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Maq:
A Macro-Fiscal Model for Ireland

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Maq:

A Macro-Fiscal Model for Ireland

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February, 2021

Abstract

This paper sets out the design of "Maq": a macro-fiscal model for Ireland. The Maq can be applied to stochastic debt sustainability analysis—a sophisticated analytical technique for assessing the sustainability of public debt—as well as other policy analyses. Maq is primarily inspired by OECD fiscal modelling. We also add a detailed interest model and incorporate work by the Fiscal Council on potential output and Irish-specific fiscal multipliers. We focus on the domestic Irish economy, separating out distortions caused by foreign-owned multinational enterprises. Illustrating Maq's usefulness, we show probabilistic fan charts for the debt ratio, a series of tailored shock scenarios and we develop a comprehensive fiscal stress test.

Keywords: Fiscal Policy, Debt Sustainability Analysis

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1. Introduction

Irish fiscal policy has suffered through several cases of excessive procyclicality — expansions in good times followed by deep cutbacks in bad times (Fiscal Council, 2019). In part, these repeated policy failures owe to a lack of understanding about the future implications of today's policy.

One way to help assess fiscal risks is what is called "fiscal stress testing". This essentially builds on traditional debt sustainability analysis by modelling different outcomes for debt under uncertainty and given historical risks and their likelihoods of occurring. In particular, fiscal stress tests can help policymakers simulate the effects of shocks to their central forecasts and their implications for government liquidity, financing needs, and solvency (IMF, 2016).

This paper sets out a new macro-fiscal model for Ireland: "Maq".[2] We augment OECD modelling work (Botev, Fournier and Mourougane, 2016) with Fiscal Council research on potential output, fiscal multipliers and debt sustainability analysis. This is essential in Ireland's case, given the unique nature of the Irish economy. Furthermore, we draw on comprehensive research by the IMF on historical fiscal shocks to focus our stress tests on past episodes that might be most informative for small open advanced economies like Ireland.

We make three key contributions to research on Irish debt sustainability by developing: (1) more sophisticated probabilistic forecasts as summarised by fan charts; (2) detailed shock scenarios; and (3) a comprehensive fiscal stress test.

The probabilistic forecasts are informative and highlight the skewed nature of risks to Irish debt dynamics. Put simply, risks that debt ratios will rise to higher levels outweigh the risks that they will fall to lower levels based on past information.

We examine some commonly considered shock scenarios. The shocks we assess are relatively modest, particularly in light of the Covid-19-related economic disruption. But they give a sense of just how sensitive Irish government debt can be to changing conditions. For example, under unchanged policies and at high debt levels (close to

[2] Maq is a derivation of "Maquette" after the original "Fiscal Maquette Model" developed by OECD staff on which it is based (Botev, Fournier and Mourougane, 2016).

95 per cent of national income), a one percentage point boost to growth is estimated to reduce the debt ratio by 4 percentage points over a four-year period. A shock to public investment equivalent to 1 per cent of modified Gross National Income (GNI*) would be expected to have marginal impacts on the debt ratio over a similar time horizon — albeit with large uncertainty around this in both directions. A 0.75 percentage point (75bps) shock to marginal interest rates—applicable for new bond issuances by the Irish government—would result in negligible increases in the debt ratio in the absence of other adverse effects, including on growth, reflecting the favourable features of the Irish debt stock (largely at fixed rates and with long maturities).

As a final contribution, we develop a comprehensive stress test that draws on a large IMF survey of fiscal risks across 80 countries over a period of two and a half decades. The stress test enables us to assess how the public finances would respond to a large, correlated shock to key variables. It incorporates a shock to growth, interest rates, the financial sector and the realisation of other large fiscal risks. These could include impacts associated with climate change and corporate or non-corporate bailouts. Recognising that the historical experiences of any country are not necessarily a good guide to future risks it faces, this bases the size and nature of shocks on realised tail-events from a range of comparator countries.

The stress test yields sobering results, with debt ratios rising to very high levels both in an international and historical sense. This offers a useful framework for assessing potential risks facing the public finances and builds on the other advantages offered by the Maq in terms of allowing for detailed, probabilistic assessments of debt sustainability in a tractable model.

2. Methodology and Data

The Maq model is primarily inspired by previous OECD work in the area of fiscal modelling (Sorbe, 2012; Rawdanowicz, 2012; Fall and Fournier, 2015; and Botev, Fournier and Mourougane, 2016). We build on this using detailed work by the Fiscal Council to develop better specified models of potential output, a model of debt securities issued by the state, and work on fiscal multipliers (Fiscal Council, 2012; Casey, 2018; Ivory, Casey; and Conroy, 2019). In addition, we develop a series of stress tests based on IMF work that are more specifically calibrated for the Irish economy (IMF 2016; Bova *et al*., 2016).

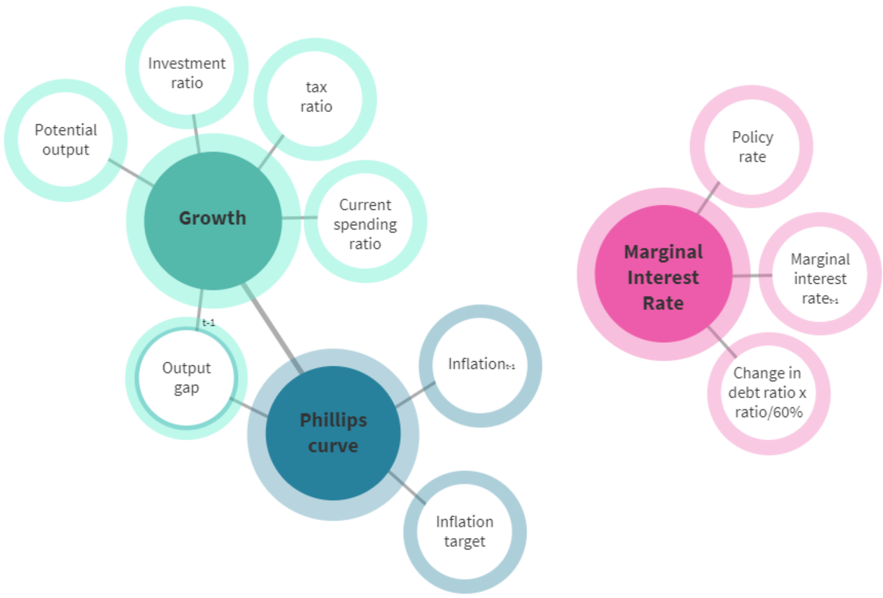
2.1 The Maq Model

This section sets out the core equations underpinning the Maq model and how these are specified. We start with a quick overview of how the model works and its three key equations. We then look at the model structure in more detail.

Overview of how the model works

There are three key behavioural equations underpinning the Maq: a Growth equation; a Phillips curve equation (modelling inflation); and a Marginal Interest Rate equation. Figure 1 depicts the three key behavioural relationships. Two of the key equations, the Growth and Phillips curve equations, are linked through the output gap channel.

Figure 1: The Maq model's key drivers



In essence, the three key equations underpinning the Maq work as follows. The Maq models growth on the basis of a number of fiscal feedbacks, with investment spending, current spending and tax ratio changes having different impacts based on assumed fiscal multipliers. Growth also depends on potential output and the size of the output gap. As modelled, economic growth reverts to its potential growth rate over time and output gaps close over a number of years. The output gap also determines inflation in the Phillips curve equation, with more positive output gaps generating higher rates of inflation. Previous inflation rates and the inflation target also matter in this context. Finally, how public finances are managed has a feedback to market interest rates charged on government borrowing. Specifically, the marginal interest rate on government borrowings depends on recent rates, policy rates, and—importantly—the change in debt ratios, with higher debt ratios relative to a 60 per cent value having a proportionally larger impact.

The model in detail

In total, there are 35 equations underpinning the Maq model. It comprises five behavioural equations and 30 identities. Appendix B shows the detailed model structure graphically. Aside from the three key equations noted in Figure 1, there is another behavioural equation relating the GDP deflator to HICP inflation and another for relating GDP to total GVA.

As in Botev, Fournier and Mourougane (2016), we model economic growth in reduced form so that growth in economic output Δy_t depends on potential output growth $\Delta {y_t}^*$ and the lagged output gap OG_{t-1}.[3]

Key equation: Growth

$$\Delta y_t = \Delta {y_t}^* - \beta_1 OG_{t-1} + \lambda_{inv} \Delta ginv_t + \lambda_{cur} \Delta gcur_t - \lambda_{tax} \Delta gtax + \varepsilon_t \qquad (1)$$

The final terms in the growth equation capture the role of fiscal variables. We incorporate feedbacks from general government investment ($ginv_t$), other general government current spending ($gcur_t$) and general government tax revenues (tax_t).

