Improving the Management of the Crown's Exposure to Risk

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Abstract

The paper discusses the management of the New Zealand Crown's exposure to financial risk. It argues that the Crown's aggregate exposure to risk can be effectively managed only centrally, and that, despite the difficulties of measuring risk and specifying an appropriate objective, the government should do more to measure, monitor, and control the Crown's aggregate exposure to risk. The paper goes on to present a new model for quantifying the Crown's exposure to risk, which integrates analysis of the government's accounting assets and liabilities with analysis of projected tax revenue and government spending. Among other results, the model suggests that the annual volatility (standard deviation) of the Crown's comprehensive balance sheet is at present approximately $30 billion.

JEL CLASSIFICATION	G32 - Financial Risk and Risk Management H11 - Structure, Scope, and Performance of Government
KEYWORDS	Risk management; Crown balance sheet

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Improving the Management of the Crown's Exposure to Risk

1 Summary

This paper considers the management of the Crown's exposure to financial risk. By financial risk we mean the variability in the Crown's net worth under planned policy. By managing risk we mean measuring it, analysing it, and, where appropriate, taking steps to reduce or otherwise change it.

It is widely acknowledged that the government should manage the Crown's exposure to risk. The cost to New Zealanders of the Crown becoming financially distressed would likely be very high, so keeping that risk very low is important. In addition, there is a case for keeping tax rates and spending stable in the face of economic shocks.

The Crown's aggregate exposure to risk can be effectively managed only centrally. The risk to which the Crown is exposed depends on the size of the risks in each part of the Crown's portfolio and on the correlations among the parts. The managers of the various parts of the Crown's portfolio can estimate and manage the risk in their portfolios, but they cannot be expected to know what contribution the risk in their portfolios makes to the Crown's aggregate exposure to risk. But central risk management does not imply micromanagement: the management of many assets and liabilities can be delegated, and central control of other risks may amount to no more than a direction to avoid or minimise certain risks.

The management of risk is already centralised in several ways. Recent central risk-management decisions have included avoiding net foreign-currency debt, limiting gross debt to 20% of GDP, and suspending contributions to the New Zealand Superannuation Fund (NZSF). Yet, the government's management of the Crown's exposure to risk is less intensive than might be expected. The government does not currently measure the Crown's aggregate exposure to risk. And it allows the managers of financial assets and other parts of the Crown's portfolio to make choices that may have significant effects on the Crown's aggregate exposure to risk.

Given the inevitable inaccuracy of any estimates of the Crown's exposure to risk, and the difficulty of precisely specifying the Crown's risk-management goal, the government's existing approach is understandable. Yet it does have disadvantages. In the absence of a comprehensive model of the Crown's exposure to risk, decisions must be based on intuition or partial, and therefore inadequate, models. In the absence of central control, managers of parts of the Crown's portfolio may unknowingly expose the Crown to too

much risk or incur costs to reduce their own exposure to risk when, from the Crown's perspective, that is unnecessary or even counterproductive. Cheap ways of reducing the Crown's exposure to risk may be overlooked.

That suggests that the government should measure and monitor the Crown's exposure to risk. Although the government should be prepared to intervene more, if necessary, in risk-related decisions of the managers of the parts of the Crown's portfolios, whether it should depends of course on the results of the measurement and monitoring and on the possible costs of the intervention such as a reduction in the accountability and independence of managers.

Building on work done by the Treasury in the late 1990s and early 2000s, and the development of consolidated Crown accounts and long-term fiscal projections, this paper presents numerical estimates from a model of the Crown's exposure to risk under current policy. The model enables the estimation of the Crown's portfolio's expected return and volatility, value-at-risk, and projections over time of the Crown's exposure to risk, defined as the frequency distribution of the Crown's net worth under planned policy. The model integrates analysis of the Crown's ordinary assets and liabilities with projections of spending and taxes under planned policy. It can be used therefore to analyse the Crown's *comprehensive* net worth, which includes the present value of projected taxes and spending as well as accounting net worth according to generally accepted accounting practice (GAAP). It can also be used to analyse recently developed measures that exclude from net worth the value of social assets, such as roads and schools.

Our base case implies that the Crown's exposure to risk is large. The Crown's comprehensive portfolio has annual volatility (standard deviation) of around $30 billion: to offset a permanent loss of this size, taxes would have to be permanently increased by 3%. (Results for other measures of net worth are also reported.) The results, it should be emphasised, are only very approximate. They are sensitive to numerous modeling assumptions and estimates, including estimates of correlations and volatilities about which reliable data are scarce.

The model can be used to estimate the effect of changes in the Crown's balance sheet on the Crown's exposure to risk. We illustrate with a hypothetical policy change, which we emphasise that we are not advocating: replacing half of the Debt Management Office's New Zealand dollar–denominated debt with US dollar–denominated debt.

We believe the model would be useful both in regular fiscal reporting, alongside the existing suite of fiscal measures, and in risk management (for example, by applying it to policy choices that have important effects on risk). But it is important to keep the limitations of the model in mind. Judgment is required in interpreting the results of the model, not least because of the uncertainties in parameter estimation. Moreover, the model is not the only approach to quantifying the Crown's exposure to risk and other complementary approaches are worth exploring.

2 Need for central risk management

The Crown's exposure to financial risk matters. The cost to New Zealand of the Crown's getting into financial distress would be very high; witness recent crises in Argentina, Iceland, and Ireland. So it is useful to assess the extent of that risk and to try to keep it very low. There is also a widely accepted case for reducing the variability of tax rates and government spending, which also requires monitoring and when necessary adjusting the Crown's exposure to risk.[1]

2.1 Crown's exposure to risk can be managed only centrally

If the government is to manage the Crown's aggregate exposure to risk, it must do so centrally. We define risk management as the measurement and monitoring of risk, as well as the setting of policy to achieve an acceptable level of risk. The riskiness of the Crown's portfolio depends on the riskiness (variance) of each part of the portfolio and on the correlations among the parts. The higher the correlations among assets and among liabilities, the greater the risk, and the higher the correlation *between* assets and liabilities, the lower the risk. Only by considering the correlations can the risk of the Crown's portfolio be understood. The managers of one part of the Crown's portfolio (for example, debt or a set of financial assets) may know how risky their assets or liabilities are considered by themselves, but they cannot be expected to know the correlations between the value of their assets and liabilities and the value of the rest of the Crown's portfolio. So the managers cannot be expected to know how their choices affect the Crown's exposure to risk. The management of the Crown's assets and liabilities can be decentralised, and individual managers can manage the risks to which their portfolios are exposed. But the Crown's aggregate exposure to risk is either managed centrally or largely left unmanaged.[2]

The nature of risk also means that the management of the Crown's exposure to risk needs to take account of all the Crown's main assets and liabilities (all its main sources of future cash inflows and outflows). This requires the analysis of a 'comprehensive' balance sheet, which includes a notional 'tax asset' and 'spending liability' as well as those assets and liabilities reported in accordance with generally accepted accounting practice (GAAP). For some purposes, it is of course useful to look at the GAAP balance sheet because it excludes policy commitments whose costs the government can influence, and focuses on debt and other liabilities that represent binding obligations. But even assessing the risk to which the GAAP balance sheet is exposed over any time period requires consideration of the correlation between GAAP assets and liabilities and spending and tax receipts over that time period.

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1 Duffie and Singleton (2003, Ch. 2) contains a useful discussion of the economics of risk management that focuses on the costs of financial distress. Barro (1979) argues for smoothing taxes over time and Bohn (1990) argues for smoothing tax over states of nature. Skilling (1997), McCulloch (1998), and Huther (1999) are examples of early discussions of the goals of risk management for the Crown.

2 This is consistent with the conclusions of Grimes (2001): '…individual Crown financial entities should each continue to be responsible for setting their own strategic asset allocation, after taking into account the nature of their liabilities. A central Crown body should, however, monitor and aggregate information from each of these entities and be delegated the responsibility and power to manage risks to the overall Crown balance sheet.'

2.2 Management does not imply micromanagement

Central management of risk does not, however, imply micromanagement of the comprehensive balance sheet. No central risk manager should try to measure the Crown's exposure to every kind of risk or to fine-tune all those exposures. Risks should be managed by the people with the information, incentives, and capability to manage them. For most of the risks to which the Crown is exposed, those people are the managers of particular business units. The risk associated with the value of the Crown's electricity assets, for example, depends on the quality of decisions to invest in and operate power stations and transmission networks. Those risks need to be managed by the people who understand the demand for electricity and the costs of supply and who (because of competition, regulation, or governance) have incentives to make good decisions. Any realistic central management of risk involves much delegation. The particular risks that are candidates for being managed centrally are those that affect many different parts of the Crown's portfolio, such as risks associated with interest and exchange rates, the price of oil, the strength of the economy, and the creditworthiness of the Crown's major counterparties.

Central management of a risk need not involve more than central measurement and monitoring of risk and certain high-level instructions to the managers of parts of the Crown's portfolio. It might, for example, involve instructions to some agencies to limit certain kinds of risks (for example, preventing certain agencies from borrowing) or instructions to other agencies to match their financial assets with certain liabilities—as, for example, the Debt Management Office matches financial assets to some of the debt the Crown has issued. If the matching is perfect—if the values of the matched assets and liabilities are perfectly correlated—the combination of the assets and liabilities is essentially risk-free.

Lastly, although the management of the Crown's exposure to risk must take account of the Crown's comprehensive balance sheet, not all risk-management decisions must refer to an analysis of the comprehensive balance sheet. An analysis of the comprehensive balance sheet might suggest that a certain category of risk was concentrated in a certain part of the GAAP balance sheet. If so, day-to-day management of the risk could be made by reference only to that part of the GAAP balance sheet.

2.3 Some central risk management already occurs

At present, the government does several things centrally to manage the Crown's exposure to risk. Some of them relate to the measurement of risk. For example, *Economic and Fiscal Updates* report 'fiscal risks' (choices that could cause spending to rise or revenue to fall) and the sensitivity of certain fiscal outcomes to economic variables such as GDP. They also show fiscal scenarios other than the central forecast and projection. Similarly, the government's financial statements report how Crown net worth would change in response to changes in share prices, exchange rates, and interest rates (Table 1). These estimates do not purport to be comprehensive: they exclude all indirect effects and even the direct effect of interest rates on the estimated present value of the Crown's non-financial liabilities, such as claims on the Accident Compensation Corporation. But they are a useful start.

