# Determinants and Dynamics of New Zealand Housing Prices:

# National- and Regional- Level Analyses

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# ABSTRACT

In this study we set out to find if macroeconomic factors have any strong association with house prices in New Zealand. To conduct our empirical analysis, we used a unique dataset with Residential Property Prices Indices with monthly frequency from SIRCA. The data sample spans 13 years from December 2003 to January 2017. Long run (cointegration) relationships and short run (error correction) relationships are estimated across 14 regions within New Zealand.

The results of our empirical study indicate that house prices at both national and regional level between 2003 and 2017 are positively determined by household income in the long run. The impact of mortgage rate on housing indices is different for before and after crises subperiods: positive influence before and negative after crisis. In short-term relationships between changes in residential property price indices and their determinants at national level indicate that household income and population growth positively influence property prices, while mortgage rate increases lead to a decrease in house prices. Regions exhibit different short run behaviours across New Zealand in the responsiveness to the economic and demographic indicators change.

We also analyse whether the movement of price in Auckland spillover to the neighbour Auckland cities and the other main cities of New Zealand. To do that, we estimate multivariate VAR models and then conduct a Granger causality test, impulse response functions and Variance Decomposition. Results suggest that the neighbouring Auckland cities are highly affected by the price trends and shocks in Auckland. When we consider the system of three main cities, we find that the price movement in Auckland shows substantial independence, while it can be useful in explaining the housing prices in Wellington and Hamilton. Additionally, we find that the movement of prices in Wellington and Auckland spillover to Hamilton.

Keywords: House prices, Residential Property Price Index, Spillover, Error Correction model, Granger Causality, Impulse response functions, Variance Decomposition

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## ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed: Olga Koveshnikova Date: 28 July, 2017

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# CHAPTER 1: INTRODUCTION

The housing market is one of the major drivers of the New Zealand economy and represents a high proportion of total wealth of New Zealand households. A high proportion of households' net worth is made up of net equity in property and is higher than in any financial assets, New Zealand Superannuation, pension or other form of assets. Below, we present some interesting statistics which support the importance of housing market in New Zealand:

- New Zealand has one of the highest ratios of home ownership in western society with over 70% of New Zealanders living in their own houses (Statistics NZ, 2016).
- About 15% of New Zealand households own some form of investment property, such as holiday homes and/or rental properties (Scobie & Gibson, 2006).
- Housing is an important element in New Zealand households' portfolios with 56% of assets being in housing (Scobie & Gibson, 2006). In addition, the total value of the New Zealand stock of residential property reached $1000 billion in 2017 (RBNZ, 2017).
- Housing construction is New Zealand's fifth largest sector by employment, having around 178,100 full time employees, with another 53,600 full-time equivalents in construction-related services; altogether this accounts for 10% of total employment across the country's economy (PWC, 2016).

A recent study of this important sector of the economy by the International Monetary Fund (IMF, 2016) reveals significant overvaluation of house prices relative to their fundamental value in New Zealand. For instance, while, by the end of 2005, house prices relative to fundamental house values were found to be overvalued by 25%, in 2015 overvaluation reached 40% as reported by the IMF (2016). The recent surge in housing prices in New Zealand can be announced as a housing affordability crisis.[1] From the period between 2003 and 2017 Auckland's prices increased by 172%, which is equivalent to 7.44% annual growth rate, while nationwide it is 139.5%, or 6.85% per year. Median house price to median household income multiple is an established benchmark for housing affordability and ideally should be equal to 3. A recent survey

[1] Chris Parker (2015), the chief economist of the City of Auckland announced that Auckland currently has a housing affordability crisis.

revealed that the median multiple for Auckland is 10, which only exceeds Vancouver, Sydney and Hong Kong (Demographia, 2016).

Taking into account that real estate market play a crucial role in New Zealand, policy-makers, as well as the public, should be concerned about the reasons that have led to the high level of house price appreciation and the impact this has on the economy and housing affordability. On the one hand, there are several key macroeconomic factors which have a strong impact on house prices in New Zealand. Firstly, we have seen increasing number of migrants entering New Zealand in recent years which leads to greater housing demand, notably in the Auckland region. Moreover, real interest rates have moved down sharply over the last years which, together with household income growth in many parts of the country, leads to increases in borrowing capacity. On the other hand, the surge in investor activity is one of the dominant factors in pushing up house prices, particularly in Auckland.