[3] Initial variants of the growth equation subsequently dropped had considered the inclusion of the real interest rate, the real effective exchange rate and a world demand variable — all important macroeconomic variables for determining growth. In the case of real interest rates and the real effective exchange rate, the variables were not found to be statistically significant. The world demand variable was statistically significant but it contributed to less sensible results for a variety of shocks and, hence, a more parsimonious model was preferred.

Current spending here is defined as all general government spending aside from investment and interest costs. Tax is defined as total general government revenue less property income, other current transfers receivable and capital transfers and investment grants.[4]

We calibrate the fiscal multipliers λ for each of these based on work in Ivory, Casey, and Conroy (2020). These parameters and others are set out in Table A2.

An important distinction from the work of Botev, Fournier and Mourougane (2016) is that our key output variable in equation (1) is Domestic GVA rather than GDP. Domestic GVA is a measure of the domestic economy that strips out the activities of sectors dominated by foreign-owned multinational enterprises, which cause significant distortions to overall GDP (Casey, 2019). The variable also tends to have a closer relationship with general government revenues than other aggregates.[5] Furthermore, the preferred potential output and output gap estimates that we use are also based on Domestic GVA, hence making them consistent with our chosen output variable.[6]

Potential output is subject to a high degree of uncertainty. This is especially true in the case of a small, open economy like Ireland's, where the economy can tend to act like a region (especially in terms of its labour market) and given the presence of large foreign-owned multinational enterprises. We determine potential output exogenously based on the suite of models developed in Casey (2018). These models take the mid-range estimates of potential output from a variety of univariate–, multivariate–, and cyclical indicators–based approaches. Domestic GVA is again the key macroeconomic aggregate underpinning these models.[7] For modelling debt developments, we set the following identity for potential output:

$$\Delta y_t^* = \Delta y_{t-1}^* + \mu * Min(OG_{t-1}, 0) + \frac{\epsilon}{(1+deprec)} ginv_t + \delta(\Delta y_{t-1}^* - \Delta y_{ss}^*) + \varepsilon_t \quad (2)$$

[4] These equate to items D4, D7 and D9N in the national accounts.

[5] The gross value added of sectors dominated by foreign-owned multinational enterprises is also estimated in Casey (2019) to have no statistically significant impact on revenues.

[6] These estimates are derived using a suite of models approach drawing on univariate filtering–, multivariate filtering–, and principal components–based procedures as in Casey (2019).

[7] The output gap is derived simply as: $OG_t = \frac{(y_t - y_t^*)}{y_t^*}$

Potential output is assumed to be affected by past developments in demand, with hysteresis having permanent impacts on potential growth. The degree of labour market hysteresis μ is assumed greater than zero. The elasticity of public capital in the production function is represented by the parameter ϵ. The depreciation rate of fixed assets is given by the constant $deprec$ for general government. The speed of convergence of potential output growth to the steady state growth rate, $y_{ss}{}^{*}$ is given by δ. And the error term ε_t denotes other supply shocks. These parameters are also set out in Table A2.

HICP inflation π_t is driven by an expectations-augmented Phillips curve where expectations are anchored to an inflation target π^T, but where past inflation and the cyclical position of the domestic economy matters.

Key equation: Phillips curve

$$\pi_t = \beta_1 \pi_{t-1} + (1-\beta_1){\pi^T}_t + \beta_2 OG_t + \varepsilon_t \qquad (3)$$

Unlike Botev, Fournier and Mourougane (2016), we assume that monetary policy is determined exogenously. This is warranted, given Ireland's relatively small size in the context of the Euro Area.

We also differ from Botev, Fournier and Mourougane (2016) on our specification of how interest costs are calculated. We recognise the need for a marginal issuance rate rather than assuming that the whole debt stock is refinanced each year as is implicitly assumed in their modelling.

The marginal issuance rate MIR_t is proxied by the ten-year yield on Irish Government bonds. In our specification, the marginal interest rate depends on (1) its lag, (2) the exogenous interest rate environment as proxied by the change in the policy rate $\Delta Prate_t$, and (3) the change in the debt ratio. The latter is scaled up or down based on the value of the current debt ratio relative to the 60 per cent Stability and Growth Pact reference value — set relative to GNI* in this context. This means that increases in the debt ratio above this ceiling impart stronger, non-linear increases in the marginal interest rate, while changes in the debt ratio below this ceiling impart relatively modest increases in the marginal interest rate.

Key equation: Marginal interest rate

$$MIR_t = \beta_1 MIR_{t-1} + \Delta Prate_t + \beta_2(\Delta Debt\_ratio_t * \frac{Debt\_ratio_t}{60}) + \varepsilon_t \quad (4)$$

The Primary Balance PB_t is split into its structural, cyclical and one-off parts.

For total revenue TR_t we have:

$$TR_t = gtax_t + gnontax_t \quad (5)$$

$$gtax_t = gtax_t^* + \alpha_{tax} OG_t + vr_t \quad (6)$$

where α_{tax} is the semi-elasticity of tax with respect to the output gap (as estimated in Carroll, 2019); vr_t are one-off revenue items; and $gtax_t^*$ is structural tax revenue.

Primary expenditure PE_t is given by the sum of general government investment; general government current spending (excluding interest); and one-off expenditure items ve_t.[8]

$$PE_t = ginv_t + gcur_t + ve_t + \varepsilon_t \quad (7)$$

$$gcur_t = gcur_t^* - \alpha_{cur} OG_t + ve_t \quad (8)$$

Current spending is cyclically related to the output gap using the semi-elasticity α_{cur} (Carroll, 2019). This gives structural current spending as $gcur_t^*$.

Together, these form the Primary Balance:

$$PB_t = TR_t - PE_t \quad (9)$$

The marginal rate is then used to calculate the interest costs. Interest costs, $interest_t$, are given by the combination of three components. The interest costs comprise: (1) interest on fixed-rate debt already issued, (2) interest on floating-rate debt already issued and (3) redemptions of debt in the forecast horizon and the primary balance.

[8] An example of one-off expenditures would be realisations of contingent liabilities.

$$interest_t = Fixed_t + Floating_t * (Prate_t + Prem_t) + \sum_0^t Min(redemptions_t + PB_t), 0) * MIR_t \quad (10)$$

The interest costs are divided over previous period's stock of debt to obtain the average effective interest rate i_t:

$$i_t = interest_t / debt_{t-1} \quad (11)$$

The debt ratio D_t is assumed to follow the standard debt-snowball equation, with the differential between nominal growth (g_t) and interest (i_t) a key driver:

$$\Delta D_t = \left(\frac{i_t - g_t}{1 + g_t}\right) D_{t-1} - PB_t + SF_t \quad (12)$$

As with other variables, the debt ratio is specified in terms of nominal potential Domestic GVA. To get ratios relative to nominal GDP and nominal modified GNI*, we rely on our output gap estimates (to get estimates as a share of nominal Domestic GVA), an assumption for growth in activities of foreign-owned multinational enterprises (MNE_{ss}^*) and the estimated relationship between GDP and total GVA.[9]

Another variable we consider as part of the debt sustainability analysis is gross financing needs. This is a practical indicator that has gained popularity in recent years (Pamies Sumner and Reut, 2020). We define it as the sum of the Exchequer Borrowing Requirement—effectively, new borrowings—plus debt rollovers and other flows.[10] The baseline gross financing need is derived from official forecasts. For scenarios, it is adjusted based on general government balance deviations. It provides a useful measure of potential refinancing risks that can be a good gauge of the relative burden associated with government debt and a complement to standard debt ratios. For example, the IMF typically considers thresholds for gross financing needs of 20 per cent of GDP as a concern for advanced economies.

[9] As we are still likely to be interested in overall GDP, we specify the following identities to link Domestic GVA to total GVA and then to GDP and GNI*. Note that we assume the same price deflator for Domestic GVA as for GDP and GNI*.

$GVA_t = y_t + MNE_t$

$\Delta GDP_t = \alpha + \beta_1 \Delta GVA_t + \varepsilon_t$

$\Delta GNI_t^* = \Delta GDP_t$

[10] The Exchequer borrowing requirement is a cash-based measure of the borrowing requirement of the central part of the Irish Government. Accrual impacts and funding requirements of other arms of government will mean the general government balance is often larger than the Exchequer borrowing requirement suggests.

2.2 Model solution

The model can be solved in different ways depending on modelling objectives.

