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Changes in the transmission mechanism of monetary policy in New Zealand*

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Abstract

Over the last few years, monetary policy in New Zealand has focused on reducing strong demand and inflationary pressures. It has been commented that this task has been frustrated by a weakening of the monetary policy transmission mechanism in New Zealand. In this paper we draw upon a range of empirical models to assess whether monetary policy has lost its potency over the recent cycle, and to identify changes in the mechanism more broadly. Our main conclusion is that the overall impact of monetary policy has not obviously weakened, and in some respects has strengthened, over the past decade.

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1 Introduction

The New Zealand economy is currently enjoying both the longest and strongest uninterrupted expansion in aggregate economic activity on record RBNZ (2007a). In part, this expansion is thought to have been driven by a sequence of positive 'shocks', including a surge in net migration peaking at over 1 percent of the population in 2004, booming house prices and construction activity, commodity prices at multi-decade highs and, more recently, by an easing in fiscal policy. In this environment of strong economic activity, the Reserve Bank of New Zealand (RBNZ) estimates that resource pressures have been and remain intense. The Bank's official measure of the output gap has been positive since 2002, whilst survey measures of capacity utilisation remain near all-time highs. The RBNZ commenced tightening monetary policy in early 2004 to arrest these inflationary pressures. At the time of writing, the Bank's primary policy instrument, the Official Cash Rate (OCR), has been increased by 325 basis points, from 5 percent in 2003q4 to 8.25 percent in 2007q3. In addition, the trade-weighted exchange rate has appreciated around 30 percent over the tightening period, reaching post-float (i.e. since 1985) highs against the US dollar. The elevated levels of interest and exchange rates in New Zealand have been sufficient to keep inflation at modest levels compared to earlier decades, an especially significant outcome given the size of the shocks faced. CPI inflation has averaged around 2.8 percent since 2004 – slightly inside the RBNZ's target band of a medium-term average of 1 to 3 percent.

Despite the impressive aggregate macroeconomic outcomes, it is fair to say there has been considerable public angst expressed over elements of New Zealand's macroeconomic performance over the past five years. This reflects the fact that the growth pattern over these years has been associated with large macroeconomic imbalances on several fronts including: record current account deficits, large declines in household savings rates, an exchange rate that is widely considered to be exceptionally and unjustifiably overvalued, and in later years, a concentration of growth in sectors of the economy relatively sheltered from international competition. This angst has spilled over to concern about the role of monetary policy and the efficacy of its recent conduct. These concerns may be characterised as being of three distinct flavours:

1. *Monetary policy has resulted in an 'unfair' burden of macroeconomic adjustment.* Arguably, policy settings have not been particularly well-targeted to the source of much of the demand pressures, which are seen as local in origin. Instead, the exchange rate has tended to carry the 'burden of adjustment', penalising exporters, especially those not involved in the agricultural sectors that have benefitted from high world commodity prices.

2. *Monetary policy has had a larger impact on the exchange rate than normal.* Some commentators have argued that a given tightening of monetary policy has had a disproportionately large influence on the exchange rate when compared with previous cycles. A common explanation for this is that international risk aversion has been relatively low through much of this decade, raising incentives for 'carry trades' wherein investors borrow in currencies with low financing costs (such as the yen) to purchase higher yielding assets such as those denominated in New Zealand dollars.

3. *The transmission of monetary policy changes from changes in the OCR to changes in domestic demand and inflation has weakened.* Several reasons have been proposed to support this conjecture. First, since the start of this decade, international interest rates have been relatively low and, in an environment of increasing capital market integration, some have argued that this limits the ability of the Reserve Bank of New Zealand (and that of central banks of other similarly small open economies) to independently influence longer-term domestic interest rates. Second, there been a growing substitution away from floating rate mortgages to longer-term fixed rate products, owing to both lower longer-term wholesale rates and to margin compression amongst mortgage lenders on fixed mortgage rates. Third, some commentary suggests the RBNZ was unable to convince financial markets of the underlying strength of inflation pressures in New Zealand in the early part of the current tightening cycle, and consequently policy has had less influence on longer-term rates than usual.

   With regard to the first conjecture above, though the RBNZ has expressed a desire for a different 'mix' of monetary conditions over the current cycle, it is well recognised that the basic monetary policy framework – an open capital account and an independent domestic monetary policy – implies that the exchange rate cannot be set independently of domestic interest rates. Whether smaller external imbalances and smaller swings in the exchange rate can be achieved while maintaining or enhancing overall economic prospects, through the application of alternative policy approaches and structural policy

settings remains an open question. To this end, the RBNZ and The New Zealand Treasury have examined a range of alternative policy instruments and settings over the past few years. Although there are seemingly no 'silver bullets', the recent submission by the RBNZ to the Finance and Expenditure Committee *Inquiry into the Future Monetary Policy Framework* contains a number of suggestions for policy changes that, if adopted, might attenuate the inflationary consequences of the sort of domestic demand pressures New Zealand has faced in recent years RBNZ (2007b).

In this paper our focus is on the second and third conjectures above. We draw upon a range of empirical models to assess whether the monetary policy does indeed exercise a greater influence on the exchange rate than previously, whether monetary policy has lost its potency in terms of its influence on long-term interest rates and on output and inflation, and to identify changes in the mechanism more broadly. To assess the impact of monetary policy on wholesale interest rates and the exchange rate we document results from a series of recent Bank researches which use an event analysis framework as in Gürkaynak et al. (1995).

To assess the overall transmission mechanism through to output and inflation, we document how the Bank's 'official' perspective has changed as viewed through the lens of its (fairly) large core macroeconomic model (Black et al. (1997)), which has been used to prepare the published forecasts since 1997. We also show how the mechanism appears to have changed through the lens of a VAR model described in Haug and Smith (2007), which uses local linear projection techniques from a recursively estimated model to improve the robustness of the model's impulse responses to model mis-specification. Finally, we examine the transmission mechanism using a small open economy New-Keynesian macro model, which is estimated using the Kalman filter with time-varying coefficients. By using the full available sample, this method provides a good indication of the *timing* of changes in the mechanism.

The main conclusion reached from our empirical work is that the transmission mechanism has, if anything, strengthened over time. There is robust evidence that since the RBNZ began using the Official Cash Rate (OCR) as its policy instrument in 1999, the impact of overnight rates on short-term wholesale rates has increased, whilst there is no evidence that the impact of the OCR on longer-term wholesale rates has waned. Second, there is mild evidence that the peak effect of policy changes on inflation has increased, despite the fact that, over this cycle, changes in the OCR have been reflected in key fixed-term

mortgage interest rates with significant and uncharacteristic delay. From the small New-Keynesian model, we note that there is some indication of a lengthening in the transmission mechanism lags from around 2002 through 2005, consistent with the delayed pass-through from OCR changes to fixed-term mortgage rates.

More specifically, in agreement with the second conjecture above, there is some evidence that monetary policy has had an increasing impact on the exchange rate over recent years, although the impact is no stronger than that estimated in the early 1990s and the finding should be seen as tentative given our inability to model the exchange rate with any degree of precision. The estimated impact of the exchange rate on the economy itself is mixed. We find that exchange rate pass-through to CPI inflation has generally declined using FPS and the small New-Keynesian model, whilst it has increased using the SVAR. As the SVAR model does not, however, directly account for energy prices at least part of the increased pass-though seen in this model might reflect the rapid increase in international oil prices over recent years. The impact of the exchange rate on real activity, the so-called 'second-round' effect, is very weak across all models with no consistent evidence of changing influences. Finally, we find that monetary policy itself has tended to become more predictable over time, entailing a higher degree of interest rate smoothing.

In the following section we briefly sketch out a view of how the transmission mechanism is thought to work in New Zealand. This serves as a 'road map' for the remainder of the paper. In section 3, we review the available literature on changes in the transmission mechanism in New Zealand, present key results from the events analysis work, and review recent literature on how the inflation process has changed over the past decade or so. Section 4 contains our analysis of the mechanism using results from the three macro models. In section 5 we offer concluding comments.

2 Overview of the transmission mechanism

Every six weeks, the Governor of the Reserve Bank decides whether current monetary policy is set appropriately to ensure that the Bank's price stability objective is met and, if not, how policy should be adjusted. This follows a comprehensive decision process which includes a review of a wide range of

economic and financial data, economic projections and information from the Bank's business contacts.

A decision to adjust policy settings can be implemented by changing the level of the Official Cash Rate (OCR) directly, or by signalling to financial markets a future course for monetary policy that differs from the prevailing market view. There are several links in the 'textbook' causal chain between a change in such settings and eventual inflation outcomes, which are collectively known as the transmission mechanism of monetary policy.

A flow chart that illustrates the key features of the transmission mechanism is shown in figure 1, and brief descriptions of these links are in table 1. The diagram provides a stylised representation of how various elements of the economy are affected by an increase in the OCR over time. In the flow chart, the links that are thought to be more important than others for the transmission of monetary policy are mapped in relatively thick arrows. This does not necessarily imply that these links represent empirically strong economic relationships as well, and so we denote 'strong' economic relationships by solid lines. Relationships that are more equivocal, for whatever reason, are depicted with dotted lines. Green lines generally form part of the interest rate channel of the transmission mechanism, blue lines denote the effects of changes in the exchange rate, and red lines refer to effects related to inflation expectations. There is some natural overlap between these, especially late in the monetary cycle, and these overlapping links are in black.

The boxes with graded shading indicate the time of *peak* change in a given variable. Since these times are naturally subject to uncertainty, the faded colours towards the ends of the boxes indicate less likely times for these peak changes.

In brief, figure 1 shows that the most immediate impact of a change in monetary policy settings is seen in the markets for short-term bank bills and bonds, and in those for highly liquid financial assets such as foreign exchange. Prices for longer-term bonds, equities, and for other asset classes such as property and housing also respond to a change in policy settings. The net effect of a change in these bond and asset prices is to prompt households and firms to re-assess their consumption, investment, employment and other business decisions. In turn, these decisions percolate through to aggregate spending in the economy, with their presence being significantly felt at the macroeconomic level after one or two quarters, and persisting for up to three years. Finally, and again with a lag, changes in aggregate activity influence

pricing pressure in the economy – prices will tend to rise as activity expands beyond a level consistent with the economy's potential and decline as activity falls below this level.

Some of the links noted above are relatively timely and well understood; others are subject to considerable uncertainty around both the timing and magnitude of their impact on the economy. For example, policy changes tend to have a well-defined impact on short-term interest rates, but much less direct and less certain consequences for house prices. Other complications may arise in practice. First, the impact of a change in settings will often depend on the current state of the economy. In a buoyant economy with rising inflation pressure, the RBNZ may need to tighten policy more aggressively than in an economy where activity and sentiment are subdued. Second, a crucial part of the transmission mechanism concerns how households and firms form expectations of future prices and activity.[1] In general, the more the Bank is able to influence these expectations, the easier is the task of maintaining low and stable inflation. Finally, the transmission mechanism tends to change over time as economies evolve, an issue to which we now turn.

3 Literature review

There is a fairly large body of work that has estimated (in some form) the monetary policy transmission mechanism in New Zealand, using a variety of economic modeling methods. From reduced form partial-equilibrium analyses to highly structural modeling exercises, the literature has generally found that a tightening of monetary policy (usually represented by an increase in the 90-day interest rate) significantly reduces output and inflation over a one to two year horizon, indicating that the policy transmission mechanism is effective.[2] However, there are only a handful of studies that have looked at *changes* in the transmission mechanism in New Zealand directly. We review these studies below along with 'events analysis' research recently undertaken at the RBNZ. We then consider the recent literature on changes in the in-

[1] This is a major argument for transparent monetary policy and hence the considerable effort the Bank expends communicating policy decisions, such as through the published Monetary Policy Statements.

[2] See, for example: Black et al. (1997), Haug and Smith (2007), Szeto (2002) and Buckle et al. (2003)