Table 1 – Government's reporting of sensitivity to risk factors, 30 June 2009

Change	Direct reduction in GAAP net worth ($ billion)
Increase of 1 percentage point in New Zealand–dollar interest rates	0.4
Increase of 10% in the exchange value of the New Zealand dollar	0.3
Decrease of 10% in share prices	1.1

Source: Financial statements of the Government of New Zealand for the year ended 30 June 2009, note 33.

The Crown also directs its agencies in a way that amounts to central risk management. For example, the Public Finance Act states that the Minister of Finance must authorise all borrowing on behalf of the Crown, and there is only one debt-management office. Treasury guidelines require government departments to hedge all but small exposures to foreign-exchange risk created by imports and other transactions (New Zealand Treasury, 2003).

Most important, fiscal strategy is risk management. Among other things, that strategy has involved limiting gross debt and avoiding net foreign-currency sovereign borrowing.[3] Until recently, the strategy involved building up equities and other financial assets instead of further reducing gross debt, in part because the expected returns from holding those assets were considered attractive enough to outweigh the risks (Huther, 1998). By contrast, the recent temporary suspension of contributions to the NZSF reflected the Government's view that the value of the expected returns from further contributions, which would be funded by borrowing, were outweighed by the risks.

2.4 But central risk management is limited

In the late 1990s and early 2000s, the Treasury intensively investigated Crown financial policy. Huther (1998) and Fabling (2002) constructed comprehensive balance sheets and estimated the expected return and the variance of the Crown's portfolio. Davis (2002) estimated uncertainty in the Crown's long-term fiscal projections. But, at least until very recently, this work had slowed nearly to a standstill. And the measurement that the government does do—including the sensitivity and scenario analysis—falls short of an analysis of risk: it provides no estimate, even approximate, of the likelihood of various outcomes. Thus the government currently has no estimate of the Crown's exposure to risk and no way of estimating how that exposure varies with policy.

In the absence of quantitative estimates of the Crown's exposure to risk, ministers must make (and officials must recommend) decisions about risk management on the basis of intuition or partial models. Intuitions about risk are, however, known to be systematically flawed. Uncertainty, for example, is frequently underestimated (see, for example, Kahneman and Tversky, 1979). And models that examine only parts of the Crown's portfolio cannot incorporate all the relevant correlations and therefore cannot adequately address questions about the Crown's exposure to risk. Although intuition and partial models can be helpful—and no comprehensive model of risk will be good enough to supplant them—exclusive reliance on them is problematic.

3 A preference for issuing long-term local-currency debt seems reasonable, is consistent with practice in many countries, and it is supported by the IMF and World Bank (2001). But there are contrary views, cited, for example, in Grimes (2001).

The range of relevant risk-management questions is wide. Do current policies expose the Crown to too much risk? Should the deficit be reduced more quickly? Or are the risks small enough that more attention should be paid to continuing fiscal stimulus? Should the Crown's exposure to risk be considered when choosing whether to alter the composition of the tax base (for example increasing GST and reducing corporate tax) or the risk-related effects small enough to ignore? Do contributions to the NZSF have a sufficiently attractive profile of risk and expected return that they should be resumed as quickly as possible? Or, on the contrary, should the NZSF be liquidated and the proceeds used to repay debt? Does foreign-currency debt really offer an unattractive combination of cost and risk? Or would some net foreign-currency debt be better than none?

Consistent with the lack of measurement, the Crown holds assets and liabilities in several portfolios that are managed more or less independently by various different agencies (the Debt Management Office, the NZSF, the Earthquake Commission, and so on). Although these agencies manage assets and liabilities for a common owner, each agency manages its own portfolios without much consideration of the interrelationships between portfolios, and thus the effects of their choices on the Crown's exposure to risk. Nor can the agencies be sure what the Crown's risk-related objectives are. True, the agencies are governed by rules that encourage them to act in the interests of the Crown, but the rules are too general to ensure appropriate actions in relation to risk.

One of the goals of the NZSF, to take just one example, is 'maximising return without undue risk to the Fund as a whole'. The risk to the Fund, however, may differ substantially from the effect of the Fund's choices on the risk to the Crown. To the extent that the NZSF's managers consider assets and liabilities that are not part of the Fund, they limit their attention to the liability (comprehensively defined) for which the Fund is named; 'we plan', they say, 'to ensure we maximise our contribution to future superannuation payments by closely aligning our assets with the characteristics that drive future superannuation payments' (Guardians of New Zealand Superannuation, 2008).

In the absence of central direction, the managers of components of the Crown's comprehensive portfolio may inadvertently take actions that are not in the Crown's interest. They might expose the Crown to too much risk or pay too much to reduce risks that, from the Crown's perspective, are very small: risks that appear large to managers of the components of the Crown's portfolios may be insignificant for the Crown.[4] Public-sector managers may be especially inclined to excessive risk aversion, given the publicity that attends bad outcomes. Worse, if the value of a particular portfolio is naturally negatively correlated with the Crown's comprehensive net worth, the manager of that portfolio may spend money to reduce the risk of the portfolio in a way that increases the Crown's exposure to risk.

Well-intentioned attempts to reduce the Crown's exposure may also fail for lack of coordination. As noted above, the NZSF has contemplated choosing its assets with a view to reducing the risk of a larger portfolio containing its assets and the government's (comprehensive) superannuation liabilities. The Debt Management Office has also contemplated matching the debt it issues against some of the NZSF's assets. If both

4 There is, for example, evidence that managers generally make decisions that are too risk averse given the preferences of the more senior managers to whom they report (Kahneman and Lovallo, 1993). See also Rabin (2000). Note, however, that some risk management by individual agencies may be helpful even if it is costly and does not improve the Crown's exposure to risk. Consider a small government agency that chooses to hedge a foreign-exchange transaction or to insure its vehicles. An assessment of the Crown's aggregate exposure to risk might suggest that not insuring or hedging was optimal. But this kind of risk management can help the agency manage its budget and aid assessment of its performance because it makes the agency's performance depend less on things it cannot control.

agencies were to match their assets against the same set of liabilities, the result would be one unintended by either, and there would no reason to think that the Crown's exposure to risk had been reduced.

Lastly, the Crown may fail to take simple actions to reduce its exposure to risk at low cost. For example, the Crown may be exposed to more counterparty credit risk than is necessary. As part of their operations, several Crown agencies enter into derivative contracts with various banks. At any one time, some agencies may owe a given bank money, while others may be owed money by the bank. Unless the Crown enters into a master agreement, however, the Crown cannot net off contracts that are assets for the Crown against those that are liabilities for the Crown. If the bank fails, the agencies that owe money must pay, while the others must join the creditors' queue.[5]

2.5 Central risk management is difficult

Several practical problems make central risk management especially difficult for the Crown.

First, concerns are sometimes expressed that opening the door to central direction of risk taking could encourage political involvement in decisions that the government had previously decided were best delegated. For example, if ministers are encouraged to direct the NZSF to take a particular approach to foreign-exchange risk, they may be less inhibited about directing it to invest in particular businesses, for reasons unrelated to risk management.

A second problem is the inevitable approximation in any measure of the Crown's exposure to risk. Risk measurement is difficult even for organisations much smaller and simpler than the Crown. Future variances and correlations are unknown. They may be estimated from samples of historical data, but the samples may not be representative. And variances and correlations change over time. During a crisis, they may suddenly increase, aggravating an organisation's exposure to risk. Other assumptions introduce further approximations. We assume that the annual changes in the values of assets and liabilities are normally distributed. This simplifies the analysis, but the distributions of actual changes in values of financial assets are often found to have fatter tails than those of a normal distribution. That means that extreme events are more likely. Our modeling may therefore underestimate the risk to which the Crown is exposed.[6]

These problems apply to any organisation. Further problems arise for organisations such as the Crown that hold many untraded assets and liabilities. To estimate the risk in the Crown's portfolio, the government needs to estimate the value of assets such as schools, roads, and the present value of future tax revenue. It also needs to estimate variances and correlations for these assets. Estimates can be made, but in some cases they may be no more than partially educated guesses.

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5 We owe this point to Pat Duignan.

6 The use of a normal distribution may be less inaccurate in our modeling than in some other contexts because we model returns on an annual basis, and the evidence is that annual returns are much closer to normal than are daily or weekly returns (Akiray and Booth, 1998; Campbell, Lo, and Mackinlay, 1997, Ch. 1; Timmerman, 1995). In addition, the biggest assets in the model are untraded GAAP assets and the tax asset, and we are not aware of any direct evidence about the nature of the distributions of returns on these assets.

And even accurate risk measurement reveals only probabilities, not a prediction of the future. Analysis might conclude, for example, that the probability of the Crown's comprehensive net worth declining by more than, say, $50 billion next year under current policies was only 1 in 20 (see below for our estimates). Even if the measurement is correct, it does not imply that the Crown could lose no more than $50 billion next year.

For these reasons, it is sometimes argued that traditional risk measurement is worse than nothing: not only are the results false, they create a false sense of security (Mandelbrot and Hudson, 2005). A more conventional view is that rough estimates of exposure to risk are better than no estimates. Decisions have to be made, and in the absence of estimates from a model they will be made on the basis of intuition alone, which may be very poor. Yet it is clear that results of risk measurement should be treated with great caution.

A third limitation on the extent of feasible risk management is the difficulty of precisely specifying the Crown's risk-measurement objective. If the objective is vague—keeping the chance of financial distress low and maintaining fairly stable tax rates and spending plans—a broad range of exposures to risk may be more or less equally acceptable: measurement may not identify any policy changes that clearly improve the Crown's position. Being precise about the Crown's appropriate objective is, however, difficult.

It is common to frame choices about risk in terms of the expected return and the risk of a portfolio.[7] Increasing the expected return of a portfolio generally implies accepting more risk, so the owner of a portfolio must generally trade off risk and expected return. In a simple world, the owner can say which of the feasible combinations of risk and expected return is best, and a risk manager can then adjust the portfolio to achieve the desired combination. This would be hard to do for the Crown. Typical Cabinet ministers are unlikely to have a numerical view about the risk to which they are prepared to expose the Crown. They are unlikely to want to answer questions such as, 'Is it better for the Crown's portfolio to have an expected return of 8% and volatility of 15% or an expected return of 10% and a volatility of 20%?'

