.005***
	+2 yrs	0.000***	0.548	0.050*	0.543
	+3 yrs	0.000***	0.740	0.255	0.769
CAT	+1 yr	0.092*	0.073**	0.103	0.157
	+2 yrs	0.000***	0.531	0.780	0.457
	+3 yrs	0.000***	0.247	0.727	0.276
CGT	+1 yr	0.023**	0.007***	0.012**	0.011**
	+2 yrs	0.004***	0.641	0.208	0.620
	+3 yrs	0.000***	0.517	0.410	0.539
Total	+1 yr	0.001***	0.713	0.571	0.134
	+2 yrs	0.005***	0.217	0.670	0.918
	+3 yrs	0.006***	0.111	0.286	0.429

Our regression now fails to reject the null hypothesis of unbiased forecasts for total taxes for one and two years ahead but rejects at the ten percent level of confidence for 3 years ahead. Interestingly, in the restricted sample, forecasts for stamp duties and capital gains tax show signs of bias in the 1 year ahead forecast but, again, the bulk of the forecasts appear unbiased.