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NZSIM: A model of the New Zealand economy for forecasting and policy analysis

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The New Zealand Structural Inflation Model, NZSIM, is the Reserve Bank's core macroeconomic model. NZSIM provides the central organising framework for the Reserve Bank's forecasting and economic analysis during the monetary policy making process. NZSIM was designed to be smaller and simpler than the previous model to make the model outcomes easier to understand and to improve its ease of use in the policy process.

1 The authors would like to thank colleagues at the Reserve Bank for their feedback on earlier drafts of this article.

1 Introduction

Central banks use structural macroeconomic models for a variety of reasons: as a framework for thinking about the economy, to codify institutional knowledge, and to produce forecasts for economic variables, among others. The Reserve Bank of New Zealand has been developing models to use in policy analysis since 1971.[2] These models have evolved with academic thinking and central bank practice, moving from large empirical models designed to explicitly capture the properties of observed economic data to theory-based models that use micro-economic agents to represent the behaviour of different groups in the economy.

The New Zealand Structural Inflation Model, NZSIM, is the latest iteration in the Reserve Bank's structural macroeconomic modelling. NZSIM provides the platform for the Bank's medium term economic analysis and scenario testing during the monetary policy making process. In this article, we first provide a brief review of the Bank's recent models and

2 See Deane (1971)

the philosophy underpinning the design of NZSIM. This is followed by an overview of the key structural and semi-structural features of NZSIM, and a discussion of its use in the forecasting process. We then illustrate NZSIM's ability to consider complex economic scenarios. The final section concludes.

Developments in central bank modelling

Central bank modelling in the 1960s and 1970s consisted primarily of large empirical macroeconomic models.[3] Some of these models contained hundreds of equations, with a correspondingly large number of parameters and many restrictions. These models could match observed correlations in the data, but the lack of internal theoretical consistency meant it was difficult to identify the underlying drivers of economic activity.[4] These models were also subject to the 'Lucas critique',[5] which argued that the model parameters depended implicitly on economic agents' expectations of future policy. Such models were useful only for assessing policy impacts within a given regime and inappropriate should the policy regime change, thus limiting their usefulness for analysing alternative policy choices.

In the 1980s, academic economists developed models that computed aggregate economic outcomes from the interactions of forward-looking consumers and firms, rather than modelling the aggregate outcomes directly. The underlying parameters that governed the choices of model agents – given their objectives and constraints – were invariant to changes in the policy regime. It became possible to evaluate how agents' behaviour (and thus aggregate outcomes) would evolve in response to a change in public policy (for example a change in the central bank's policy objective). With advances in theory and computing technology, such dynamic stochastic general equilibrium (DSGE) models have become a standard workhorse for monetary policy analysis.[6]

To be used as the core macroeconomic model in a policy environment, DSGE models must be able to forecast at least as well as simple time series models (and so overcome another criticism of the large-scale macroeconomic models of the 1970s).[7] From the perspective of policy formation, if a model cannot represent the data reasonably well then it is difficult to believe any quantitative recommendations arising from it.

By the early 2000s, DSGE models had developed to the point where they showed comparable forecasting performance to time series models (such as vector-autoregressive models) and were theoretically rich enough to be used for detailed policy analysis.[8] This encouraged central banks to develop such models for the United States, United Kingdom, Canada, Sweden, Norway, and New Zealand, among others.[9]

However, a well-designed policy model should be evaluated for more than empirical fit or forecasting accuracy. Many statistical models can produce robust forecasts for individual variables but are silent on the economic fundamentals driving their forecasts. The theoretical structure of DSGE models allows the identification of fundamental economic drivers and their transmission through the economy to explain observed

3 Fukač and Pagan (2009) provide a historical overview of structural modelling in a policy environment.

4 Sims (1980) criticised the "incredible" assumptions needed to identify these models.

5 See Lucas (1976).

6 *General equilibrium* models are those in which markets clear taking all information into account, *stochastic* refers to the assumption about the type of economic shocks that occur, while *dynamic* models capture the transition of the economy from its current state to its long-run equilibrium.