New Zealand's relatively high nominal and real interest rates by global standards (Global Markets Research, 2017) and solid economic performance in the last decade are making New Zealand an appealing place for offshore capital flows. Along with being an attractive place for foreign investors, New Zealand had consistently offered favourable taxation treatment for housing, with no taxes on capital gain at sale until 2015. This advantageous tax system for speculators to make tax-free profits had added pressure on the New Zealand housing market and may partly explain New Zealanders' preference for housing over debt or equity. According to CoreLogic (2015), the highest speculative demand appears in Auckland.[2]

Due to unaffordability in Auckland housing market, local buyers and investors to some degree were driven out and started to consider other regional areas. In our study we assume that two alternatives are possible. First, people might start looking to the nearest-neighbour regions. In this case, we might expect a high degree of integration between Territorial Local Authorities (TLAs) in Auckland region. Second, people might be attracted by the other main centres of New Zealand, such as Wellington, Christchurch and Hamilton. This tendency of Aucklanders to move and invest in other regions might add more demand into local areas which will lead to the growth in the property prices, and not just in Auckland. This reasoning motivates us to consider the 'Auckland spillover effect' of spreading values. To the best of the authors' knowledge,

[2] CoreLogic (2015) analyses all residential sales from 2014, and finds evidence of speculation in the Auckland market. Dwellings were held in ownership for shorter periods than the rest of New Zealand, and there were a relatively high number of dwellings held for less than one year.

no study has been made of the cross-regional Auckland spillover effects on residential property prices in New Zealand. The only study which touches spillover from the Auckland property market to the other metropolitan centres is done by Greenaway-McGrevy and Phillips (2016); however, their research is mainly based on the analysis of bubbles spreading.

Therefore, the aims of this paper is to describe the broad trends in New Zealand house prices, and to model their key determinants. Furthermore, we analyse the movement of price in Auckland spillover to the neighbouring Auckland cities and main cities of New Zealand.

We conduct our research into two stages. First, to answer the research question about the impacts of fundamental variables on housing market outcomes at both national and regional levels, we employed an error correction model applied to 14 Regional Councils (RC). The data sample spans 13 years of monthly data from December 2003 to January 2017. Second, to undertake the Auckland spillover analysis, we use the multivariate Vector Autoregressive (VAR) model and then conduct a Granger causality test, Impulse response functions and Variance Decomposition.

The remainder of the report is organised as follows: Section 2 presents the literature review, with the aim of choosing the explanatory variables that have an impact on house prices. Section 3 outlines data followed by empirical methodology and hypotheses development. Section 4 reports empirical results. Section 5 concludes.

# CHAPTER 2: LITERATURE REVIEW

This chapter provides a review of the New Zealand and international housing market literature, identifies and discusses the key determinants of the housing price dynamic. There are many factors affecting the housing market; some are based on economic theories and population density and others are based on more intangible factors, like the expectation of future growth. Certain conditions raise property prices and others bring them down. The purpose of this chapter is to clarify how housing price fluctuation has been defined and addressed in various historical and global contexts. Additionally, we specify important factors which affect demand and supply of housing. First, we provide a framework to analyse the impacts of fundamental variables on New Zealand housing market at both national and regional levels. Due to a lack of data availability on a New Zealand regional level, in this study we consider the most relevant and commonly studied factors, such as the net migration rate, household income and interest rate. Second, we exploring a variety of models that have been proposed in the literature to understand what determines housing prices.

## 2.1 Long-term determinants and short-term factors

The boom in New Zealand house prices is influenced by a range of factors that affect supply and demand of housing. The house price dynamic is the response to the forces of both short-term and long-term drivers of the demand and supply in the property market. It is useful to distinguish between long-term determinants and short-term factors that influence housing prices.

Based on the literature on house price inflation, factors in the long-run include macroeconomic variables, notably disposable income and mortgage rates (Capozza et al., 2002; Briggs & Ng, 2009), real interest rates and real income (IMF, 2003; Égert & Mihaljek, 2007), availability and cost of land (Grimes, Kerr & Aitken, 2003), the cost of construction including materials and labour costs (DPMC House Prices Unit, 2008). Short-term influences include a surge in net migration (Coleman & Landon-Lane, 2007), changes in regional economic activity (O’Donovan & Rae, 1997), changes in average rents (Grimes & Hyland, 2013), expectations about future house prices and incomes expectations (Coleman & Landon-Lane, 2007).

## 2.2 Strong link between economic performance and house prices at national and regional level: Gross Regional Products (GRPs) have a significant positive effect and unemployment has a significant negative effect

The first comprehensive regional econometric analysis on the drivers of house prices in New Zealand has been conducted by O'Donovan and Rae (1997). They model house prices in New Zealand at both aggregate and regional level. Due to a lack of data availability on a regional level, however, O'Donovan and Rae model each region's house prices relative to the national average. The results of their empirical study indicate, for the 14 regions' long-run house prices, relative economic performance, agricultural commodity prices, and regional population have a significant impact on relative house prices across regions. Generally, they find a strong link between economic performance and house prices, while GRPs have a significant positive effect, but unemployment has a significant negative effect on house prices. Commodity prices have a significant positive effect in most of those regions and negative effect in Auckland and Wellington. The results of relative population effect on relative house prices are not clear. While the effect is generally positive as would be expected, three regions (the Bay of Plenty, Hawke's Bay, and Nelson-Marlborough) show a negative link between population and house prices.