There is also a more fundamental problem. The Crown's exposure to risk should not be chosen in isolation from New Zealanders'. Indeed, if the Crown's goal was simply to reduce its exposure to risk, it could adopt a tax system that calculated tax due not as a proportion of income but as a proportion of the Crown's spending. Because this just transfers risk from the Crown to New Zealanders, it is unattractive as risk management.

Some insight into the formulation of the Crown's risk-related objectives can be found in the practice of asset management by pension funds and insurance companies.[8] These organisations have liabilities to their customers in the form of insurance contracts and pension obligations, and they have assets that help them meet their customer liabilities. The difference between their assets and liabilities is their net worth. Their objective can be expressed in terms of the risk and expected return of their net worth. Moreover, risk management can sometimes be framed as choosing the assets to achieve satisfactory levels of risk and expected return, *taking the customer liabilities as given*.

The government's choice might be conceived similarly. That is, risk management for the Crown might be viewed as selecting certain assets and liabilities to achieve desired risk and expected-return objectives, taking other assets and liabilities as given. For example, the composition of debt and financial assets could be varied, while other assets and

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7 Other aspects of the distribution such as skew or kurtosis could also matter.

8 On these issues, see, for example, Sharpe (2003) and Merton and Bodie (1993).

liabilities, including the present values of future tax and spending was taken as given. Doing so would help distinguish between risk-reduction policies that involuntarily expose New Zealanders to greater risk and those that do not.

But taking other assets and liabilities as given is not always desirable. For example, the Crown may be exposed to too much risk, even after the composition of debt and financial assets have been optimally chosen. If so, the government must think about changing taxes and spending plans. Taxes might be shifted to less volatile bases; eligibility criteria for spending might be changed to make spending more predictable.

These problems do not, however, mean that risk management is impossible or that risk measurement is futile. Even in the absence of consensus about a precise goal, it may still be clear that the Crown's exposure to risk is too great—or, alternatively, that it can safely be increased. Rough estimates of the Crown's exposure to risk, and of how the exposure varies with policy changes, can help inform those judgements.

2.6 But improvement is possible

Given these problems, radical departure from the government's current approach to risk management should not necessarily be expected. But there appears to be room for improvement.

First, the government should routinely measure the Crown's exposure to risk and estimate the effect of major risk-related policy changes on the exposure. Second, the government should seek to clarify the Crown's risk-related objectives. It should not necessarily aim for numerical precision. But refinement and clear expression of those goals would be desirable. Together, better measurement and a clearer view of the goal of risk management should allow the Crown to decide whether to change the Crown's exposure to risk.

Changes could be made in several ways. One option would be for the government to direct the managers of the Crown's main financial assets and liabilities to change their portfolios in certain ways—for example, to hedge or not hedge foreign exchange-rate risks; to hold or not hold domestic shares or foreign shares; to try to match their assets or liabilities with other of the Crown's liabilities or assets. A second would be to centralise management of those portfolios, either by a direct transfer of the assets in the portfolios or by requiring the managers of the portfolios to invest only in specific assets. A third—perhaps less likely option—would be to continue to allow those managers to choose their own approaches to risk management, but for a central risk manager to use derivative contracts to change the Crown's exposure when that was deemed desirable. Such an approach could involve 'undoing' certain risk-management actions of the managers of portfolios, if the interests of the portfolio diverged from the interest of the Crown. Lastly, spending plans, tax rates, and tax bases could be changed with a view to changing the Crown's exposure to risk.

3 Measuring the Crown's exposure to risk

In this section, we take up the challenge of measuring the Crown's exposure to risk.

3.1 The Crown's comprehensive balance sheet

The government publishes financial statements according to GAAP that include a balance sheet made up of the Crown's financial and physical assets and its debts and other binding liabilities. Other resources and obligations that do not meet accounting recognition criteria are nonetheless important for risk analysis—in particular, the power to tax and the implicit obligation to provide social services. Incorporating the values of these rights and obligations is the essence of an approach to fiscal analysis known as comprehensive accounting (Buiter, 1984; Bradbury, Brumby and Skilling, 1999; Irwin, 2009). The approach has received recent attention from the rating agency Moody's as a way to think about the riskiness of sovereign balance sheets (Moody's, 2009).

The ideal measure of fiscal sustainability is comprehensive net worth, defined as the present value of the government's future net cash flows. Unfortunately, it is difficult to measure with any precision. Among other things, any measurement relies on assumptions about the policy choices of future governments. The measurements underlying GAAP net worth are more reliable, and useful for many purposes, but GAAP net worth does not provide a good indication of fiscal sustainability because it represents only a subset of the cash flows that the Crown will pay or receive. And GAAP net worth is not without its measurement issues. For example, the book values of many assets do not reflect their market value. Many SOEs in particular would probably sell for more than their book value.

A further measurement issue is that some of the Crown's GAAP assets are unlikely to generate future cash flows. For example, national parks and social infrastructure such as schools are unlikely either to be sold or to be used to generate revenues and therefore cannot be used to repay debt. The relevance of the volatility of these assets to fiscal analysis is therefore questionable. Yet these assets still deliver a stream of benefits to the Crown, and if the Crown did not own them, it would presumably have to lease them to meet its implicit obligations. If so, holding the assets reduces future cash outflows.

Because each measure of net worth has advantages and disadvantages, we look at four measures of the Crown's net worth: GAAP net worth; net worth excluding social assets; and two measures of comprehensive net worth. One starts with GAAP net worth and adds the present value of future primary revenue and subtracts the present value of future primary spending flows.[9] The other excludes social assets. These measures are defined more precisely in Table 2.

9 Primary revenue is defined as core Crown tax revenue and other non-investment income. Primary spending is core Crown operating expenses excluding finance costs and without losses. These accrual-based aggregates are used to proxy cash flows.

Table 2 – Measures of net worth

Net worth measure	Definition
GAAP net worth	Total Crown assets minus liabilities, reported in accordance with GAAP
Net worth excluding social assets	GAAP net worth minus social assets. Social assets are defined as the non-financial assets of the core Crown, Crown Entities and the New Zealand Railways Corporation
Comprehensive net worth excluding social assets	Net worth excluding social assets plus the present value of future primary revenue minus the present value of future primary spending
Comprehensive net worth	GAAP net worth plus the present value of future primary revenue minus the present value of future primary spending

To quantify future primary revenue and spending we use the projections contained in Treasury's *Long-term Fiscal Statement* published in October 2009. The Statement contains two scenarios of future spending—one based on historic trends and the other on the Government's stated fiscal strategy. Both are relevant as interpretations of the Government's spending commitments. Table 3 reports estimates of the comprehensive balance sheets constructed from each of these scenarios. The projection of historic trends leads to an unsustainable increase in debt, whereas the government's stated fiscal strategy is sustainable. The projection of historic trends helps understand the implicit liabilities the government faces under current policy from population ageing and the growth in the cost of government services such as healthcare. But it is inconsistent with the Government's risk-management objectives. So we base our analysis on the projections contained in the sustainable debt scenario.

Table 3 – The Crown's comprehensive balance sheet, 30 June 2009

	Historic trends scenario ($ billion)	Sustainable debt scenario ($ billion)
GAAP net worth	99	99
Present value of primary revenue	960	960
Present value of primary expenditure	1104	962
Comprehensive net worth	**(45)**	**96**

Note: A nominal discount rate of 10% has been used to calculate the present values of primary revenue and expenditure. The long-term fiscal projections extend to 2050. An infinite discount horizon is used by assuming primary revenue and expenditure in subsequent years each grow at a constant rate, determined by the final-year rate of growth.

Sources: New Zealand Government, the Treasury, authors' calculations.

In Table 4 we report our calculation of net worth excluding social assets. At −$3 billion, it is about $100 billion lower than GAAP net worth. The difference is the estimated value of social assets.

Table 4 – Net worth excluding social assets, 30 June 2009

	$ billion
State-owned enterprises (excluding New Zealand Rail)	32
Air New Zealand (minus minority interest)	5
Financial assets of core Crown and Crown entities	91
Intersegmental eliminations	(13)
GAAP assets excluding social assets	**115**
GAAP liabilities	**118**
Net worth excluding social assets	**(3)**

Sources: New Zealand Government, authors' calculations

3.2 Modeling the Crown's exposure to risk

To model the components that contribute to the Crown's aggregate risk, we decompose the comprehensive balance sheet into entity-based classes. The most significant GAAP assets are those of state-owned enterprises, Crown financial institutions[10] and physical assets such as roads, schools, hospitals, and state houses. Among the most significant GAAP liabilities are the unhedged debt managed by the Debt Management Office, the insurance liabilities of the Accident Compensation Corporation (ACC), and pension liabilities of the Government Superannuation Fund (GSF). The net assets of smaller entities are aggregated into an 'other' category. Along with these reported assets and liabilities are the present values of primary revenue and spending, which are derived from the long-term fiscal projections using a nominal discount rate of 10%. Assets and liabilities could be broken down into smaller constituent parts if desired. We have not done this, in part to limit the number of parameters that we have to estimate.

To model the Crown's exposure to risk, we essentially integrate a standard analysis of the risk of a portfolio of assets and liabilities with an analysis of the risks created by uncertain future spending and tax revenue.[11] We estimate some results analytically (that is, with the use of closed-form formulas) and others with Monte Carlo simulation.[12] Appendix 1 describes the mathematical structure of the model.

To derive the results we need an estimate, for each class of asset and liability, of the expected return, the variance of the return, and the correlation of the return with the returns of other assets and liabilities. The most difficult parameters to estimate are the correlations. We look at historical data, typically using historical time series of indices that we believe are reasonable proxies for the assets and liabilities in the model. For some parameters we have had to use our judgement. Appendix 2 describes the estimation of the parameters in the model.

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[10] The financial asset portfolios of the NZSF, Accident Compensation Corporation, the Earthquake Commission and the Government Superannuation Fund.

[11] The literature on empirical risk quantification of sovereign net worth is limited, but see Adrogué (2005), Barnhill and Kopits (2003), Barnhill (2006), and Burnside (2004).

[12] Monte Carlo simulation enables us to numerically construct projected frequency distributions. Deriving frequency distributions analytically would be infeasible owing to the complicated nature of the functional forms in the model. All the results presented in this paper that are derived using the Monte Carlo technique are the result of running the model with 10,000 simulations.

