

Debt Projections and Fiscal Sustainability with Feedback Effects

John Creedy and Grant Scobie

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Debt Projections and Fiscal Sustainability with Feedback Effects

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Abstract

This paper analyses long-term fiscal sustainability with a model which incorporates a number of feedback effects. When fiscal policy responds to ensure long-term sustainability, these feedback effects can potentially modify the intended outcomes by either enhancing or dampening the results of the policy interventions. The feedbacks include the effect on labour supply in response to changes in tax rates, changes in the country risk premium in response to higher public debt ratios, and endogenous changes in the rate of productivity growth and savings that respond to interest rates. A model of government revenue, expenditure and public debt which incorporates these feedbacks is used to simulate the outcome of a range of fiscal policy responses. In addition the effects of population ageing and productivity growth are explored.

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Executive Summary

The provision of long-term policy advice requires projections which describe the possible paths of government debt and other related variables, under a clear set of assumptions. In New Zealand, the Public Finance Act 1989 requires the Treasury to produce a statement on the Crown's long-term fiscal position at least every four years. These statements are required to provide 40-year projections of the fiscal position. They identify challenges that are likely to face future governments, such as those arising from population ageing, and provide members of the public with information on evidence-based options for meeting those challenges.

The New Zealand Treasury has presented three Long-term Fiscal Statements and in successive reports improvements have been made to both the data and the methodology. However, an external reviewer of the 2013 Statement, suggested that the existing projections made no provision for feedbacks from the fiscal developments to the macro-economy and encouraged the Treasury to incorporate in future long-term projections plausible feedbacks arising from the growth of the debt.

The present paper therefore represents a first step in responding to this challenge. It examines long-term fiscal sustainability in the context of a modified 'bottom up' model in which a limited number of feedback effects are introduced. These may enhance or modify the intended or initial consequences of those responses. For example, tax and expenditure policy changes might be implemented to deal with a fiscal deficit. At the same time, the interest rate may vary as a result of risk premium adjustments to debt levels. This may in turn have further consequences for fiscal sustainability. The feedback effects are modelled using reduced-form specifications rather than a structural approach with explicit optimising behaviour.

Ageing populations are leading to long-term pressures on government budgets in many countries; New Zealand is no exception. In the medium term the challenge has become even more marked as countries recover from the global financial crisis and endeavour to restore their fiscal balances and reduce public debt levels. This paper develops long-term projections as the starting point for analysing options to achieve long term fiscal sustainability.

A small model is developed that captures, at a high level of aggregation, the evolution of four categories of public expenditure, revenue based on a simple income tax structure, and public debt levels. It is used to project the key outputs over a 40 year period. In the first instance the model, excluding any feedback effects, is calibrated and shown to track the long-term debt path of the highly detailed Long-term Fiscal Model used by the Treasury. Following the incorporation of a small number of feedbacks, the model is used to test the effect of policy changes with a view to achieving a net debt target of 20 per cent of GDP after 40 years. It is shown, for example, that in the case of tax changes, the presence of the feedback effects implies that a greater increase in income tax rates would be needed to achieve the same debt outcome than in their absence.

A potentially significant avenue for achieving fiscal sustainability is raising the average annual rate of labour productivity growth. However, the paper does not suggest how this might be achieved: there is no suggestion that this would be easy and it may involve other spending decisions. The model is used to demonstrate the critical importance of population ageing for fiscal sustainability. If the total size of the population were to grow at the projected rate but the age composition were to remain unchanged, fiscal sustainability would be assured without further policy responses. Reducing the rate of growth in public expenditures could lead to a sustainable fiscal position even though total absolute expenditure would continue to grow in real terms.

The present model assumes that the relevant variables are known with certainty. Furthermore, in examining alternative policies to achieve a desired debt ratio, no consideration has been given to any concept of an optimal policy response. Nevertheless the model provides a strong foundation for further extensions. In particular, incorporating uncertainty will provide a richer set of results and allow estimates of the probability that a given debt target would be reached in any given year. In addition, the model can be used, by introducing a social welfare, or evaluation, function, to examine 'optimal' government policy.

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Debt Projections and Fiscal Sustainability with Feedback Effects

1 Introduction

The provision of long-term policy advice requires projections which describe the possible paths of government debt and other related variables, under a clear set of assumptions. Indeed in New Zealand, the Public Finance Act 1989 requires the Treasury to produce a statement on the Crown's long-term fiscal position at least every four years. These statements are required to provide 40-year projections of the fiscal position. They identify challenges that are likely to face future governments, such as those arising from population ageing, and provide members of the public with information on evidence-based options for meeting those challenges.

The New Zealand Treasury has presented three *Long-term Fiscal Statements* and in successive reports improvements have been made to both the data and the methodology; see Treasury (2006, 2009, 2013a). The projection method broadly follows the most widely-used type of modelling: that is, it uses a 'bottom up' approach in which, from a given starting point, appropriate growth rates are applied to a wide range of income and expenditure categories. It uses an extensive database containing detailed population and labour force projections and is referred to as the *Long Term Fiscal Model* (LTFM).¹ Given a projected divergence between aggregate government expenditure and revenue over time, implying rising debt levels, the model can be used to consider the orders of magnitude of expenditure reductions or tax revenue increases required to achieve a specified debt target.

The projections may be described as 'mechanical', in that neither the behavioural responses of individuals nor the policy responses of governments are modelled. When reviewing the 2013 *Statement*, Ter-Minassain (2014, p. 50) suggested that:

there are several aspects of the exercise that could be improved in future LTFMs, and the Treasury should continue to refine its analytical

¹ For details, see Bell and Rodway (2014). A similar approach is adopted by the Australian Treasury (2015). Variants of this kind of procedure are also used to examine projected New Zealand social expenditures only, although allowing for stochastic elements, by Creedy and Scobie (2005) and Creedy and Makale (2014).

tools to do so. First... the non-behavioural, spreadsheet-based nature of the LTFM implies that projections do not allow for feedbacks from the fiscal developments to the macro-economy. ... it would be desirable to present, in future versions of the LTFS, scenarios with different dynamic paths of the key macroeconomic assumptions, to allow for plausible feedbacks from the growth of the debt.

The present paper therefore represents a first step in responding to this challenge. It examines long-term fiscal sustainability in the context of a modified 'bottom up' model in which a limited number of feedback effects are introduced, while a mechanical approach continues to be used for many components of the model. Policy responses to fiscal deficits, along with other endogenous responses to debt levels, have feedback effects. These may enhance or modify the intended or initial consequences of those responses. For example, tax and expenditure policy changes might be implemented to deal with a fiscal deficit. At the same time, the interest rate may vary as a result of risk premium adjustments to debt levels. This may in turn have further consequences for fiscal sustainability.

However, rather than attempting to capture all the details involved in many types of expenditure and tax, the present paper uses a more aggregative approach than the Treasury's LTFM. It distinguishes only four types of expenditure in addition to debt servicing costs, and has a very simple income tax structure together with a Goods and Services Tax (GST); other forms of tax revenue are combined into a single component. The feedback effects are modelled using reduced-form specifications rather than a structural approach with explicit optimising behaviour. The model nevertheless contains a sufficient amount of detail to enable a range of policy responses to be examined. Furthermore, careful calibration of the model produces a 'benchmark' projection of the ratio of government debt to income that closely approximates that of the Treasury's LTFM (2013c). The basic structure presented here has also been influenced by the desire in future research to introduce uncertainty into the model and to examine optimal policies to achieve sustainability, requiring a specified evaluation function.

Faced with a set of revenue and expenditure projections implying an increase in debt over a specified time period, a range of fiscal sustainability or solvency indicators can be produced, based on manipulations of the government multi-period budget constraint. The many issues involved in assessing sustainability and the

required adjustments in the face of projected debt growth are discussed by Buckle and Cruickshank (2014) in the New Zealand context.² Basic measures include the increase in the fiscal balance (the difference between revenue and expenditure including debt interest charges) in each year, expressed as a proportion of GDP, needed for the present value over an infinite horizon of surpluses to cover the current debt. Alternatively, a less restrictive measure is the increase in the fiscal balance (again as a proportion of GDP) needed to attain a specified debt target by the end of the projection period. In European Commission (2006), the first measure is denoted S2 and the second, involving a debt ratio of 60 per cent of GDP by 2050, is referred to as S1.³

These approaches are acknowledged to provide only an indication of the risk facing a country, and do not pretend to offer an optimal response. In addition, the measures ignore the time path of debt, since they relate to a required constant (relative) increase in the fiscal balance each period. The time profile may itself have consequences which raise important policy concerns. Furthermore, no consideration is given to how attainable the alternative objectives may be, and which policy instruments might be used. By contrast, the present paper considers explicit policy variations needed to achieve a specified fiscal balance at the end of the projection period.

The basic model is set out in Section 2. Feedback and other endogenous effects are added in Section 3. Benchmark calibration values are described in Section 4. Benchmark projections are presented in Section 5, where it is shown that, in the absence of feedback effects, where expenditure items are assumed to grow at specified fixed rates and tax rates are unchanged over time, the model can closely approximate the projections obtained by the Treasury's LTFM.

Having described the model, policy simulations are reported in Section 6. In the benchmark simulations, the main difference between the model with and without feedback effects arises as a result of the rising risk premium, and hence debt servicing costs, as the debt ratio increases. However, unlike a number of other countries, the debt ratio in New Zealand is not projected to increase to the levels that generate very large increases in the risk premium. Other feedbacks are

² Early definitions and measures were proposed by Blanchard *et al.* (1990). For a non-technical discussion of issues, see Schick (2005). The approach adopted by the European Union is set out in detail in European Commission (2006). For an example of its use, see also Kleen and Pettersson (2012). A recent review of approaches is by Pradelli (2012).

³ See Appendix B for further details of these measures.

largely absent because growth rates are held constant and there are no tax policy changes. Of interest are cases where expenditure and tax policy changes are imposed with particular objectives in mind. For example, if the income tax or indirect tax rates are increased, or various expenditure growth rates are reduced in an attempt to control the extent of the debt increase, other feedback effects play a more significant role. Conclusions are in Section 7.