7 Nelson (1972) found that simple time-series models showed better out-of-sample forecasting performance than the FRB-MIT-PENN model of the US economy (a large-scale econometric model) for a number of economic variables.

8 For example, see Smets and Wouters (2003).

9 See, for example, Erceg et al. (2006), Murchinson and Rennison (2006), Adolfson et al. (2007), Burgess et al. (2013), and Brubakk et al. (2009).

economic data. These underlying drivers can be used to test alternative scenarios or articulate the rationale for particular policy choices. In addition, DSGE models provide an internally consistent set of forecasts; the forecast for a given variable will take account of forecasts for all other variables. This is not necessarily the case when using statistical models to forecast individual variables.

2 Modelling at the Reserve Bank of New Zealand

2.1 Previous models at the Reserve Bank

In the early 1970s, the Reserve Bank introduced large macroeconometric models – essentially systems of equations – which were based on direct relationships between macroeconomic variables. Over time, features such as a larger role for inflation expectations were added as economic theory advanced. However, the large structural changes to the New Zealand economy during the late 1980s decreased the usefulness of existing models that relied heavily on historical relationships.[10]

The first general equilibrium model introduced at the Reserve Bank was the Forecasting and Policy System (FPS),[11] which was used between 1997 and 2009. The emphasis during the development of FPS was on a 'top-down' approach in contrast to the equation-by-equation 'bottom-up' method of constructing previous models. This was to ensure that the model as a whole embodied properties that were sensible both theoretically and empirically. However, as was common with early general equilibrium models, there were trade-offs between theoretical consistency and empirical fit.

With improved modelling techniques and computing technology, the Reserve Bank developed a new structural macroeconomic model of the New Zealand economy from 2006-2009. This model, Kiwi Inflation-Targeting Technology (KITT), reflected the advances made in macroeconomic modelling since the introduction of FPS.[12] In particular, KITT incorporated multiple sectors of the economy and explicitly allowed for structural economic shocks. In addition, advances in estimation techniques meant that many parameters of KITT could be estimated from economic data rather than calibrated by the model-builders.

Although KITT successfully incorporated many important structural features of the New Zealand economy, its size and complexity made it difficult to use in the Reserve Bank's regular forecasting process. In particular, it was difficult to produce forecasts that were well understood in the timeline required for the six-weekly monetary policy decisions.[13]

2.2 NZSIM

The current model, NZSIM,[14] was developed with this experience in mind. The challenge was to create a small, tractable model that was

10 Spencer and Karagedikli (2006) provide a fuller description of the Reserve Bank's experience with macroeconomic modelling.

11 For an introductory description of FPS see Black et al. (1997). Delbrück et al. (2008) describe how FPS evolved over time.

12 Lees (2009) provides an introduction to KITT.

13 This problem is not unique to the Reserve Bank. For example, the trade-off between model comprehensiveness and tractability is discussed by Burgess et al. (2013) in a paper introducing the Bank of England's new model and forecasting system.

14 For a more complete and technical description of NZSIM, see Kamber, McDonald et al. (2016). Note that the current version of NZSIM used for forecasting contains some differences to that described by Kamber, McDonald et al. (2016). In particular, it contains additional 'semi-structural' elements (see section 4).

sufficiently comprehensive to capture the key dynamics and empirical relationships observed in the New Zealand economy. To achieve this balance a ‘semi-structural’ approach was taken – combining a core DSGE model with auxiliary equations that reflected practical modelling experience at the Reserve Bank.

NZSIM, like many other DSGE models, is built around the concept of trends and cycles. We assume that there are trends or steady-states which capture the long-run behaviour of economic variables. However, in the short-to-medium term, economic shocks will push the economy away from this steady-state or trend path, leading to economic cycles. Examples of such shocks include a rise in foreign demand for New Zealand’s exports, a change in households’ saving preferences, or an unexpected increase in government spending.