Furthermore, the same study find that although house price dynamics across regions tend to be highly correlated over the short term, house prices are not cointegrated across regions over longer horizons (in the longer term each region's house prices follow different stochastic trends). In addition, in a related study, to investigate if regional house price show asymmetries, Hall, McDermott and Tremewan (2006) investigate the expansion and contraction phases of national house prices for 14 regions using the Classical cycle dating method and provide evidence that the duration and amplitude of housing cycles vary widely across geographical areas and through time. Overall, those findings do not exclude that some determinants affect long-run house prices similarly across regions; nevertheless it presents the existence of additional region-specific factors that cause variances in long-run house prices across regions over time (Grimes et al., 2003).

## 2.3 Rising incomes and increasing borrowing capacity of households have been pushing up housing demand

Household income growth, falling interest rates and the availability of credit have been found to be among the key drivers of housing demand. In the study of trends and cycles in New Zealand house prices, based on an affordability model, Briggs and Ng (2009) calculate a synthetic variable "borrowing capacity": the amount that a household on the average income could borrow via a table mortgage at the effective mortgage rate. They found that, despite significant household disposable incomes growth from 1992, borrowing capacity has been increasing more strongly than household disposable income. This could be explained by the fall in effective mortgage interest rate from the late 1980s. Overall, the results of the study suggest that the sharp fall in nominal inflation between 1987 and 1992 and the associated fall in mortgage rates, with a low point in 2004, did have an effect on house prices between 1987 and 2008. The increase in household income accounts for around half of the increase in the house price to household income ratio in that period. The other half is accounted for by lower mortgage rates. Over and above the income and interest rate factors, the study finds that loans have become easier to obtain and a higher propensity on the part of households to borrow also seems to be pushing up housing demand.

## 2.4 Migrant inflows have contributed to pressures on housing demand

Another factor influencing the price of the housing market is the demographic factor. Cross-country evidence suggests a significant correlation between population growth and housing prices since strong population growth creates higher demand for housing that cannot be met by short-term increase in supply (Égert & Mihaljek, 2007; Renigier-Biłozor & Wiśniewski, 2012; Rodi et al., 2013).

Important drivers of the New Zealand housing demand have been shown to be changes in size of the population and household numbers (Coleman & Landon-Lane, 2007; Stillman & Maré, 2008; McDonald, 2013; Grimes & Hyland, 2013). Population growth occurs as a result of natural changes in the population (birth and death rates) and net migration (inward and outward migration). Population growth in New Zealand has been higher than in other advanced economies, mainly because of strong immigration (Tumbarello & Wang, 2010). Waves of net immigration have been associated with increasing real house prices and rising construction activity; conversely, waves of net emigration have been associated with declining real house prices and falling construction activity (Coleman & Landon-Lane, 2007).

Coleman and Landon-Lane (2007), investigating the housing market over 1962-2006 in New Zealand, find that, in the short-to-medium term, positive net permanent migration shocks are associated with large increases in house prices: migration flow equal to 1% of the population is associated with an 8-12% change in house prices after a year, and a slightly larger effect after three years at the national level. Moreover, net migration flows and house price changes tend to be correlated.

More recent work by McDonald (2013) analyses the relationship between different types of permanent and long-term migration and the housing market. First, he identifies that the net international migration inflow equal to 1% of the population causes an 8% increase in house prices over the following three years. Hence, McDonald's results, which suggest that changes in foreign-citizen migration have a larger effect at the national level than changes in New Zealand citizen migration, are consistent with the Coleman and Landon-Lane research.

In contrast to the studies discussed above, which look at the national level, a work by Stillman and Maré (2008) looks at New Zealand house prices at regional levels and shows different outcomes in regard to the impact of migration on house prices, in both magnitude and significance. Although the correlation between high immigration and house price growth is strong, the relationship between increases in house prices and migration at a local level looks quite different: 1% increase in a region's population is associated with an increase in local housing prices of between 0.2 and 0.5%. Moreover, after splitting population growth into the New Zealand-born population and foreign-born migrants, they do not find any evidence of the immigration impact on housing prices on a regional level. The results indicate that the returning New Zealanders have the biggest effect on house prices: an increase of 1% of the local population from returning New Zealanders is associated with a 9.1% increase in house prices.

Overall, the results regarding the impact of immigration on the housing prices indicate a difference between the national and regional level, raising some questions about whether immigration and house price appreciation is in fact causal, or the strong positive correlation at the national level might be a consequence of omitted aggregate time series factors that influence both immigration and house prices. Consequently, it is of interest to have a closer look at the national and regional impact of net migration on housing prices together with other factors with more recent and frequent data.

