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2024
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Jinabhai, Nikhil. (2024). House Prices Against the Wind: Analysis of the use of Monetary Policy to Moderate [Master`s dissertation, University of the Witwatersrand, Johannesburg]. WIReDSpace.

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Title: House Prices Against the Wind: Analysis of the use of Monetary Policy to Moderate House Price Bubbles and the Case of New Zealand

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08 November 2024

CCA11 - 50% weighting of research report component

Acknowledgement

I would like to express my gratitude to my supervisor, Dr Kenneth Creamer for his invaluable guidance and patience.

To my family for their unwavering support.

And to Deon, Dhirta, Latisha, and Justin for all their help.

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1. Introduction

The role of the central bank has been traditionally limited to managing inflation as a means to maintain price stability and achieve the maximum sustainable level of employment. However, when threats to price stability arise on longer time horizons or the welfare of the state is in peril, such as during housing price bubbles; central banks must react. This reasoning gained prominence following the events preceding the 2008 Global Financial Crisis, which arose from a significant housing price bubble collapse in 2007. Thus, house prices and other asset prices serve as a critical source of macroeconomic volatility that a central bank may need to account for, in executing their mandate to maintain an inflation target. Furthermore, in modern, financialised economies, house prices act as an effective transmitter of shocks through the economy as they respond rapidly to new information, elevating the risk of an economy-wide crisis.

Therefore, against the backdrop of consistently rising house prices, with a history of speculative bubbles that has accelerated markedly during the COVID-19 pandemic in 2020, New Zeeland's Minister of Finance, Grant Robertson, instructed the Reserve Bank of New Zealand (RBNZ) to consider housing prices in setting monetary policy (RBNZ, 2021a).

New Zealand's government has opted for a policy of "Leaning Against the Wind", instructing their central bank, the RBNZ, to respond proactively to the house price bubble (Smets, 2018). "Leaning Against the Wind", using monetary policy to manage asset price bubbles, was brought into the mainstream by Ben Bernanke, Chairman of the Federal Reserve of the United States of America (USA). He discussed the complexities of setting the policy rate higher than is expected to maintain the inflation target and maximum employment in an attempt to moderate asset price bubbles. Bernanke points to the housing price bubble he identified in the early 2000s. Such measures are required when macroprudential policies alone are insufficient to ameliorate threats to financial stability. In the case of New Zealand, the house price bubble has escalated to a level that not only risks financial stability but has also caused the unaffordability of housing to result in a growing social crisis (Samarasinghe, 2020).

Therefore, as of March 2021, the RBNZ has begun to consider using monetary policy (the interest rate) to influence the demand for housing. The majority of houses purchased in New

Zealand are purchased by citizens of the country relying on mortgages even when the house purchased is a second or third property (Brockett, 2021). As a result, increasing the interest rate through contractionary monetary policy is expected to reduce the availability of debt thus, reducing the speculative demand for housing.

At the time of the announcement, New Zealand was pursuing an expansionary monetary policy with the interest rate set low at 0.25% since the onset of the COVID-19 pandemic in early 2020. Having decreased from 1.75% at the beginning of 2019. Notably, the RBNZ has had to hold interest rates at this low level through 2021 to expedite the economic recovery from the pandemic (Menon, 2021). Moreover, macroprudential policies in place to manage house price growth were also temporarily paused to aid the economy during this period (RBNZ, 2020b).

The consideration of house prices could be considered a departure from the RBNZ's historic monetary policy position which only required the inflation target of between 1% and 3% to be maintained. Even still, achieving the inflation target to sustain price stability is contextualised as a tool to promote public welfare and reduce cyclical variation (RBNZ, 2019). In the 2021 Remit for the Monetary Policy Committee, the RBNZ was instructed to "support more sustainable house prices" in addition to achieving the previous inflation target. The Remit also adds that dampening investor demand for houses is a likely solution to improve housing affordability (RBNZ, 2021b). The expansion of the central bank's mandate is still in line with the ultimate goal of New Zealand's monetary policy, i.e., that of improving the well-being and prosperity of all its citizens.

Furthermore, a housing bubble indeed jeopardises the welfare of the people of New Zealand. In addition to the potential financial crisis when the bubble bursts and its destabilising effects spilling over into other sectors of the economy, the growing unaffordability of housing has a high social cost. The country has been experiencing a large-scale homelessness crisis since the early 1990s, which escalated during the 2020 pandemic. As with most housing crises, it cannot be fully explained by supply shortages instead, steadily increasing returns from house prices inflated by speculation are the root cause identified by most analysts (Paul, et al., 2020). Housing unaffordability during the pandemic is most evident when considering New Zealand's house price to income ratio, which stabilised at approximately 110, following the 2008 Global

Financial Crisis but increased five percentage points to 115 in the third quarter of 2020 (up from 110 in the 2019 quarter three).

Nonetheless, managing the housing bubble by using monetary policy and the policy rate has been a topic of discussion since the late 1990s and most notably, immediately prior to the 2008 Global Financial Crisis. Yet, empirical research conducted into the housing price bubble in New Zealand has been scarce. This is especially important in light of the RBNZ being instructed to consider the country's increasing house prices in their monetary policy decision-making. Moreover, the developments of the recent COVID-19 pandemic and the resulting unprecedented increase in house prices, which likely prompted the directive from the government, have also not been sufficiently studied.

This research will consider the effectiveness of using monetary policy to moderate a house price bubble within the context of New Zealand's housing bubble. Specifically, the study will focus on the reaction of house prices, measured through the House Price Index (HPI) to interest rates, the primary monetary policy tool of the RBNZ. This relationship is moderated through housing debt, used to fund the purchase of housing.

2. Literature Review

There has been some literature, regarding the topic of central banks using monetary policy to moderate asset price bubbles, developed to date. While the expanded role of the central bank has been considered throughout its history, Ben Bernanke codified the expansion of the central bank's priorities. Scandinavian countries, most prominently Sweden and their Riksbank (the central bank of Sweden), were likely the first central banks to apply monetary policy to housing market bubbles in the early 1990s as they recovered from a financial crisis. Thereafter, the literature is expanded upon, in the context of a post-2008 Global Financial Crisis global economy. The 2008 Global Financial Crisis highlighted the role of house prices in financial stability and as a transmission mechanism for economic shocks.

The debate surrounding whether a central bank should consider more than just their inflation target and the maximum sustainable level of employment continues to the present. In January 2021, Jerome Powel reiterated the relationship and potential spillover effects of raising interest rates; thus, tightening monetary policy results in a costly trade-off where output or the Gross Domestic Product (GDP) is reduced to address asset bubbles. Powel questions, “Will it actually cause more damage, or will it help?” (Powell, 2021).

2.1 Inflation Targeting

Inflation targeting is a monetary policy framework that serves as the nominal anchor for a country. Central banks that are pursuing inflation targeting, apply monetary policy (interest rates) to steer price increases towards an inflation target set and publicised by the countries financial authorities. Because interest rates and inflation rates tend to have a robust negative relationship (increasing interest rates generally decreases inflation), the actions of a central bank become more transparent. A credible central bank will result in agents in the economy adjusting their inflation expectations towards the target, expediting the achievement of the inflation target (Jahan, 2012). As of 2017, 27 countries, including New Zealand, operated fully-fledged inflation-targeting regimes (Hammond, 2017).

A nominal anchor is necessary within monetary policy frameworks as policymakers are often adversely incentivised to pursue short-run objectives even though the outcome may be inferior

to that of long-run objectives, first described by (Kydland & Prescott, 1977) as the time inconsistency problem. Having a nominal anchor helps ensure the transparency and credibility of central banks so as to constrain discretionary policy (Mishkin, 1999). Thus, long-run objectives such as price stability are more likely to be achieved.

In the past, some central banks pursued a currency peg as a nominal anchor, linking their country's currency to the currency of a country with low inflation. While some success was achieved, currency pegs limited the country's ability to respond to shocks through monetary policy. In response to the loss of monetary policy freedom of currency pegs, central banks adopted flexible exchange rates with monetary targeting. Here, the growth of the money supply was targeted. While initially successful at stabilising inflation, innovation in financial markets resulted in unstable money demand, weakening the connection between money supply and inflation (Mishkin, 1999). As such, countries with flexible exchange rates began targeting inflation directly based on the transmission mechanism between the central bank's policy instruments (the interest rate) and inflation.

In an inflation-targeting framework, the central bank pursues an inflation target. The central bank forecasts the expected future path of inflation, then compares it to the target with the difference determining how much monetary policy needs to be adjusted. The interest rate serves as the primary monetary policy tool a central bank has available to adjust inflation (Jahan, 2012). Thus, if forecasted inflation is higher than the inflation target, the interest rate is increased to reduce inflation towards the target, and the reverse is also true.

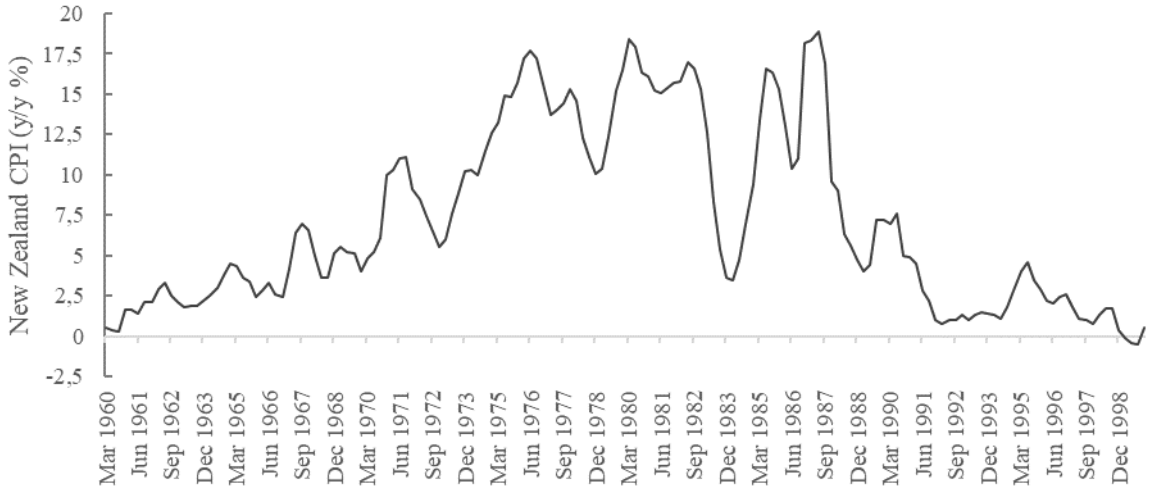
Inflation targeting allows for an algorithmic approach to price stabilisation. This aids the transparency of the central bank as all interest rate decisions can be directly tied to the pursuit of the inflation target. Therefore, policymakers have less capacity to pursue short-run objectives at the expense of long-term price stability.

Inflation targeting has proven successful in New Zealand. During the 1970s and 1980s, New Zealand's price stability was particularly low, with Consumer Price Index (CPI) inflation fluctuating between 10%-15%, significantly higher than that of its primary trading partners. The period was generally characterised by expansionary fiscal and monetary policy in New

Zealand. While there were periods of tight monetary policy, successive governments were unwilling to absorb the associated short-term costs to output and employment.

By the late 1980s, inflation targeting in New Zealand had been implemented as the political cost of price instability became more severe. New Zealand's first Policy Target Agreement (PTA) was signed in 1990 to rein in inflation and achieve price stability (defined as an inflation rate between 0% and 2%) (RBNZ, 2023a). This framework allowed the RBNZ to credibly commit to reducing inflation. The credibility that the inflation targeting framework provided was vital to its success, as it allowed inflation expectations to trend downwards (towards the target), with inflation following (McDermott & Williams, 2018). As evident in Figure 1, the switch to inflation targeting was successful at moderating inflation with significantly improved price stability in the 1990s. An inflation rate of approximately 2% year-on-year (y/y) was achieved from 1991 onwards, following the previous decades of high and volatile inflation.

Figure 1: New Zealand CPI, 1960 – 1998 (y/y %)



Source: RBNZ, 2023b

In 2021, New Zealand elected to expand the central bank's mandate from strict inflation targeting to include house prices. This has allowed them to leverage the success of the inflation-targeting framework to manage prices in specific sectors of the economy.

2.2 Prior to the Global Financial Crisis

Ben Bernanke was the first mainstream economist to consider the role of a central bank in a landscape where inflation had been largely domesticated, and the potential arose for a central bank's scope to widen and include financial stability. In his 1999 paper, *'Monetary Policy and Asset Price Volatility'*, he notes that the most economically painful crashes occurred when monetary policy either did not respond in-step to the rapidly changing economic environment or reinforced the deflationary pressures. While Bernanke is explicit in that monetary policy alone is insufficient to moderate an asset price bubble (specifically a house price bubble), monetary policy could form part of an approach to dealing with bubbles alongside macroprudential policies. Indeed, in his 2002 speech before the New York Chapter of the National Association for Business Economics, Bernanke remarked that central banks must "use the right tool for the job" (Bernanke, 2002).

A trade-off exists between monetary policy and output when approaching a potential financial crisis. Bernanke was acutely aware that tightening monetary policy (increasing the policy rate) to prevent a financial crisis might have a greater negative effect on output than the financial crisis itself. Thus, he cautions that monetary policy should only respond to the consequences of asset price fluctuations in the economy (chiefly, the potential future inflation) instead of the asset prices themselves (Kuttner, 2011). Therefore, Bernanke's work represents a moderate perspective, where monetary policy can be used as a tool to "burst" house price bubbles, given that it is deployed within a larger strategy alongside macroprudential policy. This is due to the potentially high cost to output of heightened interest rates.

2.3 Post-2008 Global Financial Crisis

Given the housing price bubble's role in igniting the 2008 Global Financial Crisis, it is understandable that there has been a focus on empirically dissecting the relationship between interest rates and house prices. In retrospect, many question whether the crisis could have been avoided by the United States Federal Reserve implementing policy rate hikes in the period preceding the housing bubble bursting. Numerous studies have emerged, examining the ramifications of using monetary policy to influence asset bubbles. Regardless, the trade-off between monetary policy and targeting speculative asset bubbles is ever present yet still

remains undefined. Indeed, the global economy may find itself in a similar situation as before the 2008 Global Financial Crisis, where inflation remains lethargic meanwhile, the financial risk continues to escalate (Fouejieu, et al., 2019). Similarly, more research needs to be undertaken to better understand how monetary policy could affect house prices and housing bubbles (Paul, 2020). Specifically, the relationship between the policy rate and house prices has been considered.

The theoretical basis for the interest rate's effect on house prices has been developed, with a focus on household and individual debt accumulation and demand for credit (Kuttner, 2011). Household debt was found to be somewhat sensitive to monetary policy with a one percentage point increase in the policy rate resulting in a 0.25% increase in debt servicing costs for households. The sensitivity of consumption to the policy rate increases disproportionately with the level of indebtedness as well as with additional mortgages to finance subsequent properties purchased (Flodén, et al., 2020).

This highlights that monetary policy would be most effective in attenuating housing price bubbles in environments where households carry high levels of debt, as well as where multiple properties are owned by the same household. The economies most sensitive to monetary policy will have households with small buffers of liquid assets and where access to further credit is limited. Under such a regime, monetary policy will have a more substantial impact on the real economy thus, acting as a more effective tool for managing speculative bubbles (Cloyne, et al., 2020). However, this also implies that the trade-off, against that of decreased output, will be more severe.

New Zealand displays many of the characteristics that would make monetary policy a powerful tool in their economy. First, household debt in the country has been increasing steeply since the 1990s, with a substantial increase in 2020 during the COVID-19 pandemic. The level of household debt is equivalent to 164% of household disposable income. Secondly, while the serviceability of household debt remains sufficient, it is primarily maintained by the low interest rates prevailing in New Zealand as well as loan-deferral schemes to alleviate the impact of the COVID-19 pandemic's lockdown and recovery (Cleland, 2020). New Zealand will need to tighten access to credit to be more effective in moderating house prices, as the economy generally relaxed restrictions on individual debt and credit extensions during the pandemic.

Even prior to the COVID-19 pandemic in 2020, speculation in the New Zealand property market was widespread. Already having the second most unaffordable housing market in the world, the demand for secondary properties has been high - as a long-term investment vehicle as well as short-term demand for speculation (Rehm & Yang, 2020). The speculative tradition carries into the current day, with house prices experiencing an almost 15% increase in 2020 from the prior year during the COVID-19 pandemic (RBNZ, 2021c).

2.4 Evolution of New Zealand's Housing Price Bubble

New Zealand's house prices reached their highest level during the COVID-19 pandemic. When tracked through the RBNZ's HPI with the year 2003 set to 1000, the index increased 15% from 3040 in December 2019 to 2630 in December 2020. The largest single-year increase in the past two decades. However, while this spike is the largest and most recent, New Zealand has historically had rapidly growing house prices, with the COVID-19 pandemic exacerbating a housing market that was already in the midst of a housing price bubble (Greenaway-McGrevy & Phillips, 2021).

Between the Global Financial Crisis in 2008 and the last quarter of 2019 (before the start of the COVID-19 pandemic in 2020), house prices increased by almost 75%, with the greatest growth in 2017 (RBNZ, 2021c). Greenaway-McGrevy and Phillips (2015) were some of the first economists to recognise this following the 2008 Global Financial Crisis bubble. Using autoregressive methods, they identified 2013 as the start of this bubble.

Moreover, real house prices more than doubled between 2000 and 2008, leading up to the 2008 Global Financial Crisis (RBNZ, 2021c). The housing market was found to have behaved as if it were experiencing a bubble in the years prior to the 2008 Global Financial Crisis (Greenaway-McGrevy & Phillips, 2015). Additionally, Dr Alan Bollard, Governor of the RBNZ from 2002 – 2012, highlighted that the expansionary monetary policy in the years before the 2008 Financial Crisis may have reinforced the growth of the house price bubble (Bollard & Delbruck, 2010). While beyond the period under review in this paper, New Zealand may have experienced housing price bubbles as far back as the 1970s and 1990s (Fraser, et al., 2008).

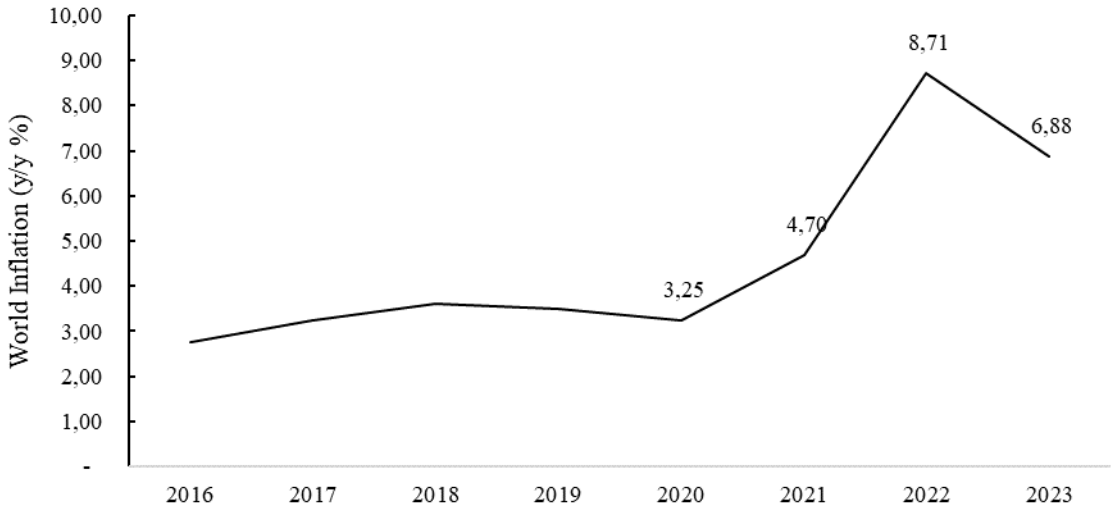
As such, the housing market of New Zealand has been steadily escalating since the early 2000s, with bubbles forming periodically as house prices peak, suggesting structural issues exist within the housing market. Macroprudential policies are generally the more appropriate avenue to moderate house price bubbles of this variety. However, the 15% increase in the first year of the COVID-19 pandemic, with a new peak compounding on a previous bubble, indicates that other methods, such as monetary policy, may need to be employed in conjunction.