The DSGE core of the model includes three key optimising agents – households, domestic firms, and import-distributing firms. These agents maximise a stated objective (for example, firms maximise profits) subject to a set of constraints. A fourth important agent is the central bank, which tries to keep inflation near target, while the foreign sector links New Zealand with the rest of the world.

The interaction of these agents provides a theoretical representation to match the key correlations observed in New Zealand economic data and reflects the well established literature of structural models in New Zealand, including KITT. Because the key macroeconomic outcomes in the model are the result of assumptions about agents’ microeconomic behaviour, this type of model is often referred to as ‘micro-founded’.

The DSGE core of the model is augmented by a number of auxiliary equations. These equations are designed to capture important empirical relationships the Reserve Bank wants to consider (such as the link between consumption and house prices in New Zealand) but that would add significant complexity to the model if based on micro-foundations. These relationships are influenced by, and in some cases affect, the DSGE core of the model. Introducing additional relationships into the model requires trade-offs between improving empirical fit, forecasting ability, and the costs of additional complexity.

3 Structural foundations of NZSIM

The DSGE core of NZSIM represents the economy using economic agents, modelled using micro-foundations consistent with standard open economy new-Keynesian DSGE models.[15] Households represent workers and consumers in the economy. There are two types of firms: domestic firms (representing businesses that produce goods or services locally) and importing firms (representing businesses that import most of their stock). The central bank sets the interest rate in the economy.

The behaviour of these agents is necessarily an abstraction from reality, but the interactions between the various agents are able to represent the key macroeconomic relationships observed in the economy. An important assumption is that households and firms display optimising behaviour; that is, we assume that people and firms make decisions that will maximise their utility (well-being) and profits respectively, subject to the constraints that they face. The behaviour of each of these agents is discussed further below.

15 See, for example, Adolfson et al. (2007).

3.1 Households

Households perform several key functions in NZSIM. They provide labour to domestic firms (enabling firms to produce output) and they consume both locally produced and imported goods. Within this framework, households are assumed to maximise their consumption, subject to a budget constraint that reflects the wage they earn, existing savings, and any borrowing.

Households are assumed to prefer stable levels of consumption through time, so expectations of future economic conditions will influence households' decisions about consumption and savings today. This generates interdependence between different time periods, such that choices with respect to consumption, saving, and labour supply take into account both current and future conditions.

The central bank influences households' behaviour by adjusting the interest rate at which households can borrow and save each period. A higher interest rate encourages saving by increasing the opportunity cost of consumption, while a lower interest rate encourages greater consumption today by reducing the payoff from saving.

3.2 Domestic firms

Domestic firms operate under monopolistic competition, producing goods that are imperfect substitutes for others. Firms therefore have a degree of market power that enables each firm to set its own price.[16] Domestic producers aim to maximise their profits by setting their price as a mark-up over marginal cost. The change in aggregate prices set by domestic firms represents non-tradable inflation in NZSIM. Domestic firms use only one input – labour supplied by households – to produce output.[17]

In the economy, firms are unable or unwilling to change prices quickly in response to changing economic conditions and we observe 'sticky' prices (a slow response of aggregate prices to changes in economic conditions). This effect is achieved in NZSIM by making larger price changes more costly for firms than smaller changes, so that they prefer to adjust prices in a sequence of small steps rather than in one large step.

The price-setting assumptions – that each firm sets its price as a mark-up over marginal costs and faces adjustment costs for changing its price – imply that firms' expectations about future labour costs will affect their price setting today. Expectations about future economic conditions (that influence demand for their output) will also affect firms' pricing decisions due to the costs associated with changing prices.

Like households, firms' behaviour is also influenced by the central bank. When the central bank raises the interest rate, firms decrease their expectations for future production (because they expect lower demand from households) and reduce their demand for labour accordingly. Households respond to the reduced demand for their labour by reducing their wage expectations, lowering costs to firms. Facing lower input costs, firms will decrease the selling price of their goods. However, due to the cost of adjusting prices, the selling price will not fall by the full amount

16 This contrasts with perfect competition in which goods are perfect substitutes and no single firm has pricing power, but must simply accept the prevailing 'market' price.