Figure 1
Stylised view of the transmission mechanism

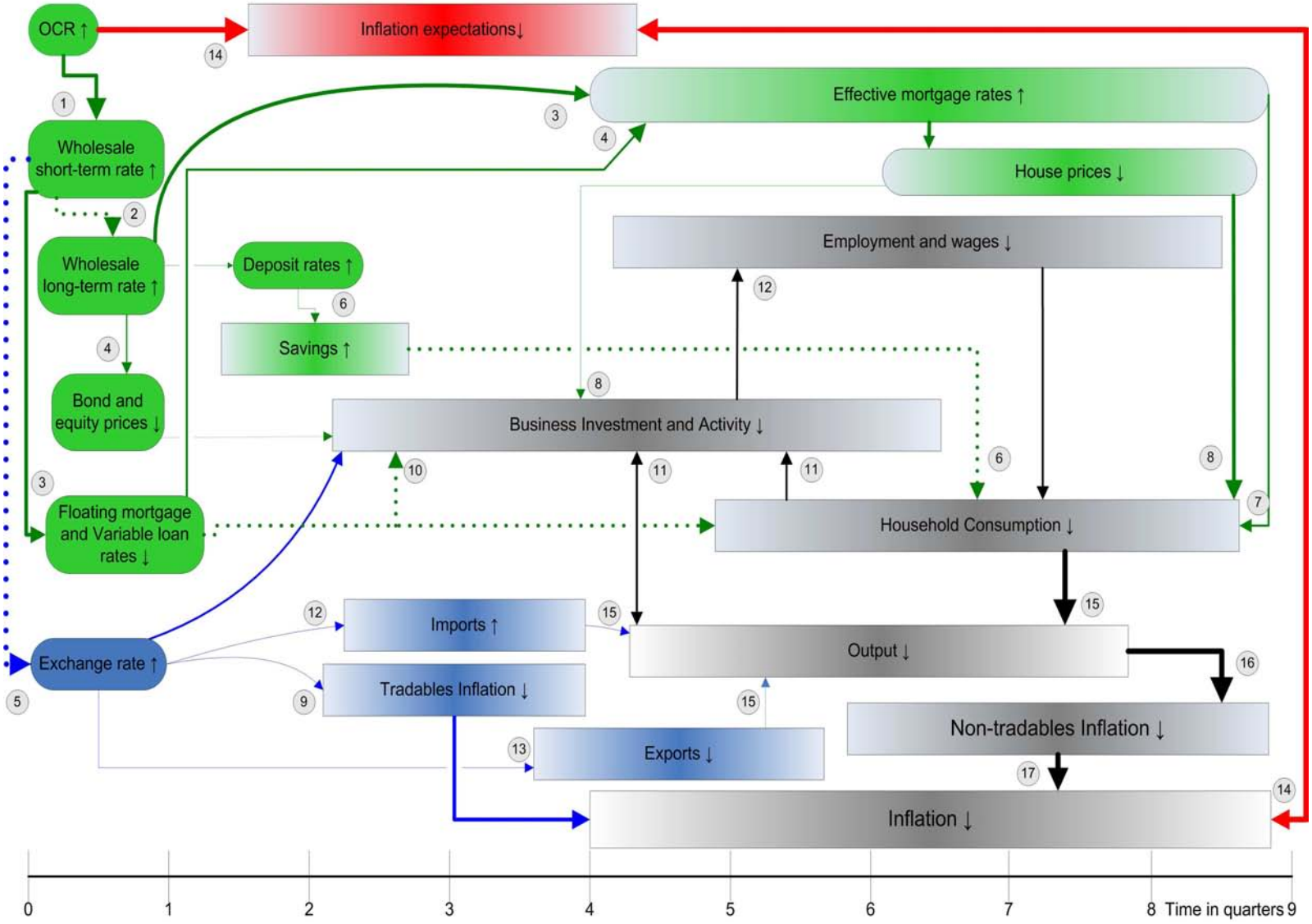


Table 1
Stylised view of the tranmission mechanism: annotations

Link	From	To	Reasons (in context of an OCR increase)
1	Official Cash Rate	Wholesale short-term interest rates	Domestic interest rate arbitrage
2	Wholesale short-term interest rates	Wholesale long-term interest rates	Expectations hypothesis; expected future activity, inflation and monetary policy; foreign monetary policy
3	Wholesale short- and long-term interest rates	Retail borrowing and lending interest rates	Margin preservation by banks and financial intermediaries
4	Wholesale short- and long-term interest rates	Asset prices including bonds, equities and housing	Future interest, dividend and rental payments are more heavily discounted; higher debt servicing costs; tighter credit criteria
5	Wholesale short- and long-term interest rates	Exchange rate	Interest parity conditions; foreign monetary policy
6	Retail borrowing and lending interest rates	Household savings and consumption	Returns to savings increase; current consumption more expensive in terms of future consumption
7	Retail mortgage interest rates	Household consumption	Higher mortgage payments; lower disposable incomes for discretionary spending
8	House prices	Household consumption and business activity	Wealth effects; less collateral available for discretionary loans
9	Exchange rate	Tradables inflation	Cheaper imports
10	Retail borrowing and lending interest rates	Business investment and activity	Higher rate of return required from investment; larger debt servicing costs
11	Expected future household consumption and overall activity	Current business investment and activity	Lower expected earnings in future
12	Exchange rate	Imports	Substitution away from domestically-produced goods in favour of imports
13	Exchange rate	Exports	Reduced competitiveness and consequently lower export earnings
14	Official cash rate	Inflation expectations	Monetary policy credibility
	Inflation expectations	Current inflation	Workers and firms reduce wage and price demands in expectation of lower future inflation; weaker incentives to spend now rather than later
15	Consumption, investment and net exports	Aggregate output	Output is the sum of consumption, investment, net exports (and government spending)
16	Aggregate output	Non-tradables inflation	Actual output declines relative to economy's supply potential, reducing pressure on economic resources
17	Tradables and non-tradables inflation	CPI inflation	CPI inflation is the sum of tradables and non-tradables inflation

flation process in New Zealand and draw implications for the transmission mechanism, to the extent possible.

3.1 The Transmission Mechanism

Links from the OCR to other interest rates

As noted in the introduction, a concern arising over the recent business cycle in New Zealand is that the transmission from the OCR to retail rates (links 2 and 3 in Figure 1) may have weakened. Tripe et al. (2005) examine the impact of the introduction of the OCR in 1999, a policy-controlled benchmark overnight interest rate, on money market and residential lending rates in New Zealand. They observe that the introduction of the OCR has reduced the volatility of both wholesale and residential lending rates. Using the standard Engle-Granger cointegration approach, they find that the degree of long-term pass-through from money market rates to floating mortgage rates has increased in the post- OCR period, while that for fixed mortgage rates has decreased slightly. Liu et al. (2007) estimate both the degree of pass-through and adjustment speed of retail rates in response to changes in policy-controlled rates over the period from 1994 to 2004. Using the Phillips-Loretan cointegration approach, they find complete long-term pass-through for some but not all retail rates. Results also show that the introduction of the OCR has increased the pass-through of monetary policy changes to floating and deposit rates, but not fixed mortgage rates, where pass-through is estimated to have always been lower. Overall, the authors conclude the move to OCR in 1999 was positive in the sense that it has increased transparency, lowered instrument volatility and enhanced the efficacy of policy via increased pass-through of policy changes to short-term retail rates.

Pais (2007) also employs a cointegration approach to examine the pass-through of OCR changes to variable retail mortgage rates, and the pass-through of 5-year swap rates to 5-year fixed rate mortgages for a number of large New Zealand banks. Her data is at a higher frequency (weekly) than the other studies cited above and covers the period from 2000 to 2004. She also finds pass-through from wholesale to retail rates is nearly complete in the long-run, but the speed of pass-through is much slower for floating mortgage rates than fixed rate products. Moreover, her estimates suggest mark-ups are much higher for floating rate mortgage than fixed rate products, from

which she concludes that the fixed rate mortgage market is much more competitive than the floating-rate market. On the whole, Pais contends that the effectiveness of monetary policy is likely to be compromised as it takes some time (around 40 weeks) for floating rate mortgages to completely adjust to changes in the OCR, whilst 5-year fixed rate mortgages are said to be "out of reach for the RBNZ" because funding for these products are largely arranged in offshore capital markets (i.e. implying link 2 in figure 1 is broken).

A rather different conclusion from Pais (2007) may be reached from recent 'events analysis' research undertaken at the RBNZ, which suggests that since the start of this decade, changes in the OCR have had both statistically and economically significant impacts on longer-term wholesale rates and the exchange rate.[3] In brief, an event analysis is thought to be a more robust way of identifying the impact of monetary policy and other economic developments on financial market prices than the traditional times-series approaches above, and as such has become an increasingly popular tool in international research (e.g. see Bernanke and Kuttner (2005)). To conduct the analysis, the unanticipated or surprise component of monetary policy and other variables such as output and inflation are derived from relevant financial market prices or surveys of expectations. The surprises are then regressed on asset prices such as interest rates, exchange rates and stock prices, at very high frequencies (the RBNZ research usually uses intra-daily data in 30-minute windows) in order to isolate the impact of the surprises on the variables concerned. [4]

In table 2 below, we present some of the key results from the events analysis work. A hypothetical monetary policy surprise of 100 basis points is estimated to cause implied 1-year forward swap rates at 1-year ahead to increase by 92 basis points, the 1-year forward 2-years ahead to increase around 40 basis points, and even the 1-year forward 5-years ahead to rise by around 30

[3] See Drew and Karagedikli (2008) and Karagedikli and Siklos (2008).

[4] Due to historic data constraints there is a paucity of prior events analysis research for New Zealand; the required intra-daily data used in the Bank's research is only available from around 2001. Unfortunately, the data constraints also prevent us from using the approach to examine how this part of the transmission mechanism has changed over longer time periods. However, formal testing for instabilities in the regressions did not reveal any problems, as might have been the case if the impact of monetary policy on the yield curve or exchange rate had changed materially since 2001.

basis points.[5] Turning to the effect of the surprise policy tightening in foreign exchange markets, the spot NZD-USD exchange rate appreciates around 3.5 percent, with a diminishing but still significant impact on forward exchange rates.

Overall, these results suggest that the impact of monetary policy on key financial market prices (links 2 through 5 in figure 1) are effective. That said, it is well recognised that monetary policy is not the only, or probably even the most important, driver of long-term wholesale interest rates and certainly the exchange rate. Other factors are also important and may work against the direction of the stance of domestic policy, as discussed in some detail in RBNZ (2007b).

[5] A 100 basis points surprise would be a very large surprise to markets. Drew and Karagedikli show that monetary policy in New Zealand tends to be fairly well-anticipated and surprises of around 8 basis points are more typical over the sample period.

Table 2
Impact of monetary policy shocks on interest and exchange rates

	1y1	1y2	1y3	1y5
mps1	0.927***	0.434***	0.362***	0.289***
se	-0.06	-0.095	-0.057	-0.055
R sq	0.87	0.34	0.46	0.21
Obs	55	55	55	55
mps2	0.598***	0.224**	0.221***	0.190**
se	-0.109	-0.1	-0.069	-0.071
R sq	0.42	0.11	0.2	0.22
Obs	45	45	45	45
mps3	0.881***	0.396***	0.300***	0.251***
se	-0.06	-0.109	-0.076	-0.084
R sq	0.64	0.27	0.28	0.28
Obs	43	43	43	43
		spot	F2	F5
nzd-usd		0.0358***	0.026**	0.0122*
se		0.0092	0.0087	0.0084
R sq		0.22	0.11	0.03
Obs		55	55	55

Notes: mps1 to mps3 denote three measures of monetary surprises calculated in Drew and Karagedikli (2008). The columns 1y1 to 1y5 report the estimated impact of these surprises at 30-minute windows on 1 year interest rate forwards calculated at 1 year to 5 years ahead.
The estimated impact of the mps1 surprise measure on the nzd-usd spot, 2-year forward and 5-year forward exchange rate is taken from Coleman and Karagedikli (2008).

Links from the OCR to output and inflation

Unfortunately, as far as the authors are aware, there is almost no research that has examined how the transmission mechanism of monetary policy in New Zealand has changed more broadly. The exception is Schmidt-Hebbel (2005), who uses a structural VAR framework incorporating output, inflation, interest rates, the exchange rate, oil prices and foreign (US) interest rates. Monetary policy in New Zealand and a range of other (mainly OECD) countries is examined from 1990 to 2005 and over two sub-periods: 1989-1997 and 1997-2005. The main conclusion reached is that monetary policy transmission in New Zealand is broadly comparable, and at least as strong, as that observed in comparable small open economies (i.e. Australia, Canada, Chile, Sweden and Norway). However, there are two interesting differences in the mechanism between the two samples:

- Monetary policy shocks in New Zealand (innovations to the domestic 90-day nominal interest rate) have significant effects on long-term rates (i.e. the 10-year Government bond rate) in the 1st sub-sample. In the latter sample the impact is smaller and less persistent, although differences between the samples are not statistically significant.

- A positive shock to foreign (US) short-term interest rates has a significant impact on New Zealand's short and long term rates, and also causes the exchange rate to depreciate (although effects are not significant over any horizon). However, the impact is smaller and much less persistent in the second sub-sample compared to a sample period that included data from 1990, particularly for the long-term domestic rate.

Overall, Schmidt-Hebbel concludes that the scope for independent monetary policy in New Zealand has, if anything, increased since the late 1990s.

3.2 The inflation process

Changes in the inflation process may also relate to changes in the transmission mechanism, although unless the relevant linkages are modeled as well-identified structural relationships, it is normally not possible to form firm inferences on this. For example, as discussed below, empirical work suggests there has been a 'flattening' in the Phillips curve in New Zealand, as in many other countries. In a strictly reduced-form sense this would imply a

weakening in the transmission mechanism as, all else equal, monetary policy is required to lean harder against the economy to effect a given change in inflation. On the other had, the flattening might reflect a better anchoring of inflation expectations to the RBNZ's inflation target, implying a strengthening of the mechanism. Below, we report the main results from the New Zealand literature on the inflation process, and form tentative conclusions from this. These conclusions are formally tested in Section 4.

Basdevant and Hargreaves (2003) observe that the establishment of low and stable inflation in New Zealand is likely to have been associated with structural changes in price-setting behaviour and expectations formation. They estimate reduced-form regressions using the Kalman filter to test whether the degree of first stage pass-through from exchange rate movements to import prices (link 9 in figure 1) and the mark-up of domestic prices over import prices and domestic unit labour costs has changed over time. The speed of first stage pass-through is shown to decline over the 1990s, but rapidly increases around 2000 following a very large depreciation in the New Zealand dollar between 1997 and 1999.[6] In contrast, the mark-up (which encompasses second stage exchange rate pass-through) is shown to generally decline across the whole period, including over the recent exchange rate depreciation episode.[7] The authors interpret their results as generally being consistent with an increased anchoring of New Zealand inflation around the inflation target, dampening the propagation of inflationary shocks, and all else equal, increasing the efficacy of monetary policy.

Hodgetts (2006) considers the inflation process more broadly. A range of evidence is presented and reviewed that suggests that inflation has become less responsive to its 'fundamental determinants', including measures of excess demand pressures in the economy, variations in the exchange rate, labour costs, and commodity prices. This is partly attributed to the reduction and anchoring of inflation expectations that followed the adoption of the inflation targeting framework. Other factors cited as being important include: various reforms to labour and product markets that have promoted competi-

[6] Note that over all periods long-run pass-through of exchange rate changes to import prices in NZ dollar terms is complete. The authors suggest that the rapid increase in pass-through around 2000 could be a result of margins reaching unsustainably low levels in the sector, perhaps because importers did not expect the exchange rate to stay as low as it did over the period. In other terms, the reduced-form pass-through relationship may contain a significant non-linearity relating to margins levels.

[7] Hampton (2001) directly finds a decline in second stage pass-through in New Zealand.

tion and muted the impact of wage and cost-push shocks; and more recently, low global inflation and downward pressure on prices from countries such as China. The relative weight of the various factors influencing the inflation process is difficult to quantify. However, at least regarding the formation of inflation expectations, Hodgetts cautions against placing a lot of weight on the anchoring of inflation. The empirical case for expectations being highly anchored is not seen as strong and, moreover, it is noted that in recent years long-term inflation expectations have begun to drift upwards – perhaps in response to revisions to the RBNZ's inflation target, but perhaps in response to the substantive cost and demand pressures the economy has experienced over the past 5 years or so.[8]

In summary, the inflation process has seemingly become more stable over the past decade. But there is uncertainty over the extent to which this reflects changes in price formation behaviours by domestic agents as a results of product and labour market reforms and/or anchoring of inflation expectations, or alternatively, as a result of greater competition as part of the broad 'globalisation' process. To the extent that stabilisation of inflation is mainly due to domestic factors, one would expect an enhancement of the transmission mechanism. In contrast, if the moderation is driven by external competition, there is less reason to suppose significant changes in the mechanism.