2 The Basic Model

This section provides a description of the main components of the model. As explained in the introduction, the aim is to construct a model that is capable of projecting the paths of government revenue and expenditure, and therefore debt, under a range of assumptions and feedback effects. To make the model as transparent as possible, a high level of aggregation is used. It is clearly necessary to allow demographic variations in both population size and its age composition to influence government expenditure and revenue. While detailed demographic projections are used, distinctions are drawn only between those of working age, retirement age and those below working age. To provide an easy reference to variables in the model, Table 1 provides a list with brief definitions.

2.1 Government Expenditure and Debt

Given that a primary concern is with fiscal sustainability and with policies designed to achieve sustainability, the evolution of government debt plays a crucial role in the model. Let D_t denote debt at the end of time period, t , for $t = 1, \dots, T$, where D_0 is the debt inherited from the past and D_T^* is the target debt level for the end of the planning period, T . If r_t is the domestic interest rate at time t , equivalent to the government bond rate, then the debt servicing cost at time t , denoted d_t , is given by:⁴

$$d_t = r_t D_{t-1} \quad (1)$$

⁴ This form is appropriate in the present discrete-time model. However, the NZ Treasury LTFM allows for debt to build up steadily during each year.

Table 1: List of Variables

Symbol	Definition
D_t	Debt at time t , for $t = 1, \dots, T$
DR_t	Debt ratio: $D_t/Y_{A,t}$
D_T^*	Target debt level for time T
d_t	Debt service charge at t : $d_t = r_t D_t$
r_w	World interest rate
$r_{p,t}$	Risk premium at t
r_t	Domestic interest rate: $r_t = r_w + r_{p,t}$
$W_{B,t}$	Untaxed welfare (benefit) payments at t
$W_{B,t}^*$	Welfare payment per person
$W_{S,t}$	Superannuation payments (net of tax) at t
$W_{S,t}^*$	Superannuation payment (net of tax) per retired person
W_t	Total welfare spending at t : $W_t = W_{B,t} + W_{S,t}$
$E_{I,t}$	Government spending on health and education at t
$E_{I,t}^*$	Health and education spending per person
$E_{O,t}$	Other government expenditure at t
$E_{O,t}^*$	Other expenditure per person
E_t	Aggregate non-welfare expenditure at t : $E_t = E_{I,t} + E_{O,t}$
G_t	Total government expenditure at t : $G_t = W_t + E_t + d_t$
$\dot{\rho}_t$	Change in productivity growth rate at t
ρ_B	Base productivity growth rate
ρ_t	Productivity growth rate at t : $\rho_t = \rho_B (1 + \dot{\rho}_t)$
$Y_{P,t}$	Potential income from labour and capital rental at t
L_t	Ratio of income to potential income
Y_t	Income at t : $Y_t = L_t Y_{P,t}$
$Y_{A,t}$	Aggregate income at t : $Y_{A,t} = Y_t + \text{interest income}$
K_t	Stock of accumulated savings at t
S_t	Aggregate savings at t
s_t	Propensity to save (from disposable income)
τ_t	Income tax rate at t
v_t	Tax-exclusive GST rate at t
τ_t^*	Effective tax rate at t : $\tau_t^* = \tau_t + v_t \frac{(1-s_t)(1-\tau_t)}{(1+v_t)}$
V_t	Indirect tax (GST) revenue at t
R_t	Total tax revenue at t
$R_{O,t}$	Other (non-tax) government revenue at t
$R_{O,t}^*$	Other expenditure per capita at t
$N_{B,t}$	Number of benefit recipients at t
$N_{S,t}$	Number of superannuation recipients at t
$N_{W,t}$	Number of workers at t
N_t	Total population at t

The interest rate depends on the world interest rate, r_w , which is assumed to be constant, and a risk premium, $r_{p,t}$. Thus:

$$d_t = (r_w + r_{p,t}) D_{t-1} \quad (2)$$

In addition to debt servicing costs, government expenditure includes welfare spending, W_t , which consists of two components. There are transfer payments (welfare benefits) of $W_{B,t}$, received by non-pensioners, and aggregate superannuation benefits of $W_{S,t}$ received by pensioners.⁵ Hence:

$$W_t = W_{S,t} + W_{B,t} \quad (3)$$

The levels per person are denoted $W_{S,t}^*$ and $W_{B,t}^*$, so that if $N_{S,t}$ and $N_{B,t}$ denote the number in receipt of the pension and welfare benefits respectively, $W_{S,t} = N_{S,t}W_{S,t}^*$ and $W_{B,t} = N_{B,t}W_{B,t}^*$.

All other spending at t is denoted by E_t . This is composed of spending on publicly-provided goods such as health and education, $E_{I,t}$, and other expenditure, $E_{O,t}$, which includes, for example, core government services, law and order and defence: hence $E_t = E_{I,t} + E_{O,t}$. The former may be considered as investment in human capital, while the other expenditure has no direct impact on individuals. As explained below, $E_{O,t}$ is assumed to have no direct impact on the labour supply, and thus incomes, of individuals. While $E_{I,t}$ does not have a direct impact, it influences income via its effect on productivity growth. Variations in these spending categories are produced by variations in per capita amounts, $E_{I,t}^*$ and $E_{O,t}^*$ and variations in the total population, N_t : hence $E_t = N_t (E_{I,t}^* + E_{O,t}^*)$.

Total government expenditure, G_t , is thus:

$$\begin{aligned} G_t &= W_t + E_t + d_t \\ &= W_t + E_t + r_t D_{t-1} \end{aligned} \quad (4)$$

Define R_t as total tax revenue from direct and indirect taxes: this is considered in more detail below. The debt in t is thus given by:

$$D_t = D_{t-1} + G_t - R_t \quad (5)$$

Substituting (4) into (5) gives:

$$D_t = (1 + r_t) D_{t-1} + W_t + E_t - R_t \quad (6)$$

⁵ New Zealand Superannuation is taxable, as are most of the working-age transfer payments. This is allowed for in the calibration of the model, discussed below, which uses net-of-tax values.

Continual substitution gives the long-term government budget constraint as:

$$D_t = D_0 \prod_{j=1}^t (1 + r_j) + (W_t + E_t - R_t) + \sum_{j=1}^{t-1} \left[(W_j + E_j - R_j) \prod_{i=j+1}^t (1 + r_i) \right] \quad (7)$$

The simpler form of this budget constraint, for the case where the rate of interest is constant, is used in Appendix B to examine the annual increase in the fiscal balance, $R_t - G_t$, as a ratio of GDP, needed to achieve a target debt ratio by a given year.

2.2 Income Generation

For the calculation of tax revenues, it is necessary to obtain the time profile of aggregate income, denoted $Y_{A,t}$ at time t . This is the sum of incomes arising from labour and (capital) rental income, Y_t , and interest income from financial savings. The model makes no attempt to treat the production side of the economy explicitly. The model thus contains no explicit wage rate, nor does it deal with labour and capital inputs into production.⁶ A base level of productivity is taken as exogenously given and, as explained below, productivity changes can arise from growth in public expenditure on health and education per person, which is considered to augment human capital.

First, define $Y_{P,t}$ as total ‘potential income’ in period t . To allow for productivity growth at the rate ρ_t , write:

$$Y_{P,t} = (1 + \rho_t) Y_{P,t-1} \quad (8)$$

Let L_t indicate the ratio of actual to potential income, so that aggregate income can be written as:

$$Y_t = L_t Y_{P,t} \quad (9)$$

Hence L_t captures all possible incentive effects. The specification of L_t is described in the following section.

Interest income then needs to be added. Assume that all forms of income are taxed at the same rate. Then if S_t denotes aggregate financial savings at time,

⁶ The high level of aggregation also means that the model cannot deal with a changing composition of output and any relative price changes which may result from population ageing and government policy.

t , as defined above, these are all assumed to be invested at the going rate, r_t . Letting financial capital be denoted K_t , then:

$$K_t = K_{t-1} + S_{t-1} \quad (10)$$

As this refers to the accumulation of financial savings, no depreciation is applied. As discussed above, the production side of the economy, including investment and capital accumulation, is not modelled explicitly. Hence aggregate income is:

$$Y_{A,t} = Y_t + r_t K_{t-1} \quad (11)$$

For simplicity, this assumes that the borrowing and lending rates are equal, and the same both for the government and individuals, and the return to investment is equal to the domestic rate of interest.

The above specification can easily be augmented to allow for population growth. A simple adjustment is made by raising $Y_{A,t}$ by a proportion that depends on the growth rate, from period $t - 1$ to t , of the population above working age.

2.3 Tax Revenue

No attempt is made here to model the complexity of the tax and transfer system. Suppose that income tax is simply a constant proportion, τ_t , of taxable income. Income tax revenue is thus easily obtained as $\tau_t Y_{A,t}$. Tax revenue is also obtained from indirect taxes. Define V_t as indirect tax revenue at t , from a GST/VAT type of system, where v_t is the tax-exclusive rate applied to all expenditure. However, indirect taxes applied to E_t are ignored here since these are netted out in the government's budget constraint. The tax-inclusive indirect tax rate is $v_t / (1 + v_t)$.

First, it is necessary to obtain expenditure, inclusive of indirect tax. Savings, S_t , are made from net income. Assume that all transfer payments, W_t , are consumed. Then if savings are a constant proportion, s_t , of post-tax income:

$$S_t = s_t (1 - \tau_t) Y_{A,t} \quad (12)$$

Indirect tax is thus:

$$V_t = \left[\frac{v_t (1 - s_t) (1 - \tau_t)}{1 + v_t} \right] Y_{A,t} + \left[\frac{v_t}{1 + v_t} \right] W_t \quad (13)$$

Total tax revenue, R_t , consists of income tax, plus V_t , plus other revenue, $R_{O,t}$. The latter is specified as an amount per capita, $R_{O,t}^*$, which is subject to an

exogenous growth rate, along with growth arising from the increase each period in the population above working age. In considering the second term in (13), $W/(1+v)$, can be regarded as the tax-exclusive value of expenditure, on which the tax-exclusive rate, v , is levied.

Total revenue is thus:

$$R_t = \tau_t Y_{A,t} + V_t + R_{O,t} \quad (14)$$

Substituting for V_t from (13) gives total revenue as:

$$R_t = \tau_t^* Y_{A,t} + \left[\frac{v_t}{1+v_t} \right] W_t + R_{O,t} \quad (15)$$

where τ_t^* is the overall effective proportional income tax rate, given by:

$$\tau_t^* = \tau_t + v_t \frac{(1-s_t)(1-\tau_t)}{(1+v_t)} \quad (16)$$

The term, $(1-s_t)(1-\tau_t)/(1+v_t)$, reflects the tax-exclusive expenditure arising from an extra dollar of gross income. This is subject to indirect tax at the tax-exclusive rate, v_t . Hence τ_t^* reflects the combined effect of the income and consumption tax rates.