## 2.5 Rising land prices and residential construction prices, together with slow housing supply response to rising housing demand, have led to a large house price increase

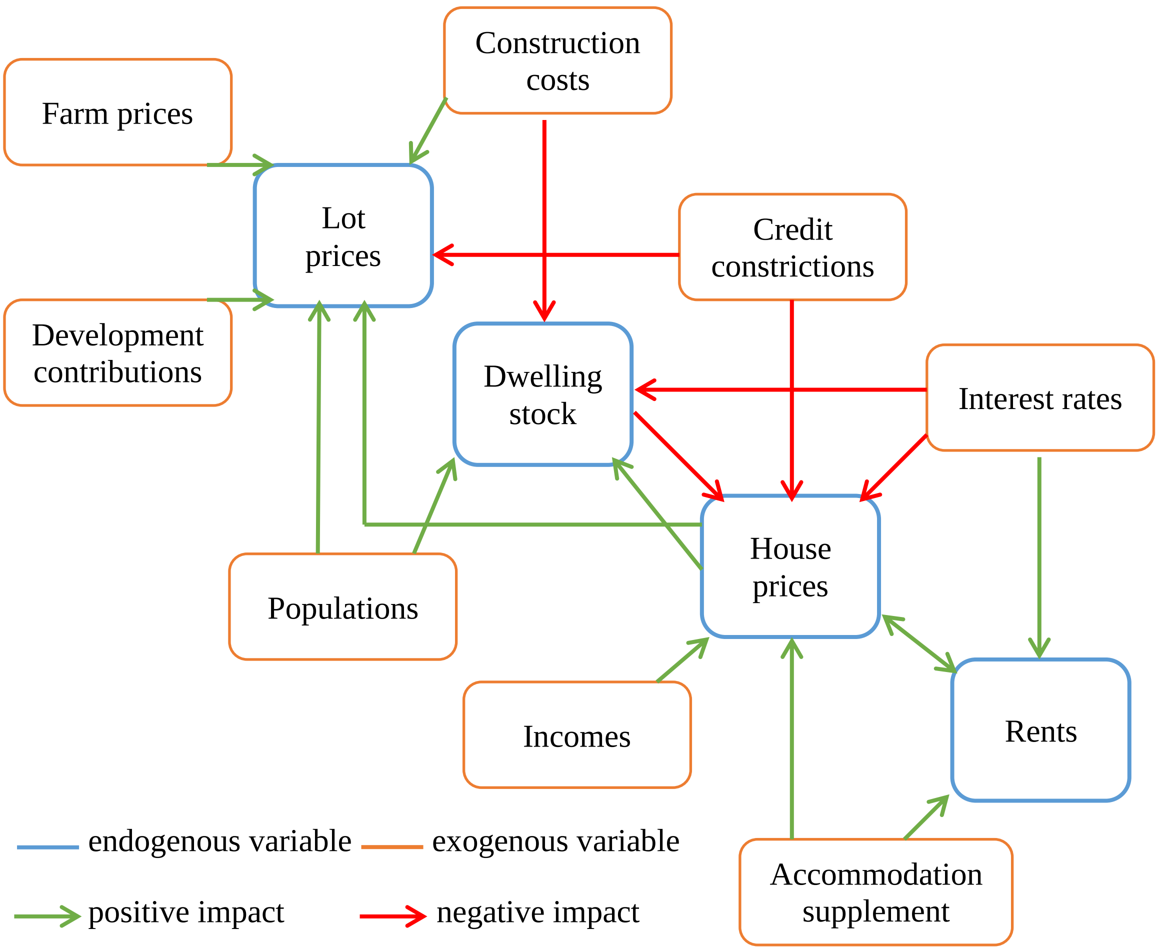
From the supply side, rising land prices and building costs (including materials, labour, associated financing and administrative costs) together with low supply responsiveness have been crucial in pushing up prices in the housing market. With a considerable surge in demand driven by large net migration inflows, wealth growth, low interest rates and increase in availability of credit, the construction sector costs have increased significantly in recent periods. This cost increase reflects a sharp increase in section prices (Watson, 2013; REINZ, 2017); the costs of almost all materials have increased substantially (BRANZ Study Report, 2013) and labour costs have increased by more in the construction sector than in the rest of the economy (due to the high demand for workers and skilled labour shortage in the construction industry) (Statistics NZ: LEED, 2017). Studies show that the sharp increase in house prices in New Zealand reflects the fact that the supply of housing has been unable to keep pace with strong demand. Grimes and Hyland (2013) show that, in New Zealand, supply has tended to be slow to respond to shocks. Land scarcity, regulatory barriers, and the time and regulatory processes associated with planning, development and building affect supply responsiveness. Land scarcity has become an increasing problem as the Metropolitan Urban Limit (MUL) has become more pressing. Zheng (2013) estimates that, in 2010, land just inside the MUL was worth nine times the value of land just outside the boundary – up from six times in 1998. As a consequence, land costs now comprise 60% of the cost of building a new dwelling in Auckland, compared with 40% in the rest of the country. As the availability of land within the MUL has decreased, rising land prices appear to have curbed housing supply.