[8] Basdevant (2003) finds that inflation expectations have become less dependent on historical inflation outturns and the output gap, and more dependent on forward-looking behaviours. In contrast, Hunter (2004) finds that it is difficult to empirically distinguish between models of expectation formation that are fairly backward-looking but place some weight on the RBNZ's target, and models where inflation expectations are fairly forward-looking, but have no explicit anchoring to the inflation target. This distinction is important for the transmission mechanism and the conduct of monetary policy. When inflation expectations are fairly forward looking and significantly influence current inflation, the transmission mechanism of monetary policy will work strongly as long as the central bank's policy stance is seen as credible. When inflation expectations are fairly backward-looking but there is a weight on the inflation target, monetary policy will have relatively more work to do to return inflation to the target by a given horizon following a shock. Note that, in principle policy does not need to be adjusted *at all* if there is no defined time horizon for the achievement of the inflation target, given that the central bank can rely on inflation and inflation expectations autonomously returning to the target – a policy 'free lunch' (though one that is contingent on expectations continuing to remain anchored). Hargreaves et al. (2006) discusses the current calibration of the Phillips curve in the Bank's main macro model, FPS. The calibration features an inflation expectations process that contains a fairly long series of both lags and leads, with no weight on the inflation target, and delivers properties that are seen as broadly plausible by RBNZ policy makers.

4 Empirical investigation of the transmission mechanism

4.1 The mechanism through the lens of FPS

The RBNZ's Forecasting and Policy System (FPS) is a medium-sized general equilibrium model that has been used as the primary tool for the Bank's published forecasts since 1997. Black et al. (1997) discusses the structure of the model, while Drew and Frith (1998) and Hampton (2002) discuss how the model is used in the projections process. In brief, the model has a two tiered structure. The first tier is an underlying equilibrium structure that determines a neo-classical balanced-growth path. Along that growth path, consumers maximise utility, firms maximise profits and the government achieves exogenously specified targets for debt and expenditures. The dynamic adjustment process overlaid on the equilibrium structure is calibrated and reduced-form in nature, for example, inflation arises from Phillips curve relationships for tradables and non-tradables inflation (Hargreaves et al. 2006). The central bank is modelled by a forward-looking reaction function that moves the short-term nominal interest rate in response to projected deviations of inflation from an exogenously specified target rate.

Although the basic underlying structure of FPS has not altered radically since its conception, the dynamic adjustment paths have been re-calibrated significantly. These recalibrations are usually prompted by evidence from both sectoral and aggregate level RBNZ research, and by judgment on changes in economic structure, the propagation of shocks and the transmission of shocks. As such, the comparison of different calibrations of FPS over time offers a very convenient synthesis of Bank research and changing judgment on various macroeconomic elasticities.[9] In this section, we report results from two shocks using three vintages of the model – from 1997, 2002 and 2007 – designed to illustrate changes in the the Bank's view of the mechanism. In particular, we examine a monetary policy shock and a temporary appreciation of the exchange rate that is not driven by any fundamental shift in the economy.

Though the different vintages of FPS can be taken as representing the Bank's

[9] Over time, the model has tended to get slightly larger, for example, through a finer disaggregation of imports to include re-exporting activities and energy imports.

changing official perspective, it is important to note that considerable judgement is and has always been applied to the model when formulating the projections. Some of this judgement will reflect concern around the model's prevailing transmission mechanism. A notable example is that the model does not include a role for house prices and housing wealth. As such, judgement is often applied to reflect the RBNZ's view on how monetary policy settings will affect house prices and how, in turn, housing market development affect consumption (i.e. a wealth effect channel, as represented by link 8 in figure 1). In addition, the initial 1997 calibration is least likely to reflect the Bank's view of the transmission mechanism as the model had yet to be subject to repeated tests of out-of-sample forecasting accuracy. Finally, the vintages should not been seen as discrete jumps in the Bank's view in the transmission mechanism; in practice this is a more continuous process that in part reflects various cyclical considerations raised in section 2.

Figure 2 shows a temporary interest rate increase of approximately 100bp for 1 year. In general, we see that the monetary policy transmission mechanism has tended to get stronger with each calibration. Output troughs at a lower level in the 2007 calibration and the impact of the policy tightening on inflation is larger. The timing of the impact on inflation and output across the three calibrations, however, is roughly similar. Driving the larger impact of interest rates on output in later calibrations is a modestly larger effect of interest rates on consumption and a much larger effect on business investment. The lower rate of inflation is, in part, due to the larger impact of interest rates on output, but more significantly, a larger impact of interest rates on the exchange rate and hence on tradables inflation. The larger impact of interest rates on the exchange rate also implies a larger impact on exports, although the timing of the peak impact is significantly lagged in the later calibrations, and is even longer than the impact of interest rates on consumption and investment. This indicates that the Bank has taken the view, over time, that the indirect effects of the exchange rate on the economy take longer to materialise.

Although more difficult to infer from figure 2, there have been re-calibrations of the model's policy reaction function between the vintages and the modeling of long-term (5-year) interest rates. In the 1997 calibration, the reaction function was written in terms of the yield curve and long-term rates were much more closely linked to short-term (90-day) rate developments via the standard forward-rate condition. In later calibrations, the impact of foreign long-term interest rates on domestic long-term rates has increased, thereby

dampening the impact of the path for 90-day rates on domestic long-term rates. Another change is that there has been a higher weight placed on interest rate smoothing (i.e. a higher coefficient on the lag of the 90-day rate in the policy reaction function). This is most easily seen by comparing the path of the 90-day rate between the 2002 and 2007 vintages.

To illustrate the exchange rate channel of the transmission mechanism directly, Figure 3 shows the result of a temporary real exchange rate appreciation of 1 percentage point that lasts for one year. This shock reveals fairly substantial differences in the effect on activity between the 1997 calibration and later vintages. In the original calibration, the exchange rate appreciation has a much larger and speedier impact on exports and import demand, causing the output gap to fall away to a lower level sooner than in the later calibrations. In addition, the deflationary impulse, although delayed relative to the 2002 and 2007 calibrations, lasts much longer reflecting the greater persistence in the inflation process. Given the larger impact on inflation, interest rates are cut to a much larger degree in the 1997 calibration, which causes investment and consumption to rise noticeably. In the 2002 vintage of the model we see that the effects of the exchange rate on exports and imports are quite muted and delayed. This is reversed slightly in the 2007 calibration, although the effects are still mild relative to the 1997 calibration.

It is difficult to formally examine the direct impact of the exchange rate on CPI inflation between the vintages given definitional changes and re-modeling of the inflation process between vintages. It may be inferred, however, that pass-through to CPI inflation has generally been reduced by comparing responses of CPI versus non-tradables inflation. For example, the CPI inflation responses are fairly similar in the 2002 and 2007 vintages yet non-tradables inflation troughs lower in the 2007 vintage, implying lower exchange rate pass-through to CPI inflation in the 2007 vintage.