3.3 The Crown's risk budget

We begin by presenting a notional risk budget for the Crown. Risk budgeting is the practice of systematically allocating a level of risk exposure across asset classes or business units (Mina, 2005). It is used by financial firms to allocate capital to achieve risk-management objectives. For example, an investment management firm may wish to allocate its market risk exposure equally among its investment managers. This is not the same as allocating an equal amount of investment capital to each manager because the risk exposure will depend on the riskiness of each manager's market position. While the government does not use risk budgeting, we apply the technique to get a rough understanding of the importance of various sources of risk.

To construct the notional risk budget, we measure the risk of each asset and liability class as its annual standard deviation.[13] If returns are normally distributed, each asset and liability class will experience a loss at least as large as this with annual probability of around 16%, or about every six years.

The model implies first that the Crown's comprehensive net worth has annual volatility of $30 billion. Offsetting a loss of that amount would require a permanent increase in taxes of 3.2%.

We can also present an approximate indication of where that risk comes from (Table 5 and Figure 1). The measures are only indicative because the contribution of an asset to the Crown's total exposure to risk depends on correlations: to the extent that the correlations are less than 1, each entity's contribution to the Crown's total risk will be less than the amount reported. The total effect of imperfect correlations is the benefit of diversification.[14] With that proviso, we can note that about half of the total risk comes from the primary balance and about a quarter from social assets (Figure 1). If social assets are excluded from comprehensive net worth, annual volatility is reduced to $26 billion, equivalent to a 2.7% permanent change in taxes and the relative importance of the other items increases (Table 6 and Figure 2).

It is not surprising that the primary balance dominates the risk budget. The present value of primary revenues, for example, is more than 20 times as great as the asset value of all state-owned enterprises. Nonetheless, other assets and liabilities also matter: the analysis shows that they may contribute up to a quarter or a third of the Crown's financial risk depending on whether social assets are excluded from the analysis.

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[13] For simplicity, this analysis does not take into account the expected returns of entities and therefore this analysis indicates the risk of deviating from the expected future level of net worth, rather than the risk of loss on the current level of net worth (which is affected by return assumptions).

[14] More technically, the diversification benefit reported in Tables 5 and 6 is the difference between a portfolio's volatility and the sum of volatilities of the portfolio's constituent parts.

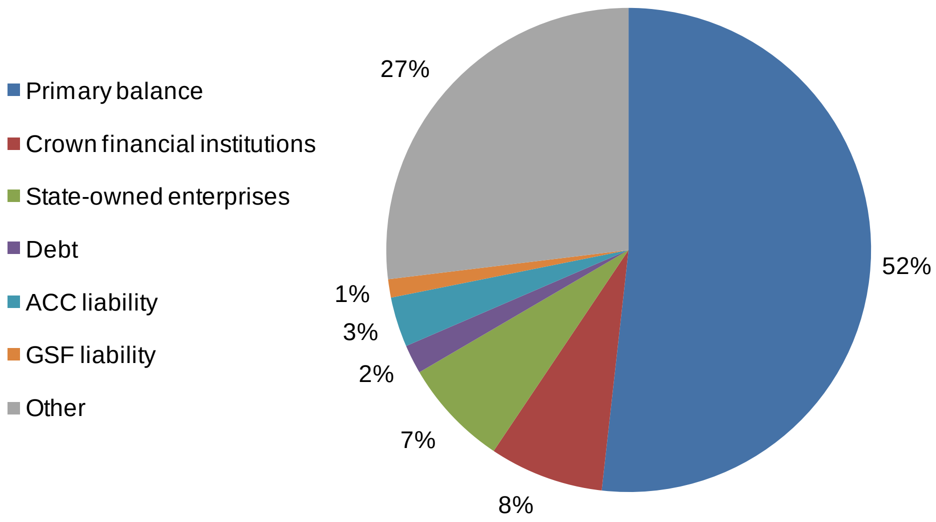
Table 5 – Comprehensive risk budget, 30 June 2009

Item	Present Value ($ billion)	Annual Volatility (%)	Annual Volatility ($ billion)	Permanent tax increase needed to fund a one standard deviation loss (%)
Primary revenue	959.5	3.0	28.8	
Primary spending	-962.4	1.5	14.4	
Diversification benefit			*-18.3*	
Primary balance	**-2.9**	**852.8**	**24.9**	**2.6**
GAAP assets				
Reserve Bank of New Zealand	2.3	4	0.1	
New Zealand Super Fund	12.9	10	1.3	
ACC	12.2	15	1.8	
Earthquake Commission	1.8	15	0.3	
GSF	2.8	10	0.3	
New Zealand Railways	13.0	12	1.6	
Meridian Energy	4.4	20	0.9	
Mighty River Power	2.8	20	0.6	
Landcorp Farming	1.3	20	0.3	
Genesis Power	1.4	20	0.3	
Transpower New Zealand	1.4	20	0.3	
New Zealand Post	0.6	20	0.1	
Other SOEs	2.6	20	0.5	
Air New Zealand	2.6	20	0.5	
Transport	23.2	12	2.8	
Housing New Zealand	13.7	12	1.6	
Ministry of Education/Schools	12.9	12	1.5	
District Health Boards	3.6	12	0.4	
Student loans	6.6	4	0.3	
Other	38.6	12	4.6	
GAAP liabilities				
DMO (unhedged debt)	-23.2	4	0.9	
ACC	-26.7	6	1.6	
GSF	-11.8	5	0.6	
Diversification benefit			*-6.6*	
GAAP net worth	**99.1**	**16.8**	**16.7**	**1.7**
Diversification benefit			*-10.9*	
Comprehensive net worth	**96.1**	**31.9**	**30.6**	**3.2**

Table 6 – Comprehensive risk budget excluding social assets, 30 June 2009

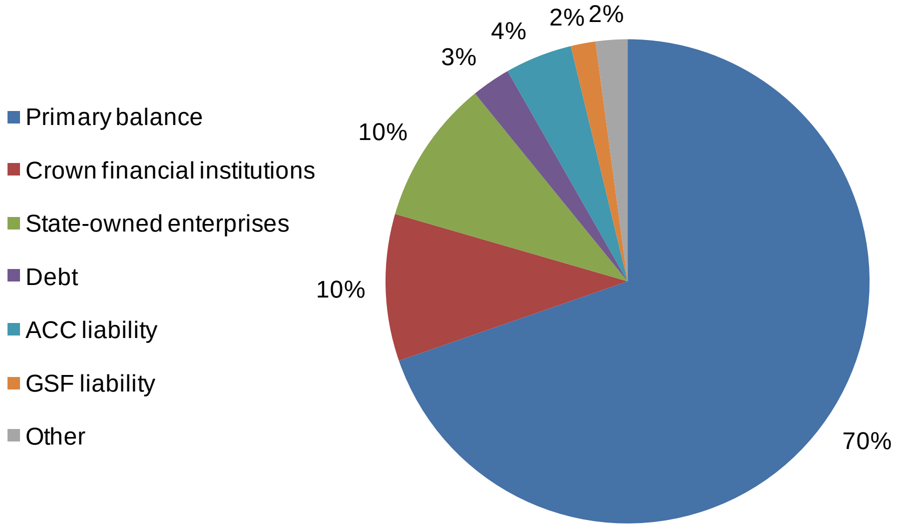
Item	Present Value ($ billion)	Annual Volatility (%)	Annual Volatility ($ billion)	Permanent tax increase needed to fund a one standard deviation loss (%)
Primary revenue	959.5	3.0	28.8	
Primary spending	-962.4	1.5	14.4	
Diversification benefit			*-18.3*	
Primary balance	**-2.9**	**852.8**	**24.9**	**2.6**
GAAP assets excluding social assets				
Reserve Bank of New Zealand	2.2	4	0.1	
New Zealand Super Fund	11.7	10	1.2	
ACC	12.0	15	1.8	
Earthquake Commission	1.7	15	0.3	
GSF	2.8	10	0.3	
New Zealand Railways	-0.2	4	0.0	
Meridian Energy	4.4	20	0.9	
Mighty River Power	2.8	20	0.6	
Landcorp Farming	1.3	20	0.3	
Genesis Power	1.4	20	0.3	
Transpower New Zealand	1.4	20	0.3	
New Zealand Post	0.6	20	0.1	
Other SOEs	2.6	20	0.5	
Air New Zealand	2.6	20	0.5	
Transport	-0.3	4	0.0	
Housing New Zealand	-0.9	4	0.0	
Ministry of Education/Schools	-0.3	4	0.0	
District Health Boards	-1.0	4	0.0	
Student loans	6.6	4	0.3	
Other	7.6	4	0.3	
GAAP liabilities				
DMO (unhedged debt)	-23.2	4	0.9	
ACC	-26.7	6	1.6	
GSF	-11.8	5	0.6	
Diversification benefit			*-4.0*	
Net worth excluding social assets	**-2.6**	**260.8**	**6.9**	**0.7**
Diversification benefit			*-5.7*	
Comprehensive net worth excluding social assets	**-5.5**	**468.9**	**26.0**	**2.7**

Figure 1 – Sources of risk on comprehensive balance sheet



Source: Authors' calculations

Figure 2 – Sources of risk on the comprehensive balance sheet excluding social assets



Source: Authors' calculations

3.4 Stochastic projections of net worth

The risk-budget results are useful indicators of the Crown's exposure to risk. But their value is limited because they do not take into account expected returns or give an indication of the future path of net worth.

We measure the Crown's projected exposure to risk as the frequency distribution of the value of these assets and liabilities and hence of the Crown's comprehensive (or GAAP) net worth. Our measures are based on projections of taxes and spending, so they are estimates of projected risk, not actual risk.[15] From the estimated frequency distributions, we derive estimates of the probability distribution of the Crown's future net worth and thus of the probability that the Crown's net worth will fall below a given value for various time

15 That is, we estimate the frequency distributions of future net worth conditional on planned policy, not the unconditional frequency distributions of future net worth.