2.5 New Zealand Contemporary Experience with House Price Targeting

Through the Monetary Policy Committee (MPC) Remit, on 1 March 2021, the RBNZ committed themselves to consider house prices in their monetary policy decision-making processes. The updated Remit reemphasises that monetary policy contributes to public welfare by reducing cyclical variations in employment and economic activity, whilst maintaining price stability over the medium term. It goes on to expand the operational objectives of the RBNZ to include supporting more "sustainable house prices by dampening investor demand for existing housing stock, which would improve affordability for first-home buyers" (RBNZ, 2021d).

Following the COVID-19 pandemic in 2020, exacerbated by global conflict-induced commodity price increases, inflation began to rise. Figure 2 shows world inflation moving from 3.25% in 2020 to 4.70% in 2021, peaking at 8.71% in 2022, followed by a slight reduction in 2023. In response to the inflationary pressure, central banks around the world began raising interest rates to return inflation to its targeted levels (IMF, 2022).

Figure 2: World inflation, 2016 – 2023 (y/y %)

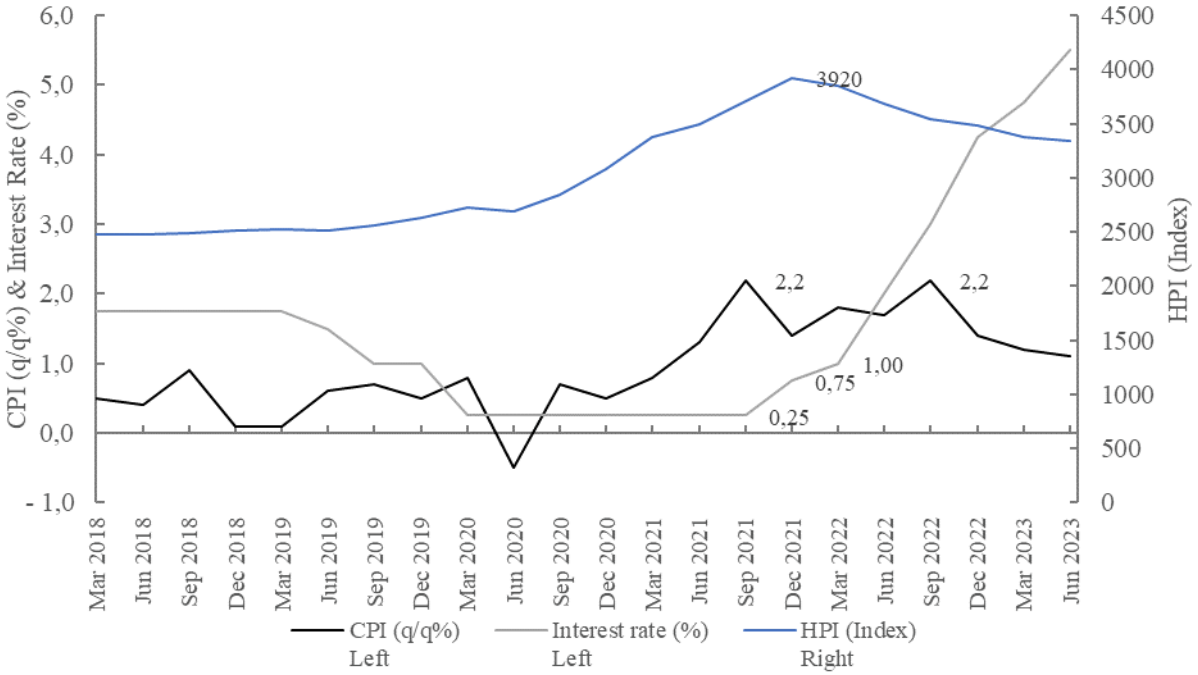


Source: IMF, 2023

Similarly, New Zealand's CPI inflation rate began to rise in 2021, peaking at 2.20% in September of that year as evident in Figure 3. In October 2021, the RBNZ raised the interest rate, first to 0.75%, then to 1.00% in November from 0.25%, where it had been from early 2020. The RBNZ cited rising inflation and the expectation that inflation will continue to increase in both of their announcements. However, they do further note that house prices remain unsustainably high (RBNZ, 2021e).

While the increases in the interest rate can be primarily attributed to rising headline inflation, it does precede a decrease in the HPI, as evident in Figure 3. House prices and quarter-on-quarter (Q/Q) CPI continued to decline into the middle of 2023 as interest rates rose significantly above pre-COVID-19 levels.

Figure 3: New Zealand CPI and interest rate compared to the HPI, 1Q2018 – 2Q2023



Source: RBNZ, 2023b; EIU, 2023

2.5.1 Monetary policy's impact on house prices in New Zealand

The RBNZ has a strong understanding of monetary policy's impact on house prices in the country. An RBNZ study from 2022 using a Bayesian Local Projections VAR found that an unanticipated 1% increase in interest rates, reduces real house prices by up to -1.6% and the growth rate of residential loans by -0.6% after 2.5 years. House prices are primarily seen to be impacted through the credit channel, the financial position of borrowers, which affects their ability to raise debt. Interestingly, total bank loans were found to remain broadly unchanged for 12 months after the positive interest rate shock. The RBNZ interprets this to imply that total bank loans may contain a countercyclical component - that firms and individuals might borrow more to make up for a shortfall in income after a rise in interest rates. In other words, reducing principal repayments when interest payments rise, or some types of credit may be insensitive to interest rate increases (Chadwick & Nahavandi, 2022). This suggests that other factors may be influencing house prices in New Zealand, likely a speculative bubble.

2.6 Other Countries that have Targeted House Prices with Monetary Policy

New Zealand's central bank has been specifically mandated to target house prices. Economists have estimated that house price movements may have played a separate role in the observed reaction functions of the central banks of Japan, the United Kingdom (UK), and the United States of America (USA).

However, many central banks, including the Irish, Finnish, and Swedish authorities, account for the housing market in monetary policy decision-making, as they are directed to ensure financial stability. Housing and real estate markets are widely accepted as sources of financial sector risk and contagion, which may jeopardise price stability (Carlin & Soskice, 2014a).

Sweden

The Swedish Central Bank (the Riksbank) does not explicitly target house prices in its monetary policy decisions. However, the Riksbank considers house prices when setting monetary policy, as it believes house prices can significantly impact financial stability and economic growth. Notably, while the Riksbank's primary objective is to maintain price stability, its secondary objective is to contribute to a balanced development in production and employment. The Riksbank believes stable and predictable house prices are essential for achieving both objectives (Riksbank, 2017).

Even so, while experiencing a significant increase in house prices, the Riksbank raised interest rates by 235 basis points between 2005 and 2008. The Riksbank explicitly recognised that the contractionary monetary policy was an attempt to counteract "household indebtedness and house prices [that] are continuing to rise rapidly" in a 2006 statement (Riksbank, 2006). House prices in Sweden continued their upward trend throughout the period and after the 2008 Global Financial Crisis (St. Louis Fed, 2024a).

Australia

Similarly, Australia has experienced consistent growth in house prices since the 1990s, outstripping most other economic indicators. House prices gained approximately 80% in real terms in the early 2000s. As such, The Reserve Bank of Australia (RBA) publicly recognised that rising house prices have " been associated with a rapid expansion in household debt" in a

2002 statement. Moreover, continuing their current stance of strongly expansionary monetary policy (low interest rates) "could fuel other imbalances such as the current overheating in the housing market." (RBA, 2008). Between 2002 and 2008, the RBA proceeded to raise their cash rate target from 4.45% in 2002, peaking at 7.25% in 2008 (RBA, 2023). Over this period, they were not able to realise a moderation in house prices which continued to increase (St. Louis Fed, 2023).

Ireland

The Central Bank of Ireland (CBI) has a mandate to consider the government's objective of supporting more sustainable house prices when setting financial stability policy. Particularly due to their experiences as a consequence of the 2008 Global Financial Crisis, the CBI recognises that financial crises are more severe, and recoveries from them are slower when preceded by surges in mortgage lending. They have opted to follow an early intervention principle where the CBI aims to identify and address the risks of house price bubbles before they become too large and complex to manage. The bank's macroprudential policies have achieved success in reducing the risk of house price bubbles in Ireland (CBI, 2016).

Finland

The Finnish Financial Supervisory Authority (FIN-FSA) is mandated to promote financial stability and sustainable economic growth. The FIN-FSA considers house prices as part of its assessment of systemic risks to the financial system (Bank of Finland, 2023).

2.7 Should Central Banks React to Asset Price Bubbles

Globally, central banks grapple with whether they should respond to asset price bubbles more than what is needed to stabilise inflation and attain the maximum level of employment. If a central bank were to refrain from "popping" an asset price bubble, it would likely continue to grow and "pop" only when market sentiment shifts against it. The effects of this readjustment can spread to other parts of the economy. They can negatively affect price stability and the country's level of output or GDP and employment – all of which is the central bank's mandate to maintain. Furthermore, central banks may discern a need to react to asset price bubbles as they generally emerge due to the central bank pursuing an expansionary monetary policy with low interest rates.

Yet, the consensus among economists is that central banks should resist reacting and attempting to moderate asset price bubbles. This is because monetary policy, the primary tool of central banks, affects the entire economy and cannot target a particular sector. Therefore, by tightening monetary policy and decreasing interest rates, the overall economy will contract, not just the sector experiencing the asset price bubble (Brunnermeier & Schnabel, 2015). Frederic Mishkin, a pre-eminent economist and central banker, similarly cautions against using monetary policy to moderate asset price bubbles and advocating instead for macroprudential policies (Mishkin, 2011).

2.8 House Price Reaction to an Interest Rate Increase

Economists commonly accept that an increase in interest rates would cause house prices to fall, as well as asset prices more generally (Carlin & Soskice, 2014d). Housing markets are a significant channel through which the effects of monetary policy are transmitted to the greater economy (Sutton, et al., 2017). The impact of interest rate changes on house prices operates through credit markets, as the cost of borrowing. Houses are assets that typically cannot be purchased entirely with an individual's present income and are thus, purchased using debt in the form of a housing mortgage.

When central banks raise the policy rate, interest rates typically increase, influencing mortgage credit rates to rise. A rising policy interest rate functions to increase the cost of borrowing, including the costs associated with purchasing a house. As such, when interest rates rise, the demand for houses decreases alongside house prices (Gnan, 2021).

2.8.1 Interest rates may be ineffective at moderating asset price bubbles

While many studies have disputed how robust the relationship between interest rates and asset prices are, research specifically into house prices is less common. Furthermore, when an asset's price has a speculative bubble component in addition to its intrinsic value, only the intrinsic value may behave as expected by economic theory. However, the bubble component of the price does not need to behave similarly, in a rational manner. Indeed, the bubble component of

an asset price may continue to increase as long as individuals in the market continue to expect the overall asset price to rise (Galí, 2014).

Some research shows that interest rates do not have a particularly strong impact on asset price bubbles. In a laboratory experiment by Fischbacher, Hens, and Zeisberger (2013) a positive interest rate shock was shown to have a strong negative effect on liquidity markets. However, only a small impact was transferred to asset price markets currently experiencing a bubble. Therefore, while debt may become more expensive and less accessible, speculative demand for the asset remains undeterred. When extending their analysis, their model found that a particularly sharp or large interest rate shock does indeed negatively impact the bubble.

Considering the asset price market experiencing a bubble more closely, if agents have rational expectations, an asset whose price has a bubble component may not react negatively to an interest rate increase. It may even be rational to expect the bubble component to grow if the asset price displays a strong history of growth (Greenspan, 2002). Moreover, agents would continue to expect high rates of return from the bubble (Mishkin, 2008).

In other research, Galì (2015) identified the price puzzle effect where prices increase in response to a monetary policy shock. This is discussed in more detail in 2.9 Price puzzle: unexpected effects of interest rate shocks in VAR analysis. When studying asset prices - specifically stock prices. Galì found that stock prices increased in response to an unexpected positive interest rate shock or contractionary monetary policy. Galì and his colleagues found further evidence contradicting the orthodoxy regarding the negative relationship between interest rates and asset prices. With experimental data, an immediate decrease in asset prices was noted after an interest rate increase, followed by the asset price rising and exceeding the initial value. The relationship, between interest rates and asset prices was shown to be volatile and not sufficiently strong to manage an asset price bubble (Galí, et al., 2021).

While current theory regarding applying interest rates to manage asset prices exists, sufficient contradictory empirical evidence has also been developed, suggesting that this relationship must be further tested. Nevertheless, macroprudential policy has a long, positive track record of managing speculative bubbles with specific evidence in the housing market.

2.9 Price puzzle: unexpected effects of interest rate shocks in VAR analysis

Across the VAR and SVAR literature, multiple researchers have identified the price puzzle effect - an unexpected interest rate increase or monetary policy tightening causing inflation to increase, contrary to standard economic thought (Eichenbaum, 1992). Multiple examples have been described in the 30-year history of the VAR methodology and the inconsistency between theory and empirical evidence have been a longstanding puzzle in macroeconomics. Regardless, the price puzzle effect may not be an artefact but an accurate representation of the data. However, as it is converse to conventional economic theory, it must be substantially justified (Galí & Gambetti, 2015).

There exists a consensus in VAR literature that the price puzzle arises as some portion of the information cannot be captured within a simplistic VAR methodology. The inflation expectations of central banks are generally challenging to capture in the VAR model and are thought to result in an unexpected relationship between interest rates and inflation. Typically, the price puzzle arises in empirical models applying standard assumptions with very few variables (approximately three variables) and contemporaneous restrictions (Estrella, 2015). Other literature has highlighted that certain relevant trends may be non-linear, which are not easily captured by linear VAR models thus, causing this unexpected relationship to arise (Bachmeier, et al., 2007). Further research has been developed, showing that the price puzzle effect is particularly strong when atheoretical recursive restrictions are used for model identification (Krusec, 2010).

The most common approach to avoiding the price puzzle effect arising in empirical analysis is to include additional variables to counteract the magnitude of the increase in prices. Sims (1992) included a high-volatility commodity price index to capture central banks' unobserved inflation expectations, as they are likely to foresee inflationary pressures before they arrive. Sims noted that while indeed reducing the impact of the price puzzle, it was not completely eliminated. Other literature has chosen to incorporate a priori restriction schemes, different to the standard contemporaneous, recursive or long-term restrictions.

2.9.1 The price puzzle in housing markets

Moreover, the price puzzle has been seen to impact not only CPI (which increases in response to an unexpected monetary policy shock) but asset prices more generally including house prices. The housing market was found to increase weakly in response to a positive monetary policy shock in South Africa, displaying the price puzzle effect. The impact became evident in the short run, where a rise in medium segment house price growth rate was identified through a Markov-Switching VAR model (Simo-Kengne, et al., 2012). Similar results were derived from USA's housing market data through the application of a standard VAR (Vargas-Silva, 2008) as well as a large-scale Bayesian VAR (Gupta, et al., 2012).

2.9.2 The price puzzle in New Zealand's macroeconomic data

Evidence supporting the existence of the price puzzle within New Zealand's macroeconomic data is mixed. Karim et al. (2012) found that the relationship between monetary policy and inflation does not show any evidence of a price puzzle in New Zealand. However, the Producer Price Index (PPI) responded with a significant lag to the unexpected monetary policy shocks. Another study that included New Zealand among a panel of countries found that the price puzzle effect further identifying that the effect was successfully averted when inflation expectations or a proxy were included in the VAR modelling. Data from the period before the 2008 Global Financial Crisis was used in a simple three-variable VAR model (Florio, 2018).

Even so, research by the RBNZ found statically significant evidence of a price puzzle in an analysis of the monetary policy impact on house prices and housing loans. Notably, the analysis was computed using local projections, an alternative to the SVAR methodology for time series analysis (Chadwick & Nahavandi, 2022). In earlier research, the RBNZ applied a factor-augmented-VAR with a large dataset (660 New Zealand and international macroeconomic series, transformed to be approximately stationary) to successfully remove the price puzzle effect seen in New Zealand's body of VAR research (Culling, et al., 2019).

2.9.3 Approach to mitigating price puzzle-like results

Even though multiple researchers have adopted the incorporation of commodity price indices as a method to avoid the effects of the price puzzle, its theoretical justification remains weak, and its impact is unreliable (Demiralp, et al., 2013). A meta-analysis showed that

approximately half of all studies that included commodity prices, still reported the price puzzle effect (Rusnák, et al., 2013). Furthermore, Bishop (2017) also found that the price puzzle persisted after including commodity prices in the analysis of Australian data. Controversially, evidence from Chile has shown that introducing commodity prices may even result in an exaggerated response by inflation (Banco Central de Chile, 2017).

A successful approach has been to estimate a factor-augmented VAR where many possibly relevant macroeconomic and financial time series are summarised by principal components. This methodology was successfully executed by Bernanke, Boivin and Eliasz (2005). However, the factor-augmented VAR approach is computationally heavy and challenging to interpret. Alternatively, time-varying VARs have been successfully applied to analyse monetary policy impacts on stock prices. Further improvements to the validity of the analysis can be gained by applying long-run restrictions or theoretically justified restrictions as opposed to recursive restrictions (Krusec, 2010).

Nevertheless, the price puzzle effect has arisen in even the most well-specified VAR analysis. Research by Galí & Gambetti (2015) found a similar yet robust price puzzle effect, with stock prices rising after a contractionary monetary policy shock. This indicates that results should not be dismissed, even if it does contradict current mainstream theory.

2.10 Costs of using monetary policy to manage house prices

The use of monetary policy to stabilise specific economic indicators (such as inflation and unemployment but also house prices) without considering the impact on overall financial stability, has been called “leaning against the wind” by economists. The Bank of International Settlements (BIS) has discussed that leaning against the wind may be associated with reduced GDP growth and higher unemployment costs. These costs have been justified by the decrease in the probability and severity of a future financial crisis (BIS, 2013). A worse macroeconomy in the short run is traded off against a better long-run outcome. However, the occurrence of an economic crisis unpredictable and the cost of the crisis is magnified when an economy enters it in a weaker position.

The primary benefit of using monetary policy to manage short-run price movements is the potential to reduce the likelihood and severity of a financial crisis. Higher interest rates can slow credit growth and reduce real debt levels, making households and firms less vulnerable to financial shocks. Even so, Svensson (2016) shows that these benefits are modest and that empirical estimates suggest a low probability of success. Moreover, he shows that the effect of higher interest rates on reducing the likelihood of a financial crisis is relatively small.