Figure 2
Impact of a monetary policy shock in vintages of FPS

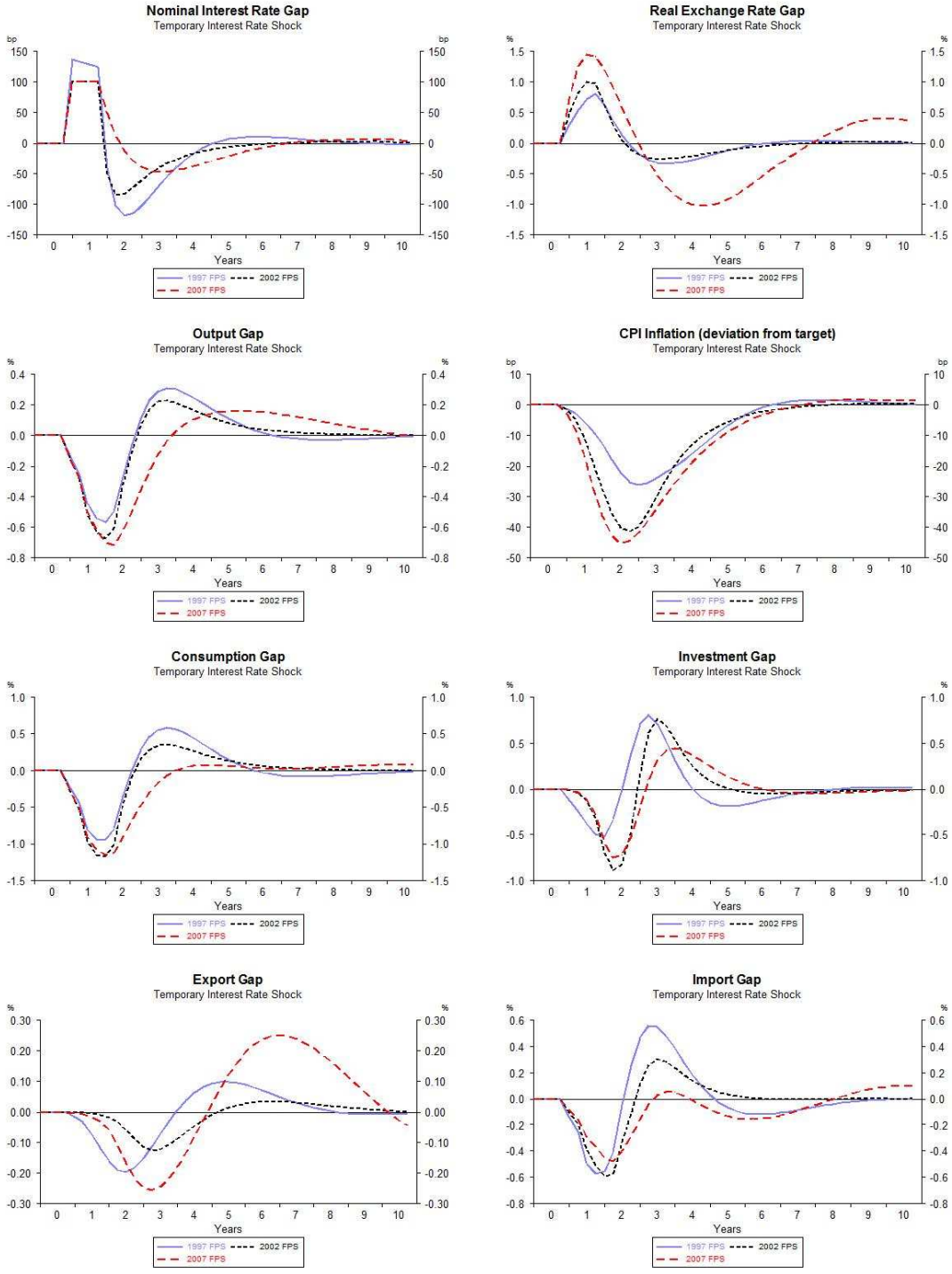


Figure 2
Impact of a monetary policy shock in vintages of FPS

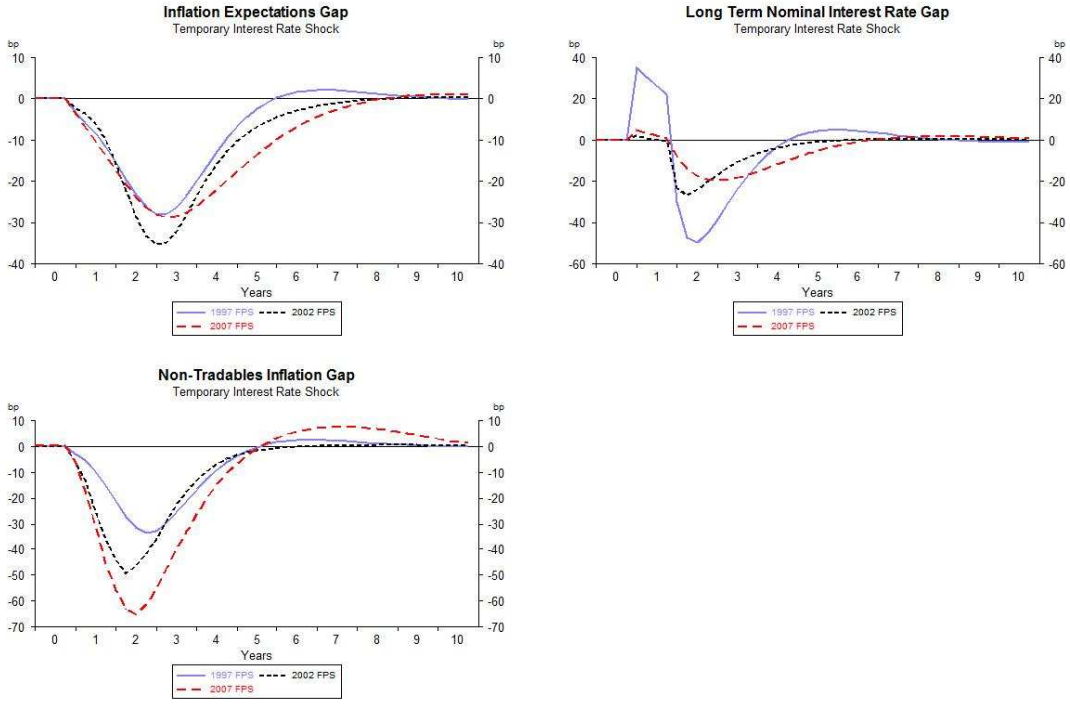


Figure 3
Impact of an exchange rate shock in vintages of FPS

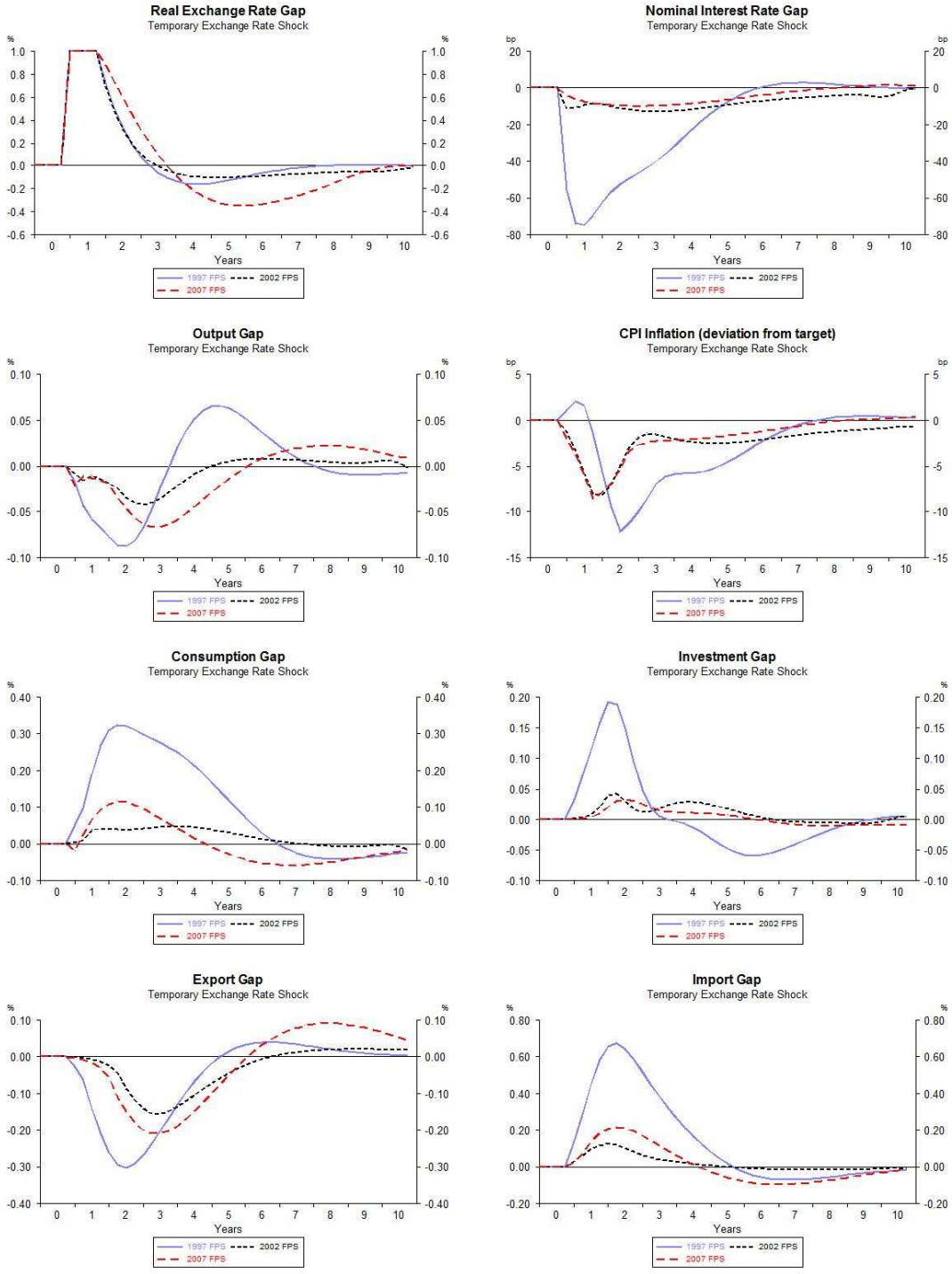
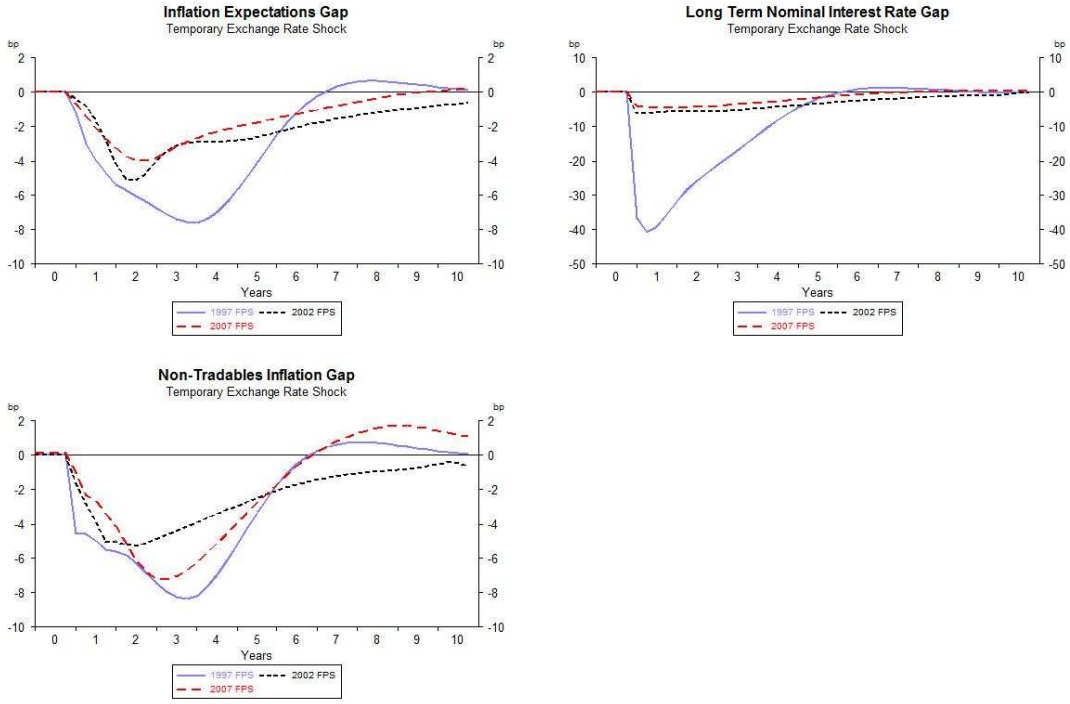


Figure 3
Impact of an exchange rate shock in vintages of FPS



4.2 The mechanism through the lens of local linear projections

As noted above, FPS is a relatively large calibrated model. In this and the following subsections we examine how the mechanism has changed through the lens of two smaller-scale estimated models. This provides a cross-check on the FPS results and a more continuous picture of how the mechanism has evolved over time.[10] In this section, the model utilised is a akin to a VAR. As in Sims (1980), this approach allows the "data to speak" – we obtain a view of the mechanism that is relatively free of imposed theory.

Following Jordà (2005) and Haug and Smith (2007), we employ local linear projections (LLPs) to compute impulse responses arising from interest rate and exchange rate shocks. The essence of an impulse response is that it reflects the change in future forecast values arising from a known shock. In principle, therefore, any forecasting method can be used to calculate an impulse response, provided that the method can correctly represent the initial impulse and can calculate the resultant effects for different time horizons. Local linear projections are akin to 'direct forecasts', that is, horizon specific models are developed by projecting the variable y_{t+s} (for $s = 1, \ldots, S$) on y_{t-1}. The impulses are obtained locally relative to each horizon, whereas traditional VAR techniques provide a global approximation to the data generating process. If the model is correctly specified then the latter VAR approach will be superior, but the former may be more robust to mis-specification – ie to omitted variables or lags. The LLP approach is of particular relevance when considering the transmission mechanism given changes in the mechanism in reduced-form studies may well arise in the guise of changes in lag structures. Annex 1 provides further details on how impulse responses are identified using the local linear projections technique.

[10] We use current vintages of data and current estimates of variables like the output gap in the analysis in this and the following section. This undoubtedly gives the model's a different information set than that available to policymakers in real time, implying *ex-ante* the estimates of changes in the mechanisms would not necessarily be recoverable in a real-time setting. On the other hand, in order to identify changes in the mechanism *ex-post*, it is preferable to use current vintages of data as presumably they provide the best estimates of the variables of interest.

LLP estimates of the changing transmission mechanism

To investigate whether there is any evidence that the impact of monetary policy has become less effective in recent years, we calculate IRFs from LLPs recursively across a sample of data. The first data sample begins in 1989Q3 and ends in 1996Q2. We then recursively extend the data sample – and re-estimate the model and IRFs after each extension – until the data sample runs from 1989Q3 through to 2006Q1. In calculating the local linear projections we regress y_{t+s} against y_t, with no higher lags. This is consistent with the specification employed by Haug and Smith (2007), based on information criteria. Since a model is estimated for each horizon, the local linear projections capture changing dynamics by updating the parameters of these horizon-specific models.

We are specifically interested in how the shocks affect gross domestic product, the consumer price index, interest rates, and the real exchange rate. Here we use the same model specification and identification scheme as Haug and Smith (2007). The local linear projections use the following vector of variables $y_t = [GDP_t, CPI_t, R90D_t, RER_t, wGDP_t, wCPI_t, wR90D_t]'$, where GDP_t is New Zealand GDP, CPI_t is the consumer price index, $R90D_t$ is the 90 day bank bill rate, RER_t is New Zealand's real exchange rate, $wGDP_t$ is a trade-weighted average of foreign-country GDPs, $wCPI_t$ is a weighted average of foreign consumer price indices, and $wR90D_t$ is an 80-20 weighted average of US and Australian 90 swap interest rates. These latter 'world' series (hence the 'w' prefix) are used to represent the international economy. GDP, CPI, and the real exchange rate are all logged, while the interest rates remain in levels. The IRFs are estimated using data in levels (or log levels). See Haug and Smith (2007) for a more extensive discussion of the data. The restrictions used to identify B_0 are described in Annex 1. Additionally, the world variables are block exogenous with respect to the New Zealand economy, since New Zealand is small and is unlikely to have predictive value for the world economy as a whole.

Figures 4-9 illustrate how the IRFs change as the data sample is extended through from 1996Q2 to 2007Q1. Each surface represents the evolution of an IRF as the sample is recursively extended. There are 40 samples (except for the GDP and RER IRFs which only have 39), and IRFs are calculated for $s = 1, \ldots, 12$ quarter horizons. The largest sample of data (indexed by the last day of the quarter) corresponds to 40, and the smallest 1989-1996 sample corresponds to 1. It is apparent that the IRFs from the earlier smaller samples

exhibit a period of instability, but then evolve more smoothly as additional data are added. The original level – the flat plane at zero – is illustrated with the transparent 'wire' surface.

Figure 4 illustrates how (log) real GDP responds to an 1 percent increase in interest rates. In this figure, it appears that the trough in output in response to interest rate shocks, at a horizon of approximately 4-8 quarters, has stayed fairly constant over time. However, there is some indication that the size of the impact of interest rates on output has varied over time. The earliest samples indicate a relatively weak impact and as the sample becomes larger, the impact increases. However, the very latest samples, from around 35 to 40 (i.e. a sample end from 2005q4 to 2007q1), indicates a slight attenuation of the impact of interest rates on output. In addition, the subsequent rebound in output after the trough occurs slightly earlier and is slightly larger. All else equal, this result suggests that the transmission of policy changes to output has weakened recently, in contrast to the results using the Bank's FPS model.

Figure 4 shows how the response of the (log) CPI to the interest rate shock. Unlike the GDP response, once the initially instability is passed, the IRFs present a picture of policy having an increasingly stronger impact on CPI inflation. This agrees with the finding in the previous section using FPS and to assess this result further, figures 6 to 8 illustrate the role played by the exchange rate. An increase in interest rates leads to an increase in the exchange rate lasting for around four quarters, before it depreciates below its initial level. The IRF profiles are little changed over the whole sample period. In addition, there is little change in the impact of the exchange rate appreciation on output, which indicates a very mild *positive* impact through samples ending from around 2000q1. [11] However, the impact of the exchange rate on CPI inflation becomes stronger over time, with peak impacts around the 1 to 2 quarter horizon. This results suggests that the direct impacts of the exchange rate on CPI inflation have tended to get stronger over time,

[11] The mildly positive impact of the exchange rate on output is, of course, the opposite sign to that depicted in figure 1 and how the exchange rate is normally viewed to affect the economy. However, the confidence intervals around the IRFs for the impact of the exchange rate on output are very wide, with considerable mass in negative territories. In addition, there is significant instability in the IRF's in samples ending prior to around 2000q1, which are omitted from 7. Overall, our interpretation of this result is that the model does not likely identify the 'true' impact of an exchange rate shock on output.

and hence largely explains the overall larger impact of interest rates on CPI inflation.

The increased impact of the exchange rate on CPI inflation is against some of the literature cited in section 2, which tends to find that the direct effect of the exchange rate on CPI inflation has either stayed stable or has declined since the early 1990s. On the other hand, Basdevant and Hargreaves (2002), using more recent data, find an increase in pass-through around 1999-2001, following the large exchange rate appreciation over this period. The result from the LLP model suggests that this may not have been a structural shift; instead, as the model does not contain energy or commodity prices (which tend to have much higher exchange rate pass-through than other imports) it is possible the increasing pass-through estimated reflects the boom in energy and commodity prices in recent years. As shown in the following section, when we separately account for the exchange rate, oil prices and commodity prices using the small semi-structural model, we find that pass-through has remained fairly stable.

