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The evolution of the Forecasting and Policy System (FPS) at the Reserve Bank of New Zealand*

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Abstract

The Forecasting and Policy System model (FPS) has been a very useful tool for forecasting and communication at the Reserve Bank of New Zealand. In part, its success has been due to pragmatic use, and the evolution of the model to reflect changing views of the New Zealand economy. However, as economic theory and modelling technology have developed, it is likely that the next core model for producing projections at the Reserve Bank will be a DSGE model. This note looks forward to that possibility with two aims in mind. First, the paper discusses how FPS has been used at the Reserve Bank over the last 11 years. Second, we describe how the structure of FPS has changed over time.

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* The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Reserve Bank of New Zealand. We have drawn on internal work by others who have worked with FPS over the last decade including, in approximate chronological order: R Black, V Cassino, A Drew, E Hansen, B Hunt, D Rose, A Scott, J McDermott, P Conway, J Breece, L Hunter, R St. Clair, Y Ha, C Hawkesby, D Stephens, J Twaddle, T Hampton, V Gaiduch, S McCaw, R Philip, A Huang, R Gray, and H Sutherland. We thank, without implication, colleagues including Leni Hunter and Troy Matheson for helpful comments. Any remaining errors are the authors' sole responsibility.

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1 Introduction

The Forecasting and Policy System (FPS) is a large macroeconomic model which has been used since 1997 by the Reserve Bank of New Zealand (RBNZ) to:

- provide policy advice on the Reserve Bank's interest rate decisions;
- produce and publish projections; and
- conduct economic research on the New Zealand economy.

FPS consists of over 150 equations which describe how different macroeconomic variables affect each other. The parameters or coefficients of these equations are not directly estimated using statistical techniques. Instead, the parameters are calibrated, partly on the basis of empirical evidence, but also to reflect the Reserve Bank's broader judgement about the behaviour of the New Zealand economy. These calibrations can change over time, as the economy evolves and new evidence that is inconsistent with the existing calibration comes to light.

Each quarter, the Reserve Bank publishes its economic projections in the *Monetary Policy Statement* (*MPS*). These projections – which are produced using FPS – reflect a plausible, internally consistent representation of the likely development of the New Zealand economy which is based on the information currently available. Since the transition to model-based projections in 1997, the published projections have incorporated an endogenous response of interest rates to the economic outlook. While other central banks have recently also begun to do so, this span of experience publishing endogenous policy projections is unique to the Reserve Bank.

FPS is a model in the tradition of the Bank of Canada's Quarterly Projection Model (QPM). It is more structural (reliant on economic theory) than the simple models described in (for example) Berg *et al.* (2006), incorporating a set of steady state relationships that are consistent with optimising behaviour and stock-flow accounting.[1] However, the dynamic relationships

[1] For example, the equilibrium capital stock is the solution to a representative firm's optimisation problem, and investment flows in equilibrium are consistent with this capital stock.

around these equilibrium paths are less structural. The basics of FPS are described in Black *et al.* (1997) and RBNZ (2004).

Overall, FPS has been a very useful tool for Reserve Bank forecasting and communication. In part, its success has been due to pragmatic use and the evolution of the model to reflect changing views of the New Zealand economy. However, as economic theory and modelling technology have developed, models which are more heavily based on microeconomic theory are starting to be used to produce economic projections, notably dynamic stochastic general equilibrium models (DSGEs). Consequently, it is likely that the next core model for producing projections at the Reserve Bank will be a DSGE model.

The remainder of this note is organised as follows. Section 2 discusses how FPS has been used at the Reserve Bank over the last 11 years. In particular, it outlines the Reserve Bank's experience with maintaining and using a 'core' model to generate published endogenous projections. In addition, it describes how the use of the model has changed and considers whether the model has met its objectives. Section 3 focuses on the key 'business cycle' stories implicit in FPS and how they have changed overtime. These calibration changes have tended to reflect discomfort with model results in live use. As a result, the model has become an increasingly useful representation of the Reserve Bank's view of the cyclical behaviour of the New Zealand economy. Section 4 concludes.

2 Evolution of model use

Since 1998, FPS has been used to generate forecast paths for key monetary policy variables including an endogenous interest rate response to the inflation environment. As described in RBNZ (2004), these projections are initially generated by staff in the Economics Department, then discussed and adjusted by the Monetary Policy Committee (MPC). FPS is also used to prepare 'alternative scenarios' to depict key economic risks, and has been used in research. In this section we first describe the use of FPS in preparing economic projections, focussing on factors that we think have added to the model's longevity. We then look more specifically at the use of endogenous interest rate forecasts and alternative scenarios, before turning to the use of FPS in research.

2.1 Model based projections

In the documentation of FPS (Black *et al.* 1997) Eric Hansen wrote that "*FPS will be a success if it comes to be treated by RBNZ staff as a reservoir of knowledge about the systematic behaviour of the New Zealand economy. This in turn will be measured by the extent to which FPS continues to be used in both projections and policy analysis*".

More than ten years later the same model framework and code base is still being used to generate projections. This is a relatively long period of time for a model to remain in active use.[2] However, it is important to note that FPS is not used as an 'independent' forecasting device. Instead, projections combine the macroeconomic model representation of the economy with staff judgement formed on the basis of 'off model' information and experience.

FPS serves two main functions in the projection process. Firstly, the model acts as a store of information of the Reserve Bank's view of the cyclical properties of the economy. For example, FPS provides a useful starting point for thinking about the implications of new economic data. Secondly, FPS assists staff with ensuring that projections are internally consistent. That is, the use of FPS has helped to ensure that changes to one part of the projection are appropriately reflected in all the other parts of the projection.

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[2] The role of FPS in generating quarterly projections has been described in RBNZ (2004).

In the remainder of this sub-section, we discuss four factors which have enhanced the durability of FPS, and its effectiveness as a tool. These factors are: the ease of making judgemental adjustments, an ability to recalibrate, the use of time series based detrending methods, and the adjustment of steady state ratios. We also describe some other features of the Reserve Bank's projections, including endogenous policy, alternative scenarios, and ready reckoners.

Judgemental adjustment

By the time a projection is first presented to the wider Economics department, it will have already been subject to significant judgemental adjustment. Judgement is often added because, as with any economic model, FPS is a simplified representation of the economy. Consequently, FPS has missing variables, and idiosyncratic events may not be well captured by the model. For example, large imported items (such as aeroplanes) may have more temporary impacts on the projection than allowed for in the FPS equations.

Judgement also serves as an interim measure, which is taken when there is a case for recalibration to part of the model. For example, new research may suggest that exports are more responsive to the exchange rate than the current model calibration implies. Until further work and a recalibration can be done, judgement may be used to achieve the desired model response.[3]

Recalibration

As noted in RBNZ (2004), FPS has been recalibrated when the Reserve Bank's view of the structure of the New Zealand economy has changed. This change in view is usually the result of new research, or consistent application of judgement. The ability to formalise this new view through recalibration has no doubt contributed to the endurance of FPS and is discussed further in section 3.

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[3] Model projections without any judgemental adjustment have also been presented to the MPC, but they are used more to discuss why particular judgments are necessary rather than as 'forecasts' in and of themselves.

Detrending to obtain a view of the business cycle

FPS consists of three layers: a long-run equilibrium or steady state; a time-varying short-run equilibrium model; and a cyclical model. The steady state values for each variable are derived from a calibrated general equilibrium model based on optimising behaviour. The short-run equilibrium (SREQ) is essentially a bridging layer between the long-run model and the short-run cyclical model, designed to allow for slow adjustment of economic processes when moving from one steady-state position to another. For many variables, obtaining the relevant SREQ paths involves applying time series filters to the historical data, which converges the SREQ to the steady state over the projection horizon. However, some SREQ variables follow logically from others. For example, an increase in the equilibrium or 'neutral' real short-term interest rate will also lead to increases in the neutral levels of other interest rates in the model.

The cyclical model seeks to capture business cycle dynamics. It is the part of FPS where inflation may deviate from the target, requiring a monetary policy response. All series in the cyclical model can be expressed in terms of 'gaps', or deviations from their SREQ. For example, the deviation of output from potential (trend) output is the main driver of deviations of non-tradable inflation from trend levels, and the difference between the real interest rate and its equilibrium determines the level of monetary policy stimulation or contraction.

FPS has been running for more than ten years, which is unusual for a macroeconomic forecasting model. We consider a key explanation for this longevity to have been pragmatic treatment of trends in the data. Specifically, earlier models had relied on the (then) relatively new statistical techniques designed to exploit long-run cointegration relationships among macroeconomic time series. One reason why these models may be unstable is that they are vulnerable to redefinition and restatement of the levels of series. Because many of the SREQs in FPS are determined by trends in the data, changes in these long-run ratios over time are automatically reflected in the SREQs, leaving the cyclical gaps relatively stable. Basdevant and Hargreaves (2003) give the example of the ratio of consumption to output. They note that the ratio had been substantially revised at times in the previous five years, but that the *detrended* values of the ratio entering the cyclical FPS had not changed to the same degree. This allowed the model to maintain a coherent view of the cyclical behaviour of consumption, with national account revisions reflected in the trends.