As a result, due to the strong growth in land prices and residential construction prices, the cost of new housing has increased substantially. The negative effect of this strong growth is that the modest supply of new housing has exerted little, if any, moderating influence on house prices over the latest cycle (Briggs & Ng, 2009). Another concern, particularly for Auckland, is that, due to the scarcity of available land, there is a significant limitation on new home building, leading to a nationwide housing shortage which has reached 60,000 and is growing by 40 houses a day, according to documents released to the Labour Party (Andrew Little, 2017).

### 2.6 Interaction between housing supply and housing demand

A recent study about interaction between housing supply and housing demand has been conducted by Grimes and Hyland (2013) across 72 Territorial Local Authorities (TLAs) within New Zealand over 1990-2011. The authors present simulated scenarios based on the New Zealand Regional Housing Model (NZRHM) of the impacts of shocks to exogenous variables (population, credit restrictions, construction costs and farm prices) as well as shocks to policy variables (developer contributions, accommodation supplement, and land availability) on key New Zealand housing market variables (house prices, housing supply, residential vacant land prices, average rents). NZRHM is designed to be a "whole of housing system" model, where the four modelled (endogenous) variables interact with each other and are influenced by a range of exogenous influences, as depicted in Figure 1.

Figure 1 Schematic Representation of Interaction between Housing Determinants and Housing Market Variables.




Source: Adapted from Grimes and Hyland Housing Model (2013).

The model's overarching conclusion is that housing markets are slow to adjust and that exogenous shocks have very long-lasting effects. The model finds that an increase in population due to a migration surge leads to a prolonged period of upward pressure on prices (house, land and rents), which continues until the dwelling stock adjusts to restore dwellings per capita. The model estimates show that it would take eight years for housing supply to catch up with demand and, until that time, house prices remain higher than their control (counterfactual) level.

As per the model by Grimes and Hayland (2013), (i) housing demand increases when per capita dwelling stock and interest rates (adjusted for capital gains) decrease and accommodation supplement and per capita regional income increase. Based on profitability considerations, (ii) new construction supply responds positively to increasing house prices, but is negatively affected by rises in residential lot prices; (iii) residential lot prices increase with increases in farm prices, development contributions paid to local councils, house prices and population pressures on land, and rents are determined such that rental yield (ratio of rents to house prices) equals financial market yield adjusted for expected capital gains on rental property.

## 2.7 Speculative element to the investment demand for housing and Auckland spillover effect

New Zealand's relatively high nominal and real interest rates by global standards (Global Markets Research, 2017) and solid economic performance in the last decade are making New Zealand an appealing place for offshore capital flows. Along with being an attractive place for foreign investors, New Zealand had consistently offered favourable taxation treatment for housing, with no taxes on capital gain at sale until 2015[3]. The key consideration of the non-neutrality of the taxation system is different investment tax rates, with the most obvious example that financial assets (dividends and interest) are taxed at a significantly higher rate than returns on investments in rental housing and with no taxes on capital gain at sale until 2015. This advantageous tax system for speculators to make tax-free profits had added pressure on the New Zealand housing

[3] The Taxation (Bright-line Test for Residential Land) Act 2015 introduces a new "bright-line" test that will require income tax to be paid on any gains from residential property that is disposed of within two years of acquisition, subject to some exceptions. The exceptions to the rule are the owner's main home, an inherited property or the transfer of property to the executor or administrator of a deceased estate. The bright-line test as part of the Government's reform package to tighten the property investment rules, came into force on 1 October 2015 (Inland Revenue, 2017).

market and may partly explain New Zealanders' preference for housing over debt or equity.

According to CoreLogic (2015), the highest speculative demand appears in Auckland. CoreLogic (2015) analyses all residential sales from 2014, and finds evidence of speculation in the Auckland market. Dwellings were held in ownership for shorter periods than the rest of New Zealand, and there were a relatively high number of dwellings held for less than one year. The continued increase in housing prices and the dominance of investors in Auckland was partly the reason the Reserve Bank introduced a ‘speed limit’ on high loan-to-value-ratios (LVRs) in October 2013 and tightened these restrictions for Auckland investors in November 2015 (RBNZ, 2017). For investors the requirement was to have 30% deposit if buying an existing dwelling within the Auckland Council area. Then, the rules were extended nationwide in October 2016 and a new requirement imposed, with a rise to a 40% deposit.