Svensson showed that the slight reduction in crisis probability achieved by higher interest rates does not justify the significant short-term economic pain caused by higher unemployment and weaker growth (Svensson, 2016). Moreover, the direct benefit from preventively increasing house prices is reduced real debt levels (which limits the impact of a financial crisis). However, the effect on real debt levels only exists in the short run. In the long run, monetary policy is neutral, in that while nominal debt levels may decline, prices will decline in step; thus, real debt leaves are unaffected (Lucas, 1996). Therefore, using interest rates to manage house prices results in only temporary effects and does not structurally impact the economy. Svensson (2016) suggests macroprudential policies may be a more effective mitigation tool.

2.11 Macroprudential Policies – Alternatives to Monetary Policy

It is salient to remember that monetary policy is not considered the primary method of managing asset price bubbles. Instead, most economists recommend macroprudential policies for this purpose (C. Lim, 2011). Macroprudential policies help manage cyclical threats to an economy, moderating booms and providing a buffer during periods of economic downturn. Credit-related macroprudential policies, such as loan-to-value ratios, debt-to-income ceilings, limits to credit growth, risk weights or loss given default floors – have displayed effectiveness in alleviating cyclical risks in housing markets (Claessens, 2014). While macroprudential policy is prevalent in the Global South (as implementing macroprudential policies has been incentivised through loans and financial aid), many more advanced economies forgo these constraints, as lenders consider them lower risk. In the past decade however, their popularity has grown, following the events leading up to the 2008 Financial Crisis.

Moreover, macroprudential policies have been shown to be extremely relevant to housing markets. Notably, credit availability, such as the expansion of subprime lending in the USA

during the 2000s, was central to the housing bubble collapse, which could have been partially mitigated by the implementation of macroprudential policies (Duca, et al., 2021). Often, these policy act directly on diminishing the impact of the financial accelerate effect. The financial accelerator effect refers to how small economic shocks are amplified through the financial system, making downturns more severe. When asset values fall during a recession, borrowers face higher interest rates and reduced access to credit, which further decreases spending and investment, deepening the economic decline. This creates a feedback loop, intensifying the impact of the initial shock (Bernanke, et al., 1999).

New Zealand has historically achieved success in implementing macroprudential policy in the banking sector, with two liquidity mismatch ratios and a core funding ratio introduced in 2010 to limit their commercial banks' liquidity risk. However, their housing market had been largely unregulated in this regard. Calls for loan-to-value ratios to be implemented have been strong from as early as 2006, before the 2008 Global Financial Crisis, when evidence of the New Zealand's housing bubble was beginning to solidify (Claessens, 2014). It is interesting to note that New Zealand house prices dropped during the 2008 Global Financial Crisis but rebounded quickly in 2012 as banks resumed their elevated volume of high loan-to-value ratio mortgage lending (Hargreaves, 2016).

In October 2013, the RBNZ set limits on high loan-to-value residential mortgage lending. Loan-to-value lending restrictions are tighter for investor loans due to the associated higher risks. When an investor loan constitutes more than 65% of the property's value (a 35% deposit), it was classified as high loan-to-value ratio lending. High loan-to-value ratio lending is restricted to no more than 5% of a bank's total new investor lending. Owner-occupier loans are secured with more collateral, which lowers the risk. They are classified as high loan-to-value ratio lending when the loan amount constitutes more than 80% of the property's value (a 20% deposit). High loan-to-value ratio owner-occupier loans are limited to no more than 15% of a bank's total new owner-occupier lending (RBNZ, 2023c).

Overall, New Zealand's application of the loan-to-value ratio has achieved mixed to moderate success from its inception in 2013 until 2019, prior to the COVID-19 pandemic. Research has shown that the implementation of this macroprudential policy had a positive impact, improving financial stability and mitigating the scale of house price falls during a potential downturn (Lu,

2019). Conversely, the effects of the loan-to-value ratio have been shown to be short-lived and most effective in the period immediately following its implementation in 2013 (Armstrong, et al., 2019). In 2020, the COVID-19 pandemic prompted expansionary monetary policy (low interest rates) to stimulate the stagnating economy (RBNZ, 2020a), and a pause of the loan-to-value-ratio for further stimulus (RBNZ, 2020b). These resulted in house prices growing rapidly; hence, there is a need to consider other price management options.

There exists several other effective macroprudential policies that could be enacted instead of or in addition to the loan-to-value ratio. First, debt-to-income ratios enforce a ceiling on the total debt a borrower can have relative to their income. It prevents excessive leverage and ensures affordability, which can be effective in an economy with a high debt burden or where the speculative bubble is supported by debt. Thereafter, risk-based capital requirements demand increased capital for banks to hold higher-risk mortgages. Risk-based capital requirements are effective in incentivising safer lending practices. Finally, margin requirements which raises the down payment needed for investors, discouraging speculative purchases using borrowed funds (McDonald, 2015). In addition, the loan-to-value ratio may be complementary to moderately contractionary monetary policy in managing house prices. Already, a combination of all these options is being considered or applied by the RBNZ (RBNZ, 2024a).

Although macroprudential policies are valuable tools in mitigating cyclical threats to economic stability, asset price bubbles, which will eventually burst, can have impacts that spill over into the rest of the economy, resulting in financial crises and, potentially, global crises. These exceptionally destabilising domestic economic threats warrant more decisive attention from central banks (He, et al., 2016). Therefore, monetary policy emerges as an effective tool with a shorter timeframe to become effective.

2.12 Value of Macroprudential Policies

While the results of a monetary policy shock may be realised in a shorter period than enacting macroprudential policy, macroprudential policy is particularly effective in building financial sector stability as well as targeting a particular sector (BIS, 2023). Even so, these tools work by effectively inhibiting growth as well as resulting in reduced credit availability.

2.12.1 Strengths of macroprudential policy

The primary strength of macroprudential policy lies in its effectiveness in building financial stability. Economies that have introduced macroprudential policies are less susceptible to shocks, especially cyclical stocks, as these policies can be applied countercyclically thus, making more of an impact during the expansionary period of the business cycle and the opposite during the contractionary period (Viñals, 2011). Macroprudential policy generally limits access to capital during expansionary periods (Masciandaro, et al., 2008). Thereby, reducing the demand for the targeted asset, house prices and, as such, its market price.

Secondly, macroprudential policies can offer precise targeting towards the housing sector without causing substantial disruptions in other segments of the economy. Policies such as loan-to-value ratios or capital buffers can be tailored to address housing market vulnerabilities (Borio & Shim, 2007). This is contrasted against interest rate increases that affect the whole economy indiscriminately. By specifically targeting vulnerabilities in the housing market, macroprudential policies contribute to reducing systemic risks thereby, enhancing the financial system's resilience (Viñals, 2011).

2.12.2 Weaknesses of macroprudential policy

Policies that raise capital requirements or impose stricter lending standards have the potential to lead to reduced credit availability. When banks need to hold more capital or limit their lending due to stricter regulations, it can dampen borrowing and spending by households and businesses. This could unintentionally restrict credit access to higher-risk groups. It particularly affects first-time buyers or those with lower incomes, potentially exacerbating systemic housing affordability issues, which the intervention attempts to solve (Stein, 2011). First-time home buyers are more likely to find a 20% deposit unaffordable opting for a smaller deposit, placing them in the high loan-to-value ratio category. Due to the limited amount of these loans available, a higher premium will be attached (Armstrong, et al., 2019). Furthermore, as housing is a significant component of wealth for many households, a contraction in this market can have a negative wealth effect, reducing consumer spending and overall economic growth (Cerutti & Claessens, 2015).

In general, if implementing macroprudential policies leads to a significant slowdown in lending and investment, it can affect the overall aggregate demand in the economy. Reduced demand for goods and services can result in slower economic growth (Mian & Sufi, 2009).

Moreover, enacting macroprudential policy is a long-term exercise. Passing the legislation may take significant time and attract political resistance, causing further delays. In addition, macroprudential policy operates systematically, with its results realised with a lag (Adrian & Shin, 2010). The delay can also cause a temporary increase in speculative behaviour before the changes come into force, during which a bubble can rapidly expand.

3. Theoretical Framework

A modified three equation, Mundell-Fleming model based on the New Keynesian framework, has been employed to analyse the effects of the policy rate (set by the central banks' monetary policy) on household debt. This is a widely used method to analyse monetary policy decisions in the macroeconomy. Moreover, the relationships between monetary policy and prices are easily understood (Carlin & Soskice, 2014d).

By considering the relationship between monetary policy and house prices to control a housing price bubble through the New Keynesian Mundell-Fleming framework, this paper settles on the following variables to conduct the empirical analysis with a Structural Vector Autoregression model: 1. interest rates, 2. real household loans, 3. GDP, 4. Inflation, 5. real exchange rate, and 6. real house prices. The specification given by Robstad (2018) model to quantify the effect of monetary policy in Norway for the Norges Bank (the Norwegian central bank) has been adopted.

3.1 New Keynesian Mundell-Fleming model

The IS-PC-MR approach is a simplified version of the New Keynesian Mundell-Fleming model used by many central banks. Through the New Keynesian Mundell-Fleming framework, the IS-PC-MR approach splits an economy into three facets (four when it is an open economy). The IS (investment equal to savings) schedule captures equilibrium output through equilibrium in the goods and money markets. The PC schedule describes the inertial inflation process based on historical information and the MR schedule unpacks the expected response of output to inflation in the following period. The model is extended to incorporate international trade by introducing the Uncovered Interest Parity Condition (UIP). Notably, the Carlin-Soskice model builds in two lags to accommodate the central bank's knowledge of shock (Carlin & Soskice, 2014b). This will serve as the beginning of the VAR analysis in this research.

Based upon the IS-PC-MR approach to modelling an economy, alongside the cyclical nature of speculative bubbles discussed in 3.3 Asset Price Bubbles and the Financial Accelerator Effect, this research has chosen to capture the equilibrium output of the IS schedule by including GDP, house prices (a commodity price), the interest rate and the volume of housing

loans which follows total loan stock. Household debt factors into the IS schedule to fund additional consumption above disposable income (Aron, et al., 2011). The interest rate functions as the cost of debt to fund additional consumption; therefore, more credit will be demanded by households when the interest rate is lower to fund additional consumption, such as the purchase of larger or additional properties.

Thereafter, a measure of inflation is used to introduce the PC schedule. The MR schedule describes an equilibrium between the output and inflation, both of which are captured by the aforementioned variables in the model. Notably, the minimum interest rate is set by a country's monetary policy as the policy rate or the interest rate at which the central bank will lend money to the commercial banks of a country. Finally, the exchange rate introduces the impacts of the open economy.

3.2 Variable Selection

Following the increase in household debt, a housing bubble can quickly form, requiring household debt and house prices to be analysed through the econometric approach. Houses or real estate are a highly sought-after investment vehicle when consumers are attracted to low-risk assets and by speculators once they determine that the price will rise, at minimum, in the short run (Dokko, et al., 2009). This is especially true in New Zealand, where the ageing population is looking for assets to fund their retirement, and the price of housing in the country has been steadily increasing since the 1990s, with only a brief hiatus during the 2008 Financial Crisis. Moreover, following the Phillips, Shi and Yu (2015) bubbles tests, methodology based on the explosiveness of asset prices analysed through an autoregressive approach, the New Zealand housing market was determined to be a bubble (Rehm & Yang, 2020), even prior to the significant house price increases identified during the COVID-19 pandemic.

In addition to household debt and house prices, the remaining four variables capture a desire to invest domestically, as opposed to investing in foreign markets in addition to tracking the demand for housing. GDP (or output), inflation, real interest rates, and the real exchange rate cover the remaining variables of the New Keynesian Mundell-Fleming model. Additionally, the lagged GDP values, along with the other variables' lags, capture the effect of the output gap. In this paper, these variables provide reasoning for households to invest in housing assets

as well as invest within the domestic market. Additionally, real house prices and household debt describe the evolving house price bubble and the demand for housing from investors.

3.3 Asset Price Bubbles and the Financial Accelerator Effect

Housing price bubbles pose a significant threat to the economy, as, through the financial accelerator effect, it can escalate into a financial crisis. The financial accelerator effect is the cyclical mechanism through which asset price changes affect an agent's balance sheet, thereby leading to changes in their borrowing and spending. Furthermore, shocks in the financial sector have a high probability of spreading through the economy with extremely destabilising effects (Carlin & Soskice, 2014a). Both processes (the asset prices bubble and the financial accelerator effect) can be seen to have amplified and propagated the financial crises, originating in housing markets, through the economy, resulting in the Swedish house price bubble in 1990 (Berg, et al., 2004) as well as the 2008 Global Financial Crisis (Giri, et al., 2019).

The dynamics of an asset price bubble can grow particularly threatening to an economy due to the self-fulfilling nature of price expectations in speculative bubbles, resulting in a dramatic downward shift in equilibrium. When prices increase for a durable good such as houses, and investors expect prices to continue rising, they will invest – further inflating prices. This quickly becomes a self-fulfilling process and will continue until there is a shock to change the expectation of continuously rising prices. The higher prices rise, deviating further from its initial 'fundamental' level, the larger the effect of a shock that bursts the bubble because the market rapidly moves to a lower equilibrium level at a lower price level. Perhaps even lower than before the bubble began (Carlin & Soskice, 2014a).

The financial accelerator mechanism results in contagion: the effects of the asset price increasing above its fundamental level and the rapid adjustment to a new lower price level when the bubble bursts are spread through the economy, causing a widespread financial crisis. As part of the asset price bubble process, when house prices rise within the asset price bubble, the household has access to additional collateral they can use to obtain more credit than before the house price bubble. As prices climb and are expected to rise persistently, the market is viewed as lower risk, attracting more investors and allowing regulatory bodies to relax credit constraints, working under the assumption that the market will continue to grow. The increase

in demand exerts an upward pressure on prices, reinforcing the cyclical nature of this process. When the bubble bursts, households find they are unable to repay their loans as their houses are no longer worth as much as they were when they received their loan. Banks, too, discover that the asset no longer has the same value upon repossession, resulting in a liquidity crisis in financial markets (Carlin & Soskice, 2014a).

Notably, housing plays a pivotal role in the financial accelerator effect and proved to be a major factor in initiating the 2008 Global Financial Crisis. House price booms are generally driven by factors including easy access to credit, lower interest rates, and rising income. These factors were common in countries with more liberalised mortgage markets, leading to larger busts in those economies. Furthermore, rising house prices (due to the increased demand) creates additional collateral, which allows more houses to be bought on debt, further inflating prices. Conversely, during the 2008 Global Financial Crisis, homeowners found themselves with negative equity (owing more on their mortgages than their homes were worth), leading to rising defaults and foreclosure. The collapse in housing prices led to a decline in lending activity, as financial institutions holding mortgage-backed securities suffered significant losses (Duca, et al., 2021). The resulting contraction in credit further depressed house prices and economic activity, leading to a more severe global recession.

The impact of an asset price bubble is propagated through the economy by the financial accelerator effect. Thus, when the bubble inevitably bursts, the entire economy is affected. Therefore, being able to moderate an asset price bubble is especially advantageous to maintaining price stability in an economy.

A key critique of the New Keynesian Mundell-Fleming approach to economy modelling, adopted in this research, is that it does not sufficiently capture the cyclical financial accelerator effect, especially during a financial crisis where perceptions of risk changes. Some authors have argued that Structural Econometric Models (SEM) are better suited to treating firms and consumers heterogeneously as they have different levels of wealth and consumption patterns. Furthermore, SEMs are able to account for cyclical bubbles as well as changing risk perceptions amid a bubble and during a financial crisis. However, the implementation of such models requires a significant quantitative burden (Hendry & Muellbauer, 2017).

In this research, the financial accelerator effect is partially captured through the inclusion of financial variables chiefly real housing debt but also interest rates. Moreover, the non-linearity amid cyclical bubbles has been partially expressed in the model by introducing a logarithmic transformation to the data used. Future research may benefit from the application of a nonlinear VAR model as well as the inclusion of additional financial sector variables such as risk perceptions and expectations.

3.4 Variable Interactions

As discussed in 2.8 House Price Reaction to an Interest Rate Increase above, house prices are expected to fall following an interest rate increase. This is because an interest rate increase raises the cost of borrowing, making mortgages or housing loans more expensive, thereby making the total cost of purchasing a house more expensive. It reduces demand for housing, reducing house prices. Similarly, an increase in the interest rate will exert negative pressure on housing loans as demand decreases.

Through the New Keynesian Mundell-Fleming framework, an interest rate increase, or contractionary monetary policy, is expected to decrease inflation. High inflation reduces purchasing power, demand for goods, services and output or GDP. The interest rate reduces inflation by raising the cost of borrowing, discouraging businesses and consumers from taking out debt and spending money (Carlin & Soskice, 2014b). This reduces demand for services and goods, reducing both prices and inflation. Moreover, reduced economic activity exerts downward pressure on GDP.

Extensions to the New Keynesian Mundell-Fleming model show that an asset price bubble (of which house prices are a subset) can have far-reaching economic impacts. It can attract foreign speculative investment, demanding more domestic currency and cause an appreciation. Increasing house prices can also be inflationary as it is a component of the CPI basket (Ryoo, 2016). Within a bubble, housing loans are expected to increase as speculators expect a higher return on housing.

4. Data Selection

The Reserve Bank of New Zealand is the source of the majority of data used in this study (RBNZ, 2023d). Only New Zealand's Real Effective Exchange Rate (REER) was obtained from the Federal (Fed) Reserve Bank of St Louis (St. Louis Fed, 2024b). All raw data used in this analysis has been constructed into a time series panel dataset covering the following variables used in the econometric analysis of this paper: 1. HPI, 2. interest rate, 3. REER, 4. real GDP, 5. CPI, 6. real housing loans. See Appendix A: Descriptive Statistics for a summary of the descriptive statistics of the data used in this analysis. Note that the interest rate and real effective exchange rate time series were obtained as higher frequency datasets and were thus, transformed into quarterly data as an average over the period.

The quarterly data covers the period from January 1999 to March 2021, beginning with the earliest available data for housing loans (specified as household financial liabilities by the RBNZ) and the interest rate measured through the Official Cash Rate (OCR). This period is considered ideal for the analysis, as it extends from the 1990s to 2009, when New Zealand's housing prices began increasing. The 2008 Global Financial Crisis provides insight into when the growth of the housing bubble paused, followed by the Era of Secular Stagnation (2010 to 2019) and the continued growth of the housing bubble. Finally, the period includes the COVID-19 pandemic (2020 to 2021), where the New Zealand housing bubble escalated to concerning heights.

5. Econometric Methodology

5.1 Model Selection

The vector autoregression (VAR) class of time series models was identified as the best fit for estimating the impact of monetary policy on household debt. Furthermore, the Structural VAR (SVAR) approach was considered in modelling the relationship between monetary policy and house prices. Non-recursive SVAR models allow for contemporaneous and theory-based restrictions to be used rather than imposing restrictions based on the Choleski decomposition (that a traditional VAR model would make use of). In surveying the literature surrounding the monetary policy transmission mechanism and sources of business cycle fluctuations (focusing on the policy rate and its impact on household debt), the SVAR approach was identified as a recurrent procedure for estimating macroeconomic variables.