A more recent example is shown in the two figures below, which plot the historical investment to output ratio and the investment gap as determined in the 1997, 2002 and 2007 versions of FPS. The investment to output ratio has moved over time (partly due to national account revisions and redefinitions, such as the incorporation of intangible asset development into investment), whereas the historical gap has not changed to the same degree: the three vintages of the model give similar estimates of the 1990-1996 gaps. After 1996, the 1997 version of the model is forecasting and naturally goes off course, but the 2002 and 2007 vintages give similar estimates of the 1997-2002 gaps.

Figure 1
Evolving view of the investment/output ratio

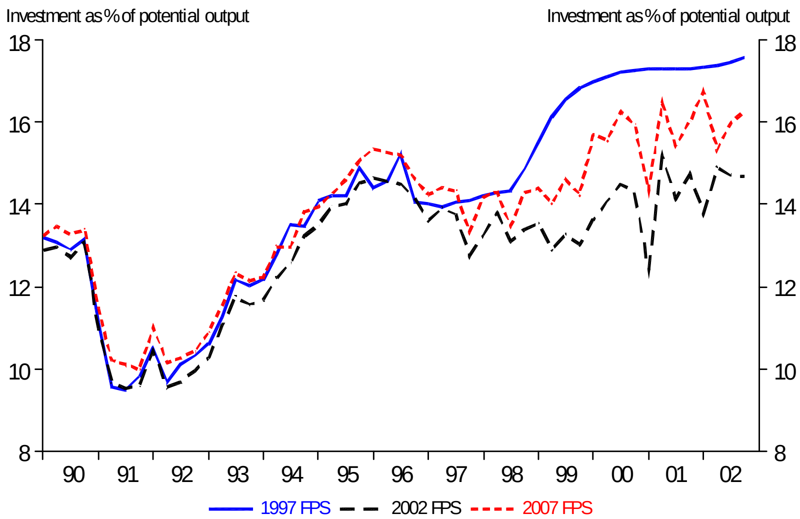
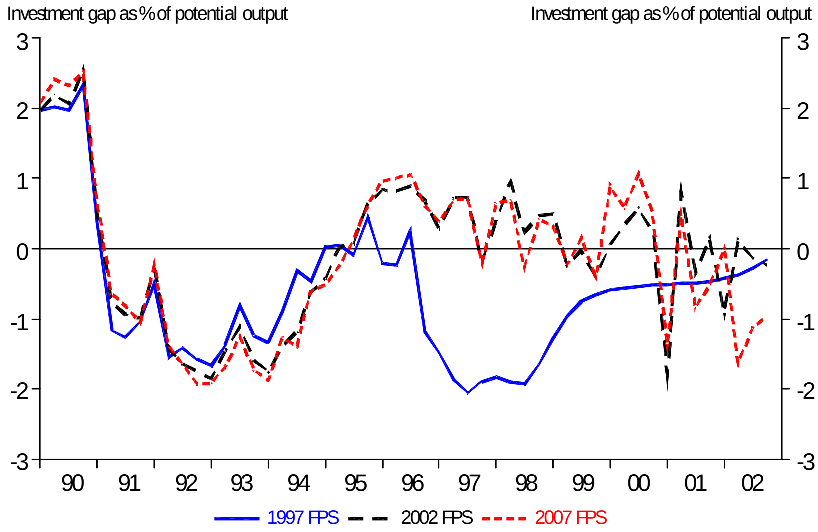


Figure 2
Evolving view of the cyclical component of investment



Pragmatic adjustment of steady states

FPS incorporates stock-flow equilibria, where (for example) historical current account deficits are reflected in the current net foreign liabilities, and these interrelationships are enforced during model simulation and projections. These stock-flow relationships imply important 'closure' relationships. For example, consumers have a target for equilibrium debt (net foreign liabilities), which is influenced by their utility function and world interest rates. If consumers are assumed to have run up greater debt than they wish to hold in equilibrium at the start of a projection, they will seek to save more than usual over the projection period, making demand relatively weak.

The steady states for stocks such as net foreign liabilities can thus have an important influence on the projections. At times, we have found this a useful part of articulating cyclical economic developments. For example, the equilibrium net foreign liabilities position in the model has often been revised. In FPS, consumers act to return net foreign liabilities to equilibrium. So, for example, if liabilities are smaller (as a ratio to output) than expected in the long run, there will be further borrowing and consumption over the period, and this will generate inflationary pressure. This has led to the net foreign liability steady state being used as an important cyclical lever, particularly as our view of the housing market has evolved. For example, when the housing market has looked stronger, we have tended to expect robust consumption growth, funded by overseas borrowing. We are able to facilitate this in the model by altering the equilibrium net foreign liability stock. Conversely, the net foreign liability stock has been pulled down at certain times when export receipts are very robust. This has reflected a view that some of the windfall gains from very strong trade receipts are likely to be used to reduce debt.

More generally, steady state ratios are typically not treated as fixed. Given the large degree of uncertainty about the values to which key macroeconomic ratios will ultimately converge, we have been willing to recalibrate the steady states as part of generating a model consistent story that fits with our view of how the business cycle is likely to evolve. The extent to which these revisions have been made may have surprised the 1996-1997 architects of FPS.

2.2 Endogenous interest rates

The Reserve Bank was for a long time unique[4] in publishing economic projections with endogenous monetary policy, as opposed to an exogenously imposed path for the 'policy' interest rate.[5] FPS solves for the path of the short-term interest rate that will return inflation to target over the medium term while avoiding unnecessary instability in other variables. Thus, the Reserve Bank's view of current and future inflation pressure is encapsulated in the projected short-term interest rate, and the interest rate projection is a tool for communicating the current view of the economy. However, it is important that it is understood that the interest rate projection is not a commitment to a future course of policy action, and is conditional

[4] Currently, the Riksbank and Bank of Norway also publish projections with endogenous interest rate response.

[5] The monetary policy instrument is the Official Cash Rate. This is different from the policy interest rate in FPS, which is the 90-day bank bill rate. The OCR and the 90-day bank bill rate have historically moved reasonably closely together, though more recently we have needed to account for divergence between the series in setting policy.

on new information as it arises. Hampton (2002) has considered the role of the endogenous interest rate forecast in more detail.

The endogenous policy interest rate creates a natural focus for summarising changes in a projection relative to the previous quarter, i.e. how has the medium term outlook for interest rates changed, and what has driven the change. The table below provides an example of how this information is presented to the MPC for their discussion and consideration of whether the impact the item has on short-term interest rates is broadly appropriate.

Table 1
A sample reconciliation table (reproduced from RBNZ (2004))

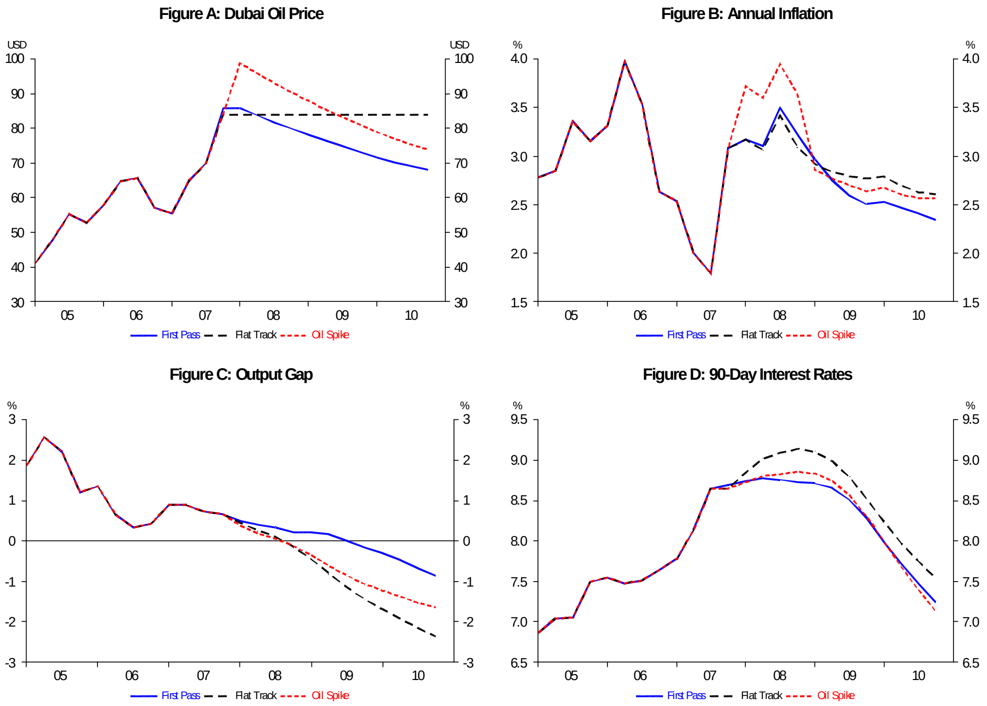
	Change to interest rate projection in: 2004 Q1
Interest rate projected in June 2003 *Monetary Policy Statement*	5.3%
1. Revised output gap starting point	+0.15%
2. June quarter CPI out-turn and new CPI monitoring quarter estimate	-0.10%
3. Weaker world output gap	-0.10%
4. Lower long-term interest rates	+0.10%
5. Higher New Zealand dollar	-0.45%
Total (1–5)	-0.40%
Updated projection of 90-day interest rate	4.9%

2.3 Alternative scenarios and model-based risk analysis

Alternative scenarios are frequently used at the Reserve Bank to get a sense of the potential impact of key risks on the economic outlook. This helps to develop a more complete understanding of the outlook, by shedding light on the sensitivity of the central projection to crucial assumptions, and on how the outlook might change if key events unfold. At times the scenarios are published in the *MPS* when discussing policy judgements (for example, chapter 2 in the September 2007 *MPS*). In much the same way as when producing the central projection, FPS plays an important, but not mechanical, role in developing these scenarios.