Figure 4
Impulse response of GDP to R90D shock

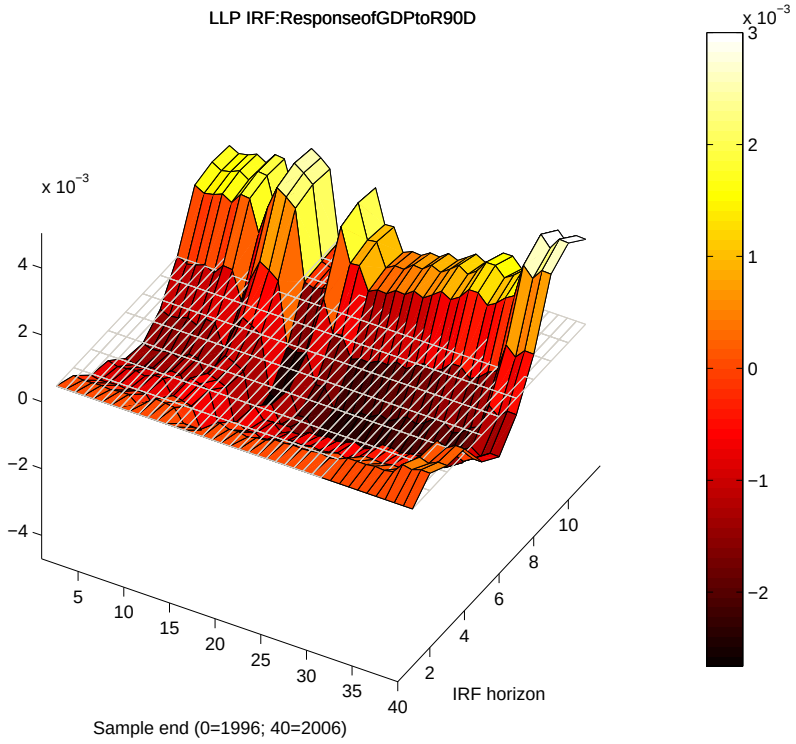


Figure 5
Impulse response of CPI to R90D shock

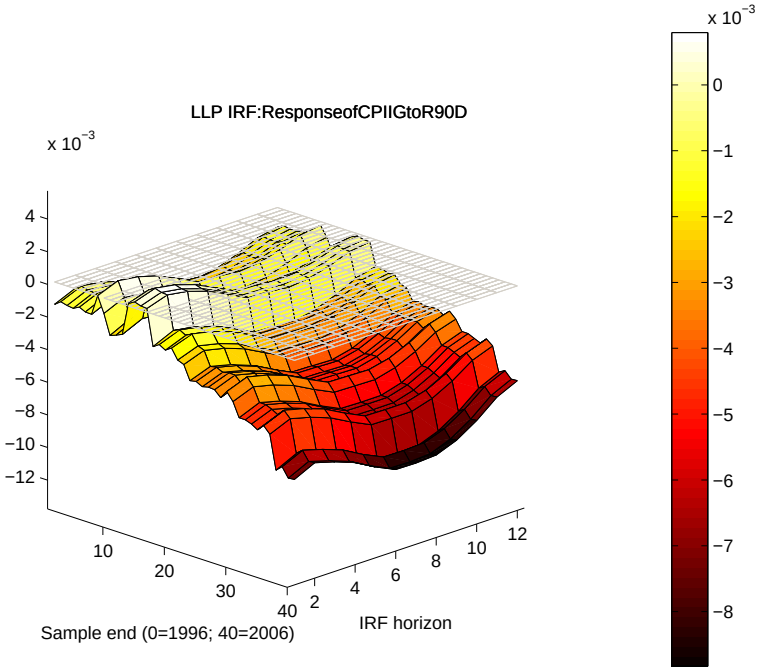


Figure 6
Impulse response of RER to R90D shock

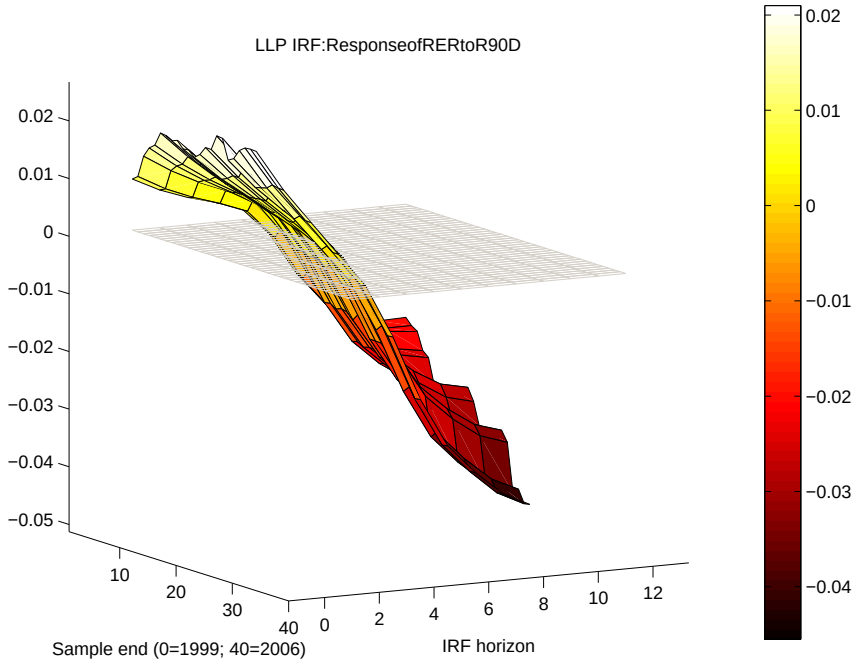


Figure 7
Impulse response of GDP to RER shock

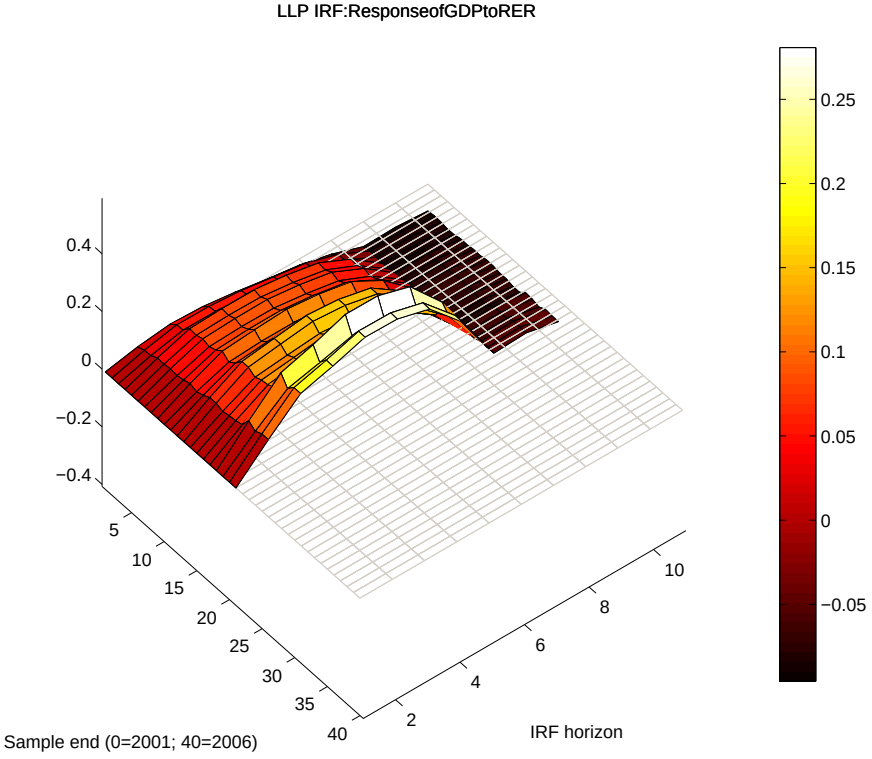


Figure 8
Impulse response of CPI to RER shock

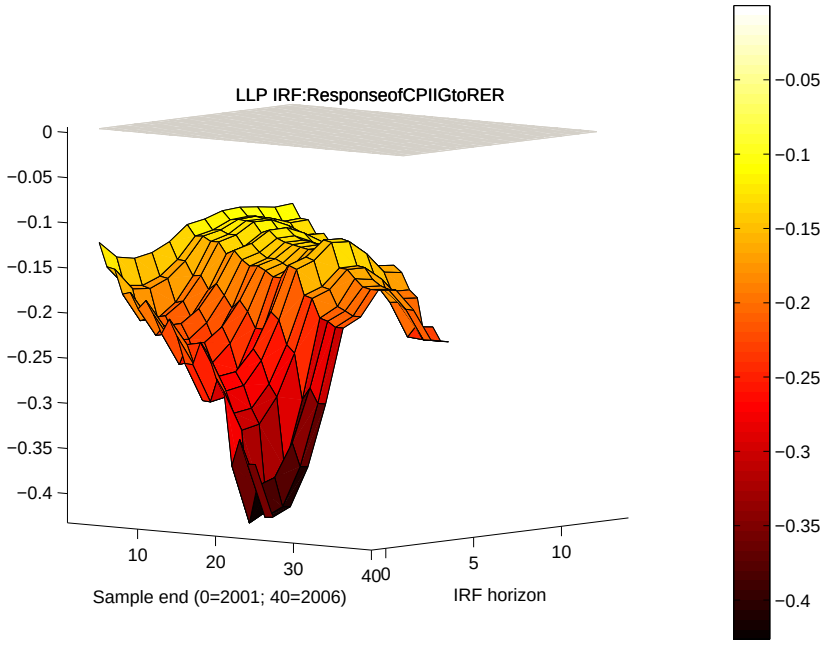
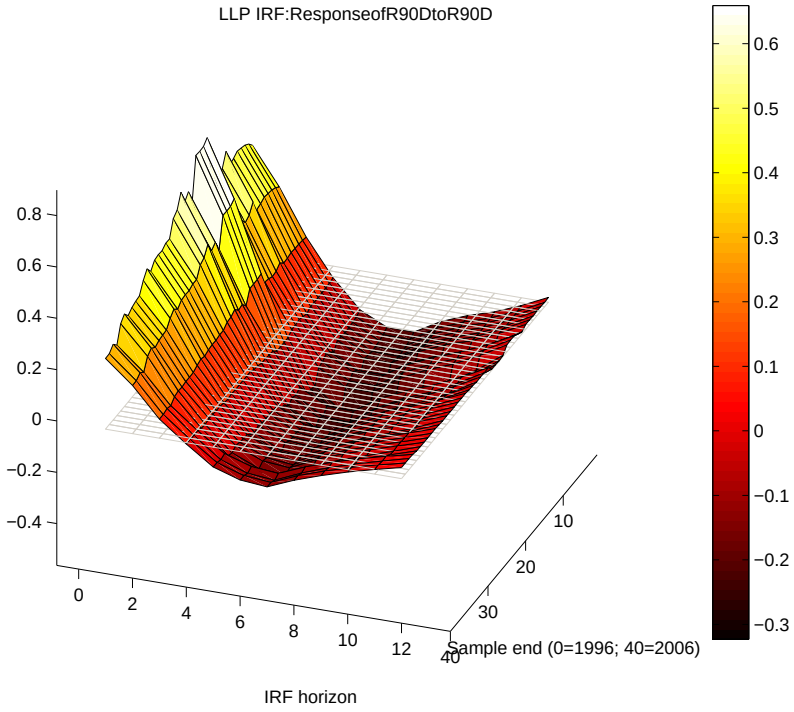


Figure 9 illustrates the effect of a monetary policy shock on interest rates. (Note that the shocks are not restricted to unit impulses in this figure.) Estimates of the contemporaneous matrix B_0 evolve as more data accumulates, which alters the own-variable effect of the various shocks. One can see the impact of this evolution in the contemporaneous behaviour of interest rates: for the full sample the structural interest rate shock has an impact effect of roughly 28 basis points, whereas the impact effect in earlier smaller samples was as much as 66 basis points, and was above 50 basis points for a considerable period of time. It thus appears that recent unpredictable innovations to short-term interest rates have moderated in size. This decline in volatility is consistent with the Policy Targets Agreements since 1999, which have required the Reserve Bank to seek to avoid unnecessary instability in output, interest rates and the exchange rate, whilst maintaining the overall price stability objective.

In summary, in the recursive estimation of IRFs there is some attenuation in the response of real GDP and short term interest rates to interest rate shocks. However, the response of the exchange rate appears to have been fairly stable over the latter half of our sample period, and the trough in inflation from a positive interest rate shocks becomes deeper as more recent data is accumulated, which appears to be largely driven by the impact of the exchange rate on CPI inflation. With respect to the RBNZ's broad price stability objective, these results suggest monetary policy does not appear to have any diminished capacity. However, given the impact on interest rates on output is estimated to have slightly moderated in recent periods, and that the increased impact of rates on CPI inflation appears mainly to be coming from direct price effects rather than via affecting non-tradables inflation, the results may also be seen as symptomatic of the imbalances problem New Zealand has faced in recent years.

Figure 9
Impulse response of R90D to R90D shock



4.3 The mechanism through the lens of an estimated small semi-structural model

In this section we use a small semi-structural model to analyse how the transmission mechanism may have changed over time. In particular, a small open economy macro model firmly-rooted in the New-Keynesian tradition is estimated. The main advantage of this approach over the model used above is that, though the parameters cannot be considered fully structural, they still have familiar interpretations given the widespread use of this class of models. This approach allows us to tell a richer – though, by no means complete – 'story' of why the mechanism may have changed.

Though the equations that describe our model are commonly derived from models of optimising household and firm behaviour, and preserve some theoretical restrictions, they have been modified to improve the in-sample fit of the model. This is the main reason why our approach is best described as being semi-structural. The modifications generally involve the inclusion of extra lags of dependent variables in the regressions, which can be hard to motivate from first principles. Also, we occasionally include additional regressors which have been found to be useful in explaining the dynamic behaviour of the dependent variables.[12]

The model

The Reserve Bank's fundamental view of the inflationary process can be represented by a Phillips curve – inflation arises when aggregate output increases beyond the economy's supply capacities. A basic specification of the Phillips

[12] Consider the example of the New-Keynesian Phillips curve. Authors have derived this inflation equation in a variety of economic settings and under different assumptions on the process by which producers update prices. A common element of these equations is that inflation in period t is specified to be a function of inflation in period $t-1$ and expected inflation in period $t+1$, a real marginal costs term, and a change in the exchange rate (in the case of an open economy). Theory suggests that expected inflation plays a crucial role in determining current inflation. Theory also implies restrictions on the coefficients of the backward and forward looking terms in the curve, often restricting them to sum to one. Finally, it is hard to theoretically motivate the inclusion of additional lags and leads of inflation into the equation. Empirical tests of the Phillips curve, however, typically find a relatively low coefficients on model-consistent expected inflation, and more generally, that additional lags are required to improve fit to the data.

curve regresses inflation on its own lag and on lags of a measure of the output gap. However, expectations of future inflation are also thought to play a crucial role in determining current inflation. Further, as seen in the blue areas of figure 1, exchange rate fluctuations also directly and indirectly influence inflation. Finally, prices for oil and other commodities and trading partner inflation are also likely to be additional important explanatory variables for CPI inflation in New Zealand, especially over recent years.

We estimate the following Phillips curve:

$$\pi_t = \rho_t^{\pi}\pi_{t-1} + (1-\rho_t^{\pi})\mathrm{E}_t\pi_{t+1} + \alpha_t^{x}x_{t-1} + \alpha_t^{q}\Delta q_{t-1} + \alpha_{\pi t}^{f}\pi_{t-1}^{f} + \alpha_t^{\mathrm{oil}}\Delta p_{t-1}^{\mathrm{oil}} + \alpha_t^{\mathrm{com}}\Delta p_{t-1}^{\mathrm{com}} + \epsilon_t^{\pi} \tag{1}$$

where π_t is an inflation gap, defined as the percentage deviation of the annual growth rate in the CPI from the inflation target, x_t denotes the output gap, Δq_t is the period change in the log effective nominal exchange rate, π_t^f is the average annual inflation rate of major trading partners, and $\Delta p_{t-1}^{\mathrm{oil}}$ and $\Delta p_{t-1}^{\mathrm{com}}$ are changes in domestic currency price of (Dubai) oil and in the (ANZ) commodity price index respectively. We assume that expectations are rational and impose the common restriction that the coefficients on the backward and forward looking inflation terms sum to one.