VAR models are commonly applied in macroeconomic analysis, especially in the analysis of monetary policy. They are particularly adept at analysing dynamic relationships between variables which interact with each other. As such, they are applied by multiple macroeconomic and policy-making institutions (Kotzé, 2023). However, VAR models often do not explicitly represent economic theory or relationships as they are identified recursively. In addition, other limitations arise when identifying a VAR model through the Choleski decomposition (Thorsrud & Bjørnland, 2015).

The Choleski decomposition relies on partial identification, where only one of the underlying structural shocks is identified; thus, the model can study only one shock, reducing its flexibility. The ordering of variables becomes important, affecting which variables can and cannot respond contemporaneously. This is problematic when multiple variables are assumed to be jointly determined and are being studied, such as interest rates, exchange rates and house prices in this study (Elbourne, 2008).

Contrary to this, SVAR models require an explicit economic or informational rationale for each of the restrictions placed on the model for the purposes of identification. First described by (Sims, 1986) (Bernanke, 1986) (Blanchard & Quah, 1988), the SVAR extension solves the “black box” issue of the VAR model. SVAR models are identified non-recursively, using only

the endogenous variables and without external variables as restrictions. It does not rely on "incredible" identifying assumptions.

Choosing an SVAR methodology allowed for the analysis of the dynamic interplay between variables and the assessment of causal relationships without the need to impose strict restrictions. This flexibility was crucial to gain insights into complex economic systems, such as the interactions between interest rates and house prices. Furthermore, SVAR models are well-suited for exploring both short-term and long-term dynamics, making them an ideal choice for research into long-term relationships between the variables (Bjørnland & Jacobsen, 2010).

5.1.1 SVAR Limitations

Even though SVARs are a popular tool in macroeconomics for analysing the dynamic relationships between economic variables, they have a number of limitations, which are considered in the interpretation of the results.

Identification problems

The primary limitation of SVAR models is the identification problem. SVARs are statistical models that can be estimated from time series data, but they do not directly identify the underlying structural relationships between the variables. In order to identify the structural relationships, researchers must impose additional restrictions on the model. These restrictions are typically based on economic theory or prior knowledge. However, it is often difficult to find a set of theoretically plausible and empirically valid restrictions.

Sensitivity to model specification

SVARs are also sensitive to the model's specifications. This includes the choice of variables considered in the model, the order of the VAR (number of variables), and the lag structure. Different model specifications can produce different results, even when the underlying data is the same.

Difficulty in interpreting shocks

SVARs can be used to identify the effects of economic shocks on the variables in the model. However, it can be challenging to interpret the shocks themselves. SVAR shocks are typically

constructed as linear combinations of the innovations in the VAR model, but these innovations may not have a clear economic interpretation. This makes it difficult to draw conclusions from SVAR impulse response functions.

Despite these limitations, SVARs remain a popular tool in macroeconomics, enabling the analysis of a spectrum of macroeconomic issues, such as the effects of monetary policy, fiscal policy, and supply shocks. However, it is important to be aware of the limitations of SVARs and to interpret their results cautiously (Bjørnland & Jacobsen, 2010).

These issues are primarily ameliorated using a restriction and identification strategy based on strong prior research. This research follows the specifications presented in the work of (Elbourne, 2008), (Robstad, 2018) and (Kim & Roubini, 2000), which is, in turn based on the approach detailed in (Sims & Zha, 1998). By limiting the customisation to the basic SVAR methodology, the validity of the results from this investigation can be better ensured. More than the minimum required restrictions were used to ensure the validity of the results. Restrictions were focused on the interest rate variable as, in the short run, its relationship to other variables can be assumed with the most certainty. The model was identified while allowing the remaining variables to stay unrestricted.

5.2 Controlling for the price puzzle effect

As discussed in the literature review, the price puzzle is an effect seen in empirical VAR research where an unexpected contractionary monetary policy shock (an interest rate increase) results in prices unexpectedly increasing. Standard economic theory suggests that contractionary monetary policy would result in prices decreasing.

While many researchers, in the past, have included a high volatility commodity price index, to control for the potential of the price puzzle effect arising, the present research has opted not to. This is due to this addition not being grounded in theory as well as its low success rate in empirical studies (Demiralp, et al., 2013). Including a commodity price index with limited theoretical justification would also be incongruous with the SVAR approach which leans heavily on theory. Instead, additional variables as well as a priori restrictions, have been included in the SVAR, as informed by economic theory and the standard understanding of the

monetary policy to interest rate transmission mechanism. By including theoretical restrictions instead of recursive restrictions to the SVAR, the potential for unintended relationships to arise is partially mitigated (Krusec, 2010). Furthermore, a larger model with six variables has been employed as opposed to the simple three-variable VAR that produces most price puzzle effects. This is still smaller than the factor-augmented VAR, which are most effective in avoiding the price puzzle arising.

5.3 Variable Selection

The following six time series were used to model the relationship between monetary policy and house prices:

1. HPI,
2. Interest rate,
3. REER,
4. Real GDP,
5. CPI,
6. Housing loans.

All indicators are quarterly, beginning in the first quarter of 1999 (March) and ending in the fourth quarter of 2020 (December), with 88 observations each. The earliest data used is from quarter one of 1999 as the Official Cash Rate (OCR), which replaced the Monetary Conditions Index (MCI) as the monetary policy instrument. As a different methodology determines the OCR and MCI, they are not directly comparable (Haworth, et al., 2020). Housing loan data was similarly only available from the beginning of 1999.

The majority of the variables selected are standard macroeconomic indicators published by the RBNZ. The interest rate refers to the New Zealand OCR set by the RBNZ as a result of their monetary policy. The SVAR model will consider a shock to the interest rate and examine the resulting impact on house prices.

Total housing loans is an indicator published by the RBNZ, which includes:

1. Housing loans with registered banks,
2. Housing loans with non-bank lending institutions,
3. Other housing loans.

This measure was chosen as it excludes consumer and student loans thus, keeping the model focused on the housing market. Thereafter, the housing loans series is divided by the GDP deflator, also published by the RBNZ, to remove the effects of inflation and ensure comparability to the other real variables.

Real indicators were selected to control for price changes over time. Real expenditure GDP of New Zealand is calculated by the RBNZ using a chain-weighting method, which considers the changing prices of goods and services over time. Real expenditure GDP is divided by nominal expenditure GDP to compute the deflator. As real GDP is calculated through the chain weighting method, it is an Implicit Price Deflator (IPD).

CPI introduces inflation into the model. CPI is measured by the changing price of a fixed basket of 650 goods and services commonly purchased by households in New Zealand. The REER accounts for the net flow of foreign currency. It is a measure of the value of the New Zealand dollar (NZD) relative to the currencies of New Zealand's 17 major trading partners, adjusted by relative consumer prices.

Finally, the HPI measures the movement in house prices for local council areas throughout New Zealand, providing an indicator of capital growth and price trends. The firm CoreLogic computes the index on behalf of the RBNZ based on the Sale Price Appraisal Ratio (SPAR) methodology. Due to its nature as an index, the effect of inflation has been isolated and is a real variable; however, it still displays seasonality. Furthermore, the RBNZ uses this index in their calculation of CPI.

5.3.1 Time series variable description

$HPIx_{it}$ (Index)

The HPI is used to represent house prices, which are currently being affected by a speculative bubble. HPI shows a steady increase from 2000 to 2010, followed by a sharp decline during the 2008 Global Financial Crisis and a strong recovery after that. House prices have maintained a roughly consistent growth rate over the last two decades until 2020, when price increases accelerated.

Interest $rate_{it}$ (%)

Interest rates, published as the OCR by the RBNZ, introduces monetary policy into the model. Interest rates have historically been moderate in New Zealand, with a sharp decrease following the 2008 Global Financial Crisis. In the 2020s, interest rates were reduced to stimulate the economy of New Zealand during the COVID-19 pandemic.

$REER_{it}$ (Index)

The REER displayed a strong positive trend in the 2010s, save for a brief depreciation during the 2008 Global Financial Crisis. In recent years, it has begun to flatten.

Real GDP_{it} (NZDm)

New Zealand's Real GDP has been steadily increasing over time. This growth indicates that the economy has grown consistently over the past two decades.

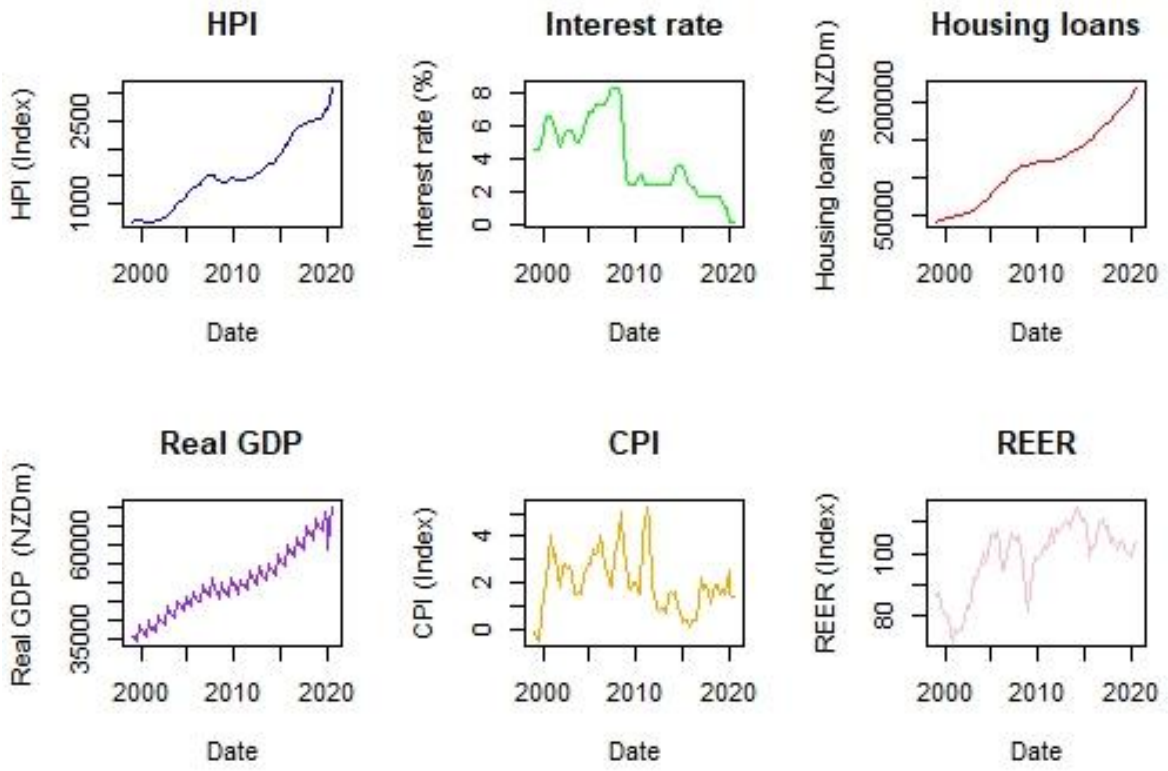
CPI_{it} (Index)

The CPI is used as a measure of the inflation rate. New Zealand is well regarded for its central bank's strong inflation-targeting performance. With a targeted range of between 0% and 3%, the has RBNZ rarely breached it.

Housing $Loans_{it}$ (NZDm)

Housing loans are a key supporting factor in the house price bubble. They follow a similar trend to the HPI, increasing at a roughly constant rate since 2000, with an interruption during the 2008 Global Financial Crisis. Housing loans are transformed into a real variable by adjusting it with the GDP deflator.

Figure 4: Time series plots of indicators



5.4 Model Construction

5.4.1 Initiation

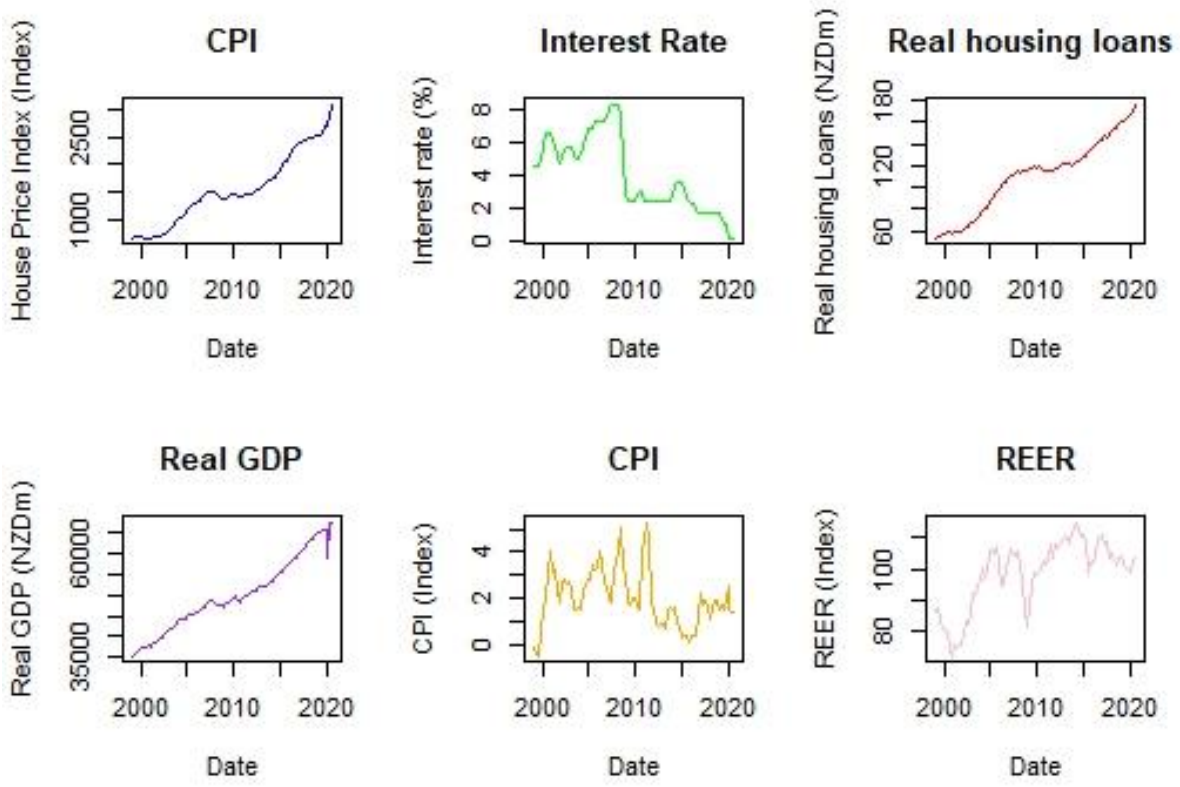
The effectiveness of monetary policy in moderating house price bubbles is estimated using an SVAR model built in the R programming language. While various time series libraries were relied upon in the analysis, the "vars" and "svars" libraries were the primary drivers of the SVAR analysis. Each indicator was cleaned and checked for missing values. Thereafter, the indicators were converted to time series objects and plotted in Figure 4 above.

5.4.2 Adjusting for prices changes over time

Nominal and Real GDP are acutely seasonal variables (Moulton & Cowan, 2016), which is immediately evident upon inspection of Figure 4. As such, house prices and housing loan stock will also be seasonal (Ngai & Tenreyro, 2014). Therefore, the real GDP, HPI and housing loan variables were seasonally adjusted to better understand the underlying trends in the series.

In addition, to ensure that the effects of price changes are controlled for in the analysis, real variables are used where possible; the housing loans series was divided by the GDP deflator. The resulting indicator, "real housing loans", is a real variable comparable to the other real indicators used in the model.

Figure 5: Time series plots of indicators with adjusted variables



5.4.3 Stationarity

By inspection, the unadjusted data can be identified as non-stationary as most time series do not exhibit a constant mean or variance. Moreover, there is a clear trend displayed in some series. To confirm, the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test were used to identify stationarity. They are the most commonly used stationarity tests in time series analysis and jointly provide more insight into the variety of stationarity. While the ADF test is used to identify strict stationarity, the KPSS test is a statistical test for determining whether a time series is stationary around a deterministic trend otherwise known as trend stationary.

The ADF test is a statistical test used to determine if a unit root exists in a time series, a feature that indicates if series is non-stationary, meaning its statistical properties change over time. The null hypothesis of the ADF test is that there exists a unit root in the time series or that the time series is non-stationary. If the time series was stationary, the null hypothesis would be rejected in favour of the alternative hypothesis, that there is no unit root and the series is stationary. The

ADF test functions similarly to the other commonly used stationarity tests including Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test (Enders, 2014).

However, the KPSS test, functions opposingly. The KPSS test, tests for trend stationarity, allowing the time series to have a linear trend but constant mean and variance over time. Furthermore, it tests for the absence of a unit root. Thus, the null hypothesis is that the time series is trend stationary and no unit root exists, and the alternative hypothesis is that the time series is non-stationary. Conversely, the DF, ADF and PP tests evaluate the presence of a unit root, with the null hypothesis that the series possesses a unit root and, hence, is not stationary (Enders, 2014). As the time series variables display a clear trend, the KPSS test is most appropriate to determine stationarity.

As evident in Table 1, through the ADF test, the p-values are greater than 0.05. Thus, the null hypothesis fails to be rejected and the time series is non-stationary or has a unit root. As such, the ADF test suggests that all variables are non-stationary at the 5% level of significance. However, the p-value of CPI is 0.07. Thus, CPI is stationary at the 10% level of significance.

Furthermore, this result is supported by the KPSS test. At the 5% level of significance, each time series except CPI, was not stationary. As each p-value was smaller than 0.05, the null hypothesis (that the time series is trend stationary) is rejected in favour of the alternative hypothesis, that the series is not stationary. Similar to the ADF test, CPI was found to have a p-value of 0.06, greater than the significance level alpha of 0.05. Thus, the null hypothesis that CPI is stationary cannot be rejected. Therefore, CPI can be considered stationary at the 10% level of significance. The risk of rejecting the null hypothesis while it is true is 6%. As most of the variables are non-stationary, they must be addressed through the appropriate transformations to ensure the reliability of the SVAR model results.

Table 1: KPSS test on unadjusted data

Variable	ADF test		KPSS test	
	Test statistic	P-value	Test statistic	P-value
HPI_{it}	-0.3181	0.99	2.1478	0.01·
Interest $rate_{it}$	-2.3870	0.42	1.5853	0.01·
$REER_{it}$	-2.1841	0.50	1.2893	0.01·

Real GDP_{it}	-1.3543	0.84	2.2131	0.01·
CPI_{it}	-3.3319	0.07	0.4376	0.06
Real housing $loans_{it}$	-1.6685	0.71	2.1715	0.01·

Significance level codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '·' 0.1 ' ' 1

The least amount of transformations were applied to make the time series stationary so that information loss was minimised and the interactions between the variables were preserved. Thus, one difference was applied to each variable, and a logarithmic (log) transformation was applied to each variable to stabilise the time series over time.

The ADF test and KPSS test were repeated for each transformed time series. Only the variables HPI and real housing loans were non-stationary through the ADF test at the 5% level of significance, as seen in Table 2. After repeating the KPSS test, the p-value for each variable was found to be greater than the 0.05 significance level. Thus, the null hypothesis that the series is stationary, cannot be rejected and each variable is determined to be stationary by the KPSS test. However, the KPSS test is a unit root test that tests for the stationarity around a deterministic trend. Therefore, the variables display a deterministic trend and are trend stationary. The deterministic trend likely caused the ADF test to reject the null hypothesis that HPI and real housing loans were stationary.