17 Firms are commonly modelled as using both capital and labour to produce output. However, modelling capital accumulation using optimising behaviour increases complexity and, in a New Zealand context, does not fit the data well. Consequently, in NZSIM we assume that capital is fixed for the length of the business cycle and thus model output as a function of labour alone. By not explicitly modelling capital and investment in the DSGE core we can significantly reduce the complexity of NZSIM. Investment expenditure is, however, modelled using a semi-structural approach.

required to maintain the firms' mark-up at a constant level. The combined impact of these effects is to reduce non-tradable inflation..

3.3 Importing firms

Importing firms aim to maximise profits by setting the price at which they distribute products imported from overseas. Rather than directly employing labour, importing firms use domestically produced goods as a second input, representing the local component of their business such as distribution costs.

As with domestic firms, importing firms operate under monopolistic competition, set their prices as a mark-up over marginal cost, and face costs for adjusting their prices. The change in aggregate prices set by importing firms represents tradable inflation in the model, and depends on both current economic conditions and expectations of the future.

Imports are priced in terms of foreign currency, hence the exchange rate affects the marginal costs of importing firms. When the exchange rate depreciates, the input cost for an importing firm rises in New Zealand dollar terms, encouraging it to raise prices to maintain its mark-up and thereby increasing inflationary pressure in the tradable sector. An increase in the world (foreign currency) price of imports works in a similar fashion.

Interest rates in the model affect importing firms' pricing decisions by affecting both domestic demand and the exchange rate. Higher interest rates increase foreign demand for New Zealand dollar assets, causing an exchange rate appreciation that reduces the marginal costs of the importing firm. In addition, higher interest rates decrease the domestic component of importing firms' costs by reducing the price of goods sold by domestic firms (as described in section 3.2). Lower costs flow through into firms' pricing decisions and aggregate tradable inflation.

3.4 The central bank

Economic shocks can cause booms or busts in the economy, which can generate unwanted changes to the inflation rate and lead to inefficient allocation of resources. The central bank aims to keep future inflation close to its target by stimulating or cooling the economy as needed, which helps to minimise the cost of these shocks. The central bank achieves this aim by changing the nominal interest rate which, because prices adjust only gradually, affects the real interest rate faced by households and firms.

In keeping with previous models, the central bank follows an empirical policy rule that responds to expected future inflation pressure while favouring smaller interest rate moves over larger movements (smoothing the path of interest rates over time). This rule was chosen to approximate past behaviour by the Reserve Bank and is consistent with the Bank's objectives as specified under the Policy Targets Agreement.

3.5 The rest of the world

New Zealand is a small open economy with many links to the rest of the world. This is reflected in NZSIM. Two of the key links between New Zealand and the world are foreign demand for New Zealand's exports and the terms of trade (the ratio of export prices to import prices). The foreign sector is treated as exogenous in NZSIM: that is, the world can affect the New Zealand economy but New Zealand cannot affect the world.

The implicit assumption behind foreign demand for exports is that New Zealand is too small to affect world markets, so any increase in the volume of New Zealand's exports will not affect the world price. A rise in foreign demand for New Zealand's exports boosts the domestic economy by increasing export receipts and overall demand.

The terms of trade can also have significant effects on the domestic economy. For example, higher export prices boost the income New Zealand earns from offshore, leading to increased spending and inflationary pressure in the domestic economy.

3.6 The exchange rate

The exchange rate in NZSIM is modelled using a modified uncovered interest parity (UIP) condition that relates the expected change in the exchange rate to changes in domestic or foreign interest rates.[18] Any shocks to the New Zealand economy that affect expected inflation – prompting the central bank to change interest rates – will therefore be reflected in the exchange rate.