One option is to solve the model deterministically. This means we produce joint projections of all variables that are fully determined by our choice of parameters and the initial conditions. This is useful when we wish to assess specific shock scenarios and when we wish to compare them to a given non-random baseline. In essence, this entails that model inputs are fixed, and a single path is calculated for the output variables we are interested in.

Alternatively, we can solve the model stochastically. This incorporates some randomness by repeatedly solving for different draws of certain parts of the model. This is useful when we want to determine uncertainty bands that may surround a given projection. We may also allow for coefficient uncertainty in the model, so that a new set of coefficients is drawn before each repetition. Errors are generated for each observation in accordance with the residual uncertainty and the exogenous variable uncertainty in the model. We bootstrap using annual data over the period 1970-2019.

For deterministic solutions, the equations of the model are solved for each observation in the solution sample. This involves an iterative algorithm being used to compute values for the endogenous variables. Stochastic solutions are similar, but the model is solved repeatedly for different draws of the random components of the model. Errors are generated for each observation in accordance with the residual uncertainty and the exogenous variable uncertainty in the model. At the end of each iteration, statistics for the endogenous variables are updated.

This set up means that we can also examine simulation results under different assumptions regarding the variables determined outside the model.

2.3 Data

The key variables we focus on in our model can be grouped into three main types.

Macroeconomic Aggregates

There are measures of Irish output such as Domestic GVA, MNE GVA, GNI* and GDP. The data used is sourced mainly from the Central Statistics Office (CSO). Central projections, where needed, are taken from the latest available set of medium-term forecasts as set out in the *Stability Programme Update (SPU) 2019*. Measures of potential output and the output gap are derived based on the approaches used in Casey (2019). Appendix A details the other variables.

Fiscal Aggregates

The fiscal variables used include the primary balance, tax and non-tax revenue, public investment and public consumption. The data used is primarily sourced from the CSO and are in general government terms. The parameters used in the Maq for fiscal multipliers are primarily sourced from Ivory, Casey and Conroy (2020) and are set out in Appendix A.

Sovereign Debt Interest Data

Data on the interest rate, ten-year yield, redemption path and debt are sourced either from DataStream or from the NTMA. Table A1 in Appendix A outlined in further detail the source of data or parameters used within the Maq model.

Our dataset is annual data from 1970 to 2019. Where data was not available back to 1970, we have backcast where appropriate or merged series to obtain a full dataset.

Our dataset does not cover the Covid-19 shock. Partly this is out of necessity given a lack of comprehensive data for 2020 at present and a lack of medium-term forecasts for the Irish economy. However, caution is warranted regarding the use of any data from 2020 in modelling the Irish economy. Relationships estimated based on 2020 data may be skewed and not represent the normal interaction of variables.

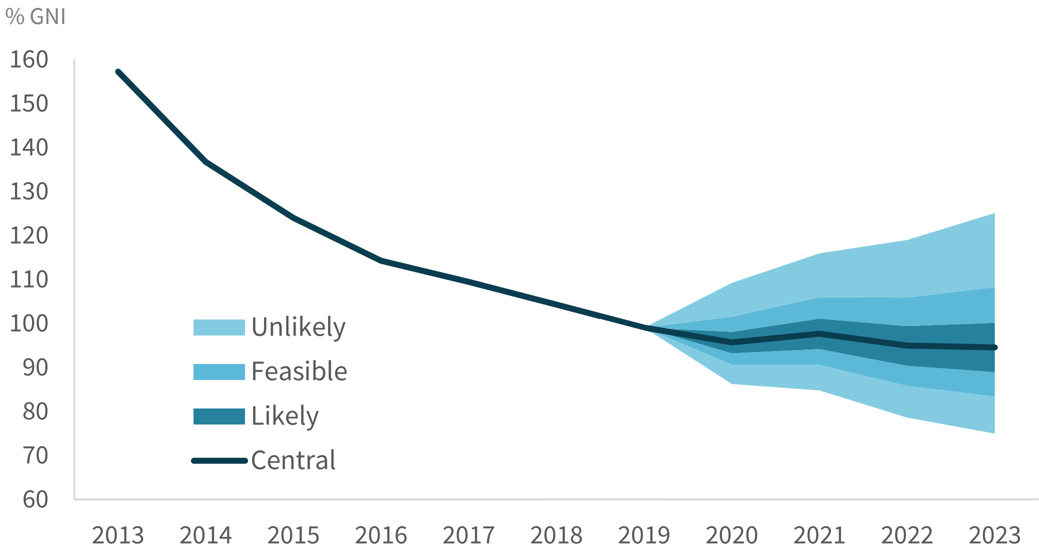
3. Results

3.1 Model projections and uncertainty

A benefit of the Maq is its ability to highlight the degree of uncertainty around central projections. This is thanks to our solving the model stochastically, which means that we can show the projections of key fiscal aggregates in the form of fan charts. This allows for a probabilistic analysis of debt sustainability projections. A distribution of debt paths is produced that corresponds to a wide set of macroeconomic conditions. These are calibrated based on bootstrapping historical data for 1970-2019. This allows us to reflect historical patterns as well as the interdependencies between underlying variables and their modelled relationships. It means we can, in turn, derive a probability of different debt paths occurring — this is often summarised with fan charts.

The approach mirrors the shift in recent years by various international institutions towards complementing conventional deterministic debt sustainability analyses with stochastic projections.

Figure 2: Stochastic debt projections from 2019



Source: Department of Finance *SPU 2019* projections; and Maq model.
Notes: “Likely” covers the 30% confidence interval, “Feasible” the remainder of the 60% interval and “Unlikely” the remainder of the 90% interval.

A fan chart for the central debt ratio projection contained in *SPU 2019* is shown in Figure 2. The uncertainty bands are determined in the Maq model around a model derived baseline, and then transplanted onto the central scenario set out in *SPU*

2019. The official projections are depicted by the central blue line. The 90 per cent confidence interval and sub-intervals are depicted by the blue bands. Specifically, we show the 90, 60, and 30 per cent confidence intervals in successively darker blue shades.

Fan charts are useful but can sometimes not lend themselves to easy interpretation. As in work by AIReF (2019), we therefore classify the probabilistic bands in a normative sense to give users a clearer interpretation. We denote the outer intervals (the 5^{th} to 20^{th} and 80^{th} to 95^{th} percentiles) as “unlikely”. Similarly, the next interval we denote as “Feasible” (20^{th} to 35^{th}; 65^{th} to 80^{th}) and the interval surrounding the central projection as “Likely” (35^{th} to 65^{th}). Interestingly, given Ireland’s historical patterns, we can see that the fan chart is skewed. For the estimates based on data to 2019, the uncertainties around the future path for the debt-to-GNI* ratio are tilted somewhat to the upside. That is, the confidence interval stretches more towards upside risks than it does downside risks for projected path of the debt ratio.

At the time of writing, the fan chart looks likely to incorporate the expected debt ratio for 2020 resulting from the impact of Covid-19 within its “unlikely” range of outcomes. This is reassuring for two reasons. First, it does not fall inside a more central or more likely range of outcomes predicted by the model. If it did, it would suggest that the model is overstating regular uncertainty, given that the pandemic is likely to have a considerable impact and is in some senses a “once-in-a-lifetime” event. Second, it does not fall outside of the range of possible outcomes predicted by the model. If it fell far outside of the bulk of the uncertainty range, this would suggest that the model was understating the potential risks around the debt path.