Figure 3 provides an example of how alternative scenarios are used, showing the implications of the upside risk to the oil price projection in December 2007. In the quarter leading up to December, oil prices had increased by more than 20 percent. The central projection had factored in these increases, making oil prices one of the key changes to the forecast since September. Nevertheless, many Reserve Bank analysts were of the view that there remained upside risk to the oil price track. Two different scenarios were produced examining different aspects of this upside risk. In the first scenario, oil prices increased for one more quarter before declining at approximately the same rate as in the central projection (an ‘oil spike’ scenario). In the second scenario, oil prices were held at elevated levels over the medium term (a ‘flat track’ scenario). As shown in figure 3, the oil spike initially has a much larger impact on inflation but this is reversed in less than a year. Interest rates do not respond to this transitory inflation spike. In contrast, the flat track scenario creates more persistent inflation, and the model’s interest rate reaction function responds to that persistent inflation pressure. The scenarios illustrate how the inflation risks, and the model’s default policy response, depend on the future evolution of the oil price as well as current spot rate. In reality the future profile for oil prices is generally unclear, so the actual policy response to a sudden rise in oil prices may well be somewhere in between these two possibilities.

Figure 3
Two scenarios with alternative paths for oil prices



In this example, the scenarios were simply constructed by specifying different tracks for oil prices and feeding them into the model. This was possible because analysts were content to use the standard FPS relationships between oil prices and the rest of the economy. However, constructing scenarios is not always such a mechanical process as some scenarios involve model variables or relationships that are not part of the FPS system. As an example, a scenario featuring a credit crunch in global financial markets would include effects on domestic investment that cannot be fully captured by the investment dynamics in FPS, and so judgemental adjustment to investment would be required.

The mechanical model responses to a set of standard shocks (e.g. higher consumption demand) can be summarised in a 'ready reckoner' table or set of charts. Such charts (similar to those in sub-section 3.2) have been provided to the MPC between policy reviews as a guide to model properties, often as part of the documentation of model changes. During policy meetings, Reserve Bank staff have preferred to focus the MPC's attention on a few scenarios that represent important and salient risks. However, we have experimented, as in table 2, with ways to tabulate the information contained in the most common scenarios.

Table 2
Ready-reckoner

No.	Variable	Description	90 day rates after 6 quarters (basis points)
1.	World oil price (temporary shock)	Raised the real Dubai oil price by USD 5 for one quarter.	-5
2.	World oil price (persistent shock)	Gradually raised the real Dubai oil price by up to USD 10 over a period of 6 quarters, letting it fall back to equilibrium over the following 6 quarters.	0
3.	Output gap	Generated an output gap of 1 percent, letting it close over the next 6 quarters.[6]	+25
4.	World export prices	Raised real export prices by 5 percent in one quarter. Prices gradually return to equilibrium over 3 years.	+10
5.	Nominal exchange rate	Imposed a 1 percent appreciation in the exchange rate from equilibrium.	-10
6.	Inflation expectations	Raised annual CPI inflation expectations by 0.2 percent for one quarter. Expectations return to equilibrium over the next 6 years.	+20
7.	Inflation (temporary shock)	Raised the annual rate of CPI inflation by 0.2 percent for one quarter. It immediately returns to equilibrium.	+5
8.	Inflation (persistent shock)	Raised the annual rate of CPI inflation by 0.2 percent, returning it to equilibrium over the next 6 years.	+20

[6] The gap was created by increasing each of the ratios of consumption, investment, government spending and exports to their respective equilibriums by approximately 1.25 percent, allowing for some automatic rise in imports.

2.4 FPS-based research

In some cases FPS has provided a starting point for empirical research. Where new research or data shows that particular economic relationships have changed, the need for revisions to specific areas of FPS has guided the allocation of analytic resource (see section 3).

The FPS model has also been used as a guide to the properties of the economy in monetary policy analysis. For example, in reviews of past business cycles (see RBNZ, July 2007, and Drew and Orr, 1999), FPS simulations were used to come to a view about the key shocks that affected the economy over the cycle, and how the Reserve Bank appeared to have responded to them.

FPS has also been used to consider the appropriate behaviour of monetary policy in a more general sense. For example, the calibration of the reaction function was tested in a series of papers including Conway *et al.* (1998), Ha (2001) and Hampton *et al*. (2006). These studies examined specific questions about how monetary policy should behave, such as whether it is desirable to look through the rapid first-round effects of exchange rate movements on inflation, and whether there are ways to formulate monetary policy so as to reduce exchange rate variability without compromising economic performance in other areas. Another study by Drew *et al.* (2001) considered the possibility of a currency union with Australia using FPS, their results suggesting that the loss of independent monetary policy would increase cyclical variability in New Zealand inflation and output.

To have had this research conducted with the same model that is used for monetary policy has proved to be especially useful. In particular, FPS-based research has often led to a better understanding of the model properties and in turn highlighted areas where the model can be improved. However, overall FPS has not been an organising framework for monetary policy research in the same way that it has been for economic projections. This is to some extent unsurprising: research takes place within a broad variety of frameworks, while a forecasting process tends to require a well defined organising framework.[7] The less central role of FPS in recent Reserve Bank research has also reflected the following issues specific to the model:

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[7] See Berg *et al*. (2006) for further discussion.

- the theoretical frontier has moved on significantly since 1997. Monetary policy research models are now generally fully derived from optimising foundations, while FPS incorporates dynamic relationships that are not;

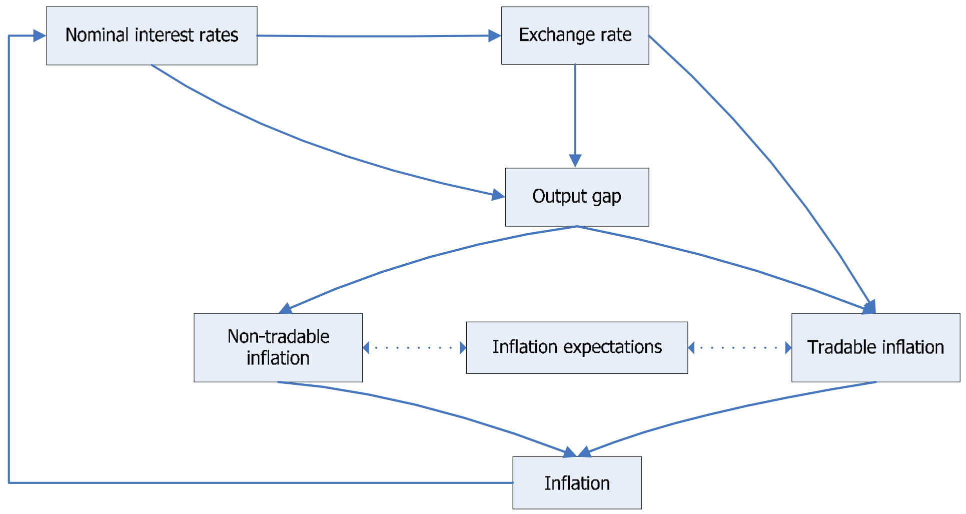
- using a model for both forecasting and policy analysis creates tensions. That is, to play a useful role in generating projections, the model needs to reflect the views of staff and policymakers about how the economy behaves, and these may not always agree with the properties of current theoretical models. For example, in FPS there is significant spending out of windfall wealth gains by households, while in many canonical macro-models consumers spend out of lifetime income and thus only spend windfalls very gradually; and

- the size of a model like FPS makes some sorts of research intractable. FPS is too large to be easily discussed in a journal article, and (until recently) could not be directly estimated. In addition, operating a model like FPS generally requires a certain amount of technical knowledge and resources. For example, using FPS requires some knowledge of proprietary modelling and database software, a good understanding of the data, and a good understanding of the appropriate channels to add different sorts of judgement.

3 The FPS cyclical model and its evolution

As discussed in the previous section, the cyclical FPS model is the most important part of FPS when generating projections. The cyclical model links key macroeconomic variables to nominal interest rates in a system, as shown in schematic form in figure 4 below.

Figure 4
Key relationships within FPS



The basic structure shown in figure 4 has been in place since FPS was constructed in 1997. In particular, the following key core stories have been part of the model over the last 11 years. They are the same core stories characterising simpler systems in use in many central banks and described in Berg *et al.* (2006):

- output above trend tends to generate inflationary pressure;
- the Reserve Bank is assumed to respond to incipient inflationary pressure by increasing interest rates;
- a rising interest rate tends to push up the value of the New Zealand dollar; and

- rising interest rates act to depress consumption and residential investment, while a rising exchange rate tends to cause net exports to contract.