4 Semi-structural components in NZSIM

NZSIM includes a number of 'semi-structural' equations which augment the DSGE core of the model. These equations capture key relationships that are observed in New Zealand data but are not easily reconciled with a DSGE framework. In this context, 'semi-structural' refers to model components that are not derived from fundamental assumptions about the behaviour of model agents. However, these components still interact with and influence the core DGSE model. The semi-structural approach is a pragmatic solution to keep the model tractable while improving empirical fit. House prices and investment expenditure are two components modelled using this approach.

4.1 Housing

The housing market is an important part of the New Zealand economy. Although some models employ micro-foundations to model housing market dynamics over the business cycle, these models tend to struggle to account for the strong correlation between house prices and consumption observed in New Zealand, and the high persistence of house price inflation.[19]

House prices in NZSIM are determined by a 'Phillips-curve' type relationship in which past prices and expectations of future price increases drive current house price inflation. In addition, increases in interest rates and migration lower and raise house prices respectively.[20] Debt provides a constraint on house price increases so that households cannot borrow indefinitely to buy ever more expensive houses.

Consumption decisions in NZSIM are explicitly linked to the level of real house prices, so that as house prices rise, households increase their consumption accordingly.[21] This addition helps to capture the observed

18 UIP ensures that equivalent domestic and foreign assets yield the same returns once expected movements in exchange rates are taken into account. The modifications to the standard UIP relationship are based on Adolfson et al. (2008).

19 Gelain and Lansing (2014), p.4, note that: "Standard dynamic stochastic general-equilibrium (DSGE) models with fully-rational expectations have difficulty producing large swings in house prices that resemble the patterns observed in the U.S. and other countries over the past decade."

20 Migration is included in this relationship to capture the observed empirical link between house prices and migration (see McDonald 2013).

21 Note, however, that households do not spend their income on buying houses; NZSIM does not explicitly model the housing stock.

correlation between house prices and consumption. The direction of causation is consistent with a narrative in which a rise in house prices lifts households' perceptions of their personal wealth, leading to higher consumption.[22]

4.2 Investment

NZSIM uses semi-structural equations to model two components of investment: housing and business investment. Housing investment shares the same fundamental drivers as house prices, and also responds directly to house price movements to further connect the two variables.

Business investment is modelled to follow the general business cycle – a booming economy leads to stronger business investment.[23] Additionally, an increase in export prices directly boosts business investment, reflecting an empirical result found by Kamber, Nodari et al. (2016). Incorporating business investment in this manner amplifies the effects that economic shocks have on output.

4.3 Challenges of incorporating semi-structural equations

Semi-structural equations can usefully embed strong empirical relationships in the model. However, a risk is that they may produce unexpected interactions with the rest of the system, contradict existing features in the model, or violate the general equilibrium conditions or constraints. For this reason, each feature has been evaluated to ensure the general equilibrium implications are desirable and that the feature improves empirical fit.

In addition, the underlying behaviour that gave rise to these relationships can change over time. For this reason, the Reserve Bank tests and evaluates the validity of these assumptions as the model is used during the forecasting process. For example, in recent quarters the Bank has dampened the impact of migration on domestic demand.[24] This adjustment reflects the observation that changes to the composition of migrants currently entering New Zealand has resulted in a weaker correlation between migration and consumption than historical relationships would imply.[25]

5 Model operation in a policy environment

5.1 The forecasting process at the Reserve Bank

NZSIM was designed to produce forecasts and facilitate policy analysis to support the monetary policy decision-making process. However, there is uncertainty associated with the specification of any model and it would be a mistake to set policy exclusively based on the output of one model of the economy.[26]