3 Feedback Effects

This section describes feedback effects involving the risk premium, savings, incentives and productivity growth. In each case simple reduced-form specifications are adopted rather than attempting to introduce microfoundations into the model. Given the absence of an explicit production function, the wage rate is not endogenous and, with only aggregate output modelled, there are no relative price effects. The model does not have an explicit role for the exchange rate (which also affects relative prices), and its possible connections with the debt ratio and the interest rate risk premium.⁷ In addition, there is no mechanism for the real interest rate to influence investment and, via this effect, the growth rate.⁸ Tax-financed government expenditure has no direct stimulus effect on the real economy except that, as discussed below, the expenditure on health and education is treated as affecting human capital and thus productivity.

⁷ One possible extension may be to distinguish between traded and non-traded goods, which have different capital intensities. Government expenditure may be considered to be mainly on non-traded goods. For a model using this distinction, see Guest and Makin (2013).

⁸ Furthermore, investment affects capital intensity and thus wage rates, which in turn affect labour supply. This potential feedback is thus excluded from the present model.

The model thus contains only a limited number of possible feedbacks, given the aim of taking an initial step towards introducing endogeneities and linking policy responses to particular policy instruments. Furthermore, the model provide the basis for possible extensions, in particular the introduction of uncertainties and the investigation of optimal policies.

3.1 The Risk Premium

Interest rates in New Zealand typically appear above those in comparator countries. This differential is widely attributed to the presence of a risk premium. Foreign investors in securities denominated in New Zealand dollars demand a margin above the world rate. Burnside (2013) attributes this compensation to the possibility of a depreciation of the New Zealand dollar following a rare and extreme event. The higher is the ratio of public debt to GDP, the more vulnerable the New Zealand economy is to some unexpected event and the greater the risk of a devaluation. Baldacci and Kumar (2010), using a panel of 31 countries for the years 1980 to 2008, find that ‘higher fiscal deficits and public debt raise long-term nominal bond yields in both advanced and emerging markets’ (2010, p. 13). They report that typically ‘an increase in the debt ratio of 1 percentage point of GDP leads to an increase in bond yields of around 5 basis points’. In an analysis of an extreme event, Gereben *et al.* (2003, p. 3) estimate that an outbreak of foot and mouth disease could raise the net public debt by approximately 10 percentage points after 5 years, with an associated ‘50 basis point increase in the risk premium on New Zealand dollar assets, as a result of foreign investors becoming more reluctant to invest in New Zealand in times of high uncertainty’.

A number of studies have made estimates for New Zealand. Hawkesby *et al.* (2000) examine the interest rate differential between New Zealand and Australia and the United States. They decompose the differentials into expected currency movements, default and liquidity risks, and unexpected currency movements. They estimate that the 10 year currency risk premium is between and 1 and 2 percentage points relative to the USA.

For the present model, it is assumed that the risk premium at time t is a function of $D_{t-1}/Y_{A,t-1} = DR_{t-1}$. Ostry *et al.* (2010) show how the cost of borrowing typically rises with higher debt levels. However, their evidence suggest that the risk

premium increases only slowly for relatively small values of this ratio, but increases rapidly once it exceeds about 1.5.⁹

A specification that can capture this kind of relationship is the following. For DR_{t-1} above a threshold, DR^* , the following quadratic applies:

$$r_{p,t} = \theta_1 + \theta_2 DR_{t-1} + \theta_3 (DR_{t-1})^2 \quad (17)$$

and for $DR_{t-1} \leq DR^*$, the premium increases linearly:¹⁰

$$r_{p,t} = \theta_1 + \theta_2 DR^* + \theta_3 (DR^*)^2 - \theta_0 (DR^* - DR_{t-1}) \quad (18)$$

The response to increasing debt ratios therefore produces a rise in the risk premium, which has a further consequence for debt as a result of the higher interest cost involved in servicing the debt. Hence this type of endogeneity has important consequences for the evolution of debt. However, there are additional consequences as a result of the influence, directly and indirectly, of changes in the interest rate.

3.2 The Saving Rate

A further possibility is to suppose that the saving rate, s_t , depends on the interest rate. In principle this effect is ambiguous, but in the simulations reported below it is assumed (in the 'benchmark case') that the interest-elasticity of savings is small but positive. This is reflected in a reduced-form relationship between s_t and r_t , with $ds_t/dr_t > 0$. For simplicity, suppose:

$$s_t = \theta_{11} + \theta_{12} r_t \quad (19)$$

where parameters, θ_{11} and θ_{12} are both positive. With a fixed world interest rate of r_W , the domestic rate, r_t , varies according to the risk premium, $r_{p,t}$, which depends on the debt ratio, as discussed above. A higher debt ratio may also lead to a Ricardian adjustment in the form of increased savings, if the higher debt were to create expectations of higher future tax rates; but this is not modelled explicitly here.¹¹

⁹ The response of the risk premium to debt ratios in New Zealand is also discussed by Fookes (2011, p. 11) in the context of a scenario analysis of shocks to New Zealand's fiscal position.

¹⁰ This specification is used to ensure that there is no discontinuity between the two segments.

¹¹ For a review of Ricardian equivalence, see Seater (1993). Similarly, the model does not allow for a possible effect on savings of changes in government expenditure (particularly adjustments to the growth of superannuation and other welfare spending per person).

An increasing debt ratio therefore not only leads to a rise in the interest rate, which increases debt repayment costs, but also to a direct effect on the savings rate. The savings rate enters into the determination of the effective tax rate, τ_t^* , as shown in (16). A higher savings rate reduces the effective tax rate, thereby reducing revenue in the relevant period.¹² This revenue-reducing effect therefore slightly reinforces the increase in debt over time.

3.3 Incentive Effects

An indirect effect of the endogeneity of the risk premium, which has the effect of raising the savings rate above what it would otherwise be, and hence reducing the effective tax rate, is that the tax rate influences taxable income as a result of incentive effects. In view of the need to consider responses to changes in government tax policy, designed to achieve a desired debt target, it is therefore important to allow for incentive effects.

Suppose the variable, L_t , is a function of the tax rate, so that $L_t = L(\tau_t^*)$, with $dL_t/d\tau_t^* < 0$.¹³ As explained above, this function reflects the extent to which income deviates from its potential. Suppose the elasticity of taxable income, defined with respect to the effective net-of-tax rate, $1 - \tau_t^*$, is constant. Then:

$$L(\tau_t^*) = \theta_8 (1 - \tau_t^*)^{\theta_9} \quad (20)$$

This is consistent with literature on the elasticity of taxable income, which combines a range of adjustments in a reduced-form expression similar to (20). This assumes there are no income effects and the elasticity of L with respect to the net-of-tax rate, $1 - \tau_t^*$, is constant at θ_9 .¹⁴

When the debt ratio is increasing, the endogeneity of both the risk premium and the savings rate means that taxable income is somewhat higher than otherwise because the effective tax rate falls. There is thus a ‘tax rate’ effect and two ‘tax base’ effects, moving in opposite directions: a higher debt ratio leads to a higher rate of interest, which raises the savings rate, leading to a fall in the tax base (via

¹² The future tax payments arising from any dissaving is ignored here. It is the aggregate saving rate which varies over time, not the rate in a life-cycle framework.

¹³ Kleen and Pettersson (2012) include labour supply effects using an elasticity of the employment ratio with respect to the tax rate. They also assume that productivity falls slightly as labour force participation increases (on the argument that the new entrants to the labour force resulting from a tax cut are relatively less productive).

¹⁴ For New Zealand estimates and further references to the literature, see Carey *et al.* (2015).

the effect on GST) but also a fall in the effective tax rate, leading to a rise in the tax base (via the effect on work incentives).

3.4 Productivity

Investments in the quality of human capital through both health and education can enhance productivity.¹⁵ Earle (2010, p. 1) argues that, for New Zealand, ‘there is evidence that increases in tertiary education have contributed to productivity growth’. This is reinforced by the work of Razzak and Timmins (2010) who found that university qualifications had a positive effect on average economy-wide productivity.¹⁶ Similarly, there is evidence that health effects productivity through various channels. Bloom *et al.* (2001) found that good health has a positive, sizeable, and statistically significant effect on economic growth. Bloom and Canning (2003) treat health as part of human capital and assess its impact on economic performance. In subsequent work, Bloom and Canning (2005) find that for developing economies a one percentage point increase in adult survival rates increases labor productivity by about 2.8 percent.

To capture these effects in the present model, suppose that changes in the productivity growth rate, ρ , depends on previous growth of the per capita public expenditure component, $E_{I,t}^*$, since this includes education and health expenditure.¹⁷ The change in ρ depends on the change ℓ years previously, that is in $E_{I,t-\ell}^*$. This is assumed to be subject to decreasing returns. Hence if a dot above a variable indicates a proportionate change, with for example, $\dot{E}_{I,t-\ell}^* = (E_{I,t-\ell}^* - E_{I,t-\ell-1}^*) / E_{I,t-\ell-1}^*$, then:

$$\dot{\rho}_t = \frac{\theta_4}{1 + \theta_5 \theta_6 \dot{E}_{I,t-\ell}^*} \quad (21)$$

This logistic form captures decreasing returns, such that the change in productivity

¹⁵ The Treasury (2013b, p. 21) suggests that, ‘increasing levels of qualifications should have a positive impact on labour market productivity’.

¹⁶ In the US context, Jorgenson and Stiroh (2000) found improvements in the quality of labour accounted for nearly 15 percent of labor productivity growth for the period 1959-98.