In the summary of the transmission mechanism in section 1, we noted that higher interest and exchange rates help dampen consumption and investment and net exports, and so output. The next equation of the model is an IS curve, which describes the relationship between real interest rates, the real exchange rate and output as:

$$x_t = \rho_t^{x(1)}x_{t-1} + \rho_t^{x(2)}x_{t-2} + \beta_t^{i(1)}(i_{t-1}-\pi_{t-1}) + \beta_t^{i(2)}(i_{t-2}-\pi_{t-2}) + \beta_t^{q(0)}\Delta q_t + \beta_t^{q(1)}\Delta q_{t-1} + \varepsilon_t^{y} \tag{2}$$

where i_t is the monetary policy instrument measured as the nominal 90-day interest rate and q_t is the real exchange rate.[13] The specific lag structures

[13] The real exchange rate enters the IS curve in change terms, i.e. regardless of the initial level of the TWI it is posited that an appreciation reduces economic activity and vice-versa. In FPS and earlier IS curve estimation work (Dennis 1996) the exchange rate influences activity as a gap variable, reflecting the view that as long as the exchange rate is above (below) some 'equilibrium' level it will depress (boost) activity. We initially experimented with gap and change terms but dropped the gap effects owing to their lack of significance and robustness.

we use are motivated by the fact that there is strong empirical evidence to suggest that changes in real interest and exchange rates influence output only with some delay.

New-Keynesian models usually specify the evolution of exchange rates to be dependent on interest rate differentials between the domestic and foreign economy. In response to a positive differential, the exchange rate immediately appreciates to a level from which the expected depreciation over the lifetime of the differential ensures that an investor is indifferent between holding domestic- or foreign-currency denominated assets. This relationship is known as uncovered interest parity (UIP). As noted in section 1, the empirical support for UIP is very weak, and consequently we include commodity prices and cyclical output differentials as additional determinants of the exchange rate. Despite these additions, the in-sample fit of the exchange rate equation is significantly inferior to those of the other equations in the model, and confidence bands around the parameter estimates below are especially wide.

$$\mathrm{E}_t \Delta q_{t+1} = \gamma_t^i (i_t - i_t^f) + \gamma_t^y (y_t - y_t^f) + \gamma_t^{\mathrm{com}} \Delta p_t^{\mathrm{com}} + \epsilon_t^q \tag{3}$$

There have been six policy targets agreements between the Governor and the Minister of Finance since 1992, and in this time the (mid-point) of the inflation target has been changed from 1 percent to 1.5 percent to 2 percent. Since 1999, the Bank has been required to pursue its price stability objective while being formally obliged to avoid unnecessary instability in output, and in interest and exchange rates. In addition, as discussed in Section 2, the introduction of the OCR was associated with a large decline in the volatility of short-term interest rates. These factors suggest that the policy setting characteristics of the Reserve Bank – at least as represented by a monetary policy reaction function – has changed over time.

A monetary policy reaction function proposes that short-term interest rates are a function of one or two (or more) carefully selected variables. The most widely studied variety of reaction functions, the so-called Taylor rules, hold that the path of short-term interest rates can be adequately described by the deviation of inflation from its target (the inflation gap), and by the output gap.

Following previous RBNZ empirical work (e.g. Drew and Plantier (2000), RBNZ (2007b)) we consider a more general reaction function, where interest

rates are a function of the exchange rates in addition to the inflation and output gaps, and smoothing of interest rates over time is permitted:

$$i_t = \rho_t^i i_{t-1} + (1 - \rho_t^i)[\phi_t^\pi \pi_t + \phi_t^x x_t + \phi_t^q \Delta q_t] + \epsilon_t^i \tag{4}$$

Estimation Methodology

To capture the changing nature of the links in the transmission mechanism, we assume that the regression coefficients are random, or time-varying.[14] That is, we estimate the model equation-by-equation, each of which can be cast in the form:

$$\begin{aligned} y_t &= X_t \theta_t + \epsilon_t \\ \theta_t &= \theta_{t-1} + \nu_t \end{aligned} \tag{5}$$

where y_t is a vector of observations on the dependent variable, X_t is a matrix of explanatory variables (including lags of y), and θ_t is a time-varying parameter vector that is modeled as a random walk. The 'measurement error' ϵ_t and the noise term ν_t are zero-mean, uncorrelated, normally distributed stochastic processes where ϵ_t has variance σ_ϵ^2, and ν_t is associated with the diagonal covariance matrix H^{-1}.

This formulation makes clear that there is another sense in which the equations can be considered semi-structural. We use the Kalman filter to derive a likelihood for the state space representation (5). This is a linear filter, and the time-varying parameters are essentially treated as unknown latent variables. The great advantages of using the Kalman filter to estimate time-varying parameters, as opposed to the more commonly used methods of rolling regressions (as we have done above) and split samples, are that it results in smoother estimates of the timing of changes in the parameters, makes use of the full sample, and is less sensitive to individual observations that may or

[14] See (Sekine 2006) for a recent example of a study in a similar vein, but using a more detailed approach.

may not be included in the regression window.[15]

The first order optimality conditions that define an equilibrium in a fully structural model are typically non-linear and must first be (log-) linearised to allow the use of the Kalman filter. To do so in our case would destroy the proposed time-varying framework.[16] To summarise our approach, we place emphasis in achieving a good fit of the models to the data, and use single equation methods with time-varying parameters and the Kalman filter.

There is one additional limitation in the regressions that we consider. We assume that the innovations ν_t and ϵ_t follow time-invariant stochastic processes which are uncorrelated with each other and subject to the usual normality assumptions. It is entirely reasonable to put forth the hypothesis that the changing transmission mechanism is due not to changing macroeconomic elasticities (the θ_t) but due to changing distributions of shocks that buffet the economy over time. In this section we limit ourselves to identifying evidence of changing behaviour on the part of households or the central bank over time and so focus on the issue of coefficient drift. As noted above, it is likely that the shocks themselves have been different over time, and a more elaborate methodology than considered here should consider the issue of stochastic volatility.[17]

Long run effects. In assessing changes in the transmission mechanism, we are partly interested in determining the long run, cumulative, effect of a change in one variable on another, such as the long run inflationary effect of a given increase in output or the exchange rate, and partly in the timing of the accumulation of these effects. In the context of the state space representation above, we can partition the parameter vector $\theta_t = [\rho_t, \delta_t^1, ..., \delta_t^K]$ where ρ_t is the vector of coefficients on lags of y, and $\delta_t^1, ..., \delta_t^K$ are parameter vectors associated with contemporaneous and lagged values of each of the other K regressors. Then, the long-run effect of variable k on y is given by $\psi_t^{ky} = \sum \delta_t^k / (1 - \sum \rho_t)$.

[15] As noted in Sekine (2006), such a specification "captures both gradual and sudden changes in the state variables θ_t." The degree of smoothness over time in the parameters depends on the covariance matrix H^{-1}, where large variances imply sudden changes in the time-varying parameters, and small variances imply gradual changes. As the variances go to zero, the parameters become time invariant.

[16] As **?**) note, "structural models involve nonlinear cross-equation restrictions on the evolving parameters, and they require nonlinear filtering methods."

[17] See Sekine (2006) for an example.

Unless noted otherwise, all data are quarterly and the sample period used is from 1992 to 2007Q2, yielding 62 observations.

The Bayesian element: An advantage of the use of time-varying coefficients is that the system naturally lends itself to estimation by Bayesian methods because these methods treat parameters as being random. In the estimations below, we impose priors on the distributions of the variance of ν_t and ϵ_t . For the most part, these priors are distributed as relatively flat inverse-Gamma distributions. Posterior distributions are simulated from 100,000 parameter draws using the Metropolis-Hastings algorithm.[18] Given that the variances $\sigma_\epsilon^2$and H are relatively uninformative in themselves, we focus on presenting the long run effects and impulse responses. The long run effects in the charts below represent the tenth, fiftieth and ninetieth percentiles of long run effects calculated after discarding the first 50,000 draws from the joint posterior.

Changes in individual equations

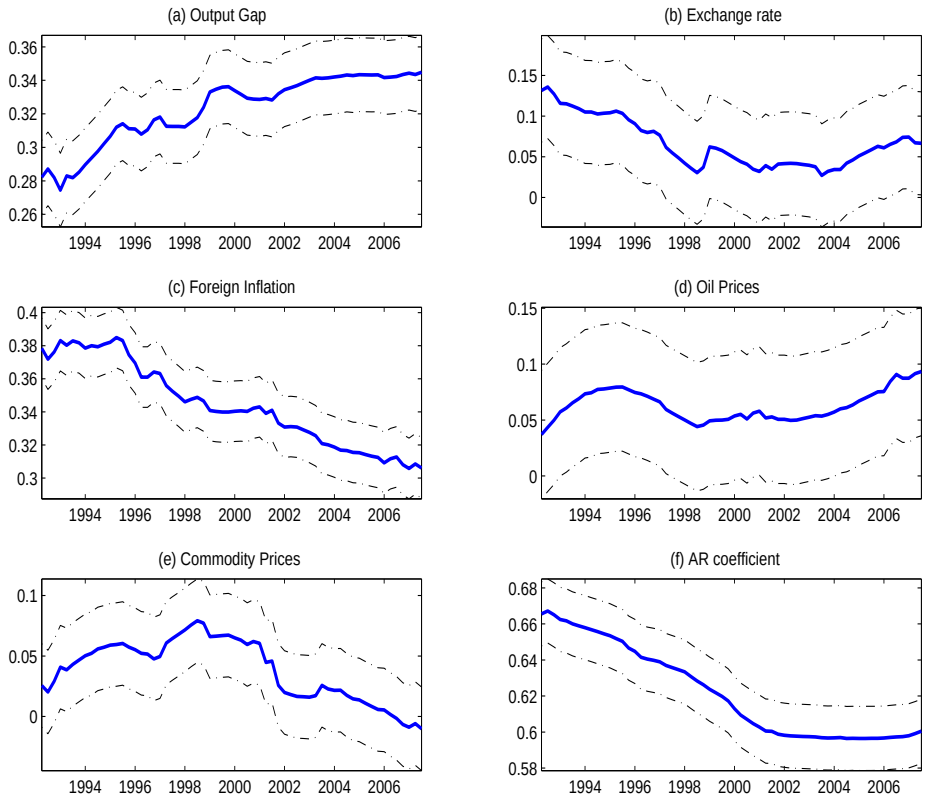
The Phillips curve

Figure 10 presents the long run impact on consumer price inflation of the explanatory variables in the regression. It appears that the relationship between excess demand and inflation became a little stronger over the 1990s, and has stabilized since 2002. Today, a one percent decrease in the output gap eventually leads to an decrease in inflation of around 35 basis points. The rise in this long-term effect is due to an increasing coefficient on the output gap in the Phillips curve, which has been tempered somewhat by the decline in inflation persistence.

The other major conclusion that we can draw from figure 10 is that inflation became increasingly forward looking over the sample period, with the autoregressive coefficient dropping from around 0.66 to 0.60. The decline in inflation persistence was steady over the 1990s, and has leveled off since 2001. Overall, these results are fairly consistent with the FPS re-calibrations reported above, and all else equal imply an increase in the effectiveness of monetary policy.

[18] The Markov chains are tested for convergence only by examining the within-chain variations.

Figure 10
The changing long run impact on consumer price inflation of (a) the output gap, (b) the exchange rate, (c) trading partner inflation, (d) oil prices, and (e) commodity prices. Panel (f) shows the coefficient on π_{t-1}.



Turning to the inflationary effects of changes in the exchange rate, the pass-through of the latter to consumer prices is estimated to be lower now than in the early 1990s, though not significantly so. The results suggest that a 10 percent depreciation in the exchange rate today eventually leads to a long-term increase in inflation of around 0.6 percent, compared with an increase of 1.2 percent in the early 1990s.

There has been no appreciable change in the pass-through of oil prices, except towards the end of the sample period when oil prices increased dramatically, possibly prompting non-linear pass-through effects. When we take this in combination with the fact that oil prices have roughly tripled in NZ dollar terms since 2003, and that petrol accounts for 5 percent of the CPI basket (around 12 percent for energy more broadly), it is clear that oil price developments have had a significant impact on CPI out-turns in recent years.

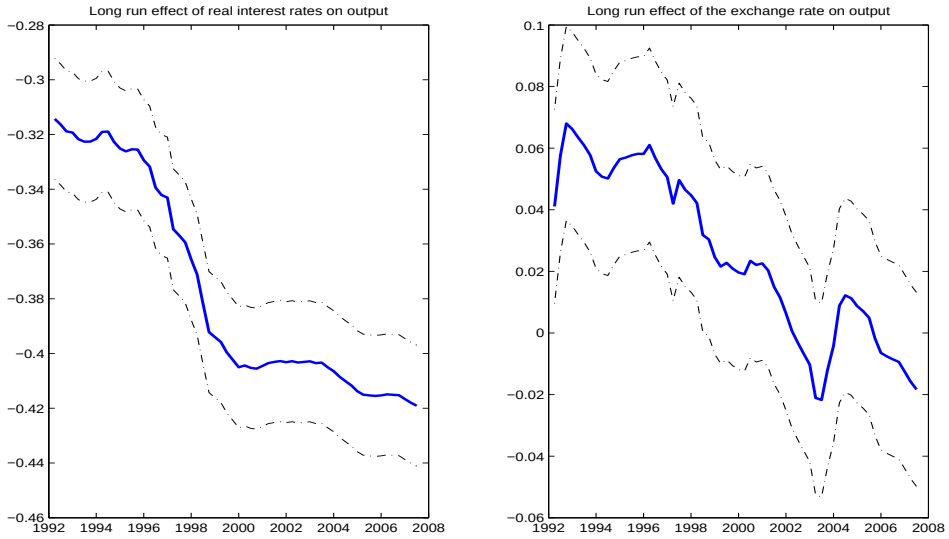
Panels (c) and (e) of the figure suggest that a given change in foreign inflation and commodity price developments (ex-oil) hold weaker consequences for domestic inflation than in the 1990s. Again, this is not to say, however, that commodity prices have been unimportant for inflation out-turns over recent times given the scale of the boom in hard commodities and selected agricultural products.