22 This is often called a 'wealth effect'. For further discussion see De Veirman and Dunstan (2008).

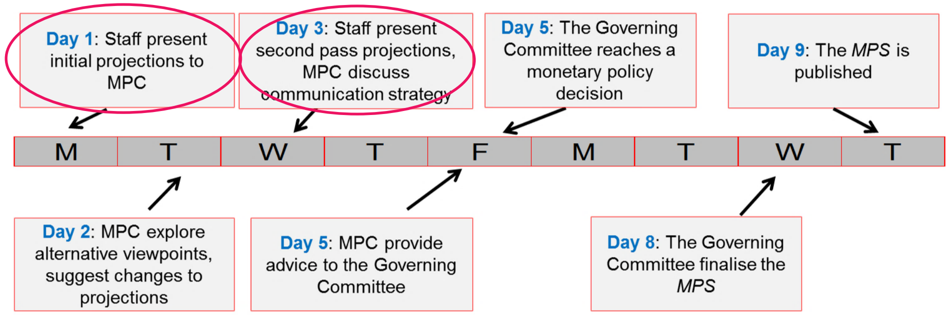
23 This is a more simplistic representation of investment than standard New-Keynesian DSGE models. See footnote 17 for more details.

24 See the March 2016 *Monetary Policy Statement.*

25 See Vehbi (2016).

26 The Reserve Bank has access to diverse data and information sources, including official statistics, financial market information, survey data, business information visits, and anecdotal information. These data are used by a suite of alternative statistical models and otherwise incorporated into the policy process.

Figure 1
The role of NZSIM in the forecast process



Source: Richardson (2016), RBNZ.

Note: NZSIM is used in the steps outlined by the red circles.

The role of NZSIM in the forecasting process is outlined in figure 1.[27] Baseline NZSIM forecasts are modified to take account of additional information not directly represented in NZSIM (for example, a pre-announced change in government charges) and policymakers' judgements about the current and future economic outlook. These forecasts are cross-checked, and altered where appropriate, using a range of other models and judgement from the Reserve Bank's staff and policy committees. In this sense, the Bank's forecasts and policy decisions are model-assisted, rather than model-produced.

NZSIM is perhaps best thought of as an organising framework which codifies policymakers' assumptions and judgements over time. NZSIM ensures a common structure is used to start the analysis in each forecast round so there is consistency and continuity in the way the Reserve Bank updates its projections based on new information.

27 More details on the forecasting process at the Reserve Bank can be found in McDermott (2013) and Richardson (2016).

5.2 *Testing alternative scenarios*

Another advantage of using a structural model such as NZSIM is its ability to consider alternative scenarios within the same modelling framework. Scenario analysis can help the Reserve Bank identify and communicate risks to the outlook, and the likely policy response should these risks eventuate. Box A, overleaf, presents a scenario included in the June 2016 *Monetary Policy Statement* illustrating how the Bank would respond to an unexpected increase in house prices.

The use of alternative scenarios can also help policymakers consider the policy implications of similar economic observations with different fundamental drivers. When there is uncertainty about the drivers of a change in economic conditions, it is often useful for the Reserve Bank to consider a variety of possible factors to assess how monetary policy should respond if different circumstances eventuate.

For example, suppose the Reserve Bank observes a fall in global oil prices. The implications for the New Zealand economy, and thus for monetary policy, may be quite different depending on whether this fall is a result of increased oil supply or reduced global demand. Using NZSIM, the Bank can run scenarios to identify possible economic consequences and policy responses in each case. Over time, as the drivers of the oil price weakness become better understood, policymakers can adapt their policy response accordingly.

5.3 *Using NZSIM for policy analysis*

The flexibility of NZSIM means that, as well as being a useful tool for the forecasting process, it can be used for wider policy analysis. NZSIM has been used internally as a framework to examine a range of policy questions. For example, Lewis and McDermott (2016) use NZSIM to