Trend stationary time series are sufficient for VAR estimation. Indeed, Sims, Stock and Watson (1990) argued that the intention of applying the VAR methodology is to identify the interrelationships between variables rather than estimate the parameters. Applying further transformations to the data through differencing to remove the deterministic trend results in vital information regarding the co-movement of the variables being lost. Furthermore, it further removes the variables from the data-generating approach, which is important in the SVAR methodology.

Table 2: KPSS test on first differenced and logged data

Variable	ADF test		KPSS test	
	Test statistic	P-value	Test statistic	P-value
$\Delta L\ HPI_{it}$	-2.3337	0.44	0.1167	0.10
ΔL Interest $rate_{it}$	-4.4472	0.01·	0.3675	0.09
$\Delta L\ REER_{it}$	-4.3122	0.01·	0.0674	0.10

ΔL Real GDP_{it}	-4.4176	0.01·	0.0854	0.10
ΔL CPI_{it}	-5.7995	0.01·	0.0822	0.10
ΔL Real housing $loans_{it}$	0.0822	0.10	0.4195	0.07

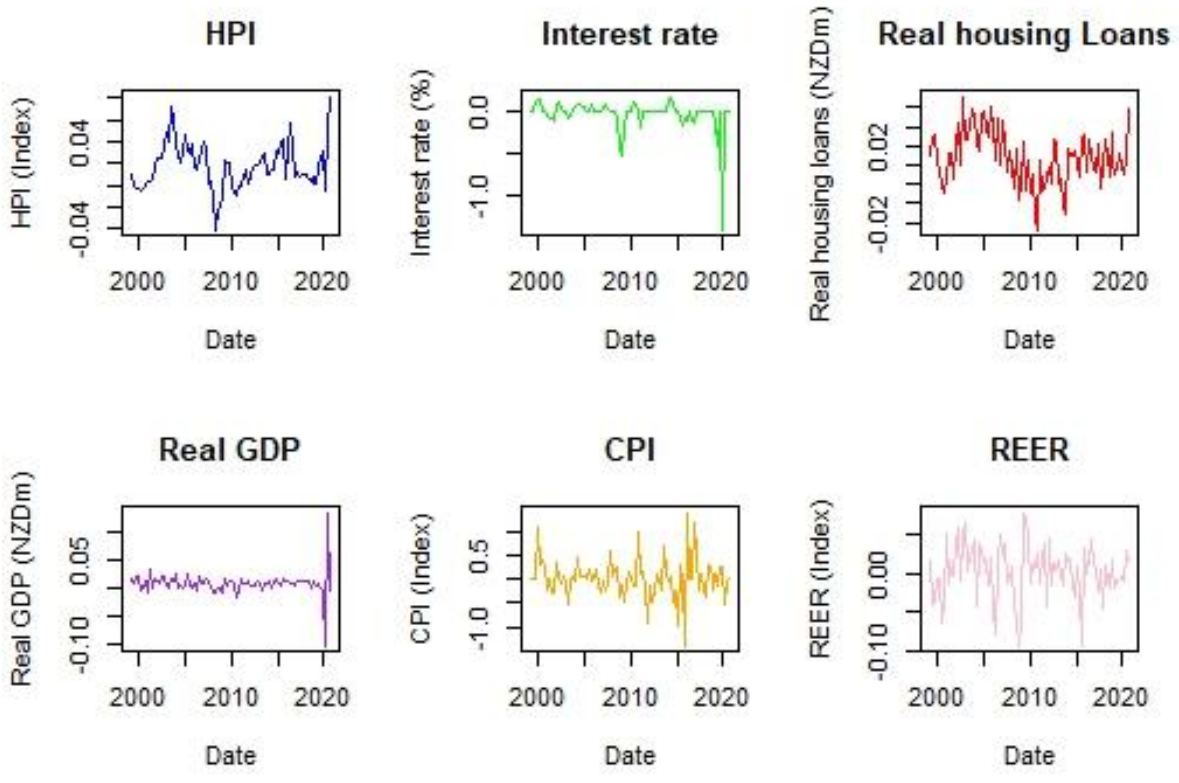
Significance level codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '·' 0.1 ' ' 1

Δ denotes a first difference transformation.

L denotes logarithmic transformation.

Furthermore, in Figure 6, where the first differenced and log-transformed time series are plotted, all have a more visibly constant mean and variance than before the transformation in Table 2. The differenced and log transformed data, which is trend stationary, is used in the modelling going forward in this research.

Figure 6: First differenced and log-transformed time series variables



5.4.4 Lag length selection

Thereafter, the first differenced and log-transformed indicators were bound to allow the variables to be run together as a model to identify the optimal lag length. The Akaike Information Criterion (AIC), Hannan-Quinn Information Criterion (HQ), Schwarz Information Criterion (SIC), and Final Prediction Error (FPE) were calculated and the results of which are shown in Table 3. A lag length of two quarters (6 months or half a year) was chosen based on the consensus from two of the four selection criteria. A lag length of two is sufficient to effectively capture the relevant time dependencies among the variables, laying a solid foundation for the subsequent SVAR analysis. This aligns with the economic theory that accepts interest rates affect the economy with a lag (Dupor, 2023). Moreover, it is consistent with the results of (Elbourne, 2008) and the New Keynesian Mundell-Fleming framework presented by Carlin & Soskice (2014b).

Table 3: Lag selection

AIC(n)	HQ(n)	SC(n)	FPE(n)
8	2	1	2

5.4.5 Estimation of base VAR

Before conducting the SVAR analysis, a base VAR model is estimated. Development of the VAR model served as a preliminary step in the research process. Estimating the VAR model allows insights into the contemporaneous relationships between the variables without imposing specific structural constraints. Moreover, it captured the dynamic interactions between the variables. The VAR model provided a foundation for understanding the short-term dynamics and interdependencies among the variables.

In Table 4, the estimated base VAR model, from the difference and log transformed data discussed above, yielded moderately significant results. The data is sufficiently fit for the model with a reasonable Multiple R-squared of 0.6849 and Adjusted R-squared: 0.6272. In addition, it is likely that the regression is not spurious as the F-statistic's p-value is $3.94e^{-13}$. This means that the null hypothesis can be rejected at the 1% significance level, indicating there is a statistically significant relationship between the independent variables and the dependent variables in the VAR model at a 1% level of significance. This is sufficiently robust for further analysis. Additionally, six variables were highly significant.

Through the estimated VAR, HPI is shown to be the most strongly dependent on the previous period's house price (HPI_{it-1}) although, at weak significance. This implies that house prices are sticky or slow to adjust following a shock. Furthermore, the strong positive relationship with the HPI's lagged value means that growth in the previous period implies that HPI will make growth in the next period very likely. This cyclical behaviour is characteristic of a speculative bubble.

There exists a delayed reaction from interest rates to HPI with a positive impact from the previous period but negatively from the interest rates prior two periods. This is also significant at the 5% level. Furthermore, house prices in the current period are less significantly dependant on historic inflation (measured by CPI) and interest rates. Hence, any monetary policy decision will require at least two quarters for the full impact on HPI to be realised. In addition, HPI will be slow to adjust, as the last two periods' inflation rate as well as interest rates are strongly affecting it.

Table 4: Base VAR stylised facts[1]

Significant variable and lag	Estimate	Std. Error	t value	Pr(>|t|)	
$\Delta L\ HPI_{it-1}$	$8.10e^{-01}$	$1.29e^{-01}$	6.294	2,25E-08	***
$\Delta L\ i_{it-1}$	$1.50e^{-02}$	$8.16e^{-03}$	1.841	0,06978	·
$\Delta L\ CPI_{it-1}$	$-7.28e^{-03}$	$3.58e^{-03}$	-2.035	0,04561	*
$\Delta L\ i_{it-2}$	$-3.04e^{-02}$	$1.06e^{-02}$	-2.859	0,00557	**
$\Delta L\ CPI_{it-2}$	$-9.00e^{-03}$	$3.56e^{-03}$	-2.527	0,01374	*
Constant	$6.97e^{-03}$	$3.95e^{-03}$	1.763	0,08212	·

Significance level codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '·' 0.1 ' ' 1

Residual standard error:	0.01246 on 71 degrees of freedom		
Multiple R-Squared:	0.6849	Adjusted R-squared:	0.6272
F-statistic:	11.87	P-value:	$3.94e^{-13}$

5.4.6 SVAR restriction matrix

[1] See full summary statistics for the VAR analysis in Appendix B

Building upon the VAR created above, an SVAR identification scheme based on contemporaneous theoretical restrictions has been applied. The model contains $n \times n(n+1) \div 2$ free parameters to be estimated. By normalising the restriction matrix's diagonal elements to one, at least $n \times n(n-1) \div 2$ restrictions are required to achieve identification (Sims & Zha, 1998). Therefore, 23, greater than the minimum of 15 restrictions have been enforced, as evident in Table 5, in the form of zero and one restrictions. As an SVAR approach with non-recursive restrictions is employed and the Cholesky decomposition is not used, a lower triangular restriction matrix does not need to be assumed. The SVAR allows any structure as long as there are sufficient restrictions. Restrictions have been based on economic theory as well as the restrictions applied in (Robstad, 2018), (Elbourne, 2008) and (Kim & Roubini, 2000).

HPI$_{it}$

In the restriction matrix, HPI is allowed to vary contemporaneously with most of the variables except for CPI, which reacts with a delay as the public is only aware of inflation retrospectively (Elbourne, 2008). Interest rates and real housing loans affect the affordability of purchasing a house thus, its demand and price. REER and real GDP also impacts the buyer's relative wealth, affordability and demand for housing.

Interest rate$_{it}$

Interest rates are modelled as a response by the RBNZ reacting solely to CPI. Central banks have more information regarding price fluctuations within the country than the general public; thus, they can react faster (Elbourne, 2008). Moreover, the RBNZ mandate to include house prices in their monetary policy decisions changed only in 2021. Zero restrictions have been imposed on the impact of all other variables on interest rates (RBNZ, 2021b).

REER$_{it}$

The REER is a broad economic aggregate; thus, it will have a negligible in-period reaction to the HPI or real housing loans. Furthermore, as a real variable, the price effect has been removed. Thus, REER will not be impacted by CPI. However, interest rates impact the return on domestic investments thus, impacting the demand for currency and the exchange rate.

Real GDP$_{it}$

Similarly, the real GDP has been allowed to respond to interest rates because of its role as the monetary policy mechanism and the REER due to the impact of external demand. Real GDP has been restricted from HPI and CPI because it is a real variable for which price changes have been controlled.

CPI$_{it}$

HPI is a component of New Zealand's CPI and is therefore, not restricted (RBNZ, 2024b). While price fluctuations have been disentangled from real GDP, its underlying growth is a determinant of inflation in the short run (while there is likely no effect in the long run); therefore, it has been allowed to impact CPI (Agarwal & Baron, 2023). While interest rates are the primary mechanism through which inflation is managed, it does impact CPI with a delay hence the restriction. Similarly, REER and real housing loans have also been restricted.

Real housing loans$_{it}$

Finally, real housing loans are primarily driven by HPI and interest rates, especially in an economy experiencing a real estate bubble (Emanuelsson, et al., 2018). Real housing loans have been restricted from reacting to the remaining variables.

Table 5: Restriction matrix

	$\Delta L\ HPI_{it}$	$\Delta L\ Interest\ rate_{it}$	$\Delta L\ REER_{it}$	$\Delta L\ Real\ GDP_{it}$	$\Delta L\ CPI_{it}$	$\Delta L\ Real\ housing\ loans_{it}$
$\Delta L\ HPI_{it}$	1	β^0_{12}	β^0_{13}	β^0_{14}	0	β^0_{16}
$\Delta L\ Interest\ rate_{it}$	0	1	0	0	β^0_{12}	0
$\Delta L\ REER_{it}$	0	β^0_{32}	1	β^0_{34}	0	0
$\Delta L\ Real\ GDP_{it}$	0	β^0_{42}	β^0_{43}	1	0	0
$\Delta L\ CPI_{it}$	β^0_{51}	0	0	β^0_{54}	1	0
$\Delta L\ Real\ housing\ loans_{it}$	β^0_{61}	β^0_{62}	0	0	0	1

5.4.7 SVAR estimation

Using these restrictions, the coefficient matrix in Table 6 is estimated. It shows a negative relationship between interest rates and all other variables. The coefficient matrix aligns with macroeconomic theory in many cases, showing that REER and real GDP impact HPI positively. Unexpectedly, interest rates have a weakly positive relationship with HPI, an effect that is also observed in the impulse response functions.

Table 6: SVAR coefficient matrix

	$\Delta L\ HPI_{it}$	$\Delta L\ Interest\ rate_{it}$	$\Delta L\ REER_{it}$	$\Delta L\ Real\ GDP_{it}$	$\Delta L\ CPI_{it}$	$\Delta L\ Real\ housing\ loans_{it}$
$\Delta L\ HPI_{it}$	1	0.29	6.28	30.17	0	-88.74
$\Delta L\ Interest\ rate_{it}$	0	-1	0	0	-2.68	0
$\Delta L\ REER_{it}$	0	-5.67	1	-19.42	0	0
$\Delta L\ Real\ GDP_{it}$	0	-1.64	-33.59	1	0	0
$\Delta L\ CPI_{it}$	-29.58	0	0	93.49	-1	0
$\Delta L\ Real\ housing\ loans_{it}$	79.82	-0.35	0	0	0	1

6. Discussion of Results

The SVAR model has been applied to estimate the impact of the interest rate on house prices thus, evaluating the viability of using monetary policy to moderate house price bubbles. Generating the SVAR model Impulse Response Functions (IRF) provides an understanding of how house prices (as measured by HPI) react to interest rate shocks. Overall, all IRFs converged to zero within 12 periods or quarters, indicating stationarity, as shocks do not persist in the long run. Further, the IRFs displayed significant volatility in the short run, narrowing in the long run.

6.1 Analysis of the IRFs

6.1.1 Interpretation of confidence intervals

Following the standard methodology, the IRFs have been computed, surrounded by upper and lower 95% confidence bands to illustrate the uncertainty associated with the estimated response coefficients, given the sample. They are commonly used as an informal check for statistical significance of the IRF with the null hypothesis that shock generates no response in the outcome (Inoue, et al., 2023). Even though the IRFs converge to zero, based on this informal assessment, most of the IRFs derived in this research are not statistically significant. This is because, at a 5% level of significance, the null hypothesis that each IRF coefficient is statistically different from zero cannot be rejected as zero falls within the 95% confidence bands. Notably, the exception is the IRF of a real housing loan shock on HPI, which is discussed in more detail in 6.3.4 Shock from the real housing loans to the HPI. As such, care must be maintained when drawing inferences from non-significant results.

Nevertheless, over the last two decades, a significant body of knowledge has emerged, indicating that the joint hypothesis testing of whether the IRF coefficients are statistically different from zero or not, cannot be assessed using these confidence bands (Inoue, et al., 2023). Research initiated by Jordà in 2009 has shown that estimating IRFs using local projections as an alternative to the traditional SVAR approach is more robust to potential model misspecification (Olea, et al., 2024). Unlike the traditional IRF which has been used in this research, local projections estimate impulse responses directly at each horizon (Jordà, 2023).

To ensure computative simplicity, the traditional SVAR approach and IRF confidence intervals are used in this research. However, future research into the impact of monetary policy on house prices may benefit from considering a local projection driven approach.

6.1.2 Interpretation of IRF coefficients

In addition, all variables used in this SVAR model have been logarithmically (log) transformed to ensure stationarity; as such, it is a log-linear model (both the dependant and independent variables have been log transformed). Therefore, the interpretation of the estimated coefficients are percentage changes, and the y-axis of each IRF is a percentage change. That is, for a 1% change in the independent variable, the dependent variable changes by the estimated coefficient of the independent variable as a percentage. For example, take the simple regression of $y = \beta_1 x$, where x and y, the independent and dependent variables respectively, have both been log transformed. Then, a 1% change in x (the independent variable), results in a β_1% change in y (Wooldridge, 2013).

The IRF is computed using the estimated coefficients produced by the SVAR model. Thus, the IRF coefficients are interpreted as a percentage change or an elasticity or alternatively a growth rate at that point. Therefore, a 1% shock in the independent variable results in the dependent variable changing by the coefficient as a percentage. As each period is a quarter, it is a quarter-on-quarter (Q/Q) percentage change.

Furthermore, to expedite the interpretation of the IRFs, they have been presented both in the standard IRF form and cumulatively. In the standard IRF form, the coefficient is interpreted as above – a 1% change in the independent variable results in the dependent variable changing by the coefficient as a percentage. In its cumulative form, the IRF show the cumulative impact of a 1% shock on the independent variable at each quarter. The cumulative IRF shows the overall change at a point in time.

6.2 Shock from the Interest Rate to the HPI

The reaction of HPI as a result of a shock from the interest rate is shown in Figure 7. A 1% positive shock from the interest rate (contractionary monetary policy) results in HPI growing at an increasing rate for the first three quarters, peaking at a 0.005% change in the third quarter. Thereafter, the Q/Q percentage change decreases gradually, crossing zero after the eighth quarter. Thereafter, the percentage change of HPI remains negative yet close to zero. Considering the cumulative IRF of a shock from the interest rate on the HPI in Figure 8, after approximately six quarters, the 1% shock from the interest rate results in a cumulative 0.02% increase in HPI, after which the percentage change in HPI stabilises, decreasing slightly. It must be remembered that the results of this IRF are not statically significant. While it may suggest a relationship, no inference can be drawn.