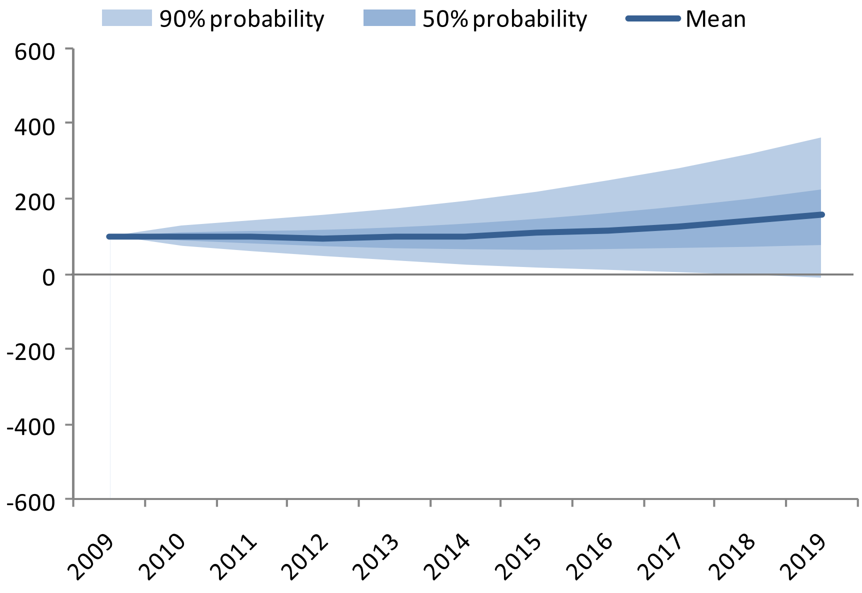
horizons (all assuming planned policy).[16] We present results for the estimated frequency distributions over the next ten years, though the nearer-term estimates (say one to five years ahead) are the most relevant: the greater the elapse of the time, the greater the chance that the government will respond to unexpected outcomes by changing its policies.

Projections are plotted in Figures 3 to 6 below. Estimates of value-at-risk at the 95% probability level for one-, three-, and five-year horizons are shown in Table 7. These estimates indicate the maximum loss in net worth that could be expected to occur with 95% probability over the given time horizon. Or put another way, an event as bad as this or worse could be expected to occur once every 20 years.

These results indicate, as would be expected, that the range of probable outcomes widens with time (holding policy constant). The comprehensive portfolio has the largest variance. There is significant volatility associated with social assets and hence the portfolio excluding social assets is much less risky than other portfolios.

The results suggest that the Crown's value-at-risk at the 95% probability level over a 5-year horizon is very large. With an estimated probability of 5%, for example, net worth excluding social assets could fall by more than $70 billion and comprehensive net worth by more than $120 billion. Such a reduction in comprehensive net worth is equivalent to a required increase in tax revenue of 12%.

Figure 3 – GAAP net worth ($ billion)



[16] Comprehensive net worth is defined here as the *expected* value of future cash flows, and so is represented as a point estimate in the current time period, rather than a probability distribution. The distributions of future values for comprehensive net worth can be interpreted as the distribution of possible expected values of cash flows (valued at the future time period), conditional on different states of the world.

Figure 4 – Net worth excluding social assets ($ billion)

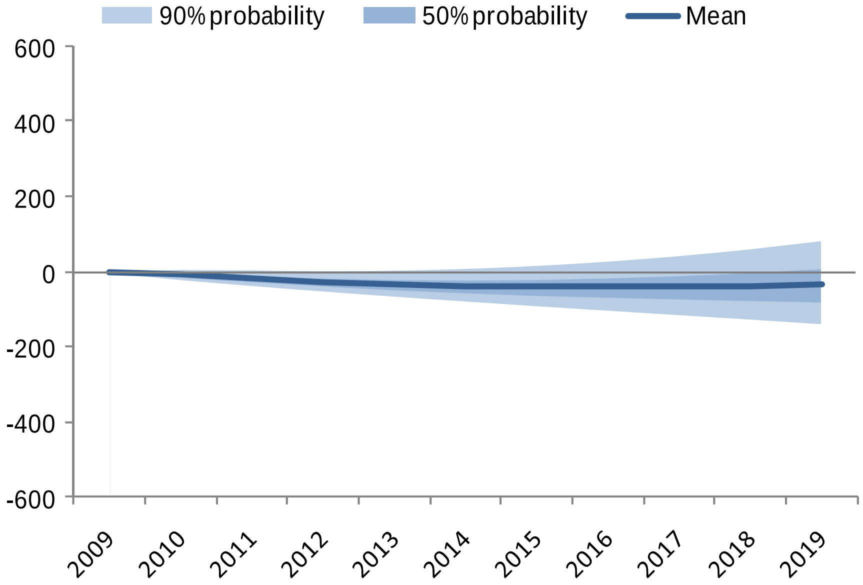


Figure 5 – Comprehensive net worth excluding social assets ($ billion)

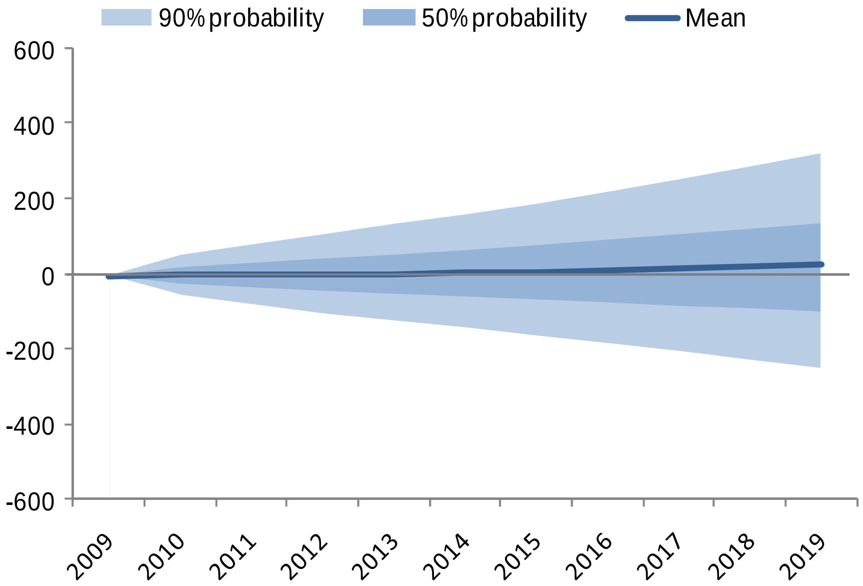


Figure 6 – Comprehensive net worth ($ billion)

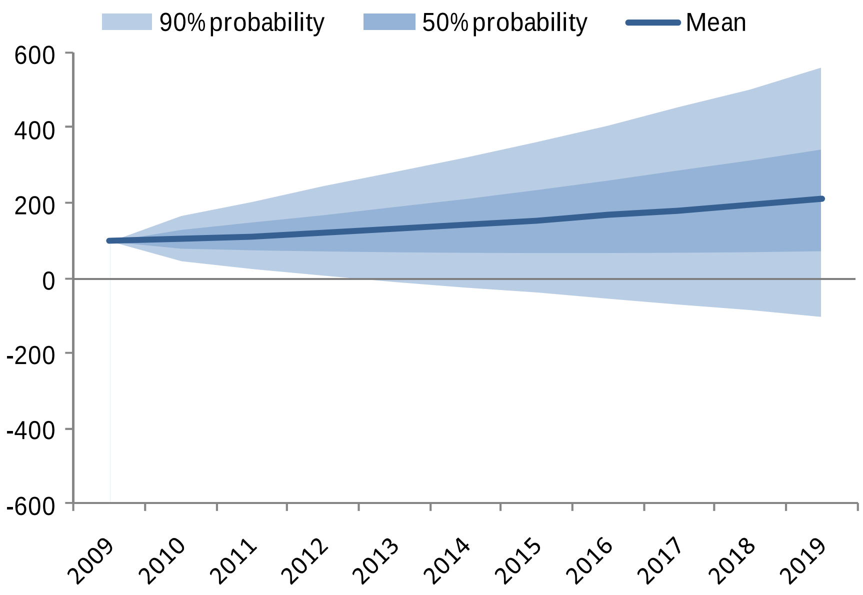


Table 7 – Value-at-risk at 95% probability level

	1 year		3 year		5 year	
	$ billion	**Tax change (%)**	**$ billion**	**Tax change (%)**	**$ billion**	**Tax change (%)**
GAAP net worth	27	2.8	54	5.7	77	8.0
Net worth excluding social assets	18	1.9	48.5	5.1	76	7.9
Comprehensive net worth excluding social assets	52	5.4	101	10.5	138	14.4
Comprehensive net worth	52	5.4	90	9.4	122	12.7

3.5 Comparison with the 2008–09 recession

At first sight, losses of this size might seem implausibly large. Certainly, the changes in comprehensive net worth are large relative to historical changes in GAAP net worth. Are they plausible?

One way to get a sense of the realism of the estimates is to consider what happened to comprehensive net worth during the recession of 2008–09. Table 8 provides a very rough estimate. The effect on the GAAP balance sheet is estimated using the reported net losses for the fiscal year to 30 June 2009. For the change in the primary balance, we use the change in projected tax revenue between the 2008 and 2009 *Budget Economic and Fiscal Updates* (but assuming tax policy is held constant).

The table shows that the Crown's comprehensive loss from the recession was about $64 billion. This loss is larger than the model's estimate of value-at-risk at the 95% probability level over a one-year horizon ($52 billion). According to the model, the estimated loss experienced in 2008–09 has an annual probability of only 2.5%. Thus, a shock this bad or worse could be expected about once every 40 years.

Table 8 – Approximate impact of the 2008–09 recession on the Crown's comprehensive balance sheet

	$ billions
GAAP total gains/(losses) for year ended 30 June 2009	(7)
Change in the present value of projected tax revenue between 30 June 2008 and 30 June 2009	(57)
Total	**(64)**

Sources: New Zealand Government, the Treasury, authors' calculations

3.6 Sensitivity analysis

To investigate the sensitivity of risk to changes in key parameters in the model, we report results using more extreme choices for volatility, correlation, and discount-rate parameters. We find that the results are materially sensitive to changes in these parameters.

Changing the volatilities of all the individual asset and liability classes in the model linearly changes aggregate volatility. Thus, a 10% increase in volatility of all entities would increase aggregate risk by 10%. An extreme scenario would be to assume a doubling of all volatilities, which would double the measured volatility of aggregate net worth.