¹⁷ In a wide-ranging review of possible productivity effects of population ageing Guest (2014, p. 165) concluded that it ‘could affect productivity through a number of mechanisms. But the magnitude and even direction of some of these effects are unclear in theory and evidence’. Infrastructure spending, not considered separately here, may also be growth enhancing.

growth is a decreasing function of the change in public expenditure.¹⁸ Hence, if ρ_B is a 'base level' of productivity change:

$$\rho_t = \rho_B (1 + \dot{\rho}_t) \quad (22)$$

If $E_{I,t}^*$ grows at a constant rate over time, so that $\dot{E}_{I,t-\ell}^*$ is constant for all t , productivity growth remains constant. A response to the anticipated debt increase which involves cutting the rate of growth of per capita expenditure on health and education therefore has the effect of slowing down the growth of incomes somewhat. Hence tax revenue would be lower than without this feedback effect.¹⁹

4 Calibration of the Model

The first step in using the model is to specify time profiles for the expenditure components, E and W , along with starting values for the various revenue and debt variables. Despite the 'simplicity' of the model, suitable orders of magnitude of many of the variables can be obtained from National Income data and demographic projections. The data sources and values are set out in detail in Appendix A. Parameter values used for the various functions are listed in Table 2.

Figure 1 illustrates the implications for the risk premium of the benchmark calibration values. An increasing debt ratio produces modest steady increases in the risk premium until the debt ratio exceeds 100 per cent of GDP (since $DR^* = 1$). An increase in the debt ratio of 100 percentage points from 50 to 150 per cent of GDP is associated with a rise in the risk premium of 50 basis points: this is consistent with findings of Baldacci and Kumar (2010). The effect on productivity changes of increases in the growth of health and education expenditure are shown by the sigmoid form taken by the logistic curve in Figure 2.

¹⁸ It may, in addition, be thought that productivity change may be influenced by changes in the interest rate. However, this effect is likely to come via possible higher investment resulting from reductions in the interest rate. The elasticity of ρ with respect to r can be expressed as the product of the elasticity of ρ with respect to investment, and the elasticity of investment with respect to the interest rate. The overall effect is likely to be very small, and is therefore ignored here.

¹⁹ It is not necessary here to consider all determinants of productivity, only the potential influence of relevant variables contained within the model. Other influences would included, for example, international connectedness and knowledge-based capital. Since the production side is not modelled here, productivity growth can be regarded as total factor productivity growth, or either labour or capital augmenting.

Table 2: Benchmark Parameter Values

<i>Risk premium: For $D_{t-1}/Y_{A,t-1} > DR^*$, $r_{p,t} = \theta_1 + \theta_2 DR_{t-1} + \theta_3 (DR_{t-1})^2$</i>	
<i>For $D_{t-1}/Y_{A,t-1} \leq DR^*$, $r_{p,t} = \theta_1 + \theta_2 DR^* + \theta_3 (DR^*)^2 - \theta_0 (DR^* - DR_{t-1})$</i>	
θ_0	0.026
θ_1	-0.03
θ_2	0.015
θ_3	0.0015
DR^*	1.0
<i>Productivity growth changes: $\dot{\rho}_t = \theta_4 / \left(1 + \theta_5 \theta_6^{E_{t,t-\ell}^*} \right)$</i>	
θ_4	0.6
θ_5	35
θ_6	0.00005
ρ_B	0.015
ℓ	5
<i>Incentive effects of taxation: $L(\tau_t) = \theta_8 (1 - \tau_t^*)^{\theta_9}$</i>	
θ_8	1.0
θ_9	0.5
<i>Saving rate: $s_t = \theta_{11} + \theta_{12} r_t$</i>	
θ_{11}	0.03
θ_{12}	0.0833

Figure 1: Risk Premium and Debt Ratio

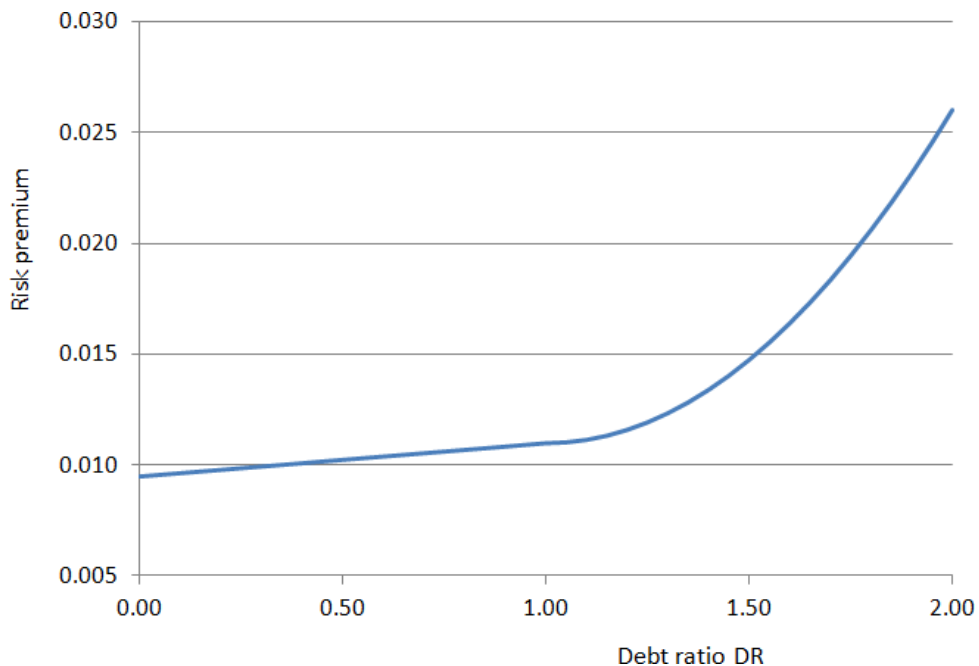
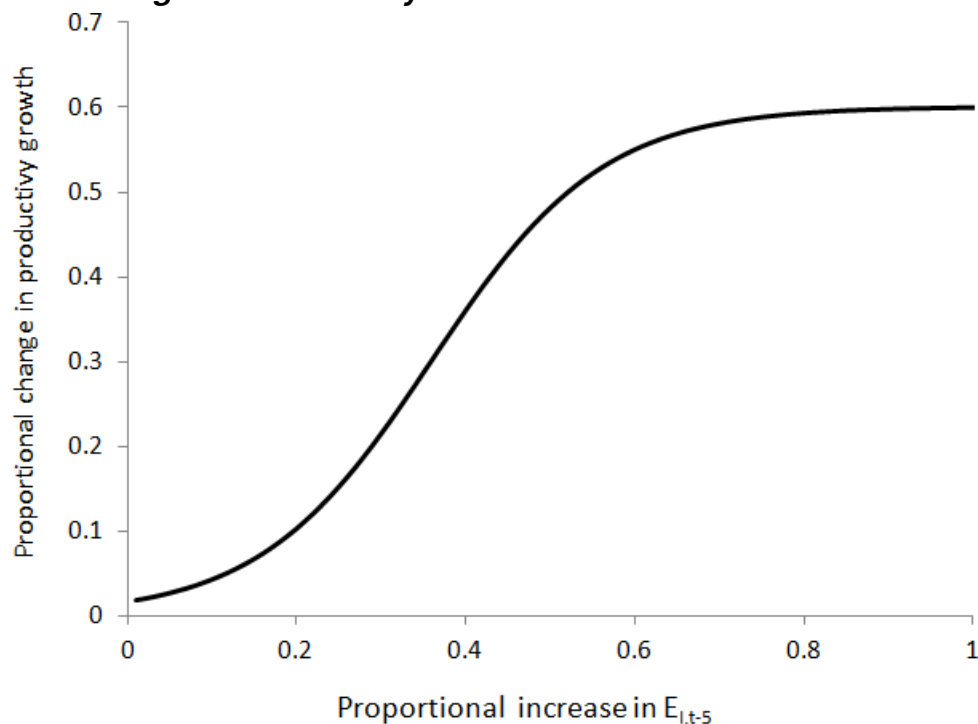


Figure 2: Change in Productivity Growth



5 A Benchmark Simulation

This section reports ‘benchmark’ projections, where it is assumed that there are no changes in tax rates and all expenditure categories (per capita) grow at constant rates over the period, using the initial values and parameters described in the previous section. This is the typical ‘no change’ assumption using in producing expenditure and debt projections. Obviously, such projections of an unsustainable debt ratio path are not regarded in any sense as ‘forecasts’ but merely as indications of the need for some kind of adjustment.²⁰

The results are shown in Figure 3. Here, the dashed line indicates the debt ratio in each year on the assumption that there are no feedback or endogenous effects. The figure also shows the base projections obtained by the Treasury’s LTFM. The solid line shows the projections allowing for the various feedbacks, implying slightly higher debt ratios in the later years. Since the various tax and growth rates are held constant over the period, the only relevant feedback effect in this case arises from the small effect on the risk premium of the increasing debt ratio. This increase

²⁰ Furthermore, there may be market adjustments (operating for example via wage and price effects) which modify the debt increase. In addition, the partial approach used does not allow for the potential adjustments arising from associated current account problems and exchange rate movements.

in the risk premium is, by assumption, quite modest over the range of debt ratios generated by the projections. If the projection period were extended, the debt ratio would clearly move into the range where a rapid rise in the risk premium, and thus in debt service charges, is generated. Hence the difference between the no feedback and feedback cases would be expected to be much larger.