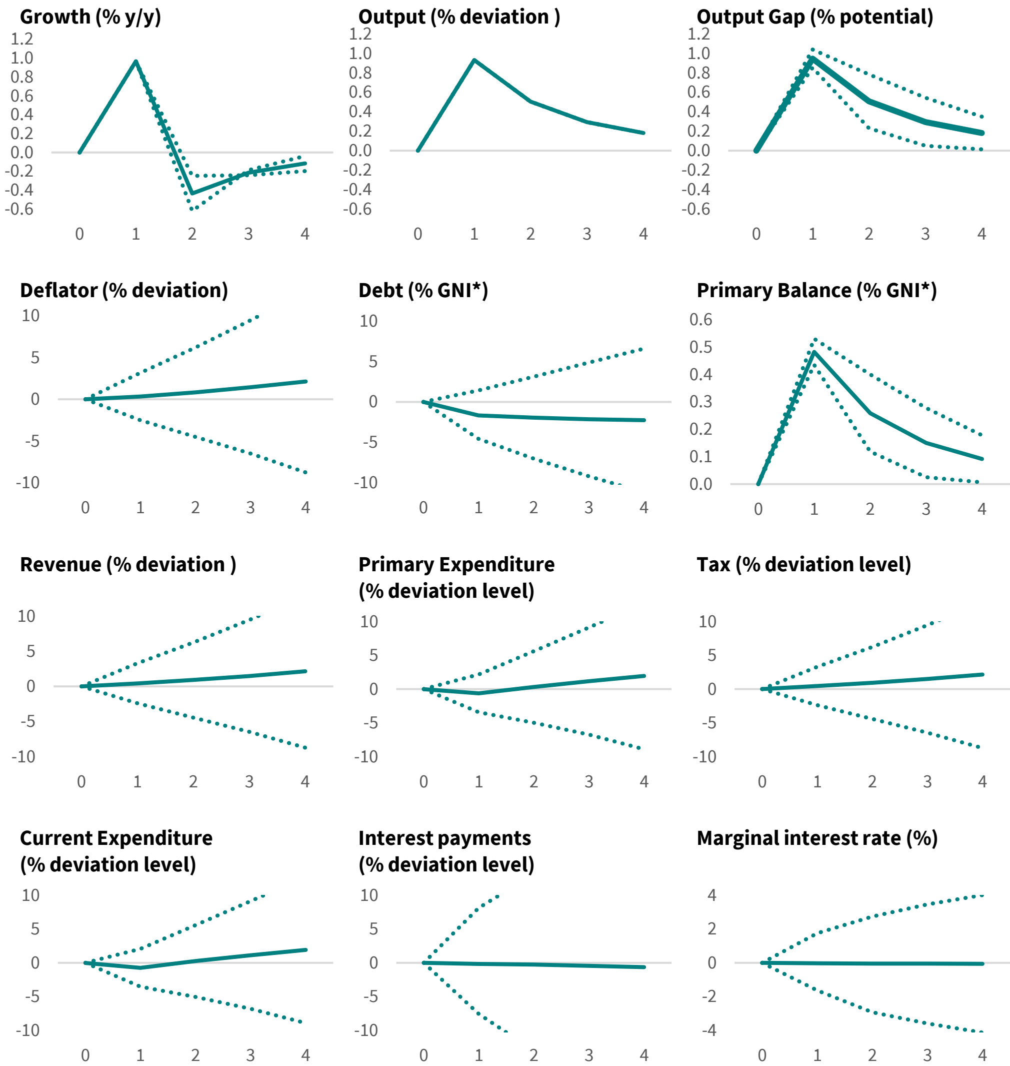
3.2 Detail of how the model works

To illustrate how the model works, we can assess the responses to various common fiscal and macroeconomic shocks.

Growth shock

The first shock we consider is a temporary positive demand growth shock of +1 percentage point for one year as might happen with a minor boost to the economy, for instance from slightly stronger demand in Ireland's trading partners. This is modelled endogenously (Figure 3).

Figure 3: Response to 1pp growth shock



Sources: Own workings.
Notes: One standard error shown for bands; bootstrapped innovations with 10,000 iterations; includes coefficient uncertainty. Periods represent years surrounding the shock, which hits in year 1.

In response to the growth shock, a positive output gap opens up. This gradually closes in line with the growth equation, reflecting the negative coefficient on the past output gap term. In turn, HICP inflation and, hence, the deflator rises slightly in response to the positive output gap. The debt ratio falls by 1.7 percentage points initially and is 2.3 percentage points lower three years after the shock. This partly reflects the improved denominator (benefiting from the shock to real growth as well as the deflator). But it also reflects the improvement in the primary balance, which is initially 0.5 percentage points but subsequently lessens as the output gap closes. The uncertainty on the debt ratio reflects uncertainty relating to (i) interest costs and (ii) inflation, which influences taxes, spending and the denominator.

Public investment shock

The second shock we consider is a temporary public investment shock. Here we assume public investment spending ($ginv_t$) is increased by an amount equal to 1 per cent of GNI* for one year (Figure 4).

The shock causes output and the output gap to increase by between 1.1 and 1.2 percentage points in year 1. The impact unwinds over the forecast horizon, though there are some lasting impacts on the level of output, which are also reflected in higher potential output.

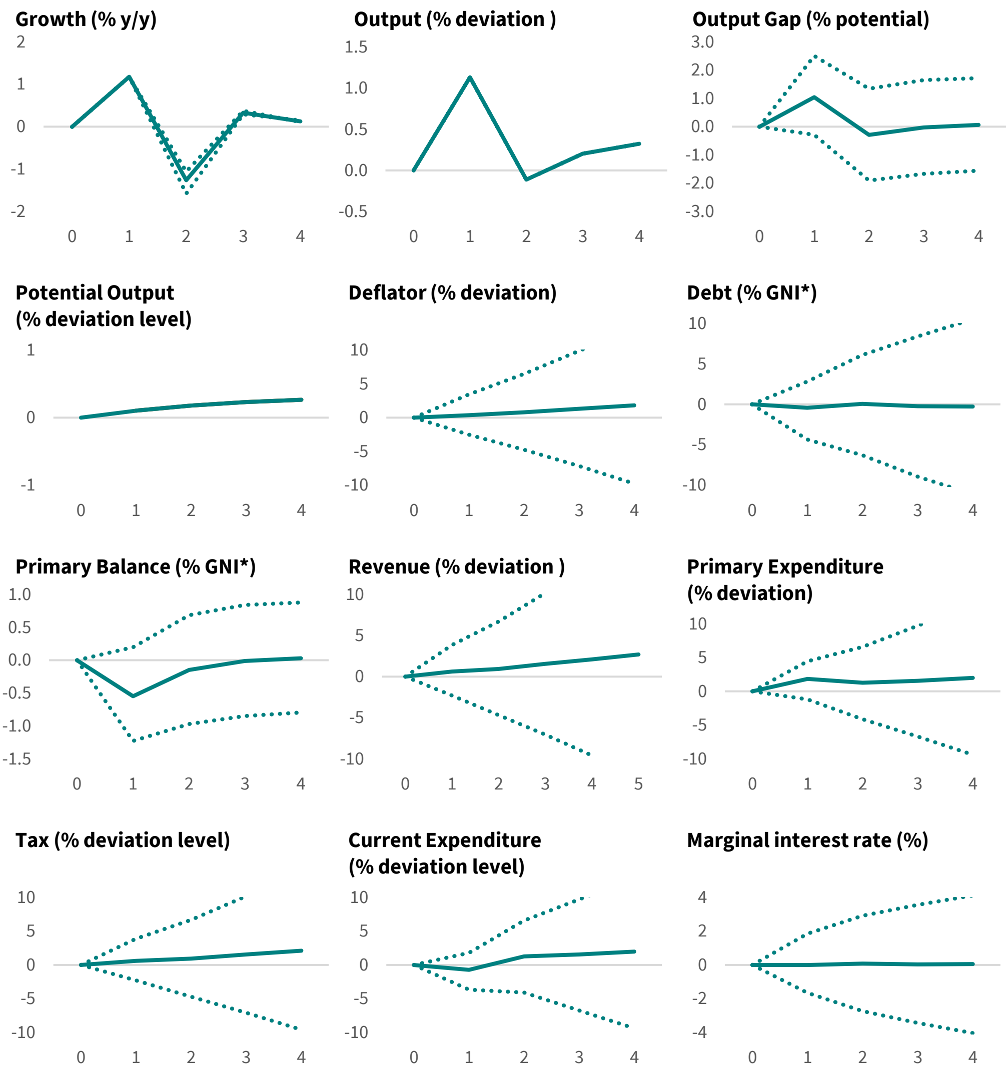
The primary balance deteriorates in year 1 when investment spending is raised, but it recovers thereafter. Revenue is marginally impacted initially, though the higher growth path results in higher revenues over the forecast horizon. This is offset by higher current spending, which is driven entirely by the rise in the price deflator (as a share of potential output, current spending is marginally lower by 0.1 percentage points).

The change in the debt ratio resulting from the temporary increase in spending is negligible, though the uncertainty bands around this are considerably wide. Similarly, the impact on interest costs and marginal interest rates are negligible.

A key result of the model illustrated in both scenarios is the large degree of uncertainty surrounding each variable.

The impact from the investment shock is immediately visible in year 1. Given that the model uses annual data, this is reasonably plausible. Though, in reality, a higher frequency model would be expected to show more of a lagged impact from a change in public investment, with impacts spread over time.