Correlations are a focus of risk analysis because they are critical and yet difficult to estimate accurately and can change over time. We report the sensitivity of results to more extreme correlations in Table 9. The more extreme assumptions lead to a doubling of the estimate of the Crown's exposure to risk. The single most important correlation coefficient in the model is that between primary revenue and primary spending. In the base case, this parameter is set to 0.5. It is less than 1 because we have an assumption of unchanged policy commitments (unexpected revenue increases are not assumed to be perfectly correlated with increased spending or decreased taxes). The economic intuition for the positive value is that even with current policy commitments, much spending is positively correlated to revenue because both are influenced by economic growth (for example, New Zealand Superannuation payments are indexed to the average wage and public-sector wages tend to increase with average wages). Sensitivity to this parameter is tested using correlation values of between 0 and 1. We also look at changing all other correlation coefficients in the model. The base case correlation coefficients are reported in Appendix 2 and average 0.4 in magnitude. To test sensitivity, we set all asset–asset and liability–liability correlations to 0.8 and correlations between assets and liabilities to –0.8.

Table 9 – Sensitivity to more extreme correlations

Permanent increase in taxes required to fund an annual one standard deviation loss in comprehensive net worth (%)		**All correlations** *except* the correlation between primary revenue and spending	
		Base case	**Asset–asset/liability–liability correlations set to 0.8 and asset-liability correlations set to −0.8.**
Correlation between primary revenue and spending	**0.0**	3.5	6.0
	0.2	3.4	5.9
	0.5 (base case)	3.2	5.8
	0.8	3.0	5.6
	1.0	2.8	5.6

The discount rate used to calculate the present value of the primary balance is set to 10% (nominal) in the base case. The choice of discount rate is largely arbitrary, but is approximately consistent with the Treasury's estimate of the social opportunity cost of capital as being 8% real (New Zealand Treasury, 2008). An increase in the discount rate decreases the size of the tax asset and the spending liability and therefore decreases the dollar value of the risk. However, this risk as a percentage of tax revenue is higher because the risk exposure of GAAP net worth is unchanged, while the tax asset is smaller. A 6% discount rate would mean that annual volatility in comprehensive net worth would be $71 billion (2.6% tax change) and applying a 14% discount rate would mean an exposure of $23 billion (4.0% tax change). This compares with the base case value of $30 billion (3.2% tax change).

3.7 Application to policy

Results such as those just presented could be included in the suite of fiscal indicators that informs the government's fiscal strategy. In addition, the model could be used to analyse the effect on risk of changes in the composition of the Crown's balance sheet. We illustrate this with a hypothetical policy change, in which half the Debt Management Office's unmatched debt portfolio (about $23 billion as at 30 June 2009) is replaced with US dollar–denominated debt. Our purpose is to model and analyse sensitivity of risk to policy, not to propose or even seriously discuss possible policy changes. We recognise that policy decisions will be based on a much wider set of considerations than those discussed here. We emphasise that further refinement of parameter estimation would be necessary to produce robust results.

We estimate that the volatility of US-dollar debt is significantly higher than the volatility NZ-dollar debt, because of the exposure to exchange-rate fluctuations.[17] Nevertheless, the change could reduce the Crown's exposure to risk if US-dollar debt is less correlated with other Crown liabilities or more correlated with the Crown's assets.

[17] For the purposes of the modeling, we have assumed that the cost of US dollar–denominated debt would be the same as NZ dollar–denominated debt. In practice, the relative costliness of debt under each approach should also be a factor in the analysis.

We find that issuing US-dollar debt would have ambiguous effects on the Crown's risk exposure. The model indicates that GAAP net worth and comprehensive net worth would be exposed to more risk, but net worth excluding social assets would be exposed to less risk. In the latter case, the effect of the correlations outweighs the effect of the higher variance of the US-dollar debt. To the extent that weight is attached to the net worth excluding social assets, the result casts some doubt on the conventional view that domestic currency debt is lower risk. It is possible that the conventional view attaches too much weight to the volatility of the value of foreign-currency debt and too little weight to its correlations with other assets and liabilities on the Crown's balance sheet. But it is also possible that our estimates of correlations are wrong. Or, even if they are accurate estimates of average correlations, it may be that foreign-currency debt is particularly risky during bad times. During the recent crisis, for example, the New Zealand dollar fell sharply against the US dollar, just when the present value of tax revenue also fell sharply.

Previous empirical work has also raised questions about optimal currency composition of debt. Fowlie and Wright (1997) used a tax-smoothing approach that found that there were benefits from issuing foreign currency debt over 1985 to 1995. However, other work, such as Hawkesby and Wright (1997), arrived at the opposite conclusion, finding that the issuance of nominal domestic debt was preferable because it hedged supply-side economic shocks.

Table 10 – US-dollar debt scenario (change in 95% value-at-risk relative to the base case)

	1 year		3 year		5 year	
	$ billion	Tax change (%)	$ billion	Tax change (%)	$ billion	Tax change (%)
GAAP net worth	0.9	0.1	4.8	0.5	4.1	0.4
Net worth excluding social assets	-0.9	-0.1	-4.2	-0.4	-8.5	-0.9
Comprehensive net worth excluding social assets	-0.5	-0.1	-6.4	-0.7	-9.4	-1.0
Comprehensive net worth	1.0	0.1	2.8	0.3	2.2	0.2

Note: Figures shown represent the difference between the results for this scenario and the values reported in Table 7. Positive (negative) values denote an increase (decrease) in value-at-risk.

3.8 Concluding remarks

The model we have developed enables quantification of the Crown's exposure to risk. It could be used in regular reporting, for example, as part of the suite of other fiscal indicators and in risk management (for example, by applying it to real policy questions).

To be incorporated in regular reporting, the model will require further refinement, particularly with respect to parameter estimation. In any case, it is important to keep the limitations of the model in mind. Judgement is required in interpreting the results of the model. And some policy issues with implications for balance-sheet risk will be too fine grained for this model to be able to shed useful light on the desirable course of action (for example, an SOE increasing its gearing). Value-at-risk models tend to be better at measuring risk under 'normal' conditions than under extreme conditions.

The modeling could be improved with more detailed analysis of some parts of the balance sheet. Moreover, off-balance sheet risks, such as contingent liabilities, could also be added to the model so long as a probability distribution of possible outcomes can be specified.

This model is not the only approach to quantifying the Crown's exposure to risk. It might also be worth exploring other complementary approaches. One is to develop a 'factor' model in which the central issue is the sensitivity of the Crown's assets and liabilities to a small set of underlying factors, such as interest rates, exchange rates, equity prices, and the strength of the economy. Another is to make the long-term fiscal model stochastic; that is, to allow projected revenues and spending to evolve with random elements as well as the existing trends. A third is to integrate analysis of the Crown's finances with those of other sectors of the economy (for example, Gray, Merton, and Bodie, 2008). This approach is attractive because the Crown's financial position depends closely on the financial position of households and businesses and because the chance of a very bad fiscal outcome is closely linked in particular to the health of the banking sector.

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Appendix 1: Structure of the model

Model variables

The balance sheet is decomposed into asset and liability classes (denoted by subscript i hereafter). The classes are based on the different entities that manage assets or liabilities on behalf of the Crown.

In addition, we model the primary balance with a notional asset class for the present value of primary revenue and a notional liability class for the present value of future primary spending.

The value of each asset or liability class i at time t is denoted as V_{it}, with assets taking positive values and liabilities taking negative ones. Net worth at time t is denoted NW_t. The particular measure of net worth (eg, GAAP or comprehensive) depends on the choice of asset and liability classes.

$$NW_t = \sum_i V_{it}$$

Table 11 – Description of variables and parameters

Symbol	Definition
V_{it}	Value of asset or liability class i at time t.
NW_t	Crown net worth at time t. Note we can choose which measure of net worth (eg, GAAP or comprehensive) by the choice of asset and liability classes.
R_t	Crown primary revenue at time t.
E_t	Crown primary expenditure at time t.
NCI_{it}	Net capital injection into asset or liability class i at time t. A negative value signifies a withdrawal of capital (ie, dividend for an asset class and borrowing for a liability class).
γ_i	Net capital injection ratio. It is assumed that the net capital injection is a constant proportion of the value of an asset or liability class.
δ	Discount rate used to compute present value of primary revenue and expenditure.
μ_i	Mean return (compounded continuously) for asset or liability class i on the reported balance sheet.
$\mu_{tax,t}$	Expected growth in R_t at time t.
$\mu_{spend,t}$	Expected growth in E_t at time t.
σ_i	Standard deviation of return to asset or liability class.
ρ_{ij}	Correlation coefficient of asset or liability classes i and j.
ε_{it}	Random number drawn from standard normal distribution with correlation structure $\boldsymbol{E}[\varepsilon_{it}\varepsilon_{jt}] = \rho_{ij}$.
$\boldsymbol{E}[\cdot]$	Expected value operator.

Modeling the dynamics

For the reported balance sheet, we assume that the value of each asset and liability class will evolve over time with a stochastic rate of return and net of any capital injections or dividends. That is: 'Change in value of asset or liability class = average return (drift) + stochastic element (volatility) + net capital injection'.

For primary revenue and spending, we also assume that growth occurs in a stochastic fashion: 'Change in revenue or expenses = expected growth rate + stochastic element (volatility)'.

We can then compute the value of the primary revenue asset or spending liability by computing the present value of expected future cash flows.

We can represent these dynamics as follows in the notation of stochastic differential equations, where W denotes a Wiener process (ie, Brownian motion):

$$\begin{cases} dV_{it} = \mu_i V_{it} dt + \sigma_i V_{it} dW + NCI_{it} \quad \text{for } i \notin \{tax, spend\} \\ dR_t = \mu_{tax,t} R_t dt + \sigma_{tax} R_t dW \\ dE_t = \mu_{spend,t} E_t dt + \sigma_{spend} E_t dW \\ V_{tax,t} = \sum_{j=1}^{\infty} \frac{\boldsymbol{E}[R_{t+j}]}{(1+\delta)^j} \\ V_{spend,t} = \sum_{j=1}^{\infty} \frac{\boldsymbol{E}[E_{t+j}]}{(1+\delta)^j} \end{cases}$$

Assumptions and constraints

Nature of the randomness

For each individual asset and liability class on the reported balance sheet, and the annual revenue and expenditure flows, the continuously compounded single-period returns are modeled as independent and identically distributed (IID) variables.

Thus, the model assumes that the variance of returns is constant over time with no serial correlation (ie, future returns are not correlated with past returns). The model assumes different means and variances of returns for different asset and liability classes and allows for cross-sectional correlation in the distribution of returns. We assume that the correlation coefficients remain constant over time.