Inflation in FPS has always been generated through excess demand and inflation expectations via a calibrated Phillips curve relationship. In this framework, excess demand or resource pressure is measured by the output gap (the difference between actual and potential output), and inflation expectations are determined by a mixture of backward and forward looking expectations. The output gap has always been measured using a multivariate filter methodology (see Conway and Hunt 1997).

This basic framework has been seen as a useful way to generate projections over the last 11 years, despite a developing cautionary literature about the idea that above trend output tends to lead to inflationary pressure.[8] Specifically, in richer conceptual models of the economy there may be certain shocks which generate sharp increases in output and sharp falls in prices. If these 'supply' shocks were important drivers of the economy, a detrended measure of output would be a poor predictor of inflation.

Hargreaves *et al.* (2006) explain why we think that the output gap may retain some validity as a predictor of inflation in the New Zealand context. Firstly, the supply shocks we face are likely to often involve export goods, for which New Zealand is a price-taker. This limits the direct CPI impact of a supply shock, and can have powerful wealth effects for producers in the sector. For example, a good dairy season in New Zealand will tend to boost demand (via farm spending) but not significantly reduce retail milk prices. More generally, supply shocks are likely to often have demand consequences that dominate the initial supply effects. For example, migration into a country leads to increased labour supply, but in the short-term that increased supply may be dominated by the need to expand housing and productive capacity (e.g. build new factories).[9]

However, while the basic structure of the cyclical model remains unchanged, the speed and strength with which the set of core macroeconomic variables have affected each other in the model have

[8] See, for example, Woodford (2001).

[9] The calculation of the output gap is discussed in Conway and Hunt (1998) and Citu and Twaddle (2003). The latter also discusses issues associated with using output gaps in monetary policy more generally.

changed in major ways over the last 11 years. At times this has reflected a genuine view that the New Zealand economy has changed, but most of the recalibrations have reflected gradual learning by the Reserve Bank about the properties of the New Zealand economy since the 1980s structural reforms. Frequently, as noted in RBNZ (2004), FPS recalibrations have been prompted by either consistent application of judgement or new research.

Applying the same judgement to successive projections is indicative that the Reserve Bank's view of the structure of the economy has changed, and that the structure of FPS needs to be changed accordingly. In this respect, the decision to publish the policy path has also played an important role in the evolution of the model. The MPC adjusts forecast paths to communicate its assessment of inflation pressures and the most likely required policy response.

New research may also lead to recalibration of the model. Recalibrations have been based on both research into the relevant interrelationship, and analysis of overall model properties. For example, the sudden rise in the exchange rate over 2002 prompted a range of econometric research into the equilibrium real exchange rate. The equilibrium exchange rate was respecified to reflect that research.

While major recalibrations have been discussed and approved by the Reserve Bank's MPC, in many cases the analysis has not been externally published. The following section reviews some of these more substantial recalibrations and the reasoning behind them.

We then go on to document (in sub-section 3.2) how the overall impulse responses and certain other characteristics of the model have changed since 1997.[10]

[10] Tetlow (2006) provides a similar discussion with regard to the Federal Reserve's FRB-US model.

3.1 Changes made to FPS since 1997

Figure 5 and table 3 summarise the key changes to FPS between 1997 and 2007. We provide more information on the evolution of these key interrelationships in the model in the remainder of this section.

Figure 5
Important changes to FPS relationships since 1997

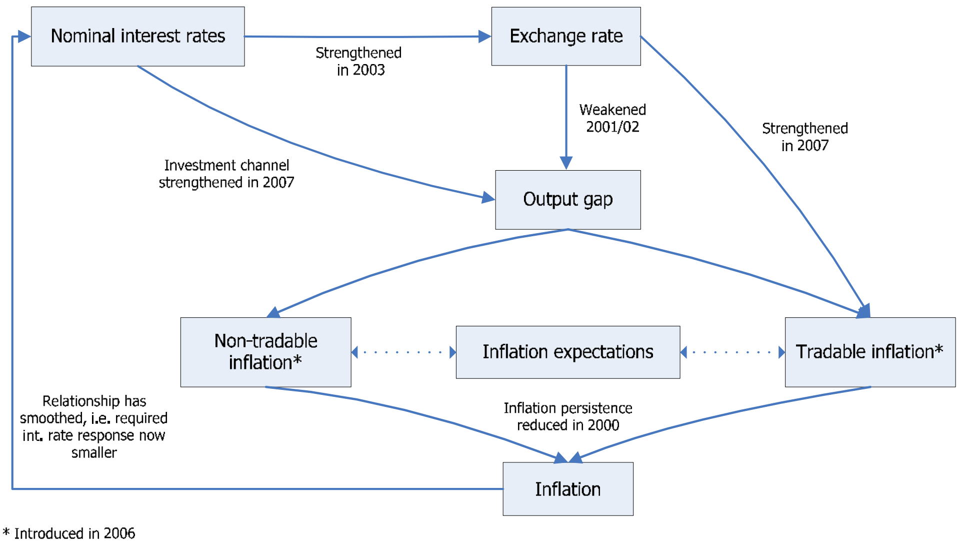


Table 3
Important changes to FPS relationships since 1997

Date	Adjustment
1997	• Long-term interest rates made less responsive to short-term rates
2000	• Inflation made less persistent, and more responsive to the output gap • Impact of interest rates on aggregate demand significantly changed
2001	• Import volume response to import prices reduced • Direct link between the real exchange rate and export volumes introduced, and the impact of export prices on export volumes slowed
2003	• Export volume response to the exchange rate increased • Sensitivity of exchange rate to interest rate differentials and export prices increased
2006	• Inflation split into tradable and non-tradable inflation; observable inflation expectations measure introduced • Specific channel for oil imports added
2007	• Observable world commodity export price measure introduced – export prices split into goods and services • Investment made more cyclical

Inflation

In 2000 the Reserve Bank altered the behaviour of inflation in FPS by reducing the effective persistence of inflation and shortening the lags between the output gap and inflation. The inflation process in the original calibration was found to imply that an unrealistically large interest rate response was required to control inflation, and thus significant judgemental adjustment was frequently required to make the projection fit the MPC's view.

The Reserve Bank (see Drew and Hunter, 2001) reviewed the inflation calibration in 2000 using a variety of statistical and model based methods. It found that the lag between the output gap and several measures of historical domestic price inflation was shorter than the relationship embodied in the original calibration. An alternative calibration that better agreed with the data was developed.

In 2006 (see Hargreaves *et al.*, 2006) the Reserve Bank split inflation into tradable inflation and non-tradable inflation, and also incorporated an observed measure of inflation expectations (from the Reserve Bank two year ahead inflation expectations survey). This left the actual model properties of FPS largely unchanged but allowed the model's consistency with the data to be assessed more easily. In the original CPI inflation structure in FPS, the domestic and imported components of inflation and inflation expectations were treated as unobserved (i.e. the relevant equations were essentially identities). Consequently, the empirical test of the system was in the way the model tracked the behaviour of aggregate CPI inflation. However, tradable and non-tradable inflation have behaved very differently over the last 11 years: non-tradable inflation has a particularly strong and reliable relationship with resource pressures (as measured by the output gap), whereas the key determinant of tradable inflation is the exchange rate, which exhibits a fairly quick pass-through into the price of traded goods via domestically denominated import prices.

Interest rates and demand

Initial calibrations of FPS in 1997 incorporated the stylised fact that long-term interest rates tend to respond more to short-term interest rates than implied by the expectation hypothesis of the yield curve. However, after a few quarters of active use it was concluded that this elasticity had been overstated and the responsiveness of long rates was reduced.

This had important policy implications, because in the 1997 version of the model the influence of interest rates on consumption and investment came through movements in the yield gap (the difference between short-term and long-term interest rates). Making long rates less responsive to short rates thus increased the potency of monetary policy.

Ultimately, around 2000 it was concluded that short-term interest rates (relative to equilibrium) provided a better measure of the impact of monetary policy on aggregate demand. Furthermore, it was felt that if anything, increases in long-term interest rates (e.g. because of international influences) would tend to have an additional contractionary effect, regardless of the level of short-term interest rates. Thus the consumption and investment equations were rewritten so that short-term and long-term real interest rates each had contractionary effects on consumption and investment.

In this recalibration, short-term interest rates were given slightly more impact on aggregate demand than previously, but the change was not dramatic. In fact, the impact of short-term interest rates on consumption (the key component of aggregate demand) has remained broadly unchanged since 1997. This elasticity is difficult to measure in the data because of simultaneity issues (interest rates may be rising because consumption is expected to be strong).

In internal work, the Reserve Bank determined that the key transmission channel through which monetary policy influenced inflation in FPS was consumption spending and residential investment. This was not true in macroeconomic models at other central banks, according to comparative studies such as Locarno *et al*. (2001). This is likely to be related to the fact that household mortgage debt as a share of GDP is relatively high in New Zealand, and unlike in other economies like the United States, at that time New Zealand mortgage debt tended to be either floating, or fixed for a relatively short time. While mortgage debt in New Zealand has risen fairly dramatically as a share of GDP since then, this has been counterbalanced by the increased use of fixed rate mortgages over recent years, leaving the potency of short-term interest rates relatively unchanged.