Figure 4: Response to 1% GNI* public investment shock



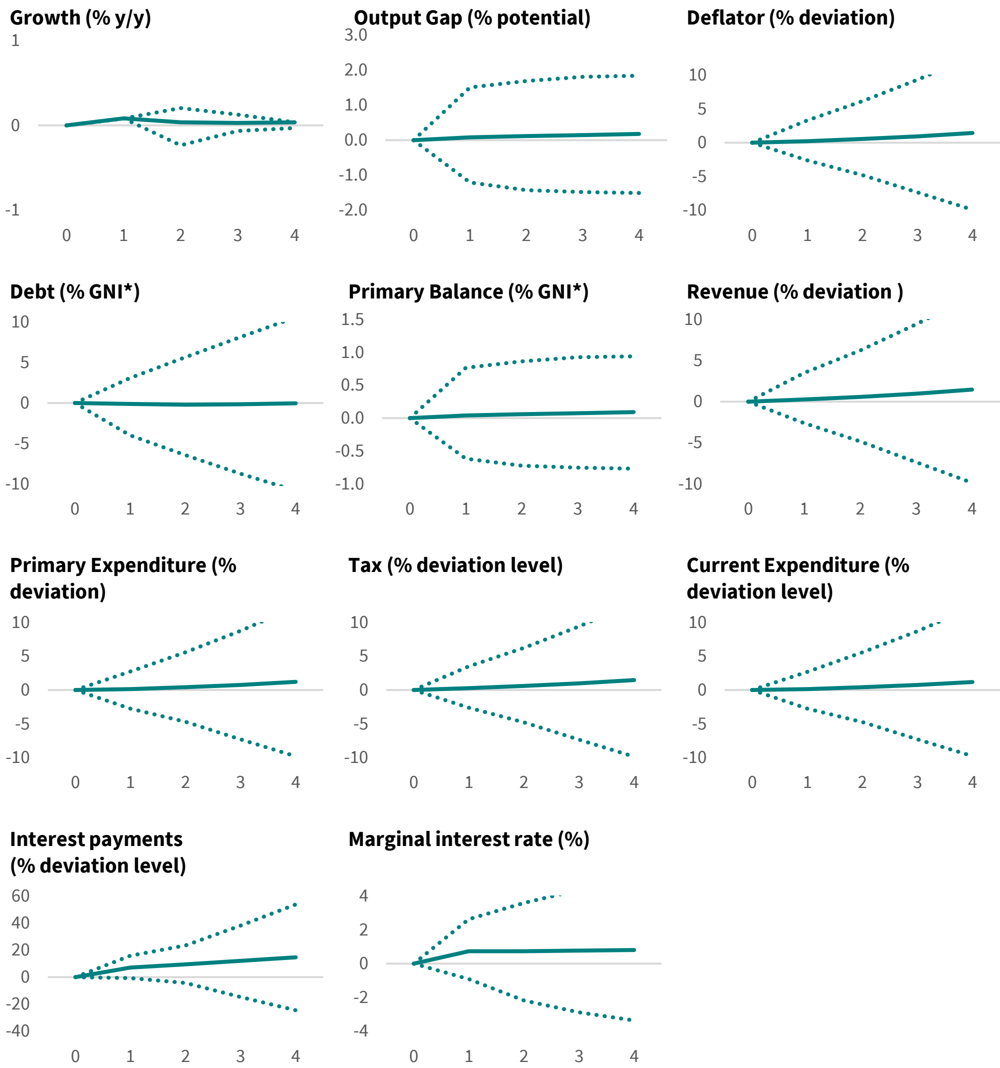
Sources: Own workings.
Notes: One standard error shown for bands; bootstrapped innovations with 10,000 iterations; includes coefficient uncertainty. Periods represent years surrounding the shock, which hits in year 1.

Interest rate shock

The next shock we consider is a shock to interest rates. We apply this at the level of policy rates, which directly influences the marginal interest rate as shown in Equation (4). Specifically, we impose a shock of +0.75 percentage points (+75bps) on the policy rate and apply this for the full forecast horizon starting in year 1 (Figure 5).

The direct result of the increase in policy rates is to (1) translate into higher marginal issuance rates applicable for new debt issuances and (2) lead to higher floating rates on existing debt securities.

Figure 5: Response to 0.75pp interest rate shock



Sources: Own workings.
Notes: One standard error shown for bands; bootstrapped innovations with 10,000 iterations; includes coefficient uncertainty. Periods represent years surrounding the shock, which hits in year 1.

We do not see a large impact on other variables arising from the increase in policy interest rates. With the model explicitly having no feedback from interest rates to growth and other areas of the public finances, this is expected.[11] As such, the

[11] Recall that our specifications of the growth equation (1) that included interest rates did not yield a statistically significant relationship.

impacts on growth, the output gap, inflation, non-interest spending and revenues are all negligible.

The Interest shock has little impact on interest costs in the short term. This is expected, given that the vast majority of Ireland's debt is fixed and at a long maturity. As such, it would take several years of an elevated marginal interest rate before the average interest rate on the debt would increase substantially. That is not to say that interest rates do not matter for debt dynamics—in the long run they are fundamental— but that for the five-year horizon we consider here the impact would not show up in a substantive way.

3.3 Stress testing

To avoid fiscal instability, Governments must have a good understanding of both their direct and contingent liabilities. The shocks presented in Section 3.1 outlined some of the direct implications of economic shocks. However, shocks to the public finances are frequently non-linear and can also happen concurrently — that is, "when it rains it pours".

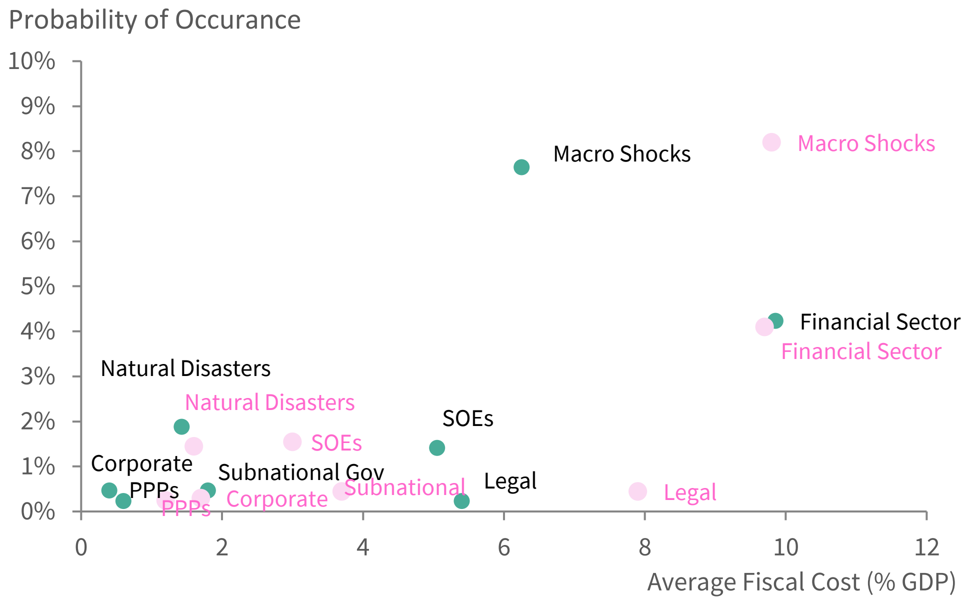
Bova *et al.* (2016) and IMF (2016) assess a variety of fiscal risks based on a comprehensive survey of 80 countries between 1990 and 2014. They find that fiscal risks are frequent occurrences, come in different forms and can tend to happen at the same time. This concurrence of various fiscal risks can put considerable strain on government finances.

A further finding by Bova *et al.* (2016) is particularly pertinent for Ireland. They show that countries with stronger institutions and low growth volatility tend to suffer less from contingent liability realizations. Ireland with its small open FDI-led economy tends to have highly volatile growth, which could amplify risks of fiscal liabilities arising — something that can be, at least partially, offset by the presence of strong institutions.

One potential use of the Maq model is to perform stress tests which allow for realisations of fiscal risks in different scenarios. A fuller stress test would allow for the possibility that fiscal risks occur at the same time. This can better inform government institutions of the debt implications of their decision making.

We adjust the dataset of Bova *et al.* (2016) and IMF (2016) to limit it to just advanced economies and to those advanced economies that are both small and highly open. This is intended to make the dataset more representative of fiscal risks facing Ireland in particular. As Figure 6 shows, this results in slight differences relative to the full dataset. For instance, macro shocks are found to have similar probabilities but relatively smaller fiscal costs for the adjusted dataset when compared to the full sample of countries. Similarly, legal cases have a relatively smaller fiscal cost for a similar probability as do costs associated with government rescues of PPP projects, private non-financial corporates, and troubled subnational (regional and local) governments.