Figure 3: Benchmark Debt Ratio Projections

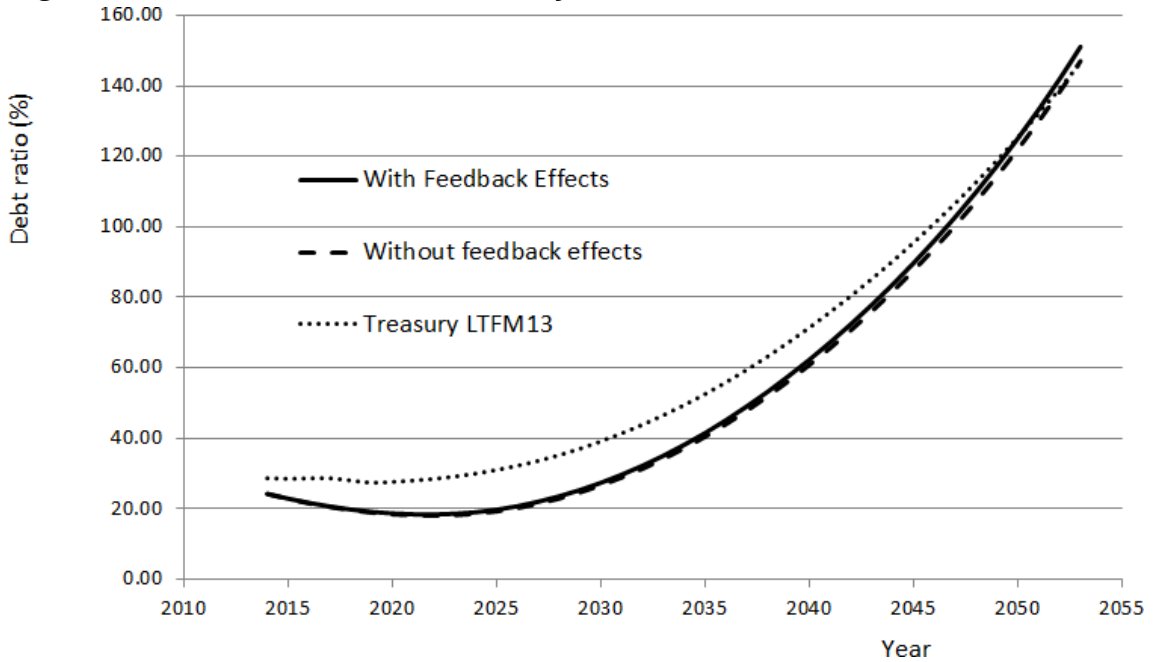
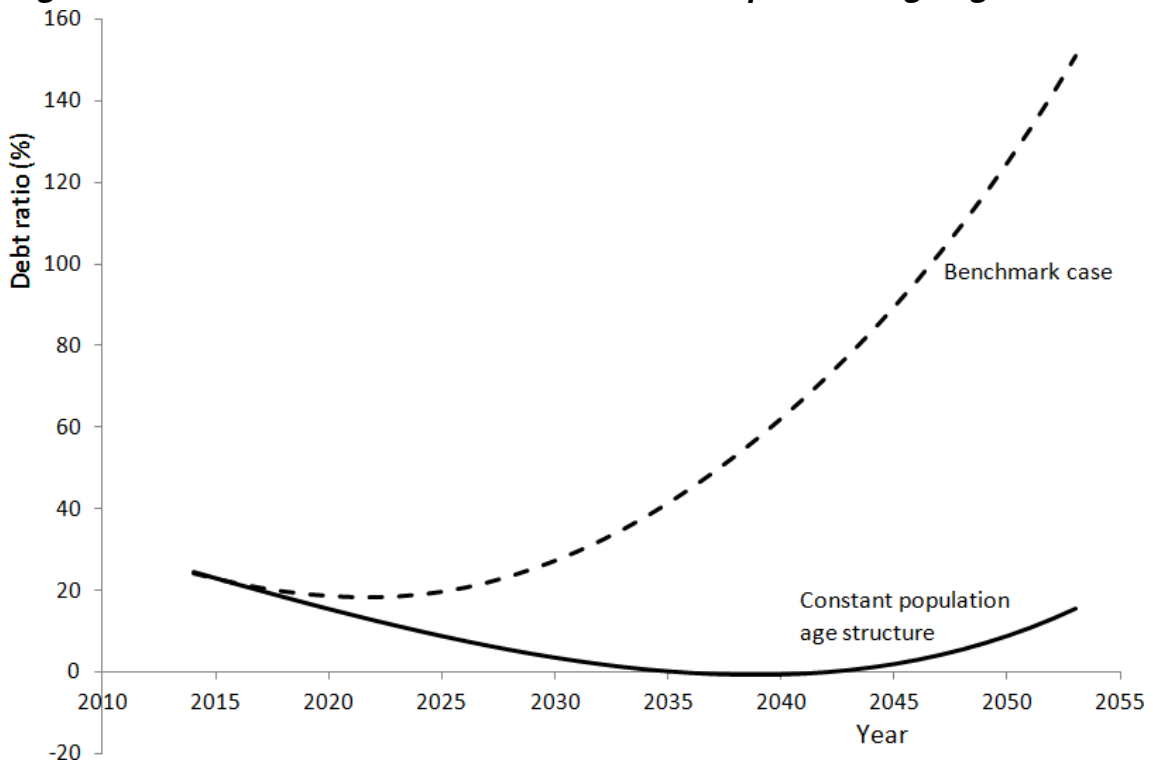


Figure 4: Debt Ratio Profiles with and without Population Ageing



These projections demonstrate an unsustainable situation were there to be no adjustments to the fiscal balance via taxation or revenue changes. The following section considers a number of policies designed to generate sustainable fiscal projections. However, it is first useful to consider the separate contribution of population ageing to the debt ratio projections, given much of the focus of the public debate on the demographic transition. Figure 4 compares the benchmark debt ratio projections and those obtained under the assumption that the population age structure remains fixed at the 2014 values, while still allowing the total population to grow at the same rate as in the benchmark projections. Clearly the lack of long term sustainability arises primarily from demographic changes rather than fundamental problems with tax and expenditure design settings.

The limited feedback effects modelled here clearly do not lead to adjustments which could modify the population ageing effects. With an assumption (common to all projection models) of constant growth rates of expenditure, there is a consequent constant growth rate of income: higher growth via productivity gains requires a change in the growth rate of health and education expenditure. This is modified only slightly towards the end of the projection period when the extra savings, stimulated by the higher interest rate, slightly reduces the effective tax rate and thus stimulates labour supply. But this is not sufficient to counteract the effect of a higher interest rate on debt servicing costs. The question arises of whether other market responses could modify the debt increase; as mentioned above, these might include general equilibrium effects on wage rates, the exchange rate and relative prices.²¹

Furthermore, the various policy instruments modelled here, such as expenditure growth rates and tax rates, cannot provide an endogenous stimulus to the economy, with the exception of a small boost to productivity generated by an increase in the growth of health and education expenditure (which is insufficient for it to be self-financing). As explained earlier, the aim here is to take a small step to endogenise a limited number of responses to policy changes designed to achieve fiscal sustainability. These are examined in the following section.

²¹ For an extensive discussion, which cautions against an excessive concern for population ageing, see Disney (1996).

6 Policies to Achieve Fiscal Sustainability

As indicated above, there is a potentially wide array of indicators of fiscal sustainability. The European Commission (2006 and 2012) has developed and applied a number of indicators, including *S1* and *S2*, defined as follows:

S1 measures the constant annual improvement (measured as a proportion of GDP in each period) needed in the fiscal balance in order to achieve a given debt target within a specified time period. This represents 'medium-term' challenges.

S2 measures the constant annual improvement (measured as a proportion of GDP in each period) needed in the fiscal balance in order to satisfy the inter-temporal budget constraint over an infinite horizon. Where projections (assuming no policy changes) are made over a finite 'medium term', the debt ratio in subsequent years is assumed to remain constant at its value in the final projection year.

The derivation of these indicators is set out in Appendix B, where equation (B.14) corresponds to *S1* and (B.9) to *S2*. A property of both sustainability measures is that they ignore the question of whether debt is increasing or decreasing at the end of the projection period.

Estimates of both indicators were made for New Zealand, based on the benchmark case of the previous section. In the case of *S1*, the annual improvement needed in the fiscal balance each year was computed over a 40 year horizon in order to reach a given terminal debt ratio. For terminal debt ratios of 20, 45 and 60 per cent, the required annual improvements in the fiscal balance (as a percentage of GDP) are found to be 3.6, 3.3 and 3.1 per cent respectively. Hence, only a modest additional adjustment to the fiscal balance is needed to achieve a terminal debt of 20 compared to one of 60 per cent. In the case of the infinite horizon (*S2*), the annual improvement in the fiscal balance would need to be 6.2 per cent.

While these indicators are useful in providing a quantitative measure of the extent to which fiscal policy would need to be adjusted, they have a number of limitations.

First, they are not realistic, in the sense that a constant increase in the fiscal balance is not a feasible approach to fiscal management. Governments typically vary tax and expenditure policies in accord with social needs and constraints imposed by prevailing economic conditions. Second, the measures make no reference to actual policy instruments. Third, it is important to know the impact of different policy choices on the time paths of key macroeconomic variables. The following sections therefore report the results of a series of simulations for a range of policies. In each case, there is no attempt to specify a precise time path of the debt ratio. Rather, a terminal debt target of 20 per cent is imposed, and the resulting path observed. As the model does not lend itself to finding an analytical solution, the critical values for a particular policy are found by iterating until the 20 per cent debt target is reached.

In examining alternative policies here, no attempt is made to produce any concept of an optimal policy response. This would require the specification of a social welfare, or evaluation, function expressed in terms of a range of performance measures.

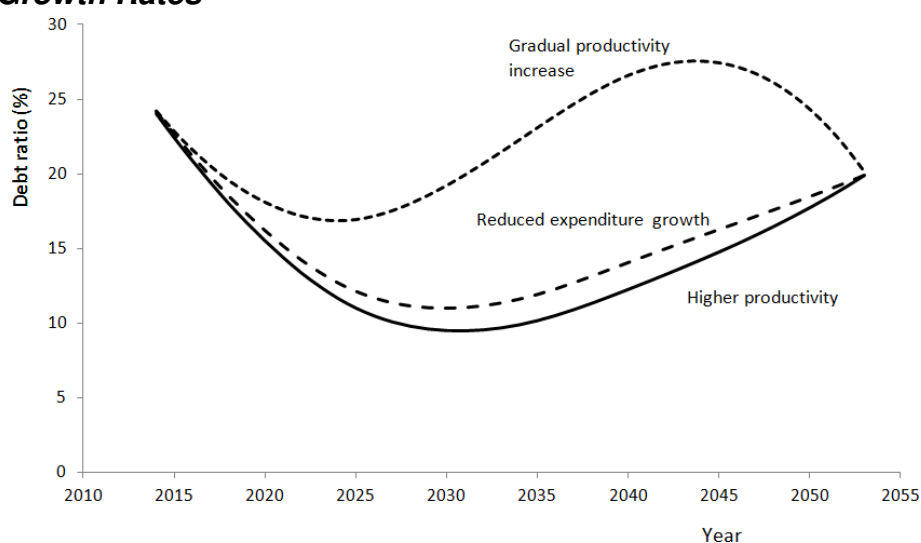
6.1 Productivity

An improvement in the underlying growth rate of productivity would obviously lead to higher rates of economic growth, increased tax revenues and potentially an improved long-term fiscal outlook. It is therefore of interest to examine by how much the annual rate of productivity growth would need to increase in order to meet a debt target of 20 per cent in 2053, that is after 40 years?²² The effect of a higher growth rate is shown in Figure 5 by the time path labelled ‘higher productivity’. To achieve this the growth rate, ρ_B would need to rise immediately from its base level of 1.5 per cent to 1.85 per cent annually and remain sustained at this rate over the projection horizon. The debt ratio would remain below its initial level throughout but, as the debt ratio rises toward the end of the period, a higher rate may be need for longer-term sustainability beyond the projection horizon. In the absence of feedbacks the required rate would be marginally higher at 1.88

²² Wilkinson and Acharya (2014), using the Treasury’s *Long-term Fiscal Model* (2013c), estimated that if the base rate of annual productivity growth of 1.5 per cent could be raised to 1.94 per cent, a debt target of 20 per cent could be reach by 2022 and maintained at that level, without any reduction in real per capita aggregate spending. However, their experiment did not use the ‘benchmark’, or expanding debt, projection but the ‘Sustainable Debt’ scenario of the LTFM.

per cent.²³ It remains a moot point as to whether these productivity increases are feasible, as they lie outside the range of historical experience.