Exchange rate

In 2003 the Reserve Bank made a substantial change to the way in which the exchange rate is determined in FPS. Prior to this recalibration, the exchange rate was determined by a modified uncovered interest parity condition, with some weight on the lagged exchange rate to increase persistence, and a small weight on the equilibrium exchange rate. Export price shocks did not enter the equation, so that any response of the exchange rate to export prices was the direct result of interest rate movements. This specification saw the exchange rate respond fairly weakly to both interest rate and export price shocks, more weakly than was consistent with analysis of the data in, for example, Munro (2005).

Consequently, a new exchange rate equation was specified to better match the historical behaviour of the exchange rate. Contemporaneous values of interest rates enter the equation with a far higher weight than previously and export prices are explicitly included. The equation has substantial persistence, which reflects an assumption that some market participants have backward looking exchange rate expectations. This allows high interest rates, for example, to cause gradual appreciation in the exchange rate rather than a jump.

It must be noted that while the new specification may better replicate historical exchange rate cycles, it is unlikely to be particularly effective in predicting short-term exchange rate movements. The exchange rate equation is frequently subject to judgemental adjustment when running projections.

Exports

In 2001 the Reserve Bank introduced a link between the real exchange rate and export volumes, and increased the lag length with which export volumes were affected by relative price changes to six quarters. The original FPS specification saw export volumes affected by domestic export prices only, with a lag of two quarters.

New Zealand is often considered to be a 'price taker' in its export markets. The New Zealand dollar (NZD) price of a commodity export such as milk powder should be a good description of the incentives to produce that commodity and thus boost export volumes. If this 'price-taking' relationship characterised all of our export markets, there would be no need for a direct exchange rate affect on export volumes. However, internal research had found that exchange rate cycles have not been passed through to the NZD export price of tourism services. Instead, a high NZD exchange rate would tend to reduce the numbers of tourists and thus export volumes, creating a need for a separate channel from the exchange rate to export volumes.

In 2003, the Reserve Bank carried out a comprehensive review into the impact of the exchange rate and domestic export prices on real export activity, with a particular emphasis on the validity of the FPS calibration (see Smith, 2004). The review sought to evaluate the model's specifications against econometric estimates, evidence from past recalibrations, comparisons with other economic models and anecdotal evidence.

The review determined that the impact of export prices on export volumes within FPS was reasonable. However, the impact of the exchange rate on export volumes was found to be too weak, and the relevant elasticity was subsequently increased. In 2007 the Reserve Bank introduced an observed measure of world export prices into FPS, based on the ANZ commodity price index. Prior to 2007, world export prices were derived from the exchange rate and NZD export price data. This measure included exports without a well-defined world price, and sometimes lagged commodity price movements.

To fit the new measure of world export prices, overall export prices in FPS now consist of goods export prices and services export prices. Goods export prices are determined by world commodity prices and the exchange rate, with a higher weight on the exchange rate to reflect the fact that not all exported goods are commodities. Services export prices are purely a function of the exchange rate, with less than full pass through to reflect that providers of export services like tourism are unlikely to be price takers on world markets.

Imports

In 2001, the Reserve Bank weakened the relationship between import prices and import volumes in FPS. Import volumes in FPS were originally thought to have a strong negative relationship with import prices, but the empirical evidence suggested a significantly weaker relationship as the exchange rate fell through 1998-2001.

In 2003, the Reserve Bank carried out a comprehensive review into the impact of the exchange rate on real import activity; with a particular emphasis on assessing the FPS calibrations (see Smith, 2004). The review examined the responsiveness of import volumes to the exchange rate and concluded that the relationship between the exchange rate and imports was approximately consistent with the data. The relatively weak elasticity for New Zealand is consistent with cross-country work by Meacci and Turner (2001), which suggested that New Zealand was one of a group of OECD countries that had relatively low responsiveness of import volumes to relative prices.

In 2006 the Reserve Bank added an explicit channel for oil imports into FPS which acknowledged the special features of oil; namely the quicker pass through from world prices and the exchange rate, and the lower price elasticity of demand. Prior to 2006, oil prices and volumes were subsumed in other consumer import prices and volumes. Judgemental adjustments to the projections were then required (usually by adding residuals to tradable inflation) to replicate the larger and more immediate effects of changes in world oil prices.

In the recalibrated model, the direct effect of a change in oil prices immediately flows through to petrol prices (and hence tradable inflation), while an indirect effect (via production costs) flows through to inflation more slowly. Because oil demand is largely price inelastic, a rise in oil prices inflates the current account deficit and eventually leads to lower consumption of other goods as net foreign debt increases. Thus, a rise in oil prices tends to depress economic activity and if this outweighs the direct inflationary effects can cause a fall in interest rates.

Investment

In 2007 the Reserve Bank made investment in FPS more sensitive to cyclical movements in output, the relative price of investment goods and interest rates.

Prior to 2007, any deviation of investment from equilibrium was very short-lived, with the only persistence in investment the result of quadratic adjustment costs. This made the cycles in investment relatively short. A positive surprise to investment would rapidly be unwound by investment below trend in order to re-equilibriate the capital stock. In reality, strong investment can be quite persistent, and a significant amount of judgemental adjustment was required to achieve sensible investment dynamics in the projection. These judgemental adjustments tended to refer to the outlook for the output gap, in view of the procyclical behaviour of investment observed in the data.

New Zealand empirical data and several international studies suggested that the investment response to cyclical fluctuations was stronger than assumed in FPS prior to 2007, particularly in reaction to temporary movements in output (positive effect), the relative price of investment goods (negative effect) and interest rates (negative effect).

Consequently, investment in FPS was replaced with a flow investment equation where the capital stock still returns to equilibrium but much more slowly. Investment dynamics are driven by the output gap, the real interest rate gap, the gap in the relative price of investment goods and quadratic adjustment costs.

Internal bank work conducted in 2002 confirmed that FPS gave a disproportionately large role to the consumption channel, with the investment channel playing only a very minor role in the transmission of monetary policy to the economy (despite the fact that both the theory and the data suggested that this should not be the case). The new specification increased the role of the investment channel in the transmission mechanism, but consumption fluctuations were still the most important way through which changes in interest rates affect aggregate demand and inflation.

3.2 Changes in the system properties of FPS since 1997

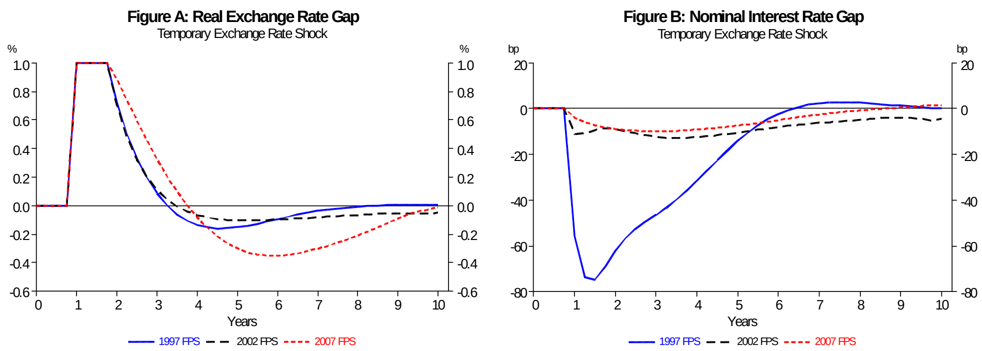
In this section we compare how three different versions of FPS– from 1997, 2002 and 2007 – respond to four different shocks – a real exchange rate shock, an interest rate (monetary policy) shock, a disinflation shock and a consumption demand shock.

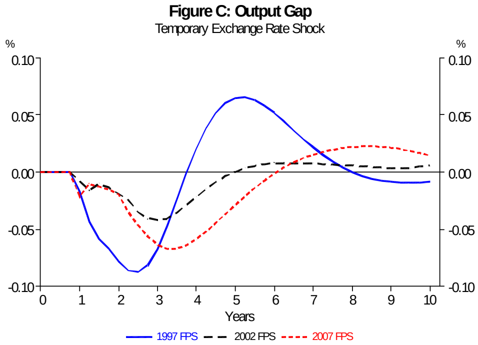
The purpose is to illustrate how the behaviour of FPS has changed over time as a result of recalibrations. We would generally interpret these changes (particularly those between 1997 and 2003) as reflecting the Reserve Bank's learning about the economy rather than changes in the economy itself.

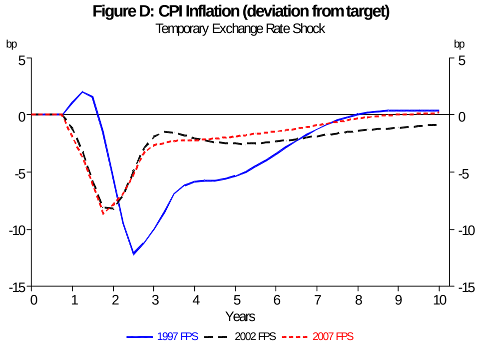
Real exchange rate shock

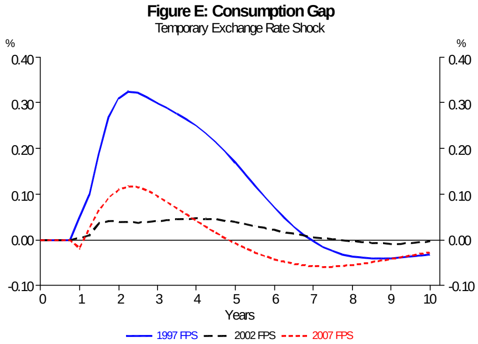
Figure 6 shows a temporary real exchange rate shock (1 percent appreciation of the real trade weighted index which lasts approximately 1 year).