Figure 6: Cost and probability of various fiscal risks



Sources: Bova *et al.* (2016); IMF (2016); and own workings.
Notes: Pink points show the costs and probabilities for all 80 countries in the dataset of Bova *et al.* (2016) and IMF (2016). Green points are based on a narrower set of countries, chosen to be more representative for Ireland based on three criteria: (1) "Advanced Economies" based on IMF classifications; (2) smaller economies (which we define as <50 per cent the size of the German economy); and (3) highly open economies (exports as a share of GDP > 30 per cent). This narrows the countries considered to 17 of the original 80 (AT, BE, CY, EE, FI, EL, IE, LV, LT, LU, MT, NL, PT, SK, SI, ES, CH).

What would happen the government's debt ratio if these shocks occurred simultaneously? Using the average impacts of various fiscal shocks considered above, we examine each of these shocks individually before combining them in a stress test that asks exactly that question. The full stress test is clearly an extreme scenario. Yet given the evidence that fiscal shocks can occur in proximity, it is worth considering so as to provide a comprehensive stress test.

The stress test comprises the following sub-shocks:

1. **"Growth" shock**: The IMF fiscal risks related to macro shocks underpinning Figure 5 assume a shock equivalent to one standard deviation of historical growth rates. Based on this, we shock growth by one standard deviation of the historical real GNI* growth rate over the period 2000–2019 (excluding the financial crisis years 2008–2009) for two consecutive years. This entails a growth rate shock of -3.6 percentage points per annum over two years relative to baseline growth rates. This shock is of a significant size at a cumulative impact of about 7.1 percentage points of real GNI* but it remains smaller than the shock

experienced following the global financial crisis. For context, the economy shrank by 13.5 per cent over the period 2008-2009.

2. **“Interest” shock**: A standard 2 percentage point shock is applied to the marginal interest rate on government debt over the entire forecast period.

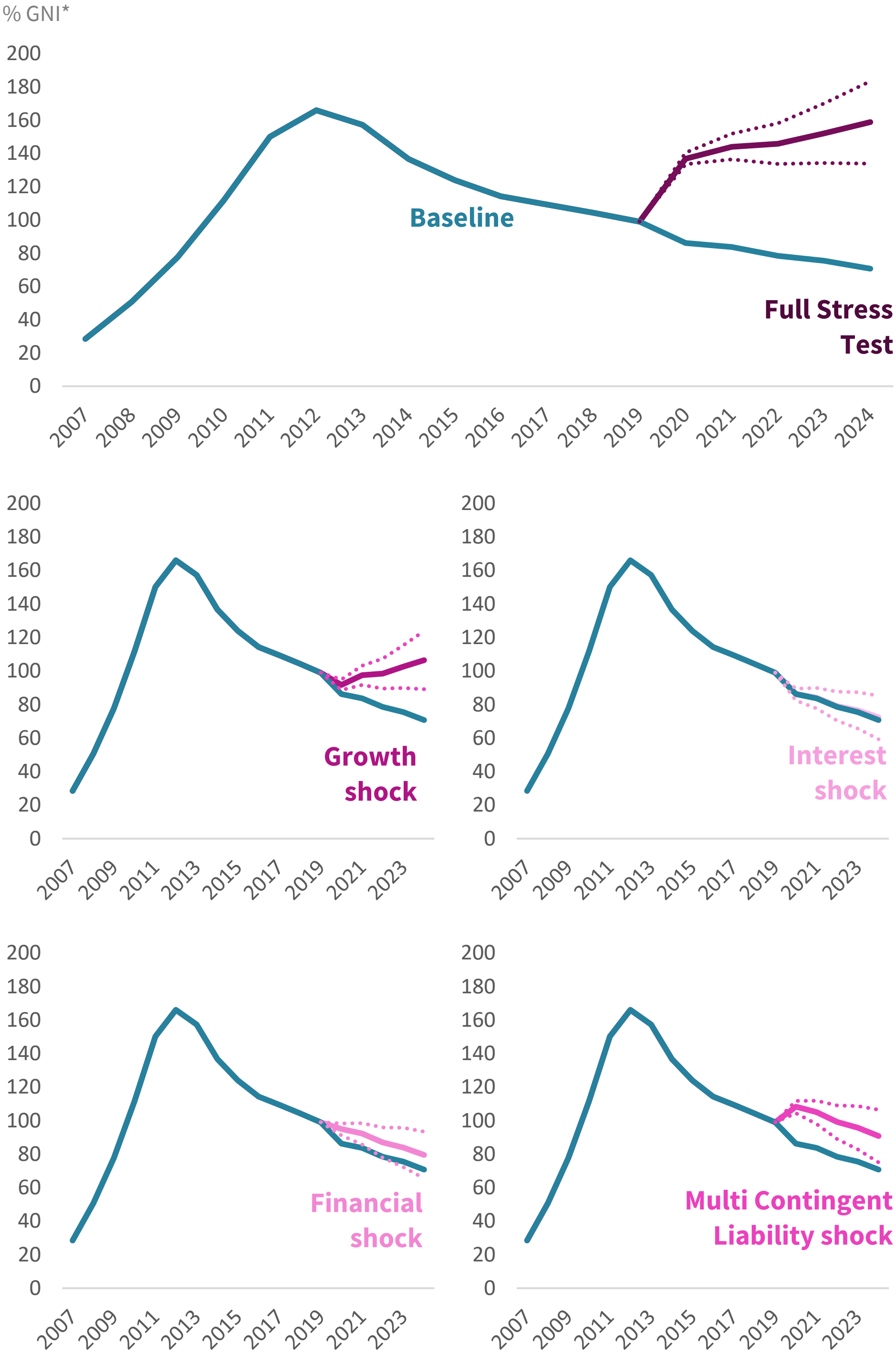
3. **“Financial sector” shock**: This shock is meant to capture the risks that a large-scale financial sector bailout materialises such that large costs are borne by the government to help stave off a financial crisis. It is modelled as a shock to expenditure one-offs that widens the general government deficit in one year by the equivalent of 10 per cent of GNI*.[12] This is in line with the average for the adjusted sample of observed fiscal risks shown in Figure 5.

4. **“Multiple Contingent Liability” shock**: This comprises the various other contingent liability shocks shown in Figure 5. Specifically, we model fiscal shocks arising from the following sources: legal claims, state-owned enterprises, subnational authorities, corporates, PPPs and natural disasters. The shock is modelled as a shock to expenditure one-offs is equivalent to 15 per cent of GNI*. This is in line with the average for the adjusted sample of observed fiscal risks shown in Figure 5.

It is important to note that these four shocks individually would be unlikely to occur in isolation. For example, one would anticipate that a financial sector shock would almost certainly have adverse macroeconomic impacts, such as those that are modelled in the growth shock. Similarly, marginal interest rates would be likely to rise in response to other adverse shocks in the absence of offsetting policy responses. Therefore, it is best to consider the individual shocks shown in Figure 7, not as an accurate representation of what might happen in these individual scenarios, but as a constituent part of the full stress test.

[12] An alternative would be to model a shock equivalent to 10 per cent of financial assets. For Ireland at end-2019, that would be equivalent to a shock of €27 billion as compared to €20 billion for a 10 per cent of GNI* shock. As an alternative, the shock could also come through on the stock-flow adjustment variable.

Figure 7: The Stress Test and its components



Sources: Own workings.
Notes: The full stress test is the combination of the individual sub-shocks shown below. One standard error bands are shown for the shocks.

Figure 7 shows the full stress test and each of the sub-shock components involved. The full stress test is shown in the first panel. It shows that in this scenario, with severe negative outcomes on all drivers, the debt ratio would be expected to rise by 38 percentage points as compared to a baseline fall of about 13 percentage points in the first year after the shock — a mammoth 51 percentage point difference. For context, the impact of the Covid-19 shock is likely to be of the order of 17 percentage points, in part helped by the fall in interest rates and absence of data of financial shocks. The error bands show the one standard error range around the shock and these put the impact at 47 to 54 percentage points. Given the official projections we use from April 2019, this results in a rise in the debt ratio from 99 per cent of GNI* to 137 per cent of GNI*. In the absence of policy action, this would put the debt ratio on a significant upward path.

Looking at the sub-shocks individually is informative:

We can see the importance of growth to debt paths in the second panel's **Growth Shock**. This leads to a sharp and persistent reversal in the debt trajectory, with revenues and, hence, the budget balance being permanently lower in level terms due to the shock.

By contrast, the **Interest Shock** is much less impactful over this horizon. This reflects the extent to which outstanding Irish debt securities are predominately fixed rate and with long maturities — a feature recognised in the Maq that translates into relatively manageable gross financing needs.