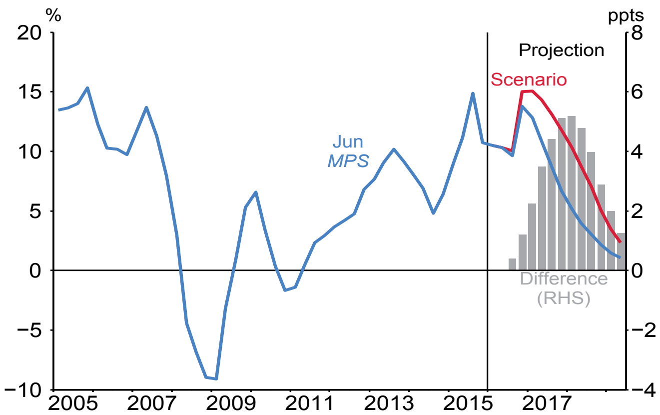
Box A

Scenario of higher house price inflation and domestic demand

In this scenario, house price inflation increases further and remains elevated for a longer period than assumed in the base forecast (figure A1). This increase is unrelated to explainable factors such as lower expected interest rates or stronger migration. Higher house price inflation translates into stronger growth in household consumption (via a 'wealth effect') and so into stronger domestic demand.

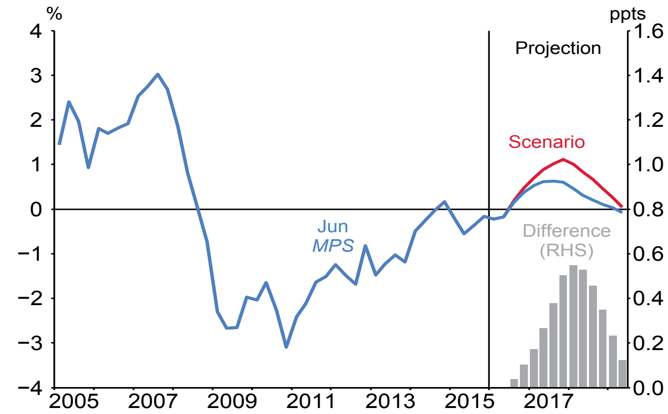
As a result, the output gap peaks at a higher level than in the base forecast (figure A2). Stronger capacity pressures would generate higher non-tradables inflation, requiring the central bank to raise interest rates (figure A3). Over the medium term, tighter monetary conditions dampen demand and output, closing the output gap and causing CPI inflation to settle near two percent.

Figure A1
House price inflation



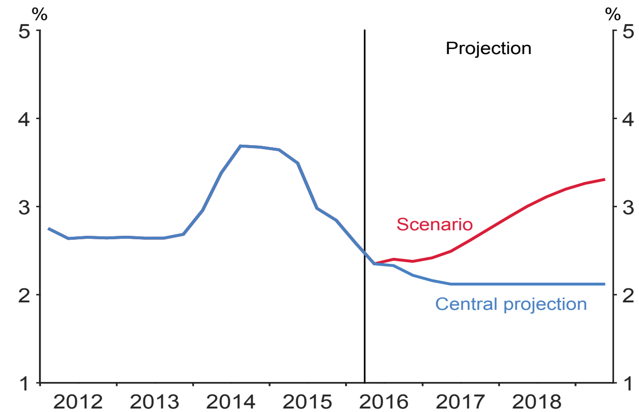
Source: RBNZ.

Figure A2
Output gap (share of potential output)



Source: RBNZ.

Figure A3
Scenario 90-day interest rate paths



Source: RBNZ.

document the experience of the Reserve Bank in changing its inflation target and the subsequent impact on inflation expectations.

6 Concluding remarks

NZSIM continues the structural approach to forecasting models used at the Reserve Bank. NZSIM is intentionally smaller in scale than its predecessor, KITT, making it easier to use in the forecasting process. Although no model can completely capture the richness and complexity of the forces that drive the business cycle, NZSIM provides a consistent structure with which to answer many questions that are relevant to the monetary policy making process.

NZSIM, as a structural model, provides a sophisticated platform for evaluating the impact of various economic scenarios and the appropriate policy response in each case. This 'risk-based' style of scenario analysis has become an important component of the Reserve Bank's forecasting process and monetary policy communication.

This article describes NZSIM as it is currently used at the Reserve Bank. It is likely that NZSIM will be updated as the Bank's understanding of the drivers of the New Zealand economy evolves, as different risks are identified, and as new data become available. The flexibility of NZSIM means these changes may come through modifications to the underlying model structure, additional semi-structural channels, or through re-estimation of model parameters.

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