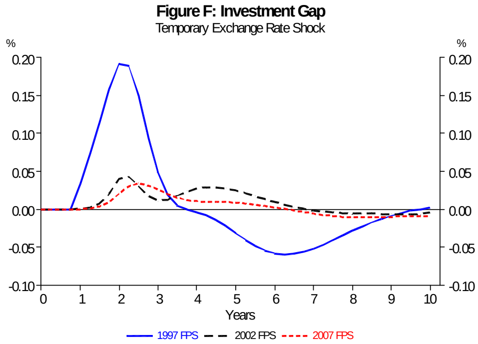
Figure 6
A temporary exchange rate shock

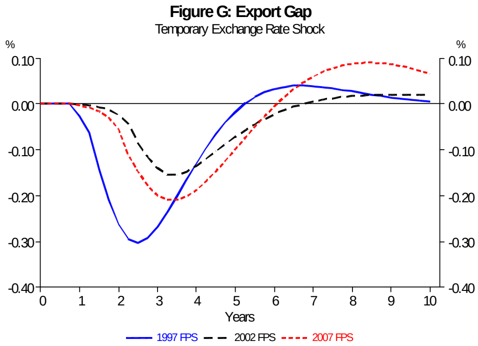


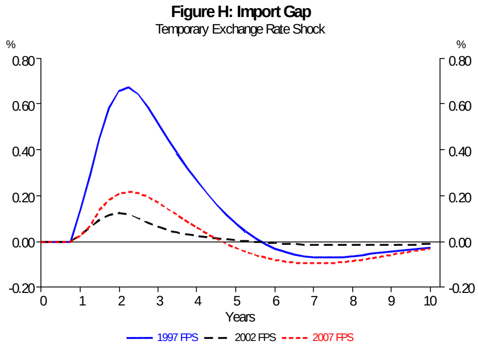












The shock to exchange rates shows more persistence in 2007 (figure A), reflecting the 2003 changes to the exchange rate equation. More importantly, the behaviour of interest rates in 1997 is vastly different than in 2002 and 2007 (figure B), with nominal interest rates declining by almost 80 basis points in response to a 1 percent appreciation of the exchange rate – approximately 60 basis points more than in 2002 and 2007. This reflects three main factors:

- the persistence of inflation and weak impact of the output gap on inflation in the 1997 model meant that a larger fall in interest rates was required to re-anchor inflation after the exchange rate caused tradable inflation to fall;

- because net exports deteriorated more in the 1997 model, this expansion had to come from larger increases in consumption and investment; and

- the ‘yield gap’ transmission mechanism that was a feature of the 1997 model, combined with the sensitivity of long-term interest rates, meant that short-term interest rates had to fall further to generate the necessary expansion. (Lower short-term interest rates caused long-term interest rates to fall, which reduced the impact on the yield gap and meant short-term interest rates needed to fall even further).

Exports and imports are more sensitive to exchange rate movements in 1997 than in 2002 and 2007 (figures G and H). Imports show a particular decline in sensitivity, reflecting the 2001/2002 recalibrations which reduced the responsiveness of import volumes to import prices.

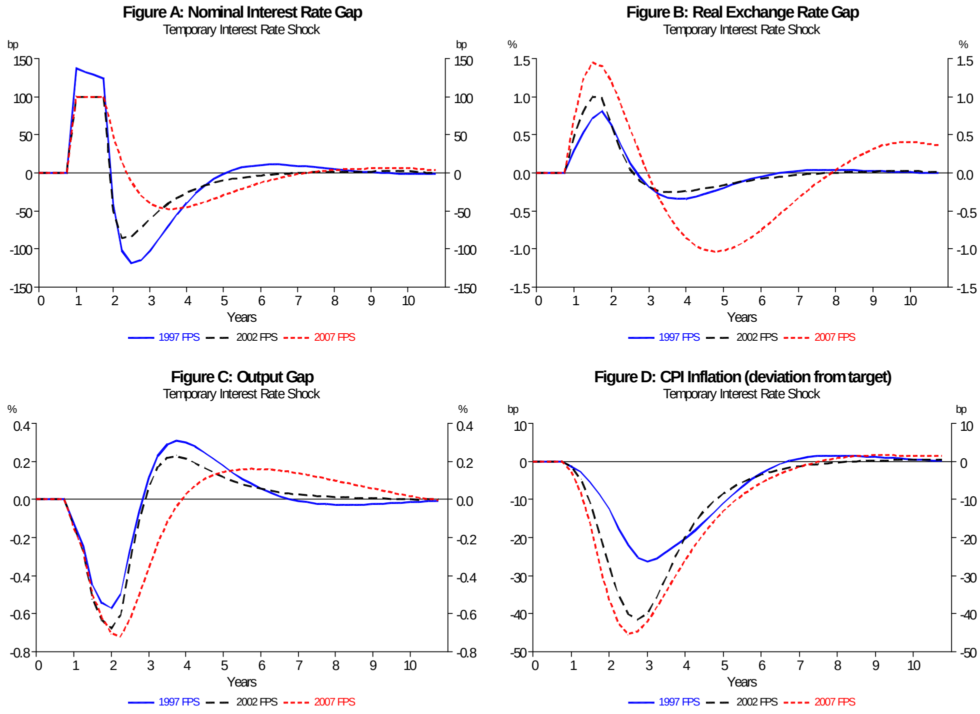
The output gap declines by more in 1997 than in 2002 and 2007 (figure C), with the greater decline in net exports outweighing the greater increases in consumption and investment. Further out, the output gap rebounds more strongly in 1997, driven by a persistent consumption response (figure E) and a recovery in exports (figure G).

Inflation behaves significantly differently in 1997 compared to 2002 and 2007 (figure D). Initially, this reflects direct price effects. Further out, inflation in all specifications of the model is driven by the demand effects of the exchange rate appreciation (the reduction in net exports, but with an offsetting expansion in domestic demand).

Interest rate shock

Figure 7 shows model responses to a temporary interest rate shock (approximately 100bp increase which lasts 1 year).[11]

Figure 7
A temporary tightening in monetary policy



[11] Owing to changes to the interest rate reaction function, a shock of a certain value has a slightly different effect in the 1997 model than in later vintages, but the discrepancy does not materially affect the results discussed.

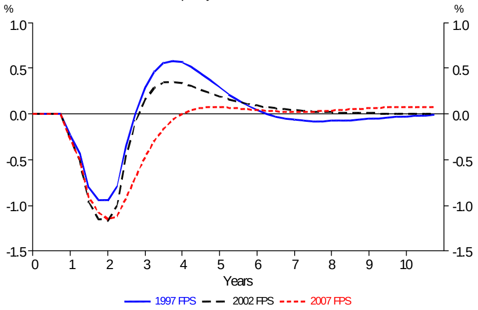


Figure E: Consumption Gap
Temporary Interest Rate Shock

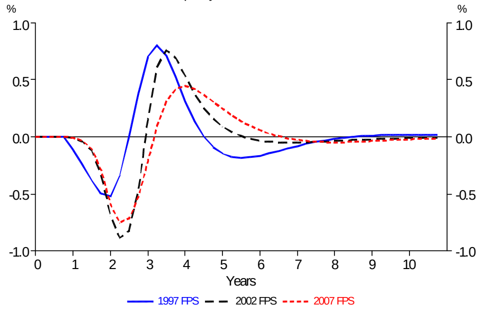


Figure F: Investment Gap
Temporary Interest Rate Shock

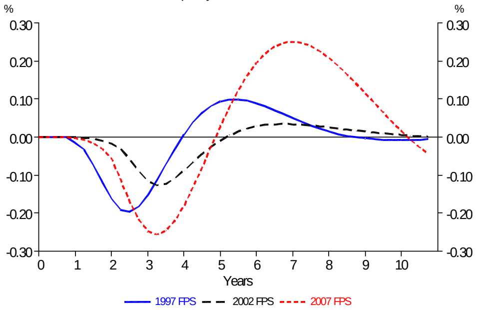


Figure G: Export Gap
Temporary Interest Rate Shock

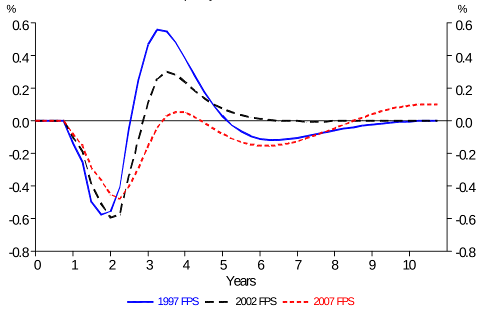


Figure H: Import Gap
Temporary Interest Rate Shock

In the 2007 vintage, the interest rate shows a more gradual decline after the initial shock (figure A). This is partly because the exchange rate in 2007 is more sensitive to changes in interest rates than in 1997 and 2002 (figure B), reflecting its recalibration in 2003. As interest rates decline after the initial shock, the 2007 exchange rate response is far more stimulatory. This allows inflation to return to target without interest rates being as low as in 1997 and 2002.