As a result, local buyers and investors to some degree were driven out of the Auckland housing market and started to consider alternative regional areas. Also, people who already had jobs in Auckland started looking to the nearest-neighbour regions first, in their hunt for affordable houses. In this case, we might expect a high degree of integration between TLAs in Auckland region: for example, Auckland City and Waitakere, Manukau, North Shore, or even between Auckland region and neighbouring regions such as Waikato and Northland. A second group of people moved out of Auckland for a new lifestyle in other regions with a new job or business. The other main centres of New Zealand which could be attractive for skilled category population are Wellington, Christchurch and Hamilton.

This tendency of Aucklanders to move and invest in other regions might add more demand into local areas which will lead to the growth in the property prices, and not just in Auckland. This reasoning motivates us to consider the ‘Auckland spillover effect’ of spreading values. Additionally, Greenaway-McGrevy and Phillips (2016) document the contagion effect of the Auckland City bubble to other regions which originated in 2003. Thus, it is of interest, in addition to macroeconomic variables, to consider the spillover effect between Auckland City and neighbouring TLAs, and other major cities.

### 2.8 Conclusion and structure of study

On balance, the available evidence suggests that migration, in conjunction with a sluggish supply of new housing and associated land use restrictions, may have had a significant effect on house prices in New Zealand. However, observable national and regional results in the different periods of time show different outcomes in regard to the impact of migration on house prices, in both magnitude and significance. Moreover, houses prices are not only affected by changes in population, but also by other factors such as borrowing capacity and the economic situation of the local area. This economic situation itself affects migration (and vice versa), which makes it difficult to establish causality between those variables. Therefore, there are several key factors which make revisiting the determinants of New Zealand housing prices interesting. Firstly, we have seen increasing number of migrants entering New Zealand in recent years. This leads to our second point, which is that greater demand has grown house prices at a significantly inflated rate, particularly in the Auckland region. Thirdly, real interest rates have moved down sharply over the last years which, together with household income growth in many parts of the country, leads to increases in borrowing capacity. Finally, there is greater and more recent availability of data from which to draw conclusions, compared to when the previous studies were conducted.

The surge in investor activity is one of the dominant factors in pushing up house prices, particularly in Auckland. This makes buyers and investors keen to purchase property outside of Auckland which adds extra weight to housing demand in local areas. Moreover, the housing prices in New Zealand show different movement, as mentioned earlier, not necessarily cointegrated across regions and dependent on the characteristics of specific regional markets. Therefore, it is important to determine how housing price fluctuation in Auckland affects other regions. To the best of the authors' knowledge, no study has been made of the cross-regional Auckland spillover effects on residential property prices in New Zealand. The only study which touches spillover from the Auckland property market to the other metropolitan centres is done by Greenaway-McGrevy and Phillips (2016); however, their research is mainly based on the analysis of bubbles spreading. The results of our study will contribute to the knowledge of regional distributional effects of Auckland price growth on neighbouring and regional price growth.

# CHAPTER 3: DATA AND METHODOLOGY

## 3.1 Data

To conduct our empirical analysis, we collected monthly data on Residential Property Prices Indices (RPPIs) from SIRCA CoreLogic New Zealand Residential Sales Index. The data are a subset of the large panel data set covering national and regional levels for the period from December 2003 to January 2017, totalling 158 observations per area. RPPI are based on the Sale Price Appraisal Ratio (SPAR) method and contain aggregate pricing measures for over one hundred localities in New Zealand. Housing price indices in New Zealand and for three major RCs (Auckland Region, Wellington Region and Christchurch Area), during the sample period, are presented in Figure 2 and Figure 3 below.

Figure 2 National Residential Property Price Index (baseline index 1000 = M12-2003)