Figure 7: IRF of a shock from the interest rate on the HPI

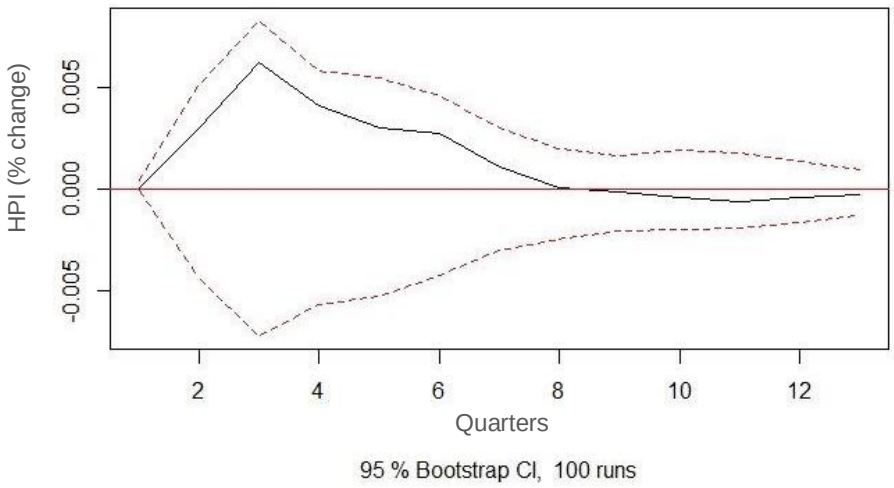
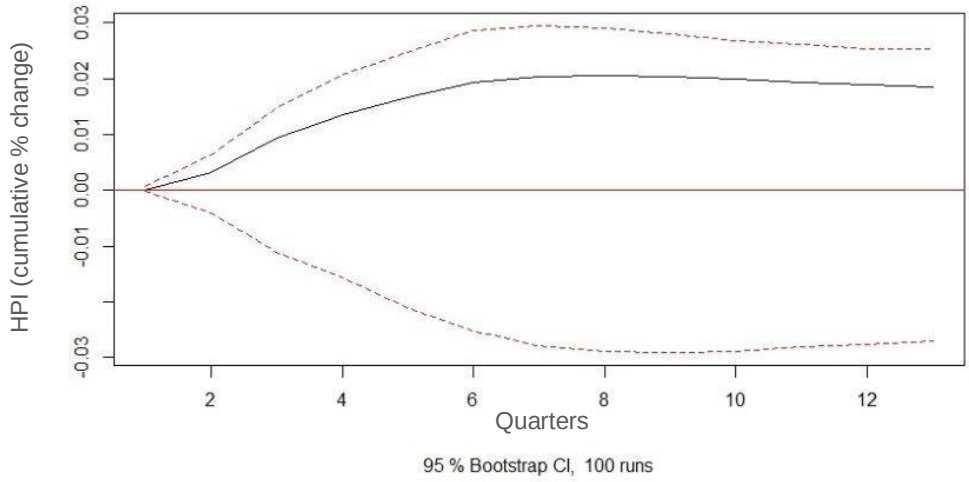


Figure 8: IRF of a shock from the interest rate on the HPI (cumulative)



6.2.1 Short-run dynamics of a shock from the interest rate to the HPI

In the short run[2], for the first two quarters or six months, house prices, grow, with a positive percentage change, in reaction to a positive interest rate shock. Thus, contractionary monetary policy appears to have the converse effect to the outcome intended by the central bank, with house prices rising slightly to approximately 0.02% higher than before the shock. While the transmission mechanism between interest rates and house prices (the asset price channel) is complex, traditional economic theory would suggest that increasing interest rates will increase the cost of borrowing. The heightened cost of borrowing thereby, increases the mortgage cost, reducing the demand for and subsequently the price of housing. However, this is not seen in the empirical results. Furthermore, it is likely due to the price puzzle effect materialising in the VAR analysis.

[2] For the purposes of this analysis, the short run is defined as the period from zero to two quarters or up to six months after the shock. The medium run is defined as the period from quarters two to eight or six to twenty-four months. Finally, the long run is everything after the medium run or quarter eight onwards.

6.2.2 Medium run dynamics of a shock from the interest rate to the HPI

In the medium run, the trajectory of HPI growth reverses after the third quarter. While still positive, the percentage change of HPI trended downwards, following the interest rate shock. The somewhat unanticipated increase in house prices due to the positive interest rate shock persists from the short run into the medium run. The positive but decreasing percentage change of HPI results in the cumulative IRF beginning to flatten in Figure 8.

After the HPI growth peaks in the third quarter, it makes a gradual decline towards zero, breaching the negative territory in quarter 8 (24 months). The downward trend indicates a stabilisation of the HPI following the interest rate shock. In Figure 8, house prices are noted to be "sticky", adjusting slowly after the peak.

6.2.3 Long-run dynamics of a shock from the interest rate to the HPI

Between the eighth and twelfth quarters (two and three years), the percentage change of house prices gradually declines to just below zero. In addition, the volatility of the IRF, which was significantly high in the short run, decreases significantly in the long run, indicating that the impact of the interest rate shock on HPI has largely dissipated. Cumulatively, the house prices are approximately 0.02% higher than prior to the shock with prices slowly decreasing.

6.2.4 The price puzzle in HPI's reaction to an interest rate shock

The unexpected increase in house prices due to contractionary monetary policy is a well-documented phenomenon in VAR analysis known as the price puzzle and discussed in 2.9 Price puzzle: unexpected effects of interest rate shocks in VAR analysis. While the increase in HPI as a result of an interest rate shock seen in Figure 8 are not in line with standard economic theory, it is commonly observed in empirical research. The price puzzle effect may be inherent to the data. However, it is also possibly due to the misspecification of the VAR model. Even though precautions were taken to avert the price puzzle effect, including theoretical restrictions to the SVAR and the incorporation of additional variables, this effect has persisted. Indeed, this effect has been observed strongly in macroeconomic analysis based on New Zealand's data

(Chadwick & Nahavandi, 2022) and may be an accurate representation of New Zealand's economy however, further research would be needed to show this definitively.

Future research on the topic may find a more optimal model specification to be useful, potentially including a high volatility commodity price index to incorporate unobserved central bank expectations (Estrella, 2015). In addition, larger models with more variables prove more effective in mitigating the price puzzle effect (Bernanke, et al., 2005). Alternatively, estimating the model on shocks rather than the standard variables transformed to be stationary may be useful to capture unobserved central bank information. However, other research has suggested that approaches different to VAR modelling may be better suited to the analysis of monetary policy in the contemporary economy (Bishop & Tulip, 2017). Even still, rising house prices in response to a monetary policy shock may be an accurate reflection of the data.

6.2.5 Alternative justifications for an interest rate shock increasing HPI

Even though the price puzzle effect surfacing in VAR analysis is common, following an unexpected interest rate hike, house price may rise for a variety of reasons. Notably, houses and other large assets (relative to an individual's wealth) have a longer earnings time horizon than a short-run interest rate, such as the one used in this research, can capture. A negative shock to the interest rate may also raise asset prices by decreasing the discount rate when determining the present values of future earnings. This is especially true if the industry borrows at a rate different from the central bank's interest rate (Ubl, 2014). This often applies to housing loans or the mortgage market, where longer-term, market-specific interest rates are often used.

Similarly, contractionary monetary policy may signal to agents that an inflationary period is forthcoming (Bekaert & Wang, 2014). In an attempt to hedge the expected price increases, demand for houses and the price of houses will increase in the short run, as buyers in the market bring housing purchases forward. This will result in the bidding-up of house prices temporarily before a decline.

In the short run, increasing interest rates increase the building costs of houses currently bunder construction, as well as those planned in the immediate future. While the house may be purchased at a longer-term interest rate, companies building the houses have shorter time

horizons and will be more affected by an increased short-term interest rate (Mbachu & Taylor, 2014). Higher building costs will be passed on to the buyer especially within an economy with a history of rapidly increasing house prices. Furthermore, even existing houses on the market will adjust their prices upwards concomitantly, with newly built houses. This is especially applicable within the context of a speculative bubble.

6.3 Shocks from Selected Indicators on the HPI

6.3.1 Shock from the HPI to the HPI

When applying a 1% shock from the HPI and observing its own IRF, Figure 9 indicates there is a slight positive growth in HPI during the short run then the percentage change decreases into the negative territory during the medium run. The IRF remains in the negative territory over the long run, where the hour prices change only marginally, stabilising at 0.005% lower than its initial level, as shown in Figure 10. While this IRF is also not significant, a sudden increase in house prices may immediately increase demand, similar to the above mentioned contractionary monetary policy. The positive shock exists only in the short run, indicating that HPI is "sticky" and slow to change. Thereafter, the percentage change of HPI falls into the negative territory, with the cumulative effect being negative after twelve quarters.

Figure 9: IRF of a shock from the HPI on the HPI

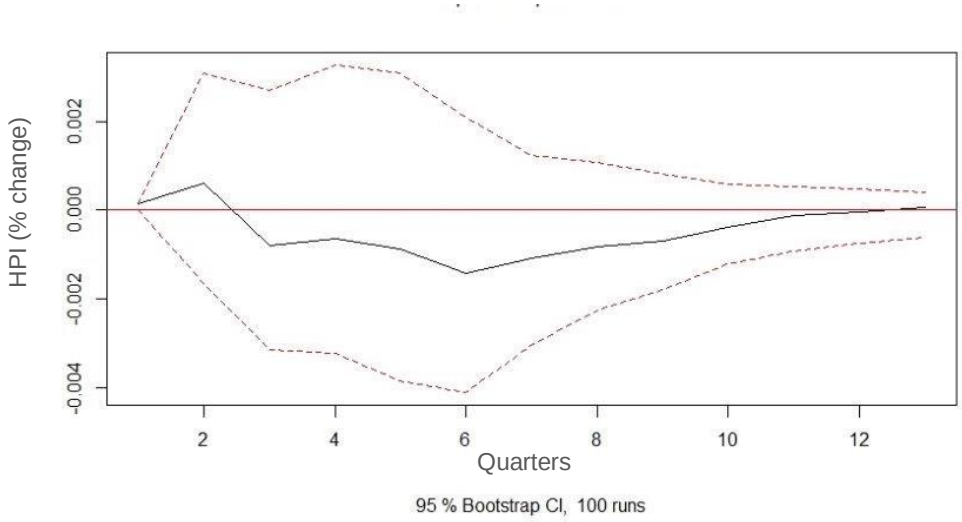
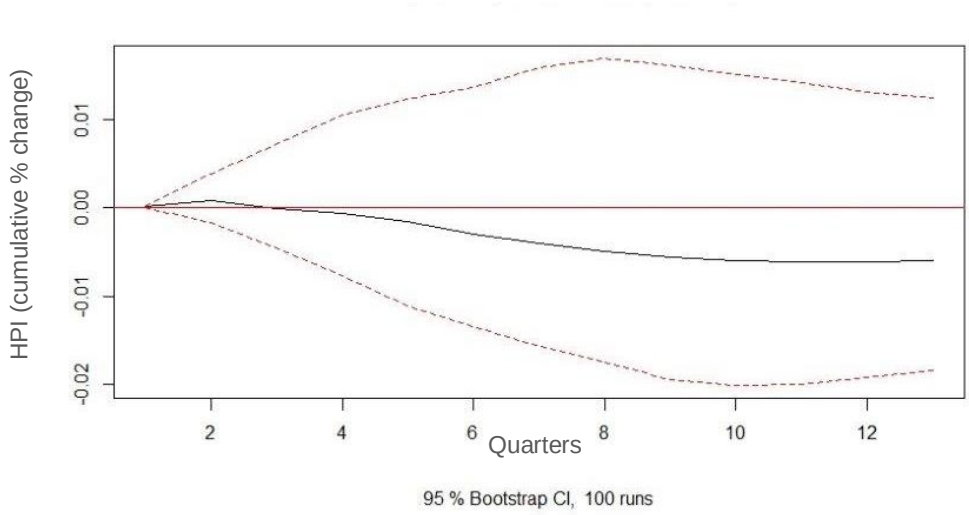


Figure 10: IRF of a shock from the HPI on the HPI (cumulative)



6.3.2 Shock from the REER to the HPI

By shocking REER, a particularly dynamic relationship emerges in Figure 11. The positive REER shock incites an immediate negative percentage change in house prices, followed by a significant increase after two quarters in the medium run. The volatility continues from the medium run into the long run. Overall, Figure 12 shows that there is small positive impact of in response to the 1% shock from the REER on HPI. As the REER is a broad aggregate that captures the impact of the rest of the world in this model, the relationship between it and house prices is multifaceted. While acting primarily in the medium run, a positive shock or appreciation in the REER may bolster domestic demand, as holders of the NZD would perceive themselves as more wealthy. In the short run, after the positive REER shock, foreign buyers will find domestic goods, including houses, more expensive immediately resulting in its negative percentage change. However, in total HPI increases slightly in response to the 1% positive HPI shock.

Figure 11: IRF of a shock from the REER on the HPI

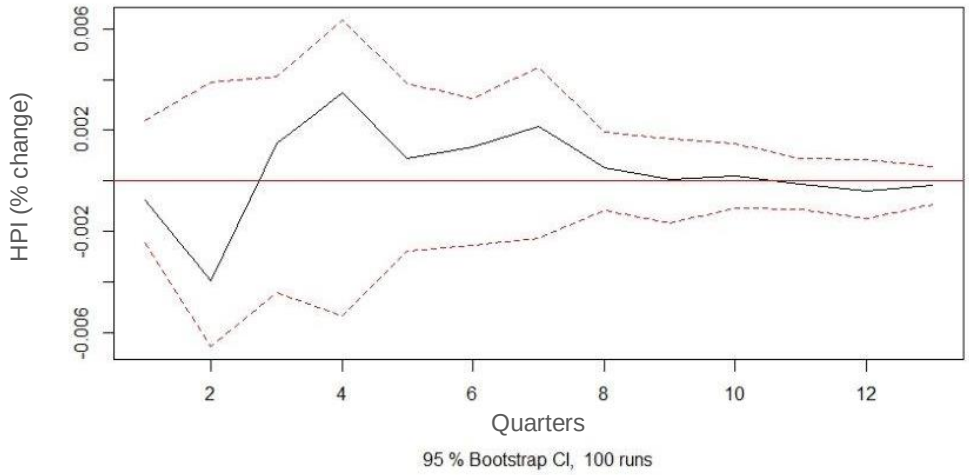
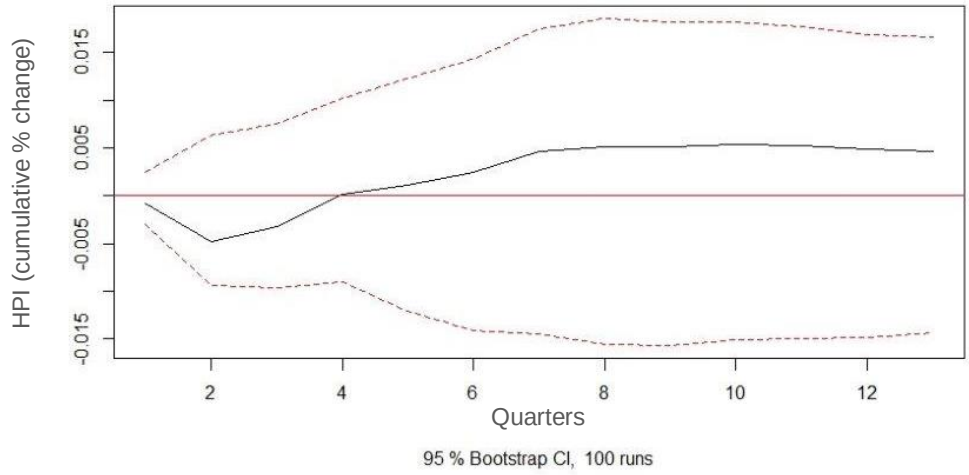


Figure 12: IRF of a shock from the REER on the HPI (cumulative)



6.3.3 Shock from the CPI to the HPI

Figure 13 demonstrates that a positive shock from the CPI causes a negative percentage change in HPI in the short run. After which, Figure 13 shows the growth rate of HPI fluctuates around the original level, with the effect of the shock largely diminishing in the medium run. While the variance is prominent at first, it narrows quickly. Overall, the cumulative IRV in Figure 14 indicates that after twelve quarters, there is a slight negative impact on house prices as a result of the positive 1% CPI shock. Notably, this relationship is not unexpected in economic theory. After a CPI shock increases prices, purchasing power reduces, making the purchase of housing difficult reducing housing demand and prices.

Figure 13: IRF of a shock from the CPI on the HPI

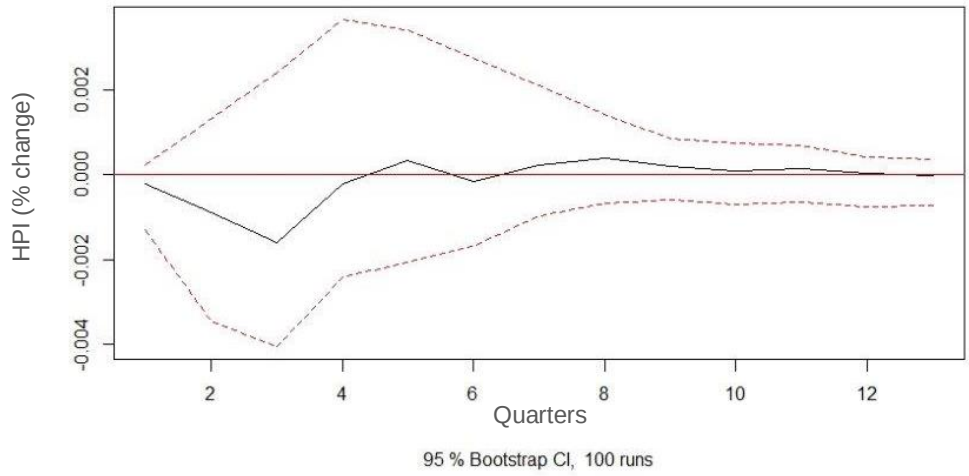
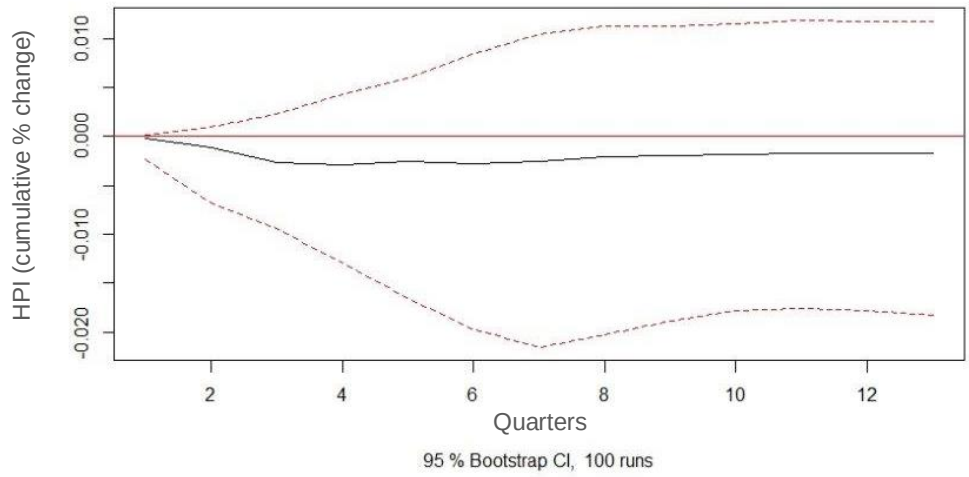


Figure 14: IRF of a shock from the CPI on the HPI (cumulative)



6.3.4 Shock from the real housing loans to the HPI

The IRF of a 1% shock from the real housing loans to the HPI is the only IRF that is significant by the heuristic check of statistical significance for IRFs. The confidence intervals do not enclose zero until approximately quarter five, where the null hypothesis that the IRF is statistically different from zero cannot be rejected. A positive relationship between real housing loans and house prices has been noted. This indicates that managing housing loan stock is a potentially effective avenue for controlling house prices, consistent with the body literature that suggests applying macroprudential policy to house price bubbles (BIS, 2023).

House prices immediately grow at a positive rate, in the short and medium run, in response to a positive real house price shock. The percentage change of HPI slowly decreases until it dips below zero after the seventh quarter. The percentage change remains negative, but close to zero through the long run.

By quarter six, when the IRF is no longer significant, there is a cumulative 4% increase in house prices in response to a 1% increase in real housing loans as seen in Figure 16. Housing loan stock is used to fund the purchase of houses thus, proxying demand, increasing demand will result in house prices rising. Moreover, a positive relationship is expected between housing loans and house prices, as more than two-thirds of houses in New Zealand are bought on debt (Smith, 2019).