In summary, the most important developments in the Phillips curve over the past fifteen years appears to be the increasing importance of the forward-looking component in determining current inflation. The output gap has come to be a more important determinant of domestic inflation over time. To translate these observations into a well-known 'lesson' for monetary policy: though the increasingly dominant role of expectations means that policy can accomplish more with smaller changes to interest rates, it remains crucial to ensure that these expectations remain well-anchored.

The IS curve

Figure 11 shows that the restraining influence of real interest rates on the output gap became significantly larger over the 1990s (thereby corroborating evidence from FPS), and has stayed roughly constant-to-increasing since around the year 2000. The figure indicates that a one percent increase in the real interest rate reduces the output gap by around 40 basis points in the long-term. The real exchange rate impact on output is estimated to be much smaller, and as in the LLP results, of incorrect sign in the early 1990s.

Figure 11
The long run impact of real interest and exchange rates on the output gap.



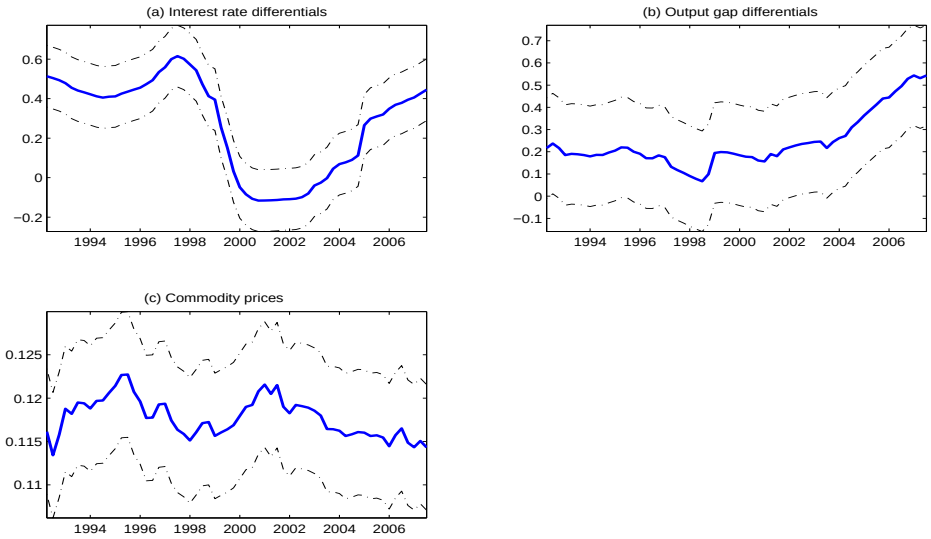
The exchange rate equation

It appears that relative interest rate differentials briefly had a lower impact on the exchange rate in the two years from 2000 – a period when the New Zealand dollar was widely considered to be undervalued. Since 2002, the link between interest and exchange rates has strengthened but is now no higher than it was over much of the 1990s. At the same time, relative output gap differentials have become a marginally more important influence on exchange rates over time.

The reaction function

The use of the formula for long-term effects given above is incorrect when considering the reaction function given that the interest rate in period t is

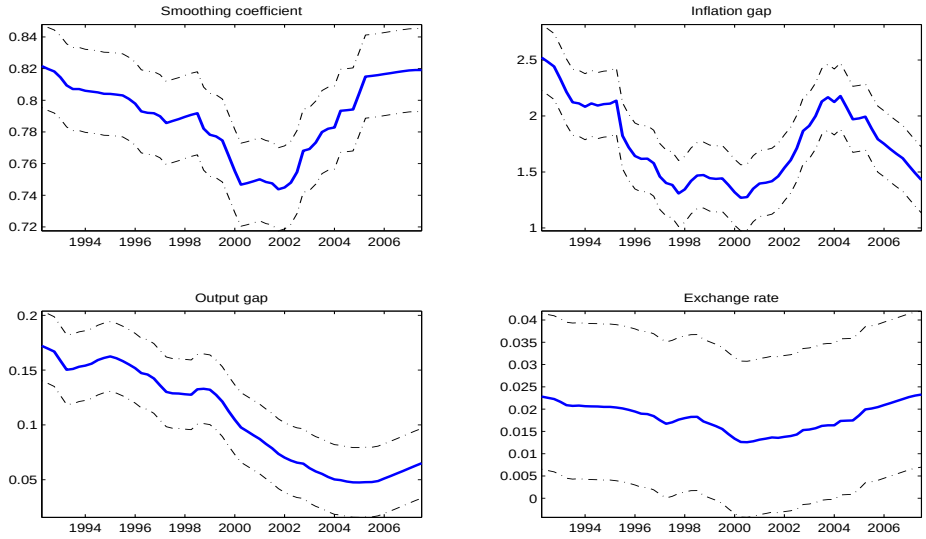
Figure 12
The exchange rate equation: time-varying coefficients of (a) relative interest rate differentials, (b) relative output gap differentials and (c) changing commodity prices



modeled as a weighted average of the interest rate in the previous period and the other regressors. Consequently, we focus solely on determining whether the smoothing coefficients and the weights placed on the inflation, output and exchange rate gaps have changed over time.

It appears that the Bank has placed increased emphasis on minimising interest rate volatility with a higher smoothing coefficient observed since 2001 (figure 13). Around the same time, the Bank also began to respond to deviations of inflation from target with greater vigor, but this has declined again since 2004. Interestingly, it seems that the output gap features less prominently in its decision setting rule now, while the exchange rate has always done so only marginally, thus confirming findings from other studies.

Figure 13
The Reserve Bank's changing reaction function



Small model estimates of changes in the transmission mechanism

To see the overall implications of the changes in the model's equations described above, in this section we present time-varying estimates of the impulse response functions arising from a monetary policy shock and a shock to the exchange rate. To facilitate comparison with simulation results from FPS and the LLPs, again the shocks are standardised at 1 percent.

Figures 14-16 illustrate the impact of the monetary policy shocks. We see that the impact of interest rates on the output gap is significant across all time-periods and has the strongest impact at the end of the sample period, both in terms of the initial impact on output and the persistence with which the interest rate increase depresses output. However, there is very mild indication of a weakening in the impacts around the 50th to 60th quarter from the start of the full sample period, corresponding to 2002q2-2004q4.

In line with the gap impacts, the impact of the policy tightening on CPI inflation is at its strongest in the very latest samples, again inconsistent with the conjecture that the monetary policy transmission mechanism has weakened in recent years and in line with both the FPS re-calibrations and the LLP results. That said, the impact of the policy shock on CPI inflation is initially relatively weak around the 50th to 65th quarter (i.e. 2002q2 to 2005q3) lending support to the (RBNZ 2007b) view that the policy transmission lags probably lengthened in the period as a consequence of the relatively slow pass-through of OCR changes to longer-term mortgage rates.

The initial impact of the policy tightening on the exchange rate generally declines through time and becomes noticeably less persistent up to around 2002q2 (corresponding to the the 50th quarter). Since that point, the estimated impact of interest rates on the exchange rate has increased, although remains below the impacts estimated in the early 1990s. These results are in line with the recent re-calibrations of FPS and support the view that the impact of policy on the exchange rate has strengthened in recent years, although as discussed above our ability to explain the exchange rate is considerably inferior to the other variables in the model.

Figure 14
The response of the output gap to a 1 percent monetary policy shock.

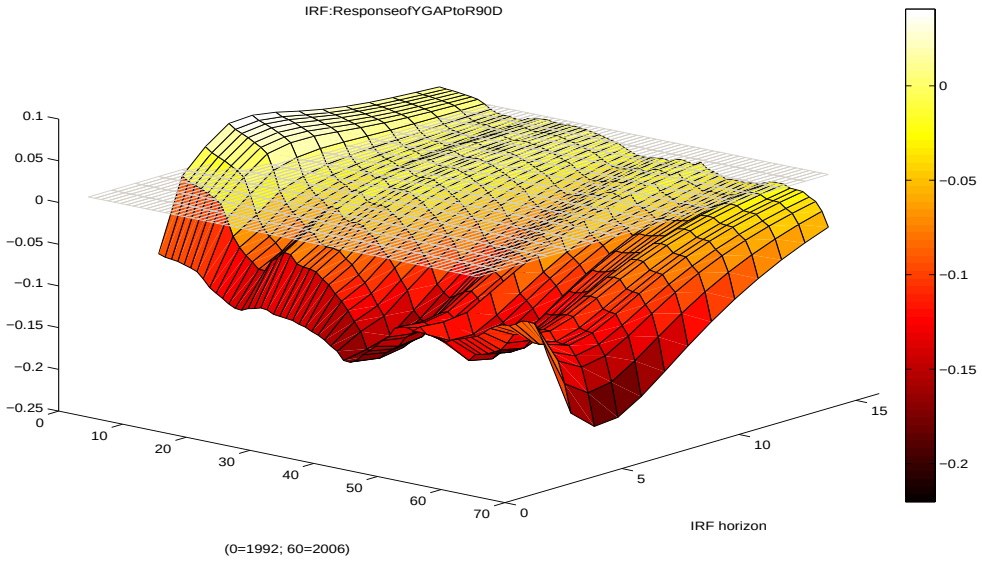


Figure 15
The response of CPI inflation to a 1 percent monetary policy shock.

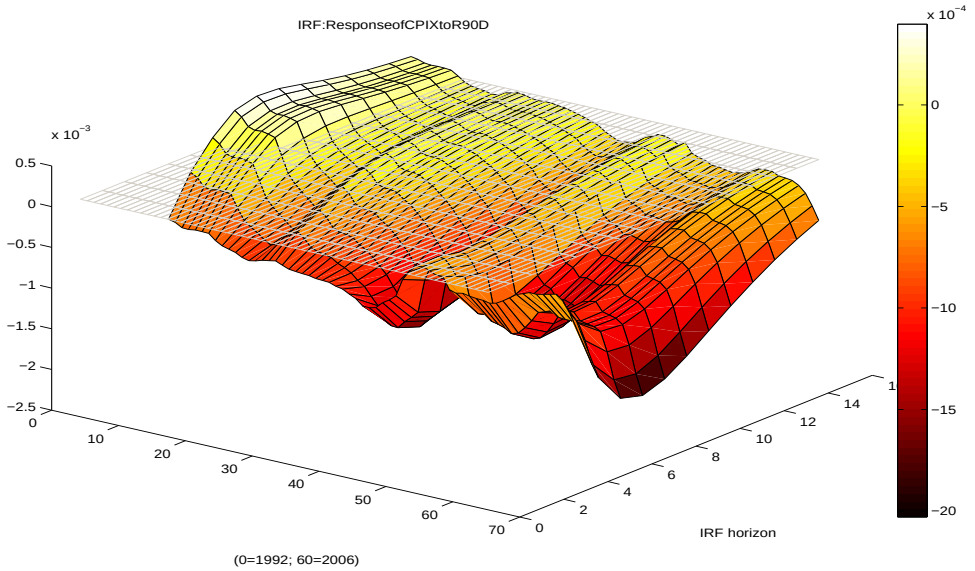


Figure 16
The response of the exchange rate to a 1 percent monetary policy shock.

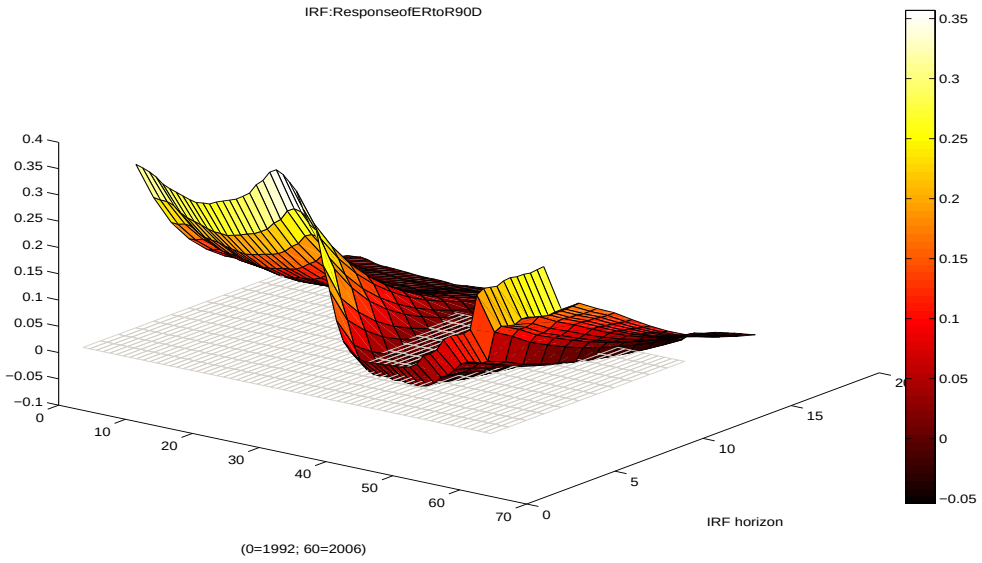
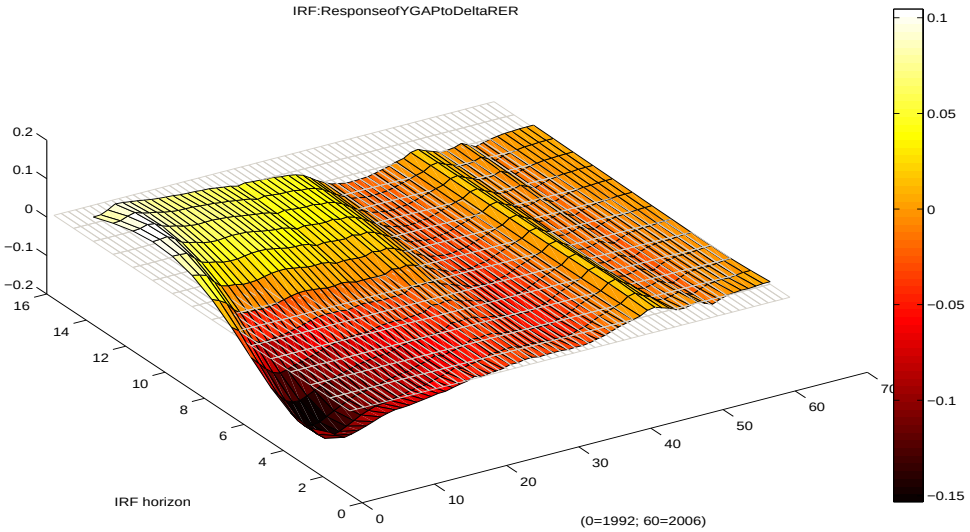


Figure 17
The response of output to a 1 percent appreciation of the exchange rate.