Figure 5: Debt Ratio Profiles with Higher Productivity and Reduced Expenditure Growth Rates



It is unrealistic to expect that productivity growth could achieve an immediate increase and be sustained indefinitely. There are many policies that affect this rate and it would take time for any changes to flow through to higher rates. An alternative case was therefore analysed in which the growth rate would, starting from the benchmark value of 1.5 per cent, increase at a slow but constant rate of 0.000297 each year. This would achieve the terminal debt target of 20 per cent, as shown in Figure 5. However after an initial decline in the debt ratio, it would rise above its starting value before falling to meet the terminal target. Furthermore, instead of a rate of improvement in productivity of 1.88 per cent annually (as in case of a constant level discussed above), the terminal rate would now need to reach 2.65 per cent.

As mentioned above, policies can influence the growth of productivity. Improvements in the quality of human capital through health and education spending provide a further channel through which productivity can be enhanced, as modelled in equation (21). The question therefore arises as to whether there could be a long-term social dividend from raising spending on health and education, such that a sustainable rise in productivity growth is achieved. To explore this effect further it was assumed that in the first instance per capita expenditure growth would continue at its historical rate of 2 per cent annually. This would raise the rate

²³ Treasury (2013a, p. 16) takes a less benign view about the effects of an increase in productivity, on the argument that there would be pressures for higher spending, arising for example from the link between NZS and wage growth.

of growth of labour productivity from its base rate of 1.5 per cent to 1.53 per cent, corresponding to a 2 per cent increase. Were the investment to increase from 2 per cent to 3 per cent the net effect would be to raise labour productivity to just 1.533 per cent.

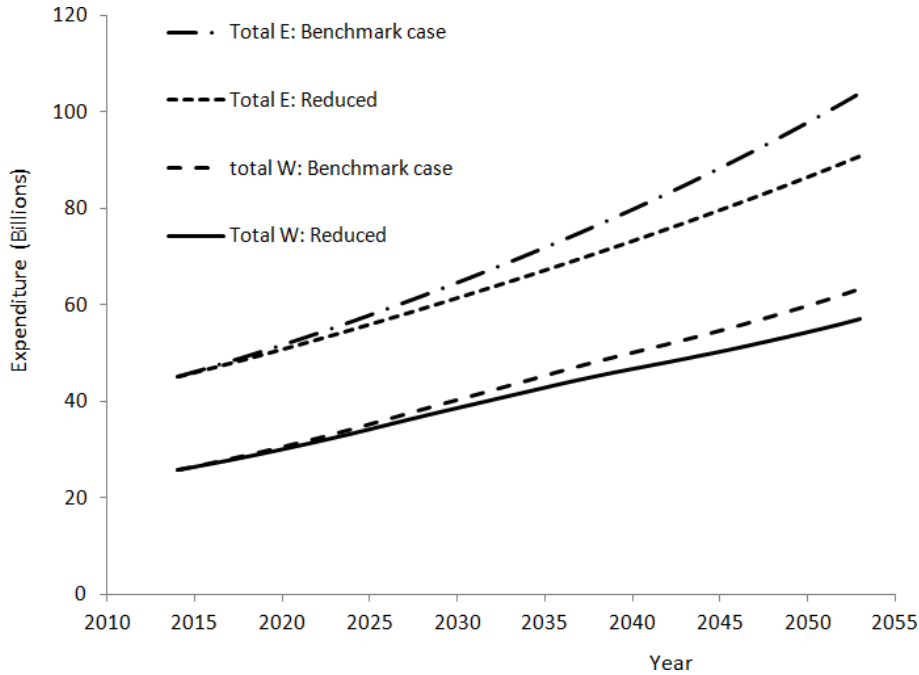
It is apparent that even with unrealistically high rates of growth of spending on health and education, the impact on productivity growth would be minimal. At the same time the debt ratio would rise as a result of greater public expenditure. This result should not be interpreted as denying the possibility of a return to social investment. Effective investments targeted at specific population groups at risk may well improve their lifetime outcomes and individual productivity in a way that would generate a positive social rate of return. But in using a highly aggregated model, it has not been possible to generate such results. Furthermore, much of this spending is actually annual maintenance (for example educating each new cohort of school entrants) and public spending is only a part of the total investment that individuals make in their own health and education.

6.2 Expenditure Policies

Reduced public expenditure is one approach to achieve fiscal sustainability. To attain a terminal debt target of 20 per cent the per capita growth rates of all categories of government spending in this model would need to be reduced equi-proportionately by 21 per cent. This would imply the growth rates of health and education spending be reduced from their historical level of 2.1 to 1.6 per cent, and NZS rates from 1.3 to 1.0 per cent. The path of the debt ratio towards its target level is shown in Figure 5. However the absolute real levels of these expenditures would still continue to increase over time, as shown in Figure 6, which illustrates the expenditure tracks with and without the reduction in per capita growth rates.

One suggested response to population ageing in New Zealand is to increase the age of eligibility for NZ Superannuation. The growth rate of total expenditure on Superannuation is equal to the sum of the growth rate of the payment per eligible person and the growth rate of the eligible population group. Such a policy change therefore operates via the latter growth rate. Total expenditure *growth* on superannuation would therefore be expected, depending on the precise response of labour force participation, to fall initially and then increase towards its former

Figure 6: Expenditure Growth Paths



level, though total NZS expenditure in absolute terms would remain lower than otherwise. However, it has to be remembered that other forms of welfare spending would rise as the growth of the working population rises. This type of policy change could be examined using the present model.

6.3 Taxation Policies

This section reports on the implications of a range of options for changes to taxation. They are summarised in Table 3 and the debt tracks are illustrated in Figure 7. In each case the policy is analysed holding all other tax and expenditure policies at their benchmark levels. For example, in the tax smoothing case, the value of τ needs to be increased from the benchmark of 16.25 per cent to 18.5 in each year, when allowance is made for feedback effects, which are here dominated by the adverse incentive effects of taxation. Not allowing for the feedbacks would suggest a lower increase to 18.0 per cent each year. Delayed tax smoothing produces less variation in the debt ratio over the projection period. Indeed, with an immediate increase in the tax rate, there are surpluses over a period of around 20 years. Furthermore, at the end of the projection period, the debt ratio continues to increase relatively sharply, suggesting that additional adjustments to the tax rate will be needed.

The fact that tax smoothing produces a period during which there is a surplus gives rise in practice to the temptation to spend part of the surplus. That is, the tax policy produces a possible endogenous expenditure change which governments often find difficult to resist.²⁴ This is of course just one consideration in evaluating alternative policies and, in particular, inter-generational comparisons are relevant. However, these aspects cannot be considered here.

If, instead of smoothing, the percentage tax rate were to be increased by 0.14 each period (so that it becomes 21.9 per cent in 2053), the target debt ratio can be achieved. In the case of delayed tax smoothing and delayed annual increase, the benchmark income tax rate is held constant for the first ten year of the projection period. The variation in the debt ratio over the projection period is lowest in the case where the tax rate is gradually increased from the beginning of the period.

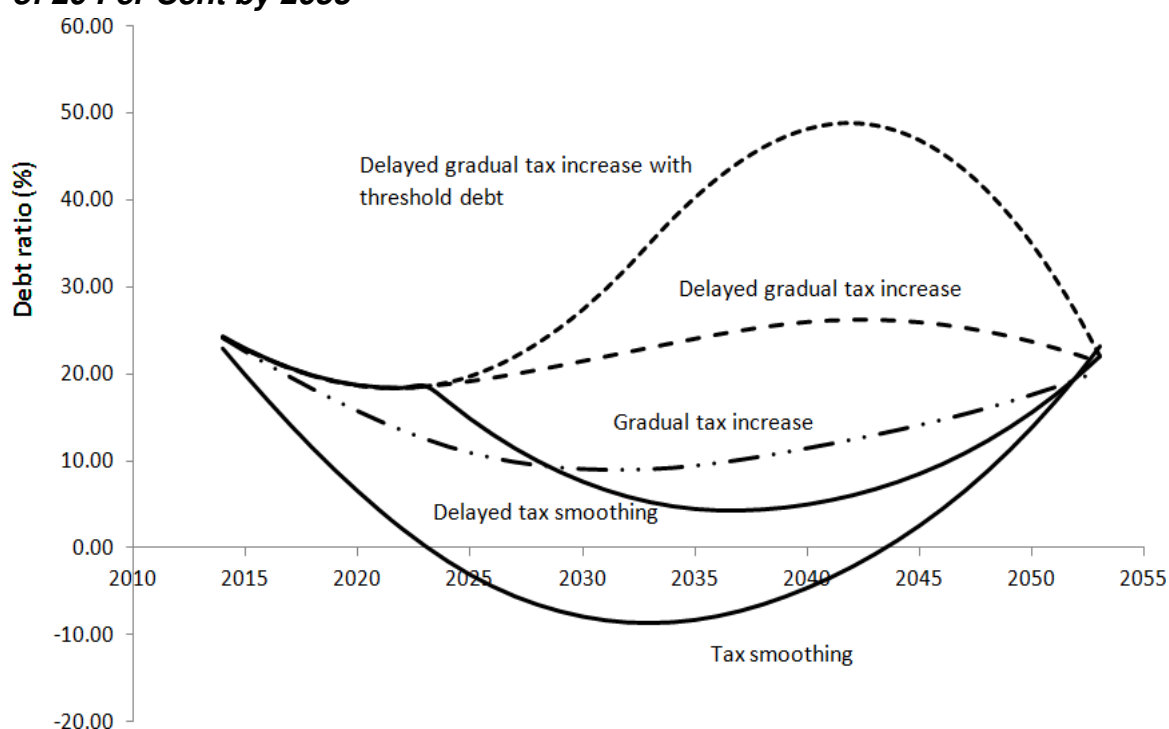
Table 3: Changes in Tax Rates Needed to Achieve Debt Target in Final Projection Year