Figure 15: IRF of a shock from real housing loans on HPI

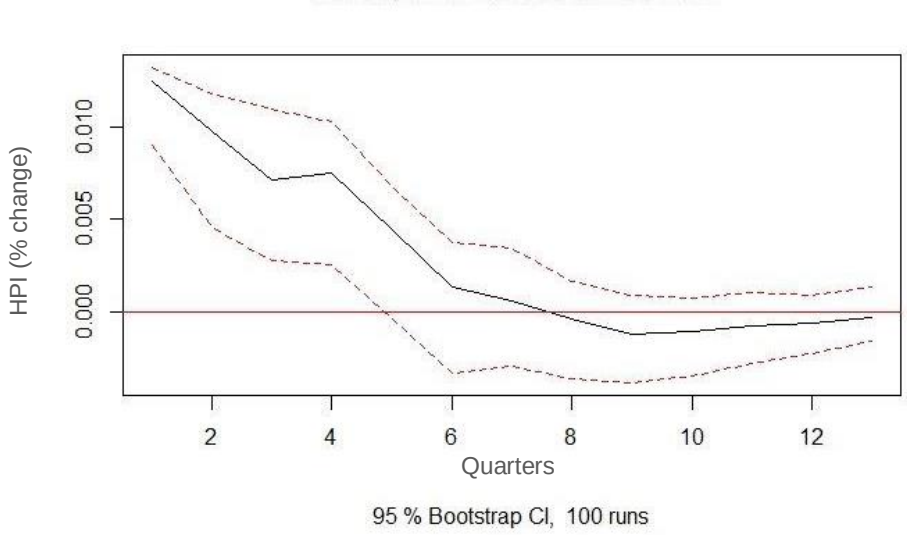
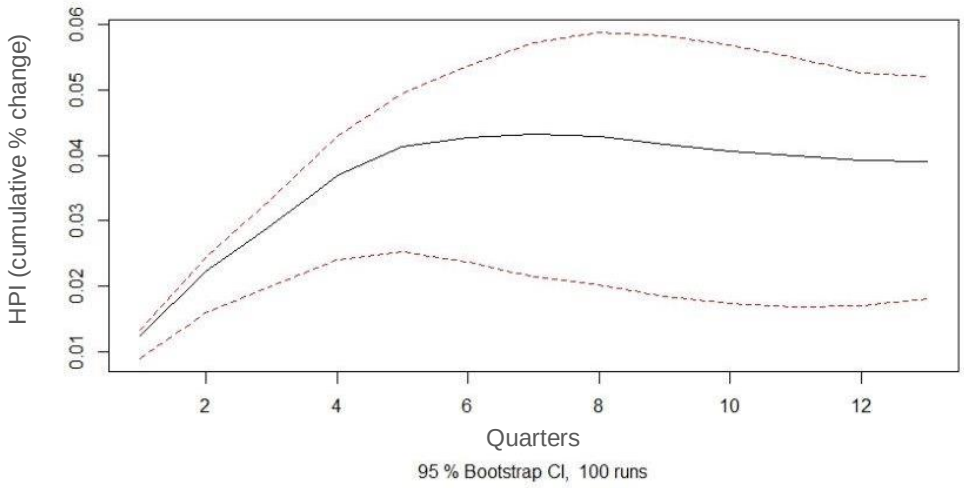


Figure 16: IRF of a shock from real housing loans on HPI (cumulative)



6.4. Shocks from the Interest Rate on Selected Indicators

Using monetary policy, through the interest rate, to manage house price bubbles is often cautioned against in economic literature. Interest rates can be considered a "blunt tool" that indiscriminately affects the whole economy, unable to target the particular sector with the asset price bubble (Brunnermeier & Schnabel, 2015). The following IRFs show the impact of a 1% positive interest rate shock on the CPI, real GDP and real housing loans. It is used to investigate the potential for spill-over effects from the application of contractionary monetary policy on the greater economy when trying to target house prices. While useful to provide insight into the nature of the relationship between monetary policy and house prices, none of the following graphs are statistically significant.

6.4.1 Shock from the interest rate to the CPI

Interest rates are traditionally used to manage inflation, measured by the CPI. As expected, a positive shock from interest rates (contractionary monetary policy) results in an immediate strong negative percentage change in CPI in the short run, as evident in Figure 17. Through the short run, the strongly negative percentage change of CPI increases almost to zero by the medium run. After which, the CPI percentage change fluctuates around zero in the long run. Figure 18 shows that there is an immediate 0.4% decrease in CPI as a result a 1% positive shock from the interest rate. This effect persists though the long run.

A positive interest rate shock, or contractionary monetary policy is expected to have a negative impact on monetary policy through standard economic theory by reducing the aggregate demand in the economy (Carlin & Soskice, 2014b).

Figure 17: IRF of a shock from the interest rate on the CPI

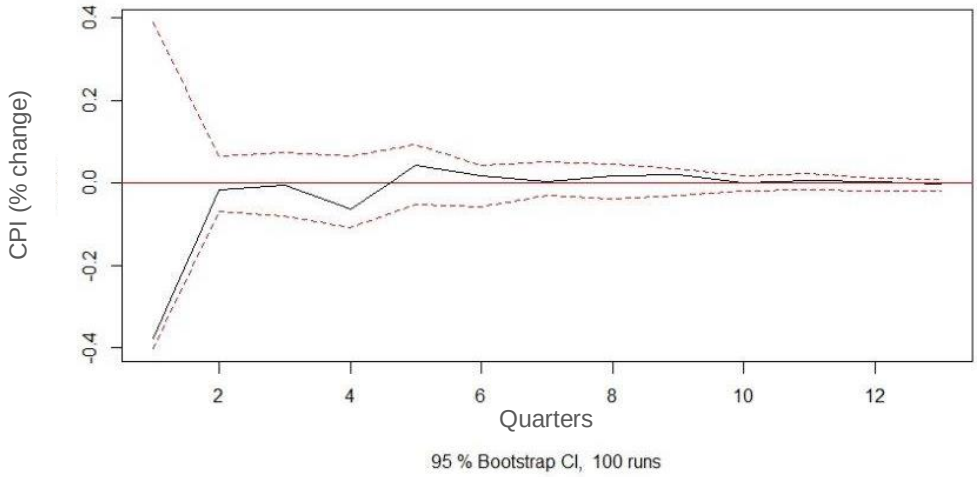
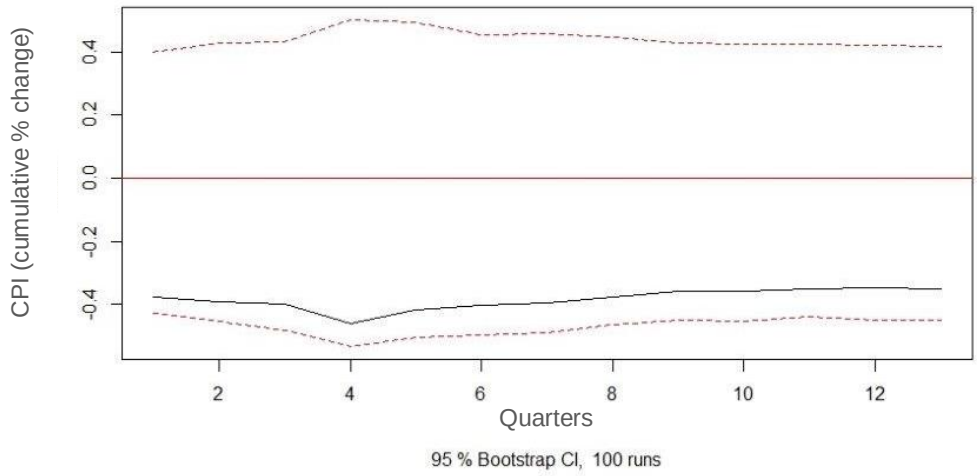


Figure 18: IRF of a shock from the interest rate on the CPI (cumulative)



6.4.2 Shock from the interest rate to real GDP

The spill-over effects of an interest rate shock become apparent when considering the real GDP IRF in Figure 19. While there is significant volatility in the short to medium run, the growth of real GDP following the interest rate shock does dissipate after eight quarters or two years. Real

GDP percentage change is reduced immediately with the positive interest rate shock or contractionary monetary policy, which is in line with mainstream economic thought. It highlights the broader economic impacts, that may result from using the interest rate to manage a house price bubble.

Figure 20, the cumulative impact of a shock from the interest rate on real GDP indicates that in the short run, real GDP suffers as a result of the increase in interest rates, which results in an overall negative percentage change in real GDP. This abates slowly, with a slight positive percentage change, from the base, seen after the fifth quarter.

Figure 19: IRF of a shock from the interest rate on real GDP

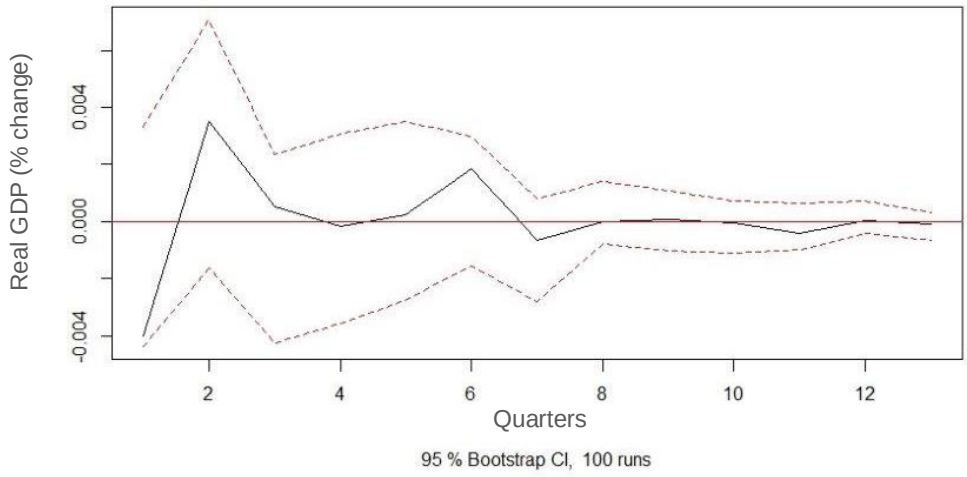
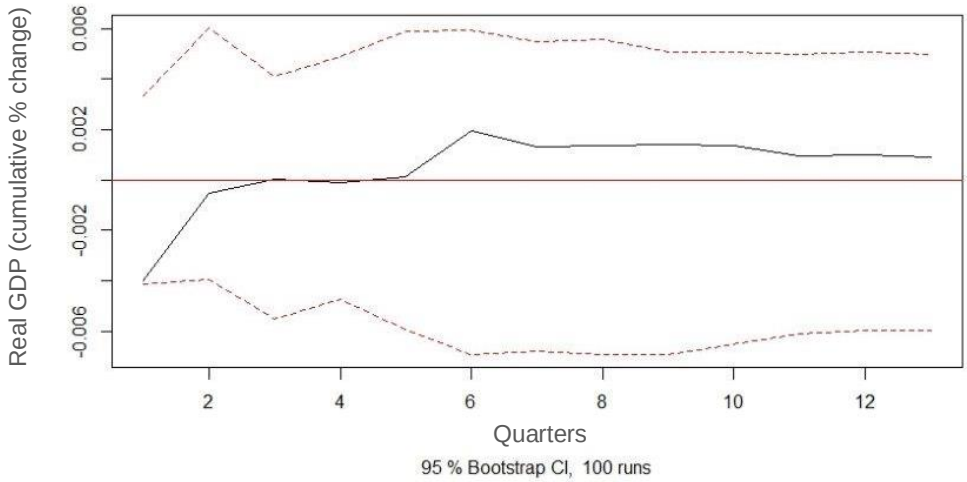


Figure 20: IRF of a shock from the interest rate on real GDP (cumulative)



6.4.3 Shock from the interest rate to real housing loans

The 1% interest rate shock caused the growth of real housing loans to decrease immediately as seen in Figure 21. The percentage change increases from the negative territory, becoming positive after the third quarter, where it remains until quarter 10, where it dips slightly back into the negative. Similarly, the cumulative exposition in Figure 22 shows that housing loan stock briefly decreases before increasing to 0.005% above the base in the long run. The negative relationship between interest rates and loan stock is expected as an interest rate increase means the cost of debt increases thus, the demand for housing loans falls. However, housing loan stock increases in the long run, indicating that there may be other factors acting on the demand for housing loans and by extension, on house prices. Likely, these are the impacts of the speculative bubble in the housing market.

Figure 21: IRF of a shock from the interest rate on real housing loans

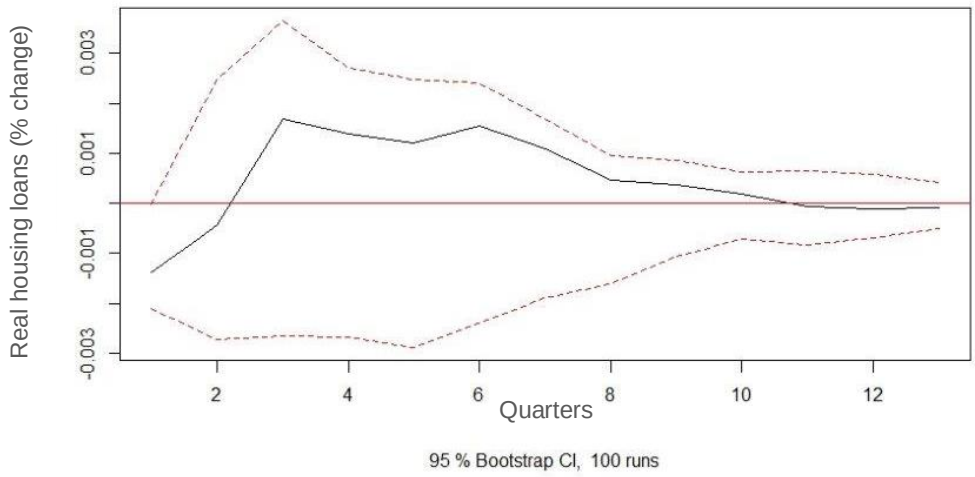
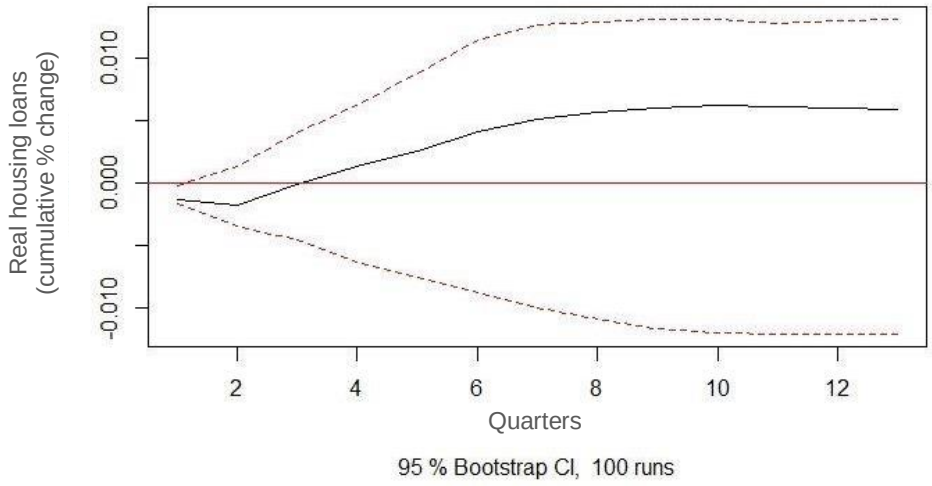


Figure 22: IRF of a shock from the interest rate on real housing loans (cumulative)



6.5 Forecast Error Variance Decomposition

Figure 23 shows the Forecast Error Variance Decomposition (FEVD) for the variables modelled by the SVAR. In this investigation of the application of the interest rate to moderate house price bubbles, the FEVD is useful to understand the intertwined relationships between the variables. It shows the contribution from shocks in each variable as the total area of the bar for each quarter.

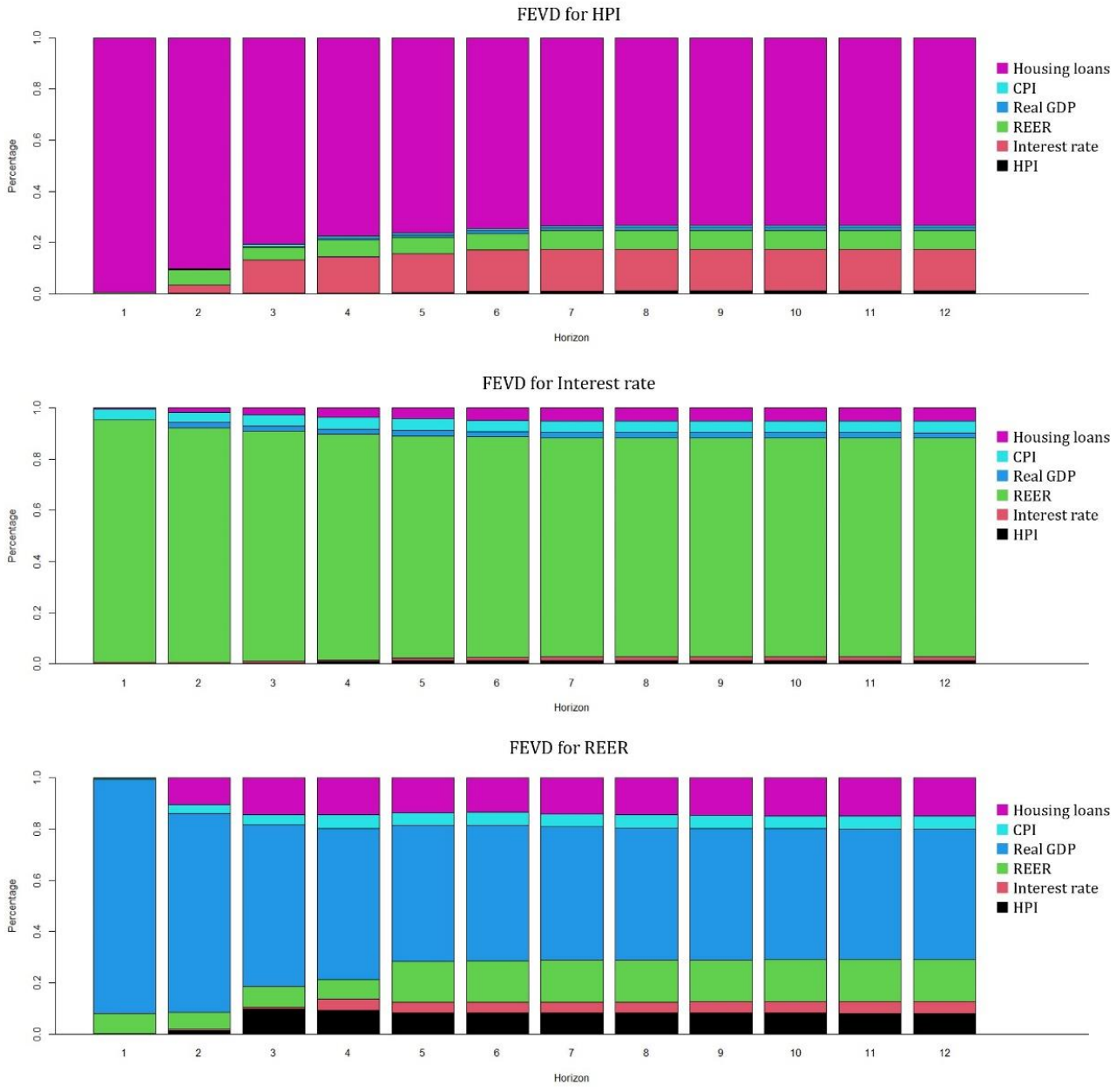
By considering the FEVD below, it is evident that approximately all of the variation in the HPI arises from real housing loan shocks in the first quarter. Over time, this proportion decreases, giving away to the interest rate, followed by the REER and real GDP. This is in line with the current understanding of housing markets where houses, a very large asset relative to a household's wealth, must be purchased on debt (Emanuelsson, et al., 2018). In addition, the IRF analysis above revealed that HPIs coefficients were statistically significant for the first five periods following a positive 1% monetary policy shock.