The continuously compounded returns are assumed to be drawn from the normal distribution. This means that single-period gross simple returns are distributed as IID lognormal (Campbell, Lo, and MacKinlay, 1997). Given that the actual distributions may have different properties to the normal distribution (eg, fatter tails), it may be worthwhile to consider modeling with alternative probability distributions in future work.

Expectations of future government tax and spending

We define the tax asset (spending liability) as the discounted sum of expected revenue (expenditure) cash flows. We compute this by first computing annual government revenue and expenditure using the stochastic process described above. Then expected values for future revenue and expenditure are derived by assuming revenue and expenditure will grow at rates determined by separate long-term fiscal projections, assuming constant terminal growth rates. That is, once we have computed single-period revenue or expenditure (ie, R_t or E_t) we can compute the expected values in $j \geq 1$ periods as:

$$\begin{cases} \boldsymbol{E}[R_{t+j}] = R_t \prod_{i=1}^{j} (1 + \mu_{tax,t+i}) \\ \boldsymbol{E}[E_{t+j}] = E_t \prod_{i=1}^{j} (1 + \mu_{spend,t+i}) \end{cases}$$

Capital budget identity

There is an accounting identity whereby the sum of net capital injections to each asset and liability cannot exceed the government's operating balance in any one time-period. That is:

$$\sum_{\substack{i \\ i \notin \{tax,spend\}}} NCI_{it} = R_t - E_t$$

The Crown may borrow to increase the capital of one of its asset holdings or reduce a liability, but this is equivalent to a negative net capital injection into debt, so the identity holds. The identity can be rewritten:

$$NCI_{debt,t} = (R_t - E_t) \quad - \sum_{\substack{i \\ i \notin \{tax,spend,debt\}}} NCI_{it}$$

In words, this says 'debt repayment = operating balance – other net capital injections'.

Debt is the residual

For asset and liability classes on the reported balance sheet, *excluding* debt, we model net capital injections to be a constant proportion of their total values. We set a parameter $\gamma_i \in [-1,1]$ which defines a constant proportional capital injection where $\gamma_i > 0$ or a constant proportional capital withdrawal (ie, dividend to the Crown) where $\gamma_i < 0$. The net capital injection into debt is the residual to maintain the capital budget identity.

Procedure for solving the model

To generate the stochastic projections of net worth we follow these steps:

1. Set initial values:

$$\begin{cases} V_{i0} \text{ for } i \notin \{tax, spend\} \\ R_0 \\ E_0 \end{cases}$$

2. Set expected return (μ), standard deviation (σ) and correlation parameters (ρ):

$$\begin{cases} \mu_i \text{ for } i \notin \{tax, spend\} \\ \mu_{tax,t} \\ \mu_{spend,t} \\ \sigma_i \\ \rho_{ij} \end{cases}$$

3. Generate a matrix of random numbers $[\varepsilon_{it}]$ for $i = 1, 2, \dots, N$ and $t = 1, 2, \dots, T$ from the standard normal distribution and with the correlation structure $\boldsymbol{E}[\varepsilon_{it}\varepsilon_{jt}] = \rho_{ij}$.

4. Compute values of the asset and liability classes for each $t = 1, 2, \dots, T$ by solving the model iteratively. The formulas of these values are:

$$\begin{cases} V_{it} = (1+\gamma_i)\left(V_{i(t-1)} e^{\left(\mu_i - \frac{\sigma_i^2}{2}\right) + \sigma_i \varepsilon_{it}}\right) \text{ for } i \notin \{debt, tax, spend\} \\ R_t = R_{t-1} e^{\left(\mu_{tax,t} - \frac{\sigma_{tax}^2}{2}\right) + \sigma_{tax}\varepsilon_{it}} \\ E_t = E_{t-1} e^{\left(\mu_{spend,t} - \frac{\sigma_{spend}^2}{2}\right) + \sigma_{spend}\varepsilon_{it}} \\ V_{tax,t} = \sum_{j=1}^{\infty} \frac{R_t \prod_{i=1}^{j}(1+\mu_{tax,t+i})}{(1+\delta)^j} \\ V_{spend,t} = \sum_{j=1}^{\infty} \frac{E_t \prod_{i=1}^{j}(1+\mu_{spend,t+i})}{(1+\delta)^j} \\ V_{debt,t} = V_{debt,(t-1)} e^{\left(\mu_i - \frac{\sigma_{debt}^2}{2}\right) + \sigma_{debt}\varepsilon_{debt,t}} + (R_t - E_t) \\ \qquad - \sum_{\substack{i \\ i \notin \{tax, spend, debt\}}} \gamma_i \left(V_{i,(t-1)} e^{\left(\mu_i - \frac{\sigma_i^2}{2}\right) + \sigma_i \varepsilon_{it}}\right) \end{cases}$$

5. Compute net worth for each $t = 1, 2, \dots, T$ using the values derived in the fourth step:

$$NW_t = \sum_i V_{it}$$

6. We use Monte Carlo simulation and thus repeatedly simulate steps 3 to 5 to construct a frequency distribution of net worth.

Appendix 2: Calibration of the model

Asset and liability values

The balance sheet is decomposed into the entities shown in Table 5.

We have used net asset values for most entities. This reflects approximate matching of assets and liabilities in the case of DMO and RBNZ, and for the SOEs reflects the fact that they manage their assets and liabilities as an integrated business. We have modeled the assets and liabilities of ACC and the GSF separately. The net assets of smaller entities are grouped for modeling simplicity.

We have eliminated intra-Crown cross-holdings so that values for each entity may be different from those reported by entities. For example, whilst the EQC manages about $5 billion in assets, much of this is in government bonds. This is an internal transaction for the Crown which has no bearing on the aggregate risk exposure to the Crown's net worth. Thus, in the model, the capital associated with EQC is only about $2 billion.

Values for primary revenue and expenditure are based on accrual measurement (which is only an approximation of cash flows) with growth rates determined by using the 2009 *Long-term Fiscal Statement* and applying a nominal annual discount rate of 10%. The choice of discount rate is largely arbitrary, although we note that this rate is consistent with estimates of the social opportunity cost of capital (New Zealand Treasury, 2008).

Expected returns and volatility

For each asset and liability class in the model, the expected return and volatility assumptions are set out in Table 14 (annual simple returns). The general approach for the different types of conventional assets and liabilities is set out in Table 12. The assumptions for the primary balance settings are discussed in more detail below.

Table 12 – Approach to estimating expected returns and volatilities for ordinary assets and liabilities

Entity type	Description of approach
DMO and RBNZ	The expected returns are set equal to the current yield on 5-year government bonds. Volatility is estimated based on the standard deviation of total returns on an index of New Zealand government bonds over 1996 to 2009.
SOEs	Expected returns are modeled to be equal to the cost of equity which is estimated to be 10% (Macquarie, 2008). Volatility is estimated based on the market volatility of equity in similar enterprises. All SOEs are assumed to have the same return characteristics, which is a modeling simplification.
Crown financial institutions (CFIs)	Return and volatility assumptions are estimated based on portfolio compositions. These have been adjusted to reflect that some CFIs hold some of their portfolios in the form of government bonds, holdings of which are eliminated because they are an intra-Crown transactions.
Government departments and Crown entities (excluding DMO, RBNZ and Crown financial institutions)	Most assets managed by government departments and Crown entities are property, plant and equipment. Expected returns and volatility have been estimated by looking at the historic return and volatility of a New Zealand commercial property index. For estimates of risk which exclude these social assets, the financial assets of government departments and Crown entities are assumed to have the same return characteristics as government bonds.
ACC liability and GSF liability	Expected returns are assumed to be the same as for government bonds. Volatility is assumed to be higher than for government bonds to reflect additional risks attributable to demographics and cost uncertainties.
Student loans	The expected return is based on an effective interest rate, which is used to impute the asset value. Volatility is assumed to be equal to that of government bonds.

Because of the relatively large size of primary revenue and expenditure components in the model, their return and volatility parameters are very important to the model's results. The primary balance is not a conventional asset or liability and does not have 'returns' in the conventional sense, but instead future expected revenue and spending increases are determined using the Treasury's long-term fiscal projections.

The model does not have any mean-reversion assumed and therefore the modeled volatility should be thought of as the permanent component of changes in taxes and spending. Thus what is needed is an estimate of forecast error in the structural level of primary revenue and expenditure, holding policy settings constant.

Keene and Thomson (2005) analyse tax forecasting errors by the Treasury. Their analysis focuses on the one-year-ahead forecasts. They adjust for policy change. Their key finding was that tax revenue errors had a standard deviation of 3.2%. This is likely to have some error attributable to non-permanent effects, which would overstate error. On the other hand, forecasting tax revenue over the longer term would be expected to be subject to greater uncertainty.

Treasury's projections of GDP may also be useful as an indicator. We looked at projections for real GDP in the *Budget Economic and Fiscal Updates* over 2003 to 2009.

The standard deviation to the annual change in projections for real GDP was 2.4% and the standard deviation in the difference to the most up-to-date projection was 3.1% (looking at projections for the 2020 fiscal year where all variables are at trend levels). Tax revenues would tend to be more volatile than GDP, so this might understate revenue volatility.

There is a literature on estimating output gaps in real time. A US study found volatility in simulated revisions to output gap estimates to be in the range of 1.5% to 3.5%, depending on the different filtering techniques (Orphanides and van Norden, 2002). A New Zealand study (Graff, 2004) estimated much smaller errors, with average absolute deviations of 0.9% for 15 quarters over 1997 to 2000. These studies are likely to represent a lower bound on the uncertainty of future tax revenues because they only analyse uncertainty in real time.

Based on this evidence (limited as it is), we chose a value for the annual volatility of 3.0% for primary revenue and 1.5% for primary expenditure. The latter is no more than an educated guess based on the intuition that volatility in expenditure, holding policy constant, is likely to be smaller than the volatility of tax revenue.

Net capital injections

We assume that SOEs pay dividends of 4.5% of their pre-dividend equity value, reflecting the average over the past eight years. Crown financial institutions do not receive capital injections, which is a simplification and reflects the temporary suspension of contributions to the NZSF. Other assets are assumed to have a net capital injection of 2% per annum, reflecting new capital expenditure and advances, but this is only an approximation.

Correlations

Correlations are estimated using historical time series of monthly returns. Sample correlations between each time series are computed with equal weight placed on each observation. A list of the datasets is shown in Table 13. The correlation coefficients used in the model are given in Table 15. The length of the time series is relatively short – around 40 quarters.