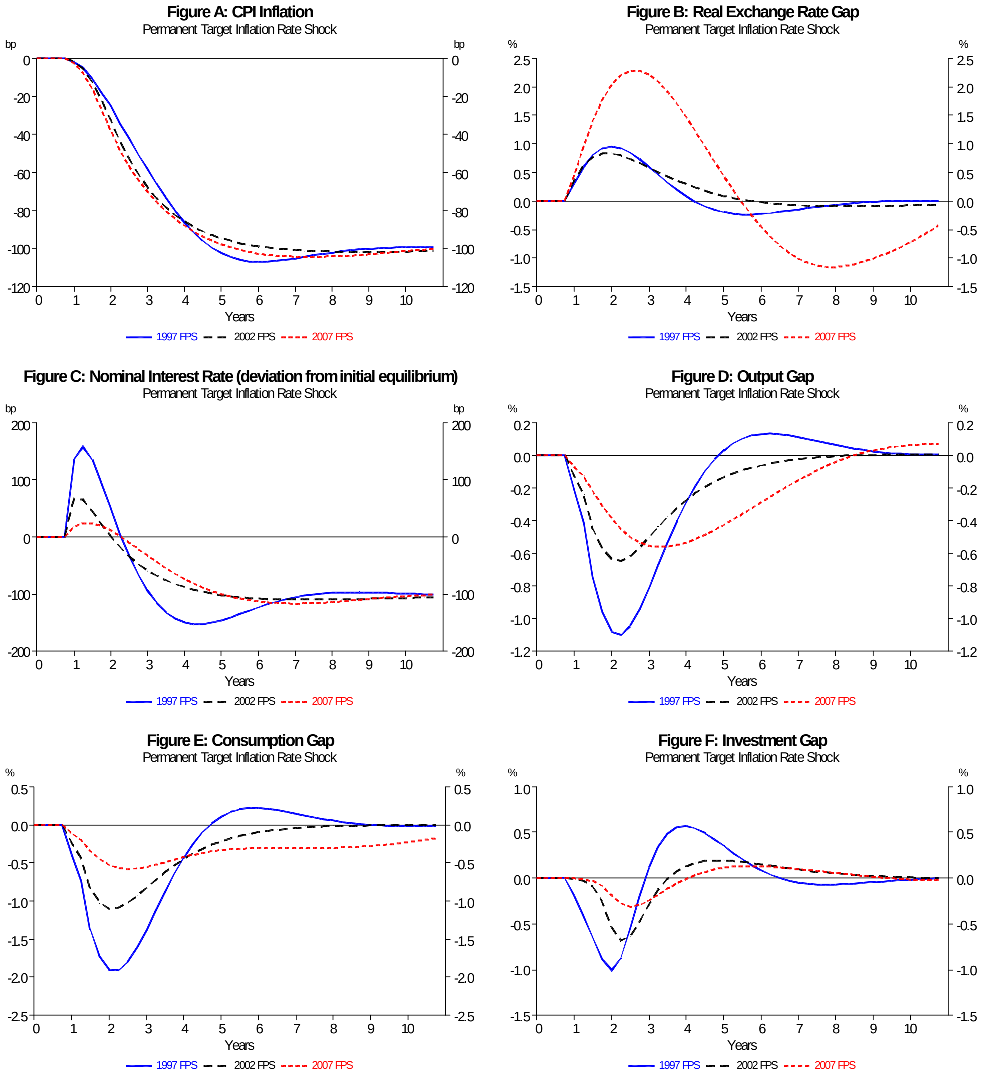
In the near term (one to two years), consumption and investment respond very similarly across all specifications. However, in the medium term (two to five years after the shock), consumption and investment in the 2007 model vintage reflect the more muted adjustment of 2007 vintage interest rates (figures E and F).

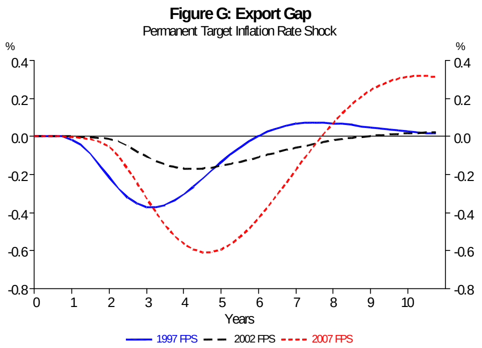
Inflation in all specifications of the model falls. The fact that it does so to a somewhat lesser extent in the 1997 vintage reflects the relatively sluggish inflation process in the original model, as well as the relatively prompt policy reversal after the shock.

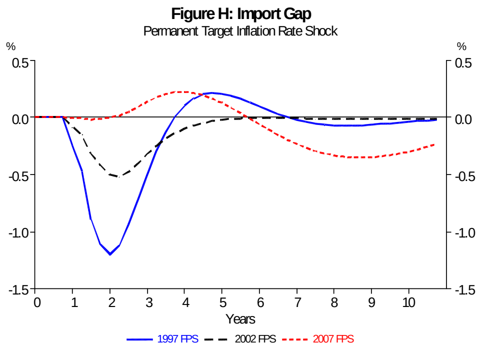
Disinflation Shock

Figure 8 shows the results of a permanent disinflation shock (1 percent permanent decrease in the target inflation rate).

Figure 8
A permanent reduction in the inflation target







The inflation dynamics resulting from the permanent shock are approximately the same for all specifications (figure A).

However, the interest rate increases required to engineer this inflation decline are very different across the model vintages. In 1997, interest rates provide the strongest response to the reduction in the inflation target, increasing more than 150 basis points to maintain the new lower inflation level, as opposed to 65 and 25 basis points in 2002 and 2007, respectively (figure C). This is almost certainly due to the inflation control problem that existed in 1997, which was alleviated by the recalibration of inflation in 2000.

The recalibration of the exchange rate equation in 2003 makes the exchange rate more sensitive to changes in the domestic interest rate in 2007 than in 1997 and 2002 (figure B).

The responses of consumption and investment appear to reflect the relevant magnitude of interest rate changes under each specification of the model (figures E and F). Exports decline as their relative price increases, with differences among the model vintages approximately reflecting the respective exchange rate responses (figure G). In 1997 and 2002, imports (figure H) reflect relatively strong responses from consumption and investment (figures E and F) and relatively small exchange rate responses (figure B). However, in 2007 the decrease in the price of imports outweighs the decline in consumption and investment, so that there is initially a mild positive movement in imports.

The output gap declines by more in 1997 than in 2002 or 2007. This reflects the fact that inflation was more sluggish in the 1997 model, so that a sharper reduction in demand was necessary to anchor inflation to the new target. In the 2007 model the decline in output is weaker but still quite prolonged, reflecting the fact that inflation expectations were still assumed to be quite inertial. The implied sacrifice ratio in the model thus fell between 1997 and 2002. In output terms, the 1997 calibration of FPS implied a sacrifice ratio around 2.3. This changed to around 1.7 in 2003, rising back to 2.1 by 2007. Tetlow (2006) found significant variation over time in the sacrifice ratio implied by the Federal Reserve's FRB-US model as well. Measuring the employment-inflation sacrifice ratio, Tetlow found that this had risen from around 2 in 1997 to over 4 by 2003. The equivalent figures in FPS were around 1.2 in 1997 and around 0.85 in the current model.

Consumption demand shock

Figure 9 shows FPS impulse responses to a temporary demand shock (2.5-3.5 percent increase in consumption which lasts for approximately 1 year). The shock is the same size in each model, but the effects on consumption are slightly different as a result of changes in the consumption equation and other equations in the model.