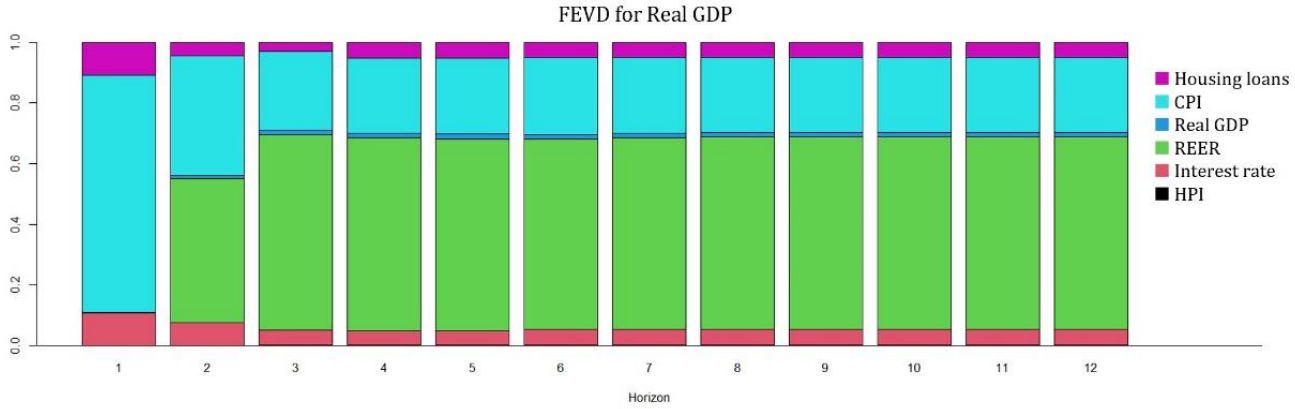
Investigating the real housing loans FEVD shows that variance in the HPI is responsible for the majority of the variation in real housing loans. The cyclical relationship where real housing loans are the largest source of variance for HPI and HPI is the largest source of variance for real housing loans is likely a result of the speculative bubble in the New Zealand housing market. This indicates that interventions directly targeting housing loans, such as the loan-to-value ratio, and other macroprudential policies, can be effective in managing the effects of the bubble. The loan-to-value ceiling macroprudential policy is particularly effective in managing booms driven by robust and credit-driven activity in the real estate market (Ryoo, 2016).

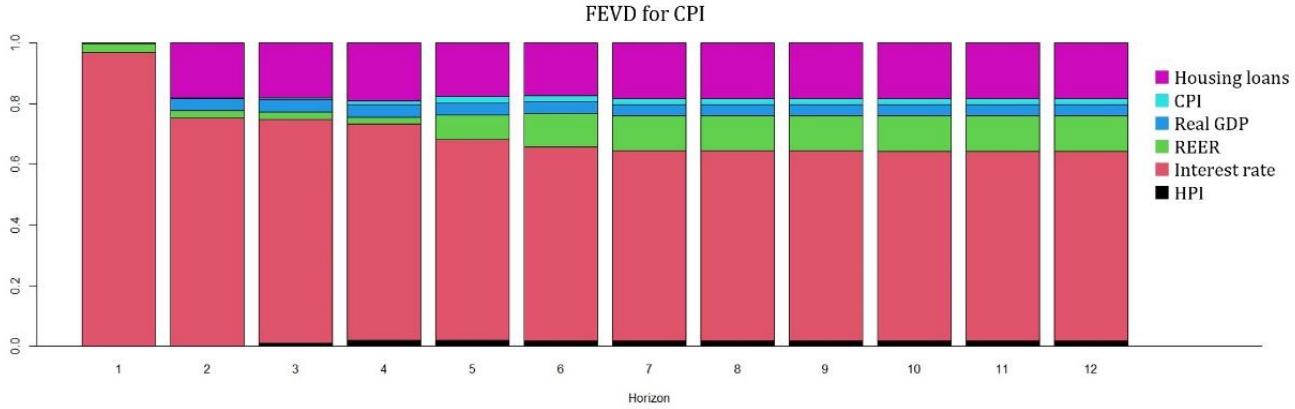
The FEVD provides further insight into the lagged effects in the model. The FEVD for HPI in Figure 23 shows that interest rates only become a significant source of variance after quarter three. Prior to that, the FEVD was dominated by real housing loans. This is mirrored in the Figure 7 IRF showing a 1% unexpected interest rate shock on HPI. HPIs percentage change peaked in quarter three and decreased thereafter. Although, it must be noted that these results may not be statically significant. The typical effect, where an interest rate increases the cost of borrowing, reducing housing demand and prices, is not observed as the data seems to exhibit features of the price puzzle.

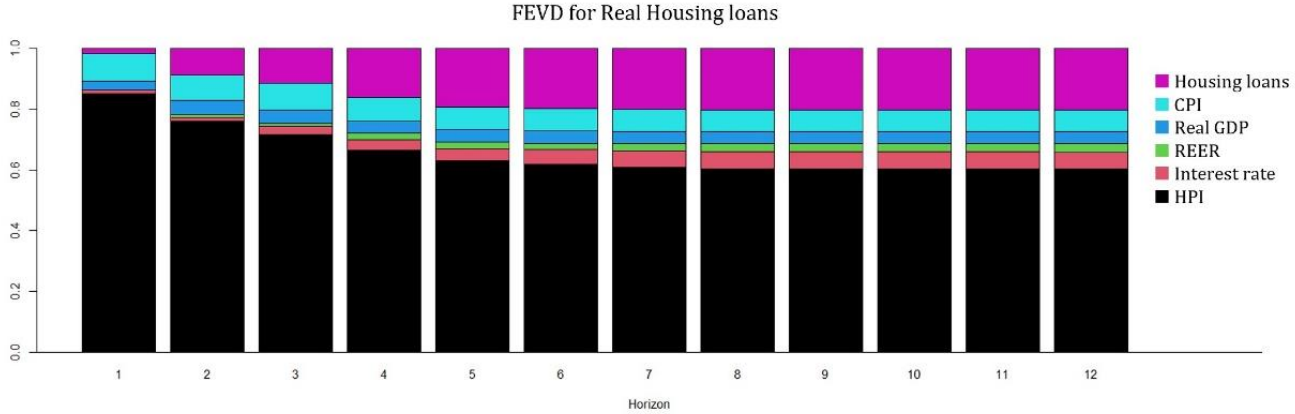
In addition, most of the variables in the FEVD stabilise after the fifth quarter, with the source of variance staying the same for the remaining quarters. This indicates that by approximately the fifth quarter, the initial shock has ceased to impact the trajectory of the variable. A similar phenomenon is observed in the IRFs, which generally converges three periods after this, after approximately year two or quarter eight.

Figure 23: SVAR FEVD for variables HIP, Interest rate, REER, Real GDP, CPI and Real Housing Loans




FEVD for Real GDP
Housing loans
CPI
Real GDP
REER
Interest rate
HPI
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
9
10
11
12
Horizon


FEVD for CPI
Housing loans
CPI
Real GDP
REER
Interest rate
HPI
0.0
0.2
0.4
0.6
0.8
1.0
1
2
3
4
5
6
7
8
9
10
11
12
Horizon


FEVD for Real Housing loans
Housing loans
CPI
Real GDP
REER
Interest rate
HPI
0.0
0.2
0.4
0.6
0.8
1.0
1
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5
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10
11
12
Horizon

7. Further research in the field

The analysis in this paper represents only a small part of the complexity of the full transmission of an unexpected monetary policy shock to housing demand and housing prices. Further research into the impact of monetary policy on housing price bubbles would benefit from larger models, capturing more variables. Especially variables that provide insights into central banks' unobserved inflation expectations, such as high-volatility commodity price indices. Furthermore, additional variables that better express the cyclical financial accelerator effect would better represent the reality of highly financialised housing markets, typical of contemporary economies.

In addition, VAR methodologies such as the factor augmented VAR and non-linear VAR specifications may prove valuable in better expressing the true relationship between monetary policy and house prices. Other potential model specifications include estimating the VAR on shocks to highlight only the unexpected component of the time series or incorporating the output and inflation gaps. All the aforementioned adjustments would be especially useful in accounting for the price puzzle effect commonly observed in VAR analysis of monetary policy and has been seen in this research. While the price puzzle effect arising may be inherent to the data, testing alternative model specifications will be helpful to ensure the increase in HPI as a result of the unexpected interest rate shock was not due to misspecification.

Some authors have argued that due to the high frequency of the price puzzle effect occurring in VAR analysis, different approaches to modelling monetary policy impacts on prices should be considered. Dynamic Stochastic General Equilibrium (DSGE) models are employed by many central banks however, price puzzle effects have still been identified. SEMs may be better suited to treating firms and consumers heterogeneously as they have different levels of wealth and consumption patterns. Furthermore, SEMs are able to account for cyclical bubbles as well as changing risk perceptions amid a bubble and during a financial crisis. However, the implementation of such models requires a significant quantitative burden.

Furthermore, to ensure the validity of the analysis of the IRFs, adopting local projection techniques may prove useful. Local projections produce significance bands, rather than

confidence bands, which are more effective when evaluating the join null hypothesises that the results of the IRF are different to zero.

8. Conclusion

Through modelling the transmission of monetary policy to house prices, it becomes evident that while a relationship exists, it is not strongly significant. The IRF, showing the impact of an interest rate shock on house prices, provides results unexpected in traditional economic theory: house prices rise in response to an unexpected increase in the interest rates or contractionary monetary policy. While this may result from the price puzzle effect, as is common in VAR analysis and on New Zealand's data, central banks must proceed with caution. Even so, the IRF showing the impact of an interest rate shock on house prices was not significant. Thus, no firm conclusions can be drawn.

Even so, the link between housing debt and house prices is strong. The IRF showing the impact of a real housing loan shock on house prices was significant for the first five quarters. House prices increased by 4% following a positive 1% shock from real housing loans. This shows the importance of debt as an influencer of housing prices. This is further supported by analysis of the FEVD. Therefore, interventions targeting housing debt may prove to be effective in curbing the escalation of housing prices. Macroprudential policies such as the loan-to-value ratios; and debt-to-income ceilings may be the most promising tools. However, further study is needed.

Analysis of the FEVD graphs showed the cyclical relationship between the HPI and real housing loans. The largest source of variance for HPI was generated by shocks from the real housing loans and vice versa. This indicates that there is additional pressure on the economic system outside of the variables captured in the model, such as a speculative bubble. Furthermore, it shows that the bubble is driven through debt. Thus, macroprudential policies such as the loan-to-value ratio, debt-to-income ratio, and margin requirements may prove effective due to their interactions with debt, which drives house price growth.

The spill-over effects from contractionary monetary policy can be observed when considering the real GDP IRF. While not significant, the positive interest rate shock to the real GDP IRF affects an immediate drop in the real GDP. Moreover, its IRF displays some volatility, emphasising the difficulty of targeting an asset price bubble in a single industry with the interest rate. When attempting to use the interest rate to target a bubble in a single market, such as the housing market, the ramifications to real GDP and the greater economy must be considered.

However, as the IRF is not significant, by the informal check of statistical significance, more research is needed to understand the potential spillover effects of an interest rate shock on the wider economy.

Therefore, alternative avenues of analysis into the effect of contractionary monetary policy on house price bubbles are required as well as to build an understanding of the potential effects of this shock on the overall economy. The cost to the economy must be compared against the risk arising from the housing price bubble. Most economists and central banks deem the cost of inflation and price instability to be significantly large so as to warrant the use of the interest rate. However, the evidence regarding its impact remains inconclusive. The potential downside of the house price bubble "popping" would need to be similar to that of inflation for the interest rate tool to be applied. Generally, macroprudential policies would be better suited to managing a house price bubble. Indeed, the primary significant results generated in this research imply that the management of housing debt would be the method for moderating house prices that is most likely to be successful. However, macroprudential policies, such as the loan-to-value ratio which directly targets the debt stock, require a longer time horizon to be effective and must thus, be implemented preventatively, earlier on in the bubbles' life cycle. While macroprudential policy are likely to be more effective, it may benefit from supportive monetary policy should future research support this.

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Appendix A: Descriptive Statistics

Variable	Housing loans	Interest rate	HPI	Real GDP	CPI	REER
Unit	NZDm	%	Index	NZDm	Index	Index
Number of observations	88	88	88	88	88	88
Mean	115 438.76	4.04	1 559.00	50 026.94	2.01	98.71
Standard Deviation	49 482.36	2.26	632.6	8 891.66	1.2	10.71
Median	119 175.50	3.25	1 468.50	49 197.00	1.8	101.83
Min	40 953.00	0.25	697	34 535.00	-0.5	72.27
Max	218 995.00	8.25	3 081.00	70 264.00	5.3	115.04
Range	178 042.00	8	2 384.00	35 729.00	5.8	42.77

Appendix B: Full summary statistics for the VAR analysis

VAR Estimation Results:

Endogenous variables: HPI, Interest rate, REER, Real GDP, CPI, Real housing loans
Deterministic variables: both
Sample size: 85
Log Likelihood: 999.452
Roots of the characteristic polynomial:
0.7638 0.7638 0.7177 0.6764 0.6764 0.6349 0.5713 0.5713 0.4238 0.4238 0.2747 0.2747
Call:
VAR(y = data, p = 2, type = c("both"))

Estimation results for equation HPI:

HPI1L = HPI.l1 + Interest rate.l1 + REER.l1 + Real GDP.l1 + CPI.l1 + Real housing loans.l1 + HPI.l2 + Interest rate.l2 + REER.l2 + Real GDP.l2 + CPI.l2 + Real housing loans.l2 + const + trend

Variable	Estimate	Std. Error	t value	Pr(>|t|)	
ΔL HPI.l1	8,10E-01	1,29E-01	6,294	2,25E-08	***
ΔL Interest rate.l1	1,50E-02	8,16E-03	1,841	0,06978	·
ΔL REER.l1	-2,45E-02	4,38E-02	-0,56	0,57756	
ΔL Real GDP.l1	1,25E-02	1,13E-01	0,11	0,91278	
ΔL CPI.l1	-7,28E-03	3,58E-03	-2,035	0,04561	*
ΔL Real housing loans.l1	-4,51E-02	1,32E-01	-0,343	0,73246	
ΔL HPI.l2	-9,41E-02	1,33E-01	-0,707	0,48204	
ΔL Interest rate.l2	-3,04E-02	1,06E-02	-2,859	0,00557	**
ΔL REER.l2	1,50E-03	4,56E-02	0,033	0,97375	
ΔL Real GDP.l2	-1,84E-01	1,29E-01	-1,423	0,1591	
ΔL CPI.l2	-9,00E-03	3,56E-03	-2,527	0,01374	*
ΔL Real housing loans.l2	1,01E-01	1,29E-01	0,785	0,43521	
const	6,97E-03	3,95E-03	1,763	0,08212	·
trend	-3,14E-05	6,38E-05	-0,492	0,62392	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '·' 0.1 ' ' 1

Residual standard error: 0.01246 on 71 degrees of freedom

Multiple R-Squared:	0.6849	Adjusted R-squared:	0.6272
F-statistic:	11.87 on 13 and 71 DF	p-value:	3.94e-13

Covariance matrix of residuals:

	ΔL HPI$_{it}$	ΔL Interest rate$_{it}$	ΔL REER$_{it}$	ΔL Real GDP$_{it}$	ΔL CPI$_{it}$	ΔL Real housing loans$_{it}$
ΔL HPI$_{it}$	1.552e-04	2.356e-05	7.852e-05	3.998e-05	0.0006458	5.466e-05
ΔL Interest rate$_{it}$	2.356e-05	3.268e-02	1.458e-03	5.321e-04	-0.009005	1.745e-04
ΔL REER$_{it}$	7.852e-05	1.458e-03	9.498e-04	-7.457e-06	0.0001421	6.067e-05
ΔL Real GDP$_{it}$	3.998e-05	5.321e-04	-7.457e-06	1.315e-04	-0.000333	4.235e-05
ΔL CPI$_{it}$	6.458e-04	-9.005e-03	1.421e-04	-3.328e-04	0.1440733	-7.974e-04
ΔL Real housing loans$_{it}$	5.466e-05	1.745e-04	6.067e-05	4.235e-05	-0.000797	1.455e-04

Correlation matrix of residuals:

	ΔL HPI$_{it}$	ΔL Interest rate$_{it}$	ΔL REER$_{it}$	ΔL Real GDP$_{it}$	ΔL CPI$_{it}$	ΔL Real housing loans$_{it}$
ΔL HPI$_{it}$	1.00000	0.01046	0.20453	0.27991	0.13659	0.36369
ΔL Interest rate$_{it}$	0.01046	1.00000	0.26165	0.25670	-0.13123	0.08003
ΔL REER$_{it}$	0.20453	0.26165	1.00000	-0.02110	0.01215	0.16319
ΔL Real GDP$_{it}$	0.27991	0.25670	-0.02110	1.00000	-0.07647	0.30617
ΔL CPI$_{it}$	0.13659	-0.13123	0.01215	-0.07647	1.00000	-0.17414
ΔL Real housing loans$_{it}$	0.36369	0.08003	0.16319	0.30617	-0.17414	1.00000

Appendix C: List of Abbreviations

ADF	Augmented Dickey–Fuller test
AIC	Akaike information criterion
BIS	Bank of International Settlements
CBI	Central Bank of Ireland
CPI	Consumer Price Index
DSGE	Dynamic Stochastic General Equilibrium
EIU	Economist Intelligence Unit
FEVD	Forecast Error Variance Decomposition
FPE	Final Prediction Error
GDP	Gross Domestic Product
HPI	House Price Index
HQ	Hannan-Quinn information criterion
IPD	Implicit Price Deflator
IRF	Impulse Response Function
IS	Investment equal to savings
KPSS	Kwiatkowski, Phillips, Schmidt, and Shin Test
L	Logarithmic transformation
Log	logarithmic
m	Million
Max	Maximum
Min	Minimum
MR	Monetary Rule
NZD	New Zealand Dollar
OCR	Official Cash Rate
PC	Phillips Curve

PP	Phillips–Perron
PPI	Producer Price Index
PTA	Policy Target Agreement
Q	Quarter
Q/Q	Quarter-on-quarter
RBA	Reserve Bank of Australia
RBNZ	Reserve Bank of New Zealand
REER	Real Effective Exchange Rate
Riksbank	Central Bank of Sweden
SC	Schwarz information criterion
SPAR	Sale Price Appraisal Ratio
SVAR	Structural Vector Autoregression
UIP	Uncovered Interest Parity Condition
UK	United Kingdom
USA	United States of America
VAR	Vector Autoregression
y/y	Year-on-year
Δ	First difference transformation

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