In some cases, the same dataset is used to proxy the returns of more than one asset or liability class in the model. This has two consequences. First, where two classes have the same dataset used to proxy returns, we have had to use our judgement for the correlation between them. We did this based on what we considered to be economically plausible relationships. The second consequence of this approach is that there is no guarantee of generating a valid correlation matrix (which must have the mathematical property of being positive semi-definite). In order to generate a positive semi-definite correlation matrix, we used an algorithm developed in Higham (2002), which finds the closest valid correlation matrix to the 'invalid' one. This algorithm finds a valid correlation matrix which for practical purposes is very close to the original specification.

A critical correlation coefficient is that between primary revenue and primary expenditure. No reliable data was available because of the endogeneity to policy choice. There is suggestive evidence in the Treasury's Long-term Fiscal Model. Here, primary revenue and expenditure are positively correlated because higher economy-wide labour productivity affects both tax revenue and expenditures on New Zealand Superannuation payments and the public-sector wage bill of existing programmes. In that model, a 1% change in tax revenues due to labour productivity variability is associated with a 0.6% change in primary expenditures, holding policy constant. Other factors can effect affect tax and not spending (or vice versa), such as changes in labour participation. We chose as a correlation parameter the value of 0.5.

Table 13 – Time series datasets for determining correlations

Entity	Dataset	Period
Primary revenue	Treasury's projections for real GDP (for 2020 fiscal year)	2003-2009
Primary expenditure	Treasury's projections for real GDP (for 2020 fiscal year)	2003-2009
Debt Management Office	ANZ New Zealand Government Bond Index	1996-2009
Reserve Bank of New Zealand	ANZ New Zealand Government Bond Index	1996-2009
New Zealand Railways Corporation	NZX property index	1997-2009
Meridian Energy	NZX energy index	1997-2009
Mighty River Power	NZX energy index	1997-2009
Landcorp Farming	NZX property index	1997-2009
Genesis Power	NZX energy index	1997-2009
Transpower New Zealand	NZX energy index	1997-2009
New Zealand Post	NZX finance index	1997-2009
Other SOEs	NZX midcap index	1997-2009
Air New Zealand	NZX transport index	1997-2009
New Zealand Railways Corporation	NZX property index	1997-2009
NZSF	NZSF actual returns	2003-2009
EQC	EQC actual returns	2004-2009
ACC assets	ACC actual returns	2001-2009
GSF assets	GSF actual returns	2002-2009
ACC liability	ANZ New Zealand Government Bond Index	1996-2009
GSF liability	ANZ New Zealand Government Bond Index	1996-2009
New Zealand Transport Agency	NZX property index	1997-2009
Ministry of Education/Schools	NZX property index	1997-2009
Housing New Zealand	NZX property index	1997-2009
District Health Boards	NZX property index	1997-2009
Student loans	ANZ New Zealand Government Bond Index	1996-2009
Other	NZX property index	1997-2009
US dollar–denominated debt	Total return index for United States Government Bonds with maturity of 3-5 years, converted to New Zealand dollars.	1996-2009

Table 14 – Return, volatility and capital injection assumptions

	Asset (if applicable)			Liability (if applicable)		
	Expected return	**Volatility**	**Net capital injection**	**Expected return**	**Volatility**	**Net capital injection**
Primary balance	N/A	3.0%	N/A	N/A	1.5%	N/A
DMO	N/A	N/A	N/A	5.5%	4.0%	Residual
Reserve Bank of New Zealand	5.5%	4.0%	0.0%	N/A	N/A	N/A
New Zealand Super Fund	6.6%	10.0%	0.0%	N/A	N/A	N/A
Accident Compensation Corporation	8.0%	15.0%	0.0%	5.5%	6.0%	0.0%
Earthquake Commission	8.0%	15.0%	0.0%	N/A	N/A	N/A
GSF	6.6%	10.0%	0.0%	5.5%	5.0%	0.0%
New Zealand Railways	7.0%	12.0%	-4.5%	N/A	N/A	N/A
Meridian Energy	10.0%	20.0%	-4.5%	N/A	N/A	N/A
Mighty River Power	10.0%	20.0%	-4.5%	N/A	N/A	N/A
Landcorp Farming	10.0%	20.0%	-4.5%	N/A	N/A	N/A
Genesis Power	10.0%	20.0%	-4.5%	N/A	N/A	N/A
Transpower New Zealand	10.0%	20.0%	-4.5%	N/A	N/A	N/A
New Zealand Post	10.0%	20.0%	-4.5%	N/A	N/A	N/A
Other SOEs	10.0%	20.0%	-4.5%	N/A	N/A	N/A
Air New Zealand	10.0%	20.0%	-4.5%	N/A	N/A	N/A
New Zealand Transport Agency	7.0%	12.0%	2.0%	N/A	N/A	N/A
Housing New Zealand	7.0%	12.0%	2.0%	N/A	N/A	N/A
Ministry of Education/Schools	7.0%	12.0%	2.0%	N/A	N/A	N/A
District Health Boards	7.0%	12.0%	2.0%	N/A	N/A	N/A
Student loans	7.0%	4.0%	2.0%	N/A	N/A	N/A
Other	7.0%	12.0%	2.0%	N/A	N/A	N/A
US dollar–denominated debt	N/A	N/A	N/A	5.5%	15.0%	N/A

Table 15 – Correlation assumptions

	Primary revenue	RBNZ	NZSF	ACC	EQC	GSF	New Zealand Railways	Meridian Energy	Mighty River Power	Landcorp Farming	Genesis Power	Transpower New Zealand
Primary revenue	**1.0**											
RBNZ	0.1	**1.0**										
NZSF	0.2	-0.5	**1.0**									
ACC	0.1	0.0	0.6	**1.0**								
Earthquake Commission	0.2	0.2	0.4	0.8	**1.0**							
GSF	0.1	-0.4	0.9	0.7	0.4	**1.0**						
New Zealand Railways	0.1	-0.2	0.7	0.5	0.3	0.6	**1.0**					
Meridian Energy	0.1	0.0	0.6	0.7	0.5	0.6	0.7	**1.0**				
Mighty River Power	0.1	0.0	0.6	0.7	0.5	0.6	0.7	0.8	**1.0**			
Landcorp Farming	0.1	-0.2	0.6	0.5	0.3	0.6	0.5	0.7	0.7	**1.0**		
Genesis Power	0.1	0.0	0.6	0.7	0.5	0.6	0.7	0.8	0.8	0.7	**1.0**	
Transpower New Zealand	0.1	0.0	0.6	0.7	0.5	0.6	0.7	0.8	0.8	0.7	0.8	**1.0**
New Zealand Post	0.0	-0.4	0.8	0.6	0.4	0.7	0.5	0.5	0.5	0.5	0.5	0.5
Other SOEs	0.1	-0.4	0.9	0.7	0.4	0.8	0.7	0.7	0.7	0.7	0.7	0.7
Air New Zealand	-0.2	-0.2	0.6	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.3	0.3
New Zealand Transport	0.1	-0.2	0.7	0.5	0.3	0.6	0.8	0.7	0.7	0.5	0.7	0.7
Housing New Zealand	0.1	-0.2	0.7	0.5	0.3	0.6	0.5	0.7	0.7	0.5	0.7	0.7
Ministry of Education/Schools	0.1	-0.2	0.7	0.5	0.3	0.6	0.5	0.7	0.7	0.5	0.7	0.7
District Health Boards	0.1	-0.2	0.7	0.5	0.3	0.6	0.5	0.7	0.7	0.5	0.7	0.7
Student loans	0.1	0.5	-0.5	0.0	0.2	-0.4	-0.2	0.0	0.0	-0.2	0.0	0.0
Other	0.1	-0.2	0.7	0.5	0.3	0.6	0.5	0.7	0.7	0.5	0.7	0.7
Primary expenditure	0.5	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
DMO (unhedged debt)	0.1	0.8	-0.5	0.0	0.2	-0.4	-0.2	0.0	0.0	-0.2	0.0	0.0
ACC liability	0.1	0.5	-0.5	0.0	0.2	-0.4	-0.2	0.0	0.0	-0.2	0.0	0.0
GSF liability	0.1	0.5	-0.5	0.0	0.2	-0.4	-0.2	0.0	0.0	-0.2	0.0	0.0
US dollar–denominated debt	-0.1	0.5	-0.7	-0.2	0.2	-0.7	-0.4	-0.1	-0.1	-0.4	-0.1	-0.1

	New Zealand Post	Other SOEs	Air New Zealand	New Zealand Transport	Housing New Zealand	Ministry of Education /Schools	District Health Boards	Student loans	Other	Primary balance	DMO	ACC liability	GSF liability
Primary revenue													
RBNZ													
NZSF													
ACC													
Earthquake Commission													
GSF													
New Zealand Railways													
Meridian Energy													
Mighty River Power													
Landcorp Farming													
Genesis Power													
Transpower New Zealand													
New Zealand Post	**1.0**												
Other SOEs	0.8	**1.0**											
Air New Zealand	0.4	0.6	**1.0**										
New Zealand Transport	0.5	0.7	0.4	**1.0**									
Housing New Zealand	0.5	0.7	0.4	0.5	**1.0**								
Ministry of Education/Schools	0.5	0.7	0.4	0.5	0.8	**1.0**							
District Health Boards	0.5	0.7	0.4	0.5	0.8	0.8	**1.0**						
Student loans	-0.4	-0.4	-0.2	-0.2	-0.2	-0.2	-0.2	**1.0**					
Other	0.5	0.7	0.4	0.5	0.8	0.8	0.8	-0.2	**1.0**				
Primary expenditure	0.0	0.1	-0.2	0.1	0.1	0.1	0.1	0.1	0.1	**1.0**			
DMO (unhedged debt)	-0.4	-0.4	-0.2	-0.2	-0.2	-0.2	-0.2	0.5	-0.2	0.1	**1.0**		
ACC liability	-0.4	-0.4	-0.2	-0.2	-0.2	-0.2	-0.2	0.5	-0.2	0.1	0.5	**1.0**	
GSF liability	-0.4	-0.4	-0.2	-0.2	-0.2	-0.2	-0.2	0.5	-0.2	0.1	0.5	0.5	**1.0**
US dollar–denominated debt	-0.3	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4	0.5	-0.4	-0.1	0.5	0.5	0.5