Figure 9
A temporary demand shock

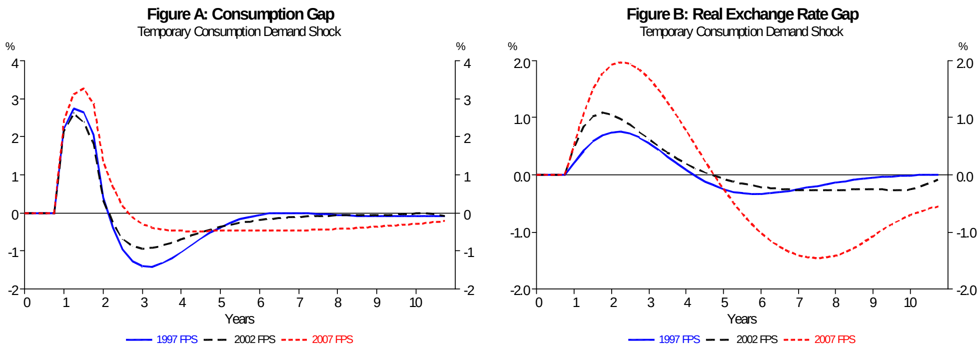


Figure C: Nominal Interest Rate Gap
Temporary Consumption Demand Shock

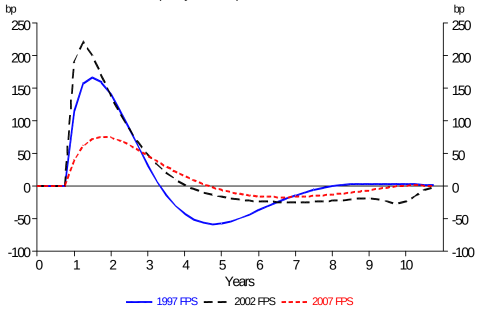


Figure D: Output Gap
Temporary Consumption Demand Shock

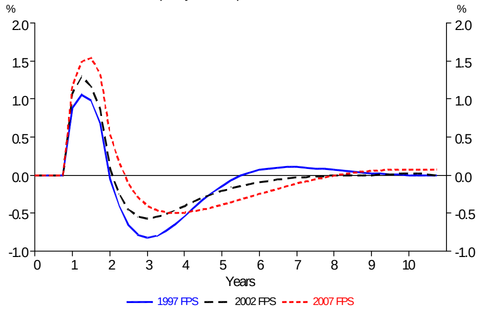


Figure E: CPI Inflation (deviation from target)
Temporary Consumption Demand Shock

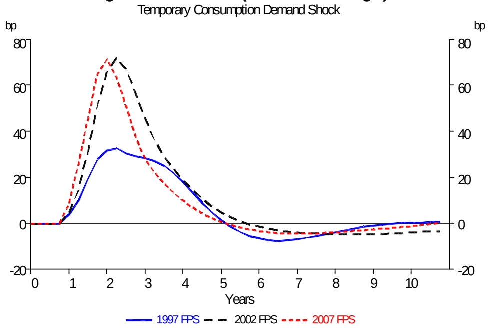


Figure F: Investment Gap
Temporary Consumption Demand Shock

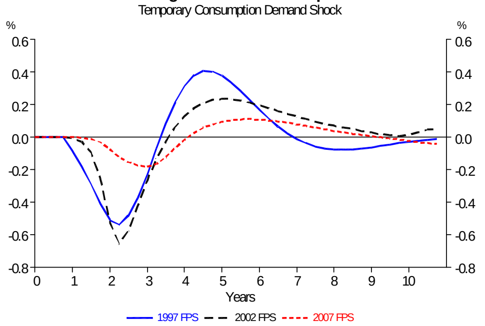


Figure G: Export Gap
Temporary Consumption Demand Shock

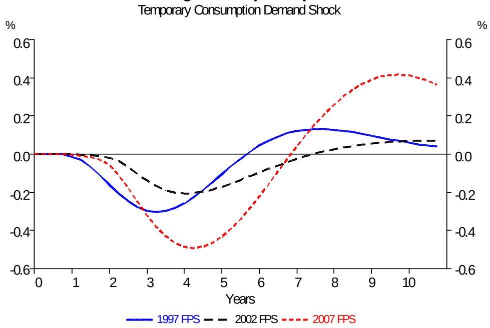
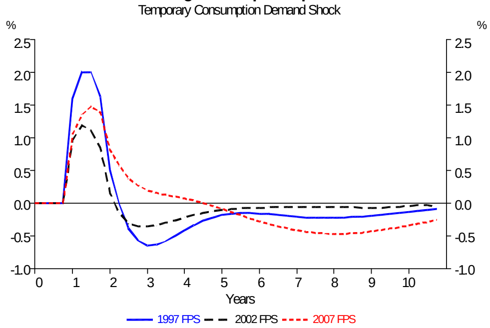


Figure H: Import Gap
Temporary Consumption Demand Shock



The shock to consumption demand in the 2007 specification does not result in as deep a subsequent undershooting of consumption as in the 1997 and 2002 models (figure A). This partly reflects the fact that the shock causes a greater appreciation in the real exchange rate, and consequent reduction in net exports. This helps to bring inflation back to target, so there is a substantially smaller increase in interest rates in the 2007 model.

Exports respond most strongly in 2007 (figure G), reflecting the substantially larger response of the exchange rate (figure B). Conversely, the import response is less pronounced in 2002 and 2007 than in 1997 (figure H), reflecting the 2000/2001 reductions in the sensitivity of import volumes to import prices.

For all specifications, the output gap increases initially and then quickly declines (figure D) as higher interest rates and an appreciated exchange rate reduce consumption, investment and net exports.

The inflation response is much stronger in 2002 and 2007 than in 1997 (figure E), reflecting the 2000 inflation recalibration which reduced the persistence of inflation and made it more responsive to current demand conditions. By the same token, inflation returns to the target level more quickly in 2007 than in 1997, despite significantly less tightening and a weaker secondary cycle in output.

3.3 Characterising the full cyclical properties of FPS

A natural way to characterise the cyclical properties of a model is to simulate the model for a long time (imposing shocks on it each period) and measuring the moments (e.g. standard deviations) of key variables. To do this, a view of the properties of the shock terms (or disturbances) is required. This can normally be recovered from running the model through history and solving for the shock terms that make the model fit the data, but this is more challenging for models which include expectation terms (or lead variables), because these cannot be observed throughout history.

This reduced our ability to directly connect FPS to the data until software tools such as Dynare became available which allowed the model to be re-expressed in terms of a *backward-looking representation*. This allowed a depiction of the historical shock terms to be obtained by running the backward looking model through history: effectively assuming in each period *that future shocks were unforeseen*. The underlying theory is described in, for example, Mancini (2007). With shock variances set to match history, it is then possible to analytically compute the moments of the model. This analysis currently suggests that the variances and autocorrelations of key variables are reasonably consistent with the data (table 4).

Table 4
Standard deviations and autocorrelations in the data and in the FPS generated business cycle

	Standard deviations		Autocorrelations	
Variable	**Data**	**Model**	**Data**	**Model**
Output	1.41	1.72	0.84	0.68
Consumption	2.72	2.96	0.77	0.86
Investment	6.65	4.89	0.77	0.69
Government spending	4.94	4.00	0.24	0.53
Exports	2.25	3.56	0.37	0.80
Imports	4.02	4.38	0.65	0.85
Inflation	0.69	1.10	0.80	0.90
Tradable inflation	2.62	2.52	0.12	0.31
Non-tradable inflation	1.51	1.96	0.39	0.57
Expected inflation	0.32	0.67	0.90	0.97
90 day nominal interest rates	1.35	1.61	0.80	0.98
10 year nominal interest rates	0.73	0.64	0.76	0.88
Real exchange rate	11.96	10.71	0.90	0.95

This sort of analysis can also be used to assess aspects of the business cycle properties of the data before and after a model recalibration. For example, the autocorrelation of investment (and other moments such as correlation with the output gap and consumption) were dramatically improved by the recent recalibration (described in section 3.2). It is not always clear that the model should seek to exactly replicate history[12], but this sort of exercise seems a useful diagnostic.

4 Conclusion

FPS appears to have passed the test set out by Eric Hansen in the foreword to Black *et al*. (1997): it has continued to be used, and has retained respect as a starting point for Reserve Bank discussions of the New Zealand business cycle. We have attributed this partly to the flexibility that was built into the model, such as the use of time series filters in extracting trends, and to the pragmatic willingness to adjust the model. That adjustment, over 11 years of live use, produced a codified view of New Zealand business cycle properties which has often been a useful starting point when forecasting or completing policy analysis.

There have been several other key advantages of using FPS for model-based projections, including the ease with which the model projections can be judgementally adjusted in a coherent way. For example, if Reserve Bank staff or the MPC considers that special circumstances mean unusual strength in investment in the next couple of quarters, this judgement is easily added to the model forecasts by adding residuals to the investment equation, with automatic consequences for other variables. Furthermore, the model will calculate a new path for investment that gradually returns the capital stock to its steady-state value. In an environment where the forecast may be adjusted (say) ten times over a week of MPC meetings, this feature of the model is quite valuable. Alternative scenarios can also be generated easily.

Indeed, certain relationships captured by the model would be very difficult to calculate in a more partial framework. This is especially the case when it comes to complex forward and backward looking dynamics: for example,

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[12]To give an example, the New Zealand exchange rate has been very procyclical over the last 15 years (it has tended to be high quite reliably when the economy is strong). This has affected other moments too, for example making tradable and non-tradable inflation negatively correlated, and reducing the variability of the overall CPI. However, since the degree of procyclicality of the exchange rate over history is difficult to justify theoretically, and research has also shown that this procyclicality is unusual relative to the Australian or US data (see McCaw, 2007), it is not clear that one should seek to literally reproduce these features of the data in FPS.

the model's reaction function solves for interest rates on the basis of projected future inflation, but the interest rate path itself feeds back to future inflationary pressures.

However, there are also costs associated with a model-based projection system. There is a risk that a projection generated using a model is seen as a 'model projection'. In fact, the Reserve Bank has tended to put relatively low weight on FPS projections that do not incorporate additional judgement. If the role (and accuracy) of the model is overstated, this may impede discussion about the outlook. Nevertheless, even with the addition of judgement, no model can incorporate everything. Consequently, there is another risk that the channels incorporated into the model are given undue weight. For this reason, we think it is important that the role of a model within a projection process is not oversold.

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