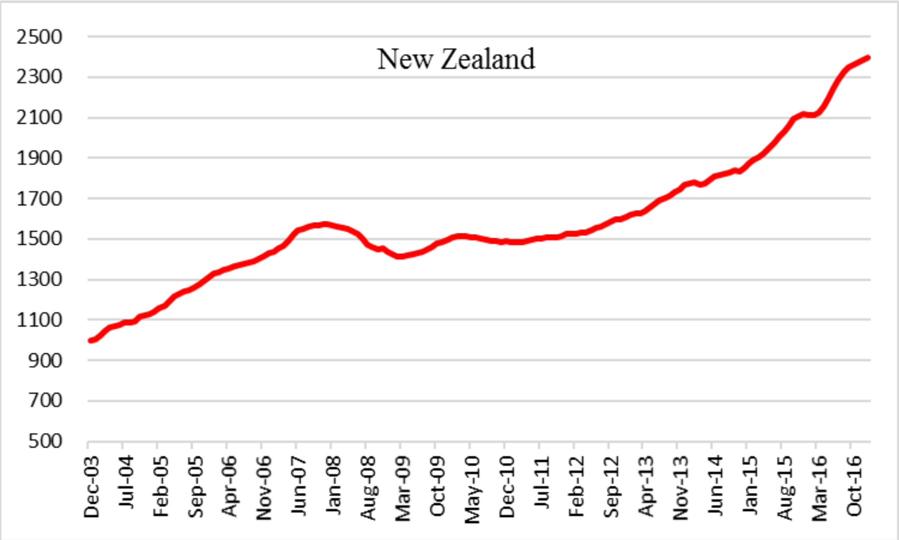
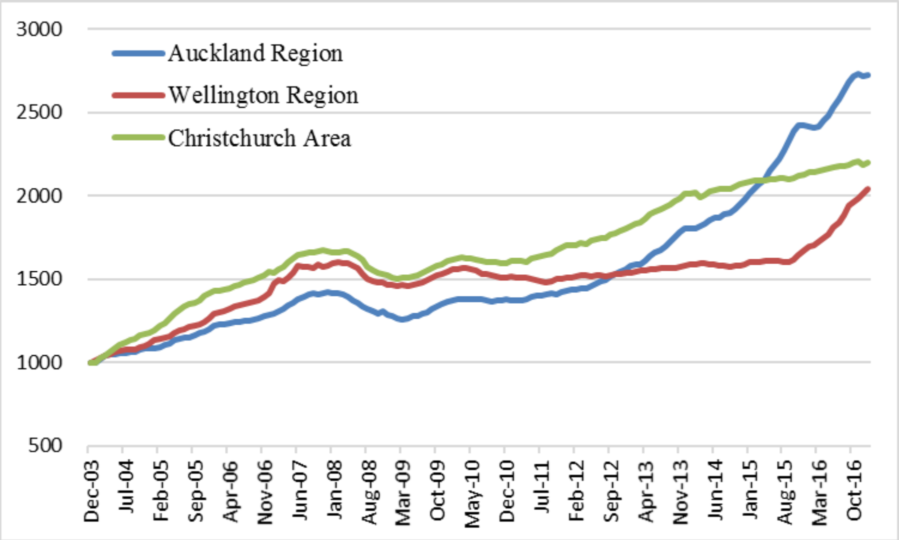



Figure 3 Regional Residential Property Price Index (baseline index 1000 = M12-2003)



Nationwide, the housing price index has increased by 139.5% between 2003 and 2017, with a stronger growth from 2012 onwards. As an illustration, Figure 3 demonstrates the residential property price index trends with the strongest growth in the Auckland region, which shows 172% increase from December 2003 to January 2017. In contrast, the Christchurch area experienced slightly lower growth (120%). Interestingly, Christchurch had the highest trend in housing prices in New Zealand until April 2014; a number of earthquakes had devastated the city, leading to a surge in construction until 2014 when the price index slowed down and stayed relatively flat. Meanwhile, the Wellington regional price increased by 104% from 2003 to 2017.

Figure 4 shows monthly residential property price indices over 2003 - 2017 for the central TLAs in the four most populous metropolitan areas: Auckland, Wellington, Christchurch and Hamilton. All four indices exhibit a large increase over the 2003 to 2008 period, after which there is a small decline. Price indices in Wellington and Christchurch remain relatively constant over the subsequent period, 2008-2017. In contrast, housing price indices for Auckland and Hamilton begin to increase again in late 2013.

Figure 4 Residential Property Price Index in the Main Centres (baseline index 1000 = M12-2003)