Policy	Benchmark (per cent)	Rate for 20 per cent debt ratio in 2053	
		With feedback	Without feedback
Income tax smoothing	16.25	18.55 per cent	18.0 per cent
Delayed tax smoothing	16.25	20.0 per cent	19.15 per cent
Annual tax increase	16.25	+0.14 per year (21.9 in 2053)	+0.11 per year (21.5 in 2053)
Delayed tax increase	16.25	+0.29 per year (27.8 in 2053)	+0.22 per year (25.1 in 2053)
Delayed tax increase with debt threshold	16.25	+0.75 per year (31.25 in 2053)	+0.55 per year (27.25 in 2053)
GST	15.0	18.0	17.4

For the case where the gradual tax increase is delayed until a debt threshold of 35 per cent of GDP is reached, this implies that the first change in the tax takes place in the year 2034. Not surprisingly, the annual increase and the final tax rate needed to achieve the 20 per cent debt target in 2053 is much higher than when action is taken earlier. In addition, it implies higher intermediate debt ratios. The fact that tax rates are ultimately higher also means that the adverse incentive effects are greater. This means that the difference between the required tax adjustment with no-feedbacks and those allowing for feedback effects is also much higher: the rates differ by four percentage points in 2053.

²⁴ Davis and Fabling (2002) model 'expenditure creep' and report that it can completely erode the efficiency gains from tax smoothing. They conclude that, 'strong fiscal institutions are a prerequisite for achieving the welfare gains from tax smoothing' (2002, p. 16).

Figure 7: Debt Ratio Profiles for Alternative Tax Strategies to Achieve Ratio of 20 Per Cent by 2053



Consider further the profile of the debt ratio in the case where the gradual increase in the income tax rate is delayed until 2034. The projections show that a steady increase in the tax rate can achieve a 20 per cent debt ratio by 2053, the end of the period. However, the debt ratio continues to increase until around 2043 so that, without longer-term projections, it may be thought during this period that the tax rate should be increased even faster – it would not be evident that the profile will turn down towards the end of the period.

The profiles in Figure 7 allow for the various feedback effects, the most important of which concerns adverse incentive effects of taxation. The tax policies all ensure that the debt ratio, despite variation over the period, remains within a reasonable range of the target value. This means that the risk premium remains relatively steady. In the absence of feedback effects, the main implication is that both the income tax rates and, where relevant, their annual increases are lower, as indicated in Table 3. However, the fact that the resulting debt ratio profiles intersect at the start and end dates means that the ratios for intermediate years, when allowing and not allowing for feedbacks, do not deviate significantly from each other.

However, this should not lead to the conclusion that feedbacks have a minor influence. If the economy is allowed to get into very high debt ranges, then

considering tax and expenditure policy changes that do not allow for feedbacks will give much too optimistic a view of what is needed. If, from a high debt position, a policy change does not prevent the economy from moving into the range where the risk premium rises sharply, severe problems can arise from the high debt servicing costs. This interest rate problem is exacerbated by large changes in taxation, which give rise to strong adverse incentive effects. It is very hard to reverse severe problems – perhaps leading to default. But the no-feedback case allows the economy to move through periods of very high debt ratios and reduce debt with sufficiently large tax increases. It appears, incorrectly if the feedbacks are ignored, that a large degree of inter-generational redistribution is able to get the economy out of trouble.

7 Conclusions

Ageing populations are leading to long-term pressures on government budgets in many countries; New Zealand is no exception. In the medium term the challenge has become even more marked as countries recover from the global financial crisis and endeavour to restore their fiscal balances and reduce public debt levels. This paper develops long-term projections as the starting point for analysing options to achieve long term fiscal sustainability.

A principal focus of the paper has been on incorporating some selected economic feedbacks into a demographically driven model of government revenues, expenditure and debt.

For example rising debt levels could be expected to influence interest rates paid to foreign holders of New Zealand dollar denominated securities. Furthermore, higher tax rates could have disincentive effects. When fiscal policy responds to ensure long-term sustainability these feedbacks can potentially modify the intended outcomes by enhancing or dampening the effect of the policy interventions.

A small model is developed that captures, at a high level of aggregation, the evolution of public expenditure, tax revenue and public debt levels. It is used to project the key outputs over a 40 year period. In the first instance the model, excluding any feedback effects, is calibrated and shown to track the long-term debt path of the highly detailed Long-term Fiscal Model used by the Treasury. Following

the incorporation of a small number of feedbacks, the model is used to test the effect of policy changes with a view to achieving a net debt target of 20 per cent of GDP after 40 years. It is shown, for example, that in the case of tax changes, the presence of the feedback effects implies that a greater increase in income tax rates would be needed to achieve the same debt outcome than in their absence.

It should be stressed that the achievement of a specified debt ratio target by the end of the projection period is rather arbitrary and is used purely to illustrate the different debt paths taken as a result of different policies. In particular, the different policies were seen to imply very different debt profiles at the final projection year, with some (such as tax smoothing) imply a large rate of increase while others (such as a delayed tax increase after a threshold debt ratio is reached) implying a rapid decrease in year 40, and others (such as a gradual tax increase) involving a much smaller rate of change.

A potentially significant avenue for achieving fiscal sustainability is raising the average annual rate of productivity growth. However, the paper does not suggest how this might be achieved: there is no suggestion that this would be easy and it may involve other spending decisions. The model is used to demonstrate the critical importance of population ageing for fiscal sustainability. If the total size of the population were to grow at the projected rate but the age composition were to remain unchanged, fiscal sustainability would be assured without further policy responses. Reducing the rate of growth in public expenditures could lead to a sustainable fiscal position even though total absolute expenditure would continue to grow in real terms.

The present model assumes that the relevant variables are known with certainty. Furthermore, in examining alternative policies to achieve a desired debt ratio, no consideration has been given to any concept of an optimal policy response. Nevertheless the model provides a strong foundation for further extensions. In particular, incorporating uncertainty will provide a richer set of results and allow estimates of the probability that a given debt target would be reached in any given year. In addition, the model can be used, by introducing a social welfare, or evaluation, function, to examine 'optimal' government policy.

Appendix A: Further Details of Model Calibration

This appendix provides details of the benchmark calibration values and data sources. These are summarised in Tables 4 to 9. Data for Table 6 are drawn from: <http://www.treasury.govt.nz/government/financialstatements/yearend/jun14/27.htm>. Data for Table 8 are derived from LTFS13: <http://www.treasury.govt.nz/government/longterm/fiscalmodel>. Data for Table 9 are derived from LTFS13: <http://www.treasury.govt.nz/government/longterm/fiscalmodel>.

Table 4: Income, Debt and Saving (\$bn)

Name	Symbol	Value	Source and Notes
Aggregate income (GDP)	$Y_{A,0}$	230.0	Nominal GDP: http://www.treasury.govt.nz/government/data
Income excluding interest income	Y_0	227.8	Computed from eqn. (9)
Ratio of actual to potential income	L_0	0.92	Computed from eqn. (20)
Potential income	$Y_{P,0}$	248.2	Computed from eqn. (8)
Net Core Crown Debt	D_0	59.9	As at 30 June 2014 http://www.treasury.govt.nz/government/financialstatements/yearend/jun14/93.htm (Table 9)
Debt service charge	d_0	2.7	Computed from eqn. (1)
Net household financial wealth	K_0	50.0	As at 31 December 2013 http://www.rbnz.govt.nz/statistics/tables/c18/
Saving	S_0	6.0	Total domestic net saving less general government saving National Accounts Year ended March 2104 http://www.stats.govt.nz/browse_for_stats/economic_indicators/NationalAccounts/NationalAccountsIncomeExpenditure_HOTPYeMar14.aspx

Table 5: Public Expenditure (\$bn)

Name	Symbol	Value	Source and Notes
New Zealand Superannuation (gross)	NZS(g)	10.9	http://www.treasury.govt.nz/government/assets/nzsf/contributionratemodel
New Zealand Superannuation: (net)	NZS (n)	9.3	http://www.treasury.govt.nz/government/assets/nzsf/contributionratemodel
KiwiSaver subsidies	KS	0.9	http://www.treasury.govt.nz/government/financialstatements/yearend/jun14/93.htm (Note 6, p.54)
Total social assistance grants	SAG	21.9	http://www.treasury.govt.nz/government/financialstatements/yearend/jun14/93.htm (Note 6, p.54)
GSF Pension expenses	GSF	0.3	http://www.treasury.govt.nz/government/financialstatements/yearend/jun14/93.htm (p.29)
Superannuation payments	$W_{S,0}$	9.6	NZS (n)+ GSF
Total benefits payments	$W_{B,0}$	11.9	SAG-NZS(g)+KS
Total welfare and social spending	$W_{T,0}$	21.5	$W_S + W_B$
Official development assistance	ODA	0.5	http://www.treasury.govt.nz/government/financialstatements/yearend/jun14/93.htm (Note 6, p.54)
Social investment spending	$E_{I,0}$	27.2	Health+Education spending http://www.treasury.govt.nz/government/financialstatements/yearend/jun14/93.htm (p.29)
Other public expenditure (nie)	$E_{O,0}$	17.0	http://www.treasury.govt.nz/government/financialstatements/yearend/jun14/93.htm (p.29)
Expenditure	E_0		$E_{I,0} + E_{O,0}$
Total government expenditure	G_0	67.9	Computed from eqn. (4)
Superannuation per person	$W'_{S,0}$	\$14,638	$W_{S,0}/N_w$
Benefit payments per person	$W'_{B,0}$	\$4,036	$W_{B,0}/N_s$
Social investment spending per person	$E'_{I,0}$	\$6,042	$E_{I,0}/N_P$
Other expenditure (nie) per person	$E'_{O,0}$	\$3,767	$E_{O,0}/N_P$