Figures 17-18 illustrate the impact of the exchange rate on output and inflation respectively. We see that pass-through has tended to decline over the period, although it is estimated to have mildly increased in the very latest samples. With regards the impact of the exchange rate on real activity, the model suggests an increasing impact on output. That said, in earlier samples, as in the LLP results, the impacts of the wrong sign and impacts are pretty small at all horizons with output contracting at most around 0.15 percent following the appreciation. Overall, across all models used, the indirect impact of the exchange rate on activity is estimated to be very weak.

Figure 18
The response of CPI inflation to a 1 percent appreciation of the exchange rate.

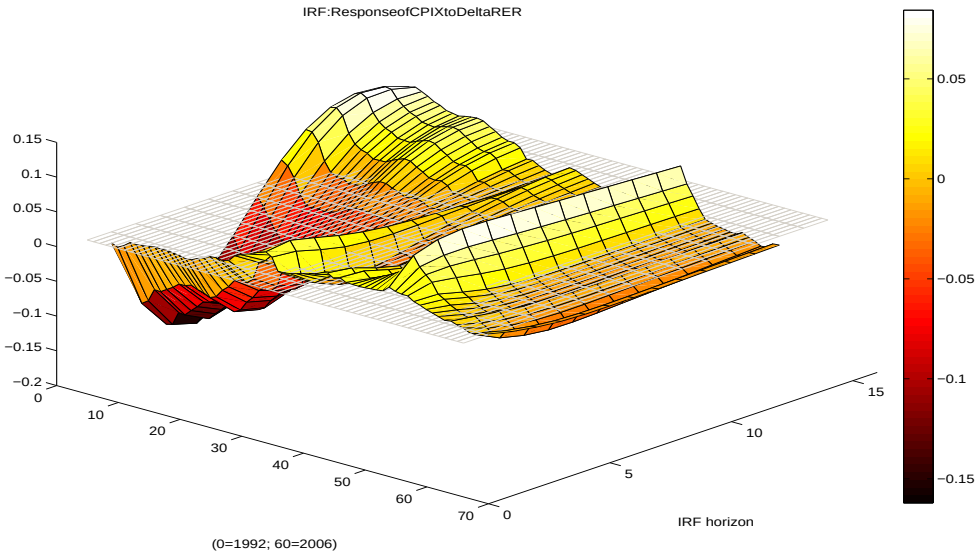
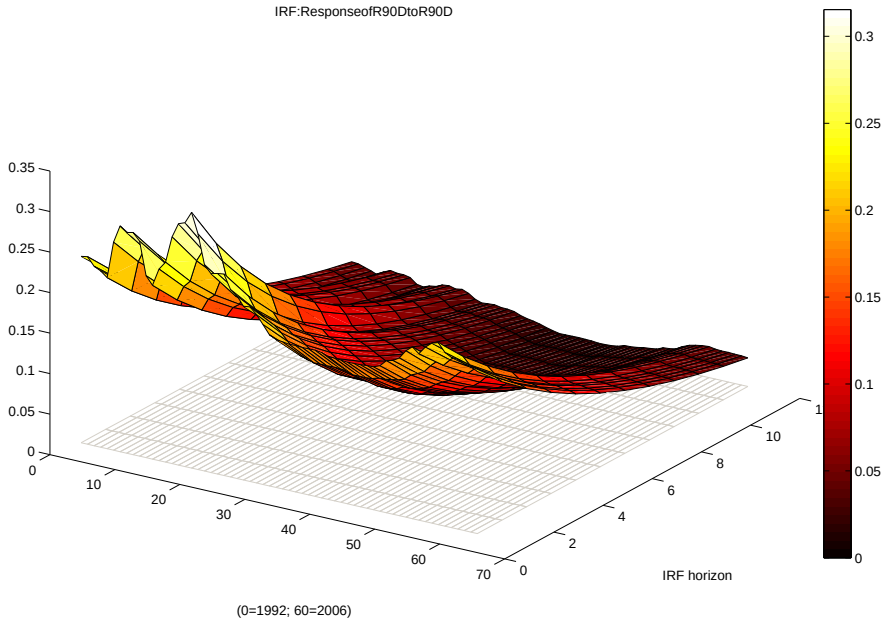


Figure 19
Impulse response of R90D to R90D shock



In the SVAR results it was founds that monetary policy shocks have tended to decline over time, a finding not inconsistent with the re-calibrations of the FPS policy reaction function which have placed a higher weight on interest rate smoothing. In Figure 19 we show the effect of an interest rate shock on interest rates when the shocks are 1 unit structural impulse. In line with the LLP results, we find an attenuation in monetary policy shocks over time, although the attenuation is smaller in this model.

5 Summary and conclusions

Concern has been raised over the effectiveness of monetary policy in the recent business cycle. In this paper we used three macro models of differing scale and design to test this concern and to estimate changes in the transmission mechanism more broadly. Although there are differences between the models regarding the timing and magnitude of the peak impact of policy on output and inflation and how the exchange rate affects the economy, a common element is that the overall impact of policy on inflation is estimated to be as strong as ever. In addition, recent RBNZ events analysis work finds that policy has a strong impact on longer-term wholesale rates and the exchange rate, while most of the literature examining the impact of policy on other interest rates over longer historical time frames finds that since the late 1990s this part of the transmission mechanism has strengthened. Overall, we conclude that the monetary policy transmission mechanism today is at least as strong as the mechanism over the 1990s.

So, if the mechanism remains effective what accounts for the intense inflation pressures New Zealand has faced over the past 5 years of so? Two points may be made in this regard. First, there is no doubt New Zealand has faced a sequence of very large positive 'shocks', notably the rapid turn-around in net migration flows over 2001 - 2004 and a housing and commodity price boom of a scale not seen since the early 1970s. Maintaining inflation, on average, at under 3 percent in this environment is, of course, in stark contrast to the 1970s experience. The inflation outcomes achieved points to the efficacy of the monetary policy framework and the reforms in the late 1980s and early 1990s that have enhanced the general flexibility of labour and product markets. That said, as discussed in RBNZ (2007b), there may be a case for further policy reforms, particularly in the housing market area.

Second, as discussed in (RBNZ 2007b), with the benefit of hindsight monetary policy settings in New Zealand (and in many cases internationally) were too loose for too long in the early part of this decade. Since early 2004 policy has been tightening, off and on, in 25 basis points steps. Our work on the RBNZ's reaction function suggests that this policy approach is less aggressive (i.e. involves a higher degree of interest rate smoothing) than earlier approaches to running monetary policy at the RBNZ. Again with the benefit of hindsight, we speculate that a more aggressive approach of 'shocking' the markets with larger policy changes, once the persistence of the inflationary

problem was realised, may have dampened the inflationary problem earlier. An interesting avenue for future research would be to examine the optimal policy responses to the sort of large shocks New Zealand has seen over this decade.

A large part of the public angst raised over New Zealand's macroeconomic performance and the conduct of monetary policy this decade is related to the massive appreciation in the exchange rate over the period and the pressure this has placed on the exporting sector. Our empirical work suggests that monetary policy has an influence on the exchange rate, but this influence has not become any stronger over the recent business cycle than what has been seen at times in the 1990s. In addition, the empirical analysis suggests that the impact of the exchange rate on real activity is fairly small, or in other terms, it takes quite large exchange rate changes to see a noticeable impact on aggregate output. Indeed, the RBNZ and other economic forecasters have generally been surprised by the resilience of the exporting sector to the rapid currency appreciation. It thus appears that firms engaged in exporting in New Zealand are better placed to manage swings in the exchange rate today than previously. Research currently underway at the RBNZ and Motu using firm-level data aims to identify how successful firms manage exchange rate risk, amongst other factors.

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Annex 1 Deriving impulse responses using local linear projections

Usually impulse response functions (IRFs) are computed using vector autoregressions (VARs). Conventionally, IRFs are obtained by transforming VARs into vector moving average representations, appealing to Wold's decomposition. However, VARs are subject to a number of problems that may bias estimates of impulse responses. A prime issue is whether sufficient lags have been included in the VAR to fully characterise the process. (Kapetanios, Pagan, and Scott 2005) illustrate an extreme scenario where a VAR with 50 lags is required to estimate some of the IRFs from a structural model. Omitting variables from a VAR has similar consequences to omitting lags, since when variables are omitted the included variables will follow a VARMA process (Wallis 1977 and Zellner and Palm 1974). A large number of lags may then be needed to capture the moving average properties of the process.

The problem of bias is compounded in VAR analysis because impulse responses are nonlinear functions of the underlying parameters. The nonlinearity is readily apparent in a VAR(1):

$$y_t = F y_{t-1} + e_t \tag{6}$$

where y_t is an $n \times 1$ vector at time t, F is an $n \times n$ matrix of parameters, and e_t is an $n \times 1$ vector of (possibly correlated) shocks. For convenience, constants have been suppressed. By iterating on this function we see that

$$y_{t+s} = F^{s+1} y_{t-1} + e_{t+s} + F^1 e_{t+s-1}, \ldots, F^s e_t \tag{7}$$

Conventionally, $F^s e_t$ is the effect of the shock e_t on y_{t+s}. This IRF is thus a nonlinear function of F, and the nonlinearity may compound any bias in the estimates for longer-step impulse responses.

Local linear impulse responses

As in Jordà (2005), define the impulse response at time $t+s$ arising from the experimental shock d_i at time t as:

$$IR(t, s, d_i) = \frac{\partial y_{t+s}}{\partial \delta_t} = E(y_{t+s} | \delta_t = d_i; X_t) - E(y_{t+s} | \delta_t = \mathbf{0}; X_t), \tag{8}$$

where $i = 0, 1, 2, \ldots, n$; $s = 0, 1, 2, \ldots$; $X_t \equiv (y_{t-1}, y_{t-2}, \ldots)'$; d_i is a vector additively conformable to y_t; and $\mathbf{0}$ is a vector of zeroes. The expectations are formed by projecting y_{t+s} on to the linear space of X_t (i.e., from local linear projections):

$$y_{t+s} = \alpha^s + B_1^{s+1} y_{t-1} + B_2^{s+1} y_{t-2} + \cdots + B_p^{s+1} y_{t-p} + e_{t+s}^s, \tag{9}$$

where α^s is a vector of constants and the B_j^{s+1} are coefficient matrices at lag j and horizon $s+1$. For every $s = 0, 1, 2, \ldots, S$ a projection is carried out. The estimated IRF is then given by

$$\widehat{IR}(t, s, d_i) = \hat{B}_1^s d_i \tag{10}$$

with the normalization $B_1^0 = I$ (where I is an identity matrix of an appropriate dimension). For example, d_i can be thought of as an innovation to the vector y_t, yielding an impulse response of $\hat{B}_1^s$. The horizon of the forecast is thus s, indicating how $E(y_{t+s}|\delta_t; X_t)$ changes in response to a shock at time t.

The impulse responses from local approximations can be implemented by using univariate least squares regressions for each variable at every horizon, and standard errors can be calculated using standard heteroscedastic and autocorrelation (HAC) robust standard errors, such as Newey-West standard errors (to account for moving average errors at different horizons). As noted in (Haug and Smith 2007), (Weiss 1991) establishes consistency and asymptotic normality of direct forecasts and (Jordà 2005) demonstrates that impulse response estimates from local projections are consistent.[19]

At a one-step forecast horizon, VAR and LLP impulse responses coincide (since for a 1-step horizon both the VAR and LLP methods project y_t on y_{t-1}). If contemporaneous restrictions are applied, then both VARs and local linear projection methods are identified in a similar manner. Consider a structural vector autoregression of the following form:

$$B_0 y_t = \alpha + B_1 y_{t-1} + \ldots + B_p y_{t-p} + u_t \tag{11}$$

where y_t is an $n \times 1$ vector of macroeconomic variables at time t, α is an $n \times 1$ vector of constants; B_j is an $n \times n$ matrix of parameters for $j = 0, 1, \ldots, p$, and u_t is an $n \times 1$ vector of structural shocks with a variance-covariance matrix that is an $n \times n$ identity, ie $E_t(u_t u_t') = I_n$, where E_t is the expectation formed at time t. Suppose also that $u_t \sim \mathrm{N}(0, I_n)$.

A reduced form innovation e_t to y_t is then $e_t = B_0^{-1} u_t$, where B_0^{-1} determines the contemporaneous responses of y_t to u_t. The matrix B_0 is identified by noting that $E_t[B_0^{-1} u_t u_t' (B_0^{-1})'] = E_t[B_0 B_0'] = E_t[\Omega]$, where Ω is the variance-covariance matrix of e_t. As is well-known, since Ω is symmetric, there can

[19] Local linear projections are part of the class of direct forecasts. Some authors refer to direct forecasting as dynamic estimation, adaptive forecasting or multi-step forecasting.

only be $n(n+1)/2$ free parameters in B_0, and so at least $(n^2-n)/2$ restrictions must be applied to identify the parameters of B_0. These parameters can be estimated by (approximately) maximising the log-likelihood of the VAR. See (Hamilton 1994) for details. Since the variance-covariance matrix of the structural shocks is an identity matrix, the diagonal values of B_0 are unrestricted. (An alternative would be to restrict the diagonal of B_0 to be a vector of ones, with the diagonal of structural errors being freely estimated. For computational reasons our approach is more straightforward.)

Table 3
Identification scheme for contemporaneous relations: B_0

Shock coefficient for	Variable that is shocked in period t						
reaction in period t:	GDP	CPI	R90D	RER	wGDP	wCPI	wR90D
GDP	b_{11}	0	0	0	0	0	0
CPI	b_{21}	b_{22}	0	0	0	0	0
R90D	b_{31}	b_{32}	b_{33}	0	0	0	b_{37}
RER	b_{41}	b_{42}	b_{43}	b_{44}	b_{45}	b_{46}	b_{47}
wGDP	0	0	0	0	b_{55}	0	0
wCPI	0	0	0	0	b_{65}	b_{66}	0
wR90D	0	0	0	0	b_{75}	b_{76}	b_{77}

Note: The inner cells of the table form the matrix B_0 with elements b_{ij} and $i, j = 1, \ldots, 7$. The vector u_t of structural shocks relates to the reduced form shocks e_t^0 as follows: $u_t = B_0 e_t^0$.