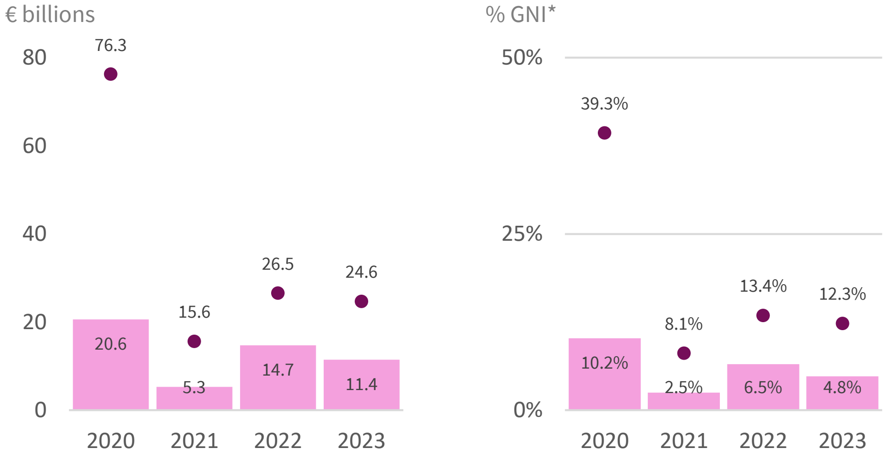
The **Financial Shock** has a considerable level impact on the debt ratio that persists over time. This amounts to about 8½ percentage points of GNI*. It's important to note that this sub-shock—as with other sub-shocks—does not reflect any growth impacts or other adverse impacts that would be expected to accompany it. Instead, these are modelled separately and are brought in as part of the full stress test.

The **Multiple Contingent Liability Shock** has similar features to the Financial Shock in that it leads to an even more substantial level shock on the debt ratio, which also persists, but does not dramatically alter the trajectory of the future debt path.

Taken together, we can see that the stress test offers a glimpse into what an extreme set of shocks to the Irish economy and public finances might look like. It also gives a sense of the uncertainty around this scenario and of the factors that drive it.

In terms of the implications for gross financing needs, we can see that the stress test results in a sharp rise initially, with smaller increases in funding requirements for subsequent years.[13] The combined shock would be estimated to lead to a drastic one-off increase in gross financing needs for the first year of the shock. This reflects the costs of severe contingent liabilities that materialise associated with the financial sector, state-owned enterprises, subnational authorities, corporates, PPPs and other areas. Figure 7 compares the baseline scenario with the stress test scenario. In the first year, gross financing needs rise sharply from about €21 billion (10 per cent of GNI*) to €76 billion (39 per cent of GNI*).[14] However, in subsequent years the funding needs increase are less severe, rising from an average of about €10 billion (4.3 per cent of GNI*) per annum to about €23 billion (11 per cent of GNI*) per annum.

Figure 7: Gross financing needs impact of stress test



Sources: Own workings.
Notes: Baseline figures are based on estimates from SPU 2019, which are pre-Covid estimates.

[13] There can be a timing discrepancy between gross financing needs and the debt raised to meet those needs. That is, issuance may not occur in the same year as the gross financing needs arise. For example, issuance in prior years can be used to fund current year's needs. Alternatively, short term money markets can be tapped to "roll" the financing need into the next year. Ireland has tended to run high cash balances as a prudent measure to ensure a smooth funding process. This pre-funded stance means issuance tends to occur before the gross financing needs. Notwithstanding this timing issue, gross financing needs are a useful metric to gauge the debt sustainability of a sovereign in the short term.

[14] Note that we assume that the additional funding needs are covered using ten-year maturity sovereign bonds at fixed interest rates.

3.4 Discussion and further work

Comprehensive stress tests and probabilistic assessments of debt paths are key tools for bodies that want to assess the sustainability of the public finances. Yet they should not be seen as a silver bullet (see Pamies Sumner and Reut, 2020 for an excellent discussion of the limitations of such approaches). This section considers some features of these tools that users should be aware of and how future work might overcome some of their limitations. In producing the Maq, we have made careful choices regarding the size and complexity of the model. But we view the Maq as a starting point for even more future development.

Results depend on the methods used

While we rely on a small-scale structural model to develop our projections, there are other ways to develop stochastic projections. The stochastic projections we produce and the stress test we apply could look very different under different methods. Alternatives used elsewhere include vector auto regressions of variables that are assumed to be stochastic.

History might not be a good guide and inputs play a big role

These frameworks require reasonably large datasets to be reliable. While we were able to obtain sufficiently long time series to produce reliable estimates, this might not be possible for other bodies that are trying to implement this approach. There is also a risk that the inputs we used might not be that representative of drivers of the economy in future. We attempt to overcome this by focusing on measures of domestic economic activity like Domestic GVA rather than GDP.

It is also important to note that historical patterns drive the results obtained in this framework. That is, the uncertainty we measure depends on the historical volatility of each variable and the correlation between variables. Yet this historical information might not be a good guide to future shocks.

For example, the multiple contingent liability sub-shock we consider incorporates the impact of natural disasters, which are based on historical observations. While this could be taken to represent some of the possible results of climate change, it might not necessarily be representative of future risks. Natural disasters associated with climate change in future might be more severe as well as being more frequent.[15]

Structural changes are also likely to cause problems for this framework. For instance, a major change in economic policy that promoted a more stable tax base could lessen the impact of growth shocks and hence make for more favourable debt paths.

Moreover, the stochastic projections may overestimate risks faced if past events or policies are judged to be more persistent than they might actually be.

Lastly, the focus of the Maq and similar debt sustainability models tends to be on more direct and easily available variables such as that captured by general government data. However, there are often other influences on debt that may reside outside of the general government sector. That is one reason why comprehensive stress tests allowing for tail risks and contingent liabilities outside of the government's balance sheet are so important.

Fiscal multipliers are uncertain and depend a lot on context

A key aspect of the Maq and of any debt sustainability model is the role of fiscal multipliers. Fiscal adjustments will likely affect economic growth. However, the affect can depend on many conditions: the economic cycle, the monetary policy stance, pre-existing debt ratios, the level of development, the exchange rate regime, and openness to trade (Ilzetzki, Mendoza and Vegh, 2013).

The Maq primarily draws on previous work on fiscal multipliers (Ivory, Casey and Conroy, 2020) to incorporate these feedbacks. It does so by using the parameters that represent the typical relationship between these variables over the cycle and in the historical context. But these parameters do not allow for changes in circumstances that might lead to stronger or weaker impacts, including for the cycle. Of course, doing so would require a more complex specification.

[15] While on the topic of climate change, there are also additional fiscal costs associated with the transition to reducing carbon dependency in countries such as Ireland that are not considered in this framework. However, these can be built into baselines and scenarios considered.

Other feedback effects are important too

The feedback between underlying variables—how they respond to changes in each other endogenously—matters greatly for how reliable estimates are. While we model many of these feedbacks in the Maq, there are other feedbacks that could prove important.

One option, which some international institutions use, is to incorporate policy responses directly. Our work currently assumes there is no policy change. Instead, a "fiscal reaction function" could be assumed. That is an explicit assumption that things like the budget balance or monetary policy, which policymakers have a lot of discretion over, will respond to changing circumstances. This might entail the modeller allowing for typical policy responses to be factored into how the model assumes shocks will play out. For example, the ESM explicitly account for debt financing decisions in terms issuance maturity when projecting debt and gross financing needs (Athanasopoulou *et al.*, 2018).

Relationships can often be non-linear, and context or time-dependent

As with many relationships between macroeconomic variables, the behaviours underpinning debt sustainability frameworks can be complex. As we note, this can be true of fiscal multipliers. It is also true of interest rates. Interest rates can be particularly sensitive to different policy regimes and market expectations can change rapidly. The assumed form of the relationship and the elasticities generated will have an important bearing on the results obtained. We attempt to recognise potential non-linearities in our marginal interest rate equation (4), with increasingly higher debt ratios leading to proportionally higher changes in interest rates. But there are other ways in which the complex relationship between marginal interest rates and macroeconomic and fiscal conditions could be modelled. This could include forward-looking factors such as projected growth rates, which may form a key input to market expectations and the pricing of debt securities.

Tractability is an important goal

It is important to ensure that debt sustainability analysis frameworks are fairly simple and transparent, given their role in policy discussions. A greater emphasis on feedback effects, developing more complex relationships between variables and producing more granular assessments of macroeconomic and fiscal impacts is an interesting way to improve models. But modellers involved in policy contexts should also seek to ensure that their tools remain tractable. Replacing simpler frameworks with more complex "black box" models might not necessarily improve the assessment. Transparency is a virtue in and of itself. These tools also serve important pedagogical roles — policymakers and users learn from observing the relationships between different variables and the relative importance of different shocks. This role can be dampened as models are made more complex.