Table 6: Public Revenue (\$bn)

Name	Symbol	Value	Source and Notes
Note 2, p.51			
Income tax revenue	IT	27.8	
Tax from NZS	NZST	1.6	
Income tax revenue (net of NZS)	IT(n)	26.3	
Corporate	CT	9.3	
Resident with-holding tax: interest	RWT(i)	1.6	
Resident with-holding tax: dividends	RWT(d)	0.5	
Total direct tax revenue	TDT	37.6	IT(n)+CT+RWT(i)+RWT(d)
GST Revenue	V_0	16.0	
Other indirect (roads, excise, etc)	OIT	5.6	
Other revenue	OR	5.5	
Total other revenue	TOR	11.1	
Total Sovereign Revenue	R_0	64.8	TDT+ V_0 +TOR

Table 7: Saving and debt ratios

Name	Symbol	Value	Source and Notes
Saving rate	s_0	0.03	Computed from eqn. (12)
Debt ratio	D'_0	0.26	$D_0/Y_{A,0}$
Net debt ratio	DR_0	0.23	$(D_0 - S_0)/Y_{A,0}$

Table 8: Growth Rates: Revenue and Expenditure per capita

Name	Symbol	Value	Source and Notes
Growth rate of total other revenue (TOR) per capita	r_O	0.015	
Total superannuation payments	r_{WS}	0.0124	In each case, the annual average growth rates for 2013-14 to 2053-54 were computed from the series in the Long term Fiscal Model 2013 (In real terms) adjusted for population growth rates.
Total benefits payments	r_{WB}	0.0120	
Social investment spending	r_{EI}	0.0205	
Other public expenditure (nie)	r_{EO}	0.0015	

Table 9: Population: Numbers and annual average growth rates

Name	Symbol	Value	Source and Notes
Number aged 0-14	N_o	892,890	
Number aged 15-64	N_w	2,951,760	
Number aged 65 and over	N_s	656,850	
Total number	N_P	4,501,500	
Growth rate aged 0-14	g_o	0.00168	All annual average growth rates calculated on the population projections for 2013-14 to 2053-54
Growth rate aged 15-64	g_w	0.00406	
Growth rate aged 65 and over	g_s	0.01929	
Total growth rate	g_P	0.00651	

Appendix B: Solvency and Sustainability Indices

This appendix examines alternative indices which may be used to describe fiscal sustainability, given a projected profile of government debt over a finite period. Given projected revenues and expenditures over a specified period, which typically implying increasing debt as a ratio of GDP, along with an initial level of debt, the problem is to obtain a measure that indicates the extent of any adjustment required to achieve a given definition of sustainability. Alternative definitions are clearly available, but this appendix considers one that requires complete elimination of debt over an extremely long period, and an alternative which requires the debt ratio to be reduced to a specified target by the end of a finite time period.

First, suppose the real interest rate is constant at r . As above, R_t and G_t denote government revenue and expenditure in period t . The long-run government constraint requiring solvency is:

$$D_0 - \sum_{t=1}^{\infty} (R_t - G_t) \left(\frac{1}{1+r} \right)^t = 0 \quad (\text{B.1})$$

where D_0 is the initial debt and all magnitudes are in real terms. This requires the present value of expected future ‘fiscal balances’, $R_t - G_t$, to be equal to the initial debt.

As above, letting $Y_{A,0}$ denote initial GDP, and noting that for constant growth at the rate, g , $Y_{A,t} = (1+g)^t Y_{A,0}$, the above condition can be converted to ratios of GDP

by dividing throughout by $Y_{A,0}$ to give:

$$\frac{D_0}{Y_{A,0}} - \sum_{t=1}^{\infty} \frac{(R_t - G_t)}{Y_{A,t}} \left(\frac{1+g}{1+r} \right)^t = 0 \quad (\text{B.2})$$

Define the discount rate, r' , such that $1+r' = (1+r)/(1+g)$, so that loosely speaking (by neglecting cross product terms) r' is the difference between the interest rate and the growth rate of GDP.²⁵

In the context of the model presented here, the various endogenous effects imply that the growth rate and rate of interest are not constant. But for present purposes it is a reasonable approximation. Define the initial debt ratio, $D'_0 = D_0/Y_{A,0}$, and the fiscal balance, as a ratio of income at time t , as $B_t = (R_t - G_t)/Y_{A,t}$, so that the solvency condition (B.2) becomes:

$$D'_0 - \sum_{t=1}^{\infty} \left(\frac{1}{1+r'} \right)^t B_t = 0 \quad (\text{B.3})$$

This strong condition does not of course generally hold. Hence, where increasing debt ratios are expected (the typical case when considering projections for which policy variables are held constant), long term solvency requires a substantial improvement in revenue or a reduction in expenditure (compared with the 'business as usual' basis of projections). Given the time profiles of D'_t and B_t , along with initial values, the sustainability index, B^* , is defined as the permanent improvement in the annual fiscal balance (as a share of GDP) which ensures that the solvency condition is satisfied. Hence B^* is implicitly defined by:

$$D'_0 - \sum_{t=1}^{\infty} \left(\frac{1}{1+r'} \right)^t (B_t + B^*) = 0 \quad (\text{B.4})$$

Using $\sum_{t=1}^{\infty} \left(\frac{1}{1+r'} \right)^t = \frac{1}{r'}$, this can be solved to give:

$$B^* = r' \left\{ D'_0 - \sum_{t=1}^{\infty} \left(\frac{1}{1+r'} \right)^t B_t \right\} \quad (\text{B.5})$$

This corresponds to the European Commission (2006) measure, S_2 . Calculation of (B.5) is complicated by the fact that it requires projections of B_t over a very long period (until discounting means that any additional years add a negligible amount to B^*). For this reason the European Commission (2006) uses a simple decomposition of the index, based on the strong assumption that that beyond the

²⁵ In fact, the sustainability condition could initially be expressed in nominal terms, and then all terms converted to real terms, with an appropriate definition of r in terms of the nominal rate and the inflation rate.

end of the projection period, at T , the fiscal balance remains constant. First, define $\Delta B_t = B_t - B_0$ as the difference between period t 's balance and that of the initial period. Then (B.4) can be rewritten as:

$$D'_0 - (B_0 + B^*) \sum_{t=1}^{\infty} \left(\frac{1}{1+r'} \right)^t - \sum_{t=1}^{\infty} \left(\frac{1}{1+r'} \right)^t \Delta B_t = 0 \quad (\text{B.6})$$

Solving for B^* gives:

$$B^* = r' D'_0 - B_0 - r' \sum_{t=1}^{\infty} \left(\frac{1}{1+r'} \right)^t \Delta B_t \quad (\text{B.7})$$

Using the assumption that for $t > T$, $\Delta B_t = \Delta B_T$, (B.7) becomes:

$$B^* = (r' D'_0 - B_0) - r' \sum_{t=1}^T \left(\frac{1}{1+r'} \right)^t \Delta B_t - r' \Delta B_T \sum_{t=T+1}^{\infty} \left(\frac{1}{1+r'} \right)^t \quad (\text{B.8})$$

and since $\sum_{t=T+1}^{\infty} \left(\frac{1}{1+r'} \right)^t = \frac{1}{r'} \left(\frac{1}{1+r'} \right)^T$, this is:

$$B^* = (r' D'_0 - B_0) - r' \sum_{t=1}^T \left(\frac{1}{1+r'} \right)^t \Delta B_t - \Delta B_T \left(\frac{1}{1+r'} \right)^T \quad (\text{B.9})$$

Hence, B^* can be expressed as the sum of three components:

$$B^* = B_0^* - B_1^* - B_2^* \quad (\text{B.10})$$

By comparison with (B.9), the terms in (B.10) are: $B_0^* = r' D'_0 - B_0$, $B_1^* = r' \sum_{t=1}^T \left(\frac{1}{1+r'} \right)^t \Delta B_t$ and $B_2^* = \Delta B_T \left(\frac{1}{1+r'} \right)^T$.

The above condition is extremely strong. It requires complete solvency over an infinite period, which generates a large sustainability index where, as here, fixed-policy projections generate very high future debt ratios. Furthermore, the assumption that beyond the projection period the fiscal balance (as a ratio to GDP) remains constant is also very strong.

An alternative approach is to return to the debt equation (7) and consider a different question. Suppose it is required to reach a given debt target by a specified date, say T . In the case (again a useful approximation for present purposes) where interest and growth rates are constant, modification of (7) gives the projected debt at T of:

$$D_T = D_0 (1+r)^T + \sum_{j=0}^{T-1} (G_{T-j} - R_{T-j}) (1+r)^j \quad (\text{B.11})$$

Converting to debt and fiscal balance ratios gives:

$$D'_T = D'_0 (1 + r')^T - \sum_{j=0}^{T-1} B_{T-j} (1 + r')^j \quad (\text{B.12})$$

where, as before, $B_t = (R_t - G_t) / Y_{A,t}$, and $D'_t = D_t / Y_{A,t}$. The annual addition to the fiscal balance, say B_T^* , as a ratio of GDP, needed to achieve a debt target of, say D'_T^* , rather than D'_T , is given by the solution to:

$$D'_T^* = D'_0 (1 + r')^T - \sum_{j=0}^{T-1} (B_{T-j} + B_T^*) (1 + r')^j \quad (\text{B.13})$$

Using $\sum_{j=0}^{T-1} (1 + r')^j = \left\{ (1 + r')^T - 1 \right\} / r'$, the required B_T^* is given by:²⁶

$$B_T^* = \left\{ \frac{r'}{(1 + r')^T - 1} \right\} \left\{ D'_0 (1 + r')^T - D'_T^* - \sum_{j=0}^{T-1} B_{T-j} (1 + r')^j \right\} \quad (\text{B.14})$$

The value of B_T^* gives an indication of the extent to which government expenditure or tax revenue, or a combination of both, must be adjusted each year in order to attain the debt target ratio, D'_T^* , in the final projection year.

²⁶ In European Commission, this is decomposed further as above using $\Delta B_t = B_t - B_0$.

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