Uncertainty is staggeringly large over longer time horizons

Some economists would go so far as to say that stochastic debt sustainability analysis should become the central tool for operationalising a revised fiscal rules framework (Blanchard *et al*., 2021). However, a key risk to basing policy and rules on such tools is the fact that they show a stark level of uncertainty for how debt ratios evolve after just a few years.

Other variables

Other variables could be useful to integrate into the model. In particular, the current account, the real exchange rate, and migration are often understood to be key channels for how the Irish economy evolves. These mechanisms also seem to be key to understanding macroeconomic imbalances in the Irish setting. Another variable that would be desirable to have interacting with output is the real interest rate. We have attempted to incorporate these in the current version of the model with little success. Initial efforts showed variables to be insignificant or there was insufficient time series data available to develop reliable indicators. However, these could still prove to be useful avenues for future model development. Another interesting extension in the Irish case could be to include house prices as function of real interest rates and income growth. Lastly, the impact on the marginal interest rate of unconventional monetary policy measures could be reflected through the inclusion of a variable such as ECB asset purchases or the size of the Eurosystem balance sheet. Our model includes standard monetary policy through the inclusion of the ECB policy rate, and the lagged term captures past changes that have reduced rates. However, unconventional monetary policy measures clearly impact government debt dynamics in ways that could be expected to change in future.

4. Conclusions

The Maq model we set out in this paper adds to the analytical capacity for assessing Ireland's debt sustainability. The Maq is at the forefront of stochastic debt sustainability techniques typically developed by other institutions for assessing risks around government debt. Importantly, we draw on many of the country-specific aspects that are important for modelling Ireland's debt dynamics.

There are many advantages to the Maq model. It incorporates a detailed interest model, with non-linearities on marginal issuance rates. The model uses calibrated fiscal multipliers based on research specific to Ireland. It also builds on bespoke measures of the Irish cycle and it focuses on the domestic economy to account for distortions linked to activities of foreign-owned multinational enterprises.

We make three key contributions to assessments of Ireland's debt sustainability with the Maq: (1) it can be used to develop sophisticated probabilistic assessments of future debt paths, (2) it can be used to explore tailored macro-fiscal shocks in detail, and (3) it can be used for comprehensive stress tests of the public finances.

Moreover, we find that the Maq provides some useful insights. The large confidence intervals produced by the Maq are indicative of the highly volatile nature of Ireland's historical debt dynamics. As we show, economic growth is a key source of this volatility. We show that the distribution of outcomes is skewed towards relatively greater risks to debt ratios rising rather than falling based on past data. While interest rate shocks pose relatively little short-term risk on their own, growth shocks can be a key driver of vulnerability.

Future work might consider ways to augment the Maq in terms of its modelling of key variables such as inflation and the nature of feedbacks between growth and budgetary outcomes. There is also scope to further develop the relationship between interest rates and more forward-looking variables.

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Appendix A

Our dataset is annual data from 1970 to 2019. The sources for the data are outlined in Table A1. Where data was not available back to 1970, we have backcast where appropriate or merged series to obtain a full dataset.

Table A1: Variables used in the Maq

€ billions unless stated

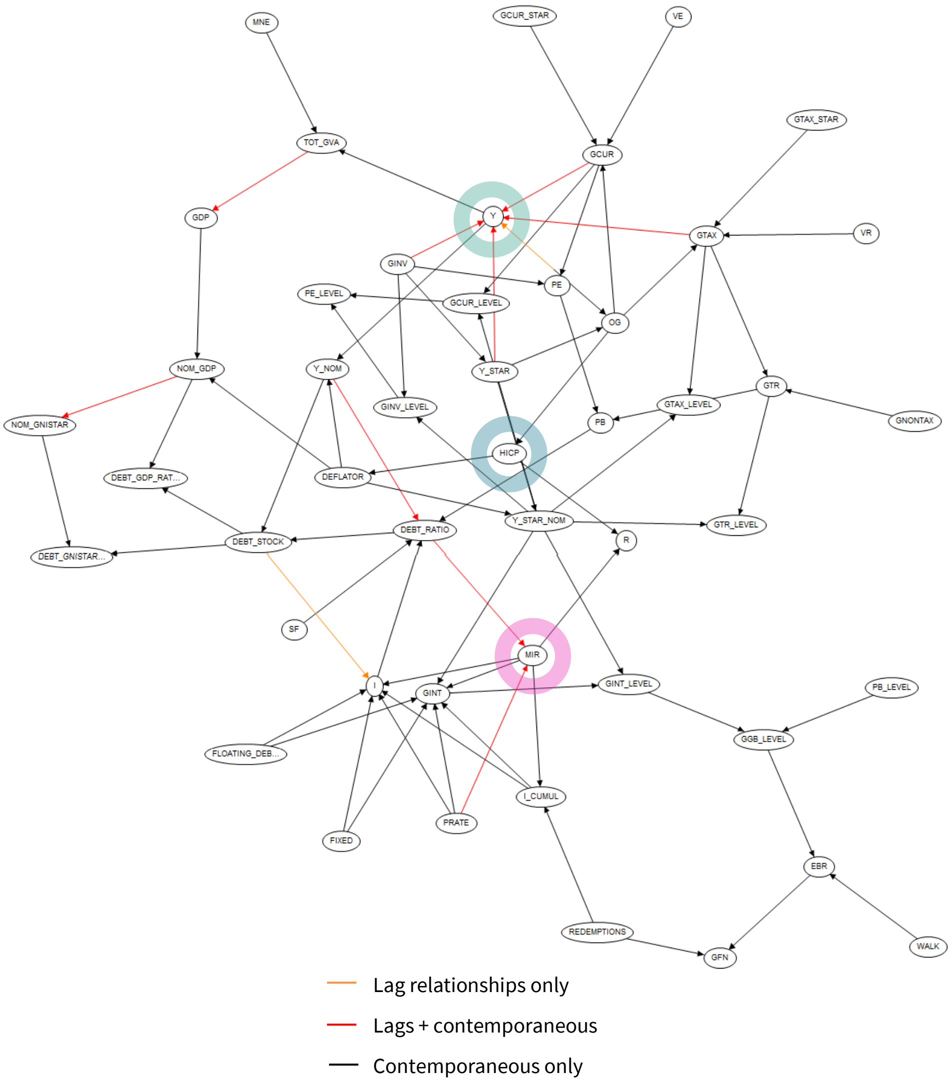
Variable	2019 value	Source
Domestic GVA	€189.4	CSO
MNE GVA	€132.7	CSO
Potential Output	€343.7	Fiscal Council
Output Gap (% potential output)	1.0	Fiscal Council
Public Investment	€8.1	CSO
Public current consumption	€73.6	CSO
Inflation (% annual rate)	1.1%	CSO
Interest Cost (average interest rate)	2.2%	NTMA/CSO
Policy Rate (%)	0.0%	ECB
Debt Stock	€204	NTMA/CSO
Primary Balance	€5.8	Fiscal Council /CSO

Table A2: Parameters used in Maq

Parameter	Value	Source
Degree of labour-market hysteresis (μ)	0.1	Botev, Fournier, and Mourougane (2016)
Elasticity of public capital in the production function (ε)	0.2	Botev, Fournier, and Mourougane (2016)
Depreciation Rate (deprec)	0.035	Calculated using data from CSO for general government depreciation (P51c) relative to Non-financial assets (NFA) for 2000-2019
Potential Output speed of convergence (δ)	-0.3	Botev, Fournier, Mourougane (2016)
Fiscal multiplier: public investment (λ_{inv})	1.1	Ivory, Casey, and Conroy (2020)
Fiscal multiplier: public current consumption (λ_{cur})	0.5	Ivory, Casey, and Conroy (2020)
Fiscal multiplier: tax (λ_{tax})	0.3	Botev, Fournier, Mourougane (2016)
Inflation target (π^T)	2.0	ECB
Steady State Domestic GVA Growth (y^*_{ss})	2.5	Fiscal Council estimate for LT potential growth
Steady State MNE Growth (MNE^*_{ss})	2.5	Assumed same as domestic economy for baseline

Appendix B

The Maq dependency graph provides a graphical representation of the relationships between model variables. Each node represents a variable. Lines are shown between pairs of related variables. The lines show the direction of information flow.



For example, in the graph above growth (Y) depends on the variable GINV (public investment), which, in turn, influences potential output (Y_star) and primary expenditure (PE). Variables may be mutually dependent, in which case there are arrows at both ends. For example, this is the case for growth and the output gap (OG) where the lagged output gap influences the current period's growth rate. If the relationship applies for lags of a variable, the line is orange. If it is a contemporaneous relationship, the line relating the two variables is black. In the case where there is both types of relationships, a red line is shown.