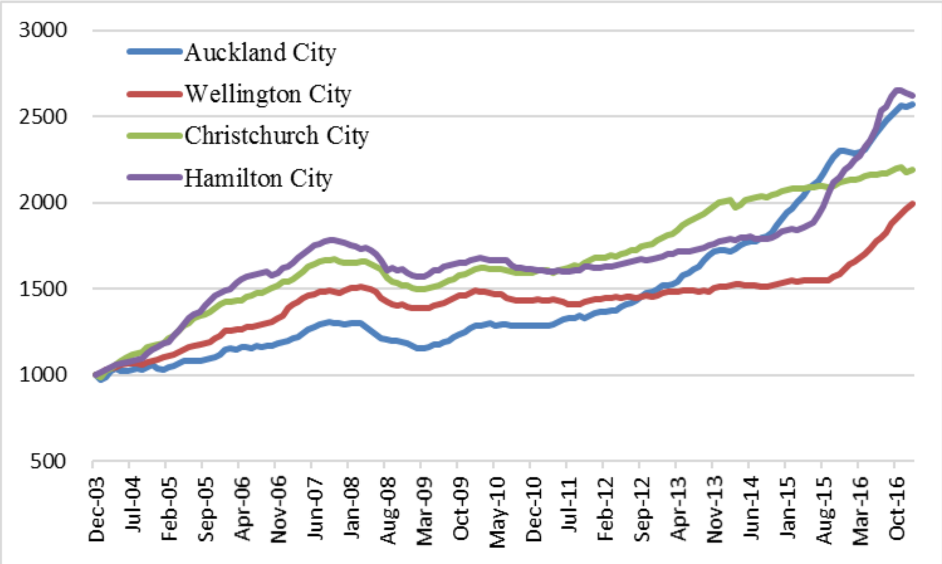
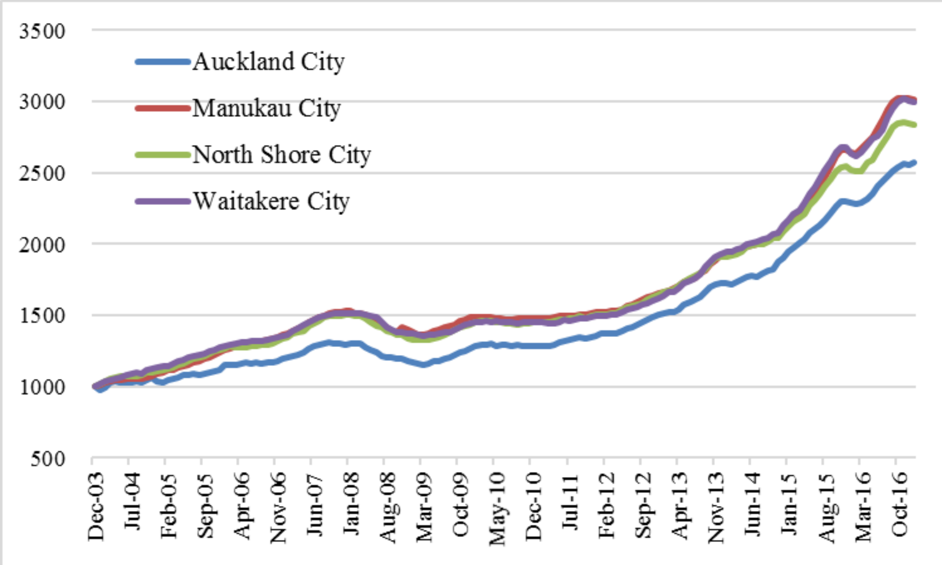



Figure 5 shows housing price indices for the four main TLAs within the broader Auckland metropolitan area: Auckland City, North Shore, Manukau and Waitakere. All four series exhibit very similar movements over time.

Figure 5 Residential Property Price Index of Territorial Authorities in the Auckland Metro Area (baseline index 1000 = M12-2003)




We use RPPIs data for our research at the Territorial Local Authority (TLA) level. For some of our analysis, we aggregate these data to the Regional Council (RC) level using the correspondence shown in Appendix 1. (Appendix 1 also defines the abbreviations used for each RC and TLA.)

The economic indicators used in our study are collected from the Reserve Bank of New Zealand (RBNZ) and Statistics New Zealand (SNZ). A brief description of the raw series used in our modelling, and their sources, is summarised in Table 1. The data frequency in this table refers to the frequency of the source data.

Table 1 Data Definitions – Raw Series

| Variable | Name | Definition | Source |
|---|---|---|---|
| **Dependent** | RPPI | Residential Property Prices Index (index 2003: M12=1000), monthly | SIRCA |
| **Independent** | HI | Average weekly household income, annually | SNZ |
| | MR | 2 year fixed mortgage interest rate, monthly | RBNZ |
| | NM | Net permanent & long-term migration, monthly | SNZ |
| | POP | Estimated resident population, annually | SNZ |

Notes: SIRCA = Securities Industry Research Centre of Asia-Pacific; SNZ=Statistics New Zealand; RBNZ=Reserve Bank of New Zealand.

Average weekly household income is the sum of weekly income of all people in the household from wages and salaries, self-employment and government transfers, divided by the number of households. To transform annual household income into monthly series we use linear interpolation, where for each consecutive years n-1 and n for each month from January (t = 1) to November (t = 11) we define $HI_t^{n\text{-}1,n}$ as follows:

$$HI_t^{n-1,n} = HI^{n-1} + t * \left(\frac{HI^{n} - HI^{n-1}}{12}\right), \quad t=1, \ldots, 11, \qquad (3.1)$$

where $HI^{n}$ and $HI^{n-1}$ are known household income at years n and n-1, respectively, and $HI_t^{n-1,n}$ is unknown household income for month t between $HI^{n}$ and $HI^{n-1}$.

The data series of household income at national and regional levels after linear interpolation are plotted on Figure 6 and Figure 7. Household income from wages and salaries has steadily increased over the last years at both national and regional levels.

Figure 6. National Average Household Income and Residential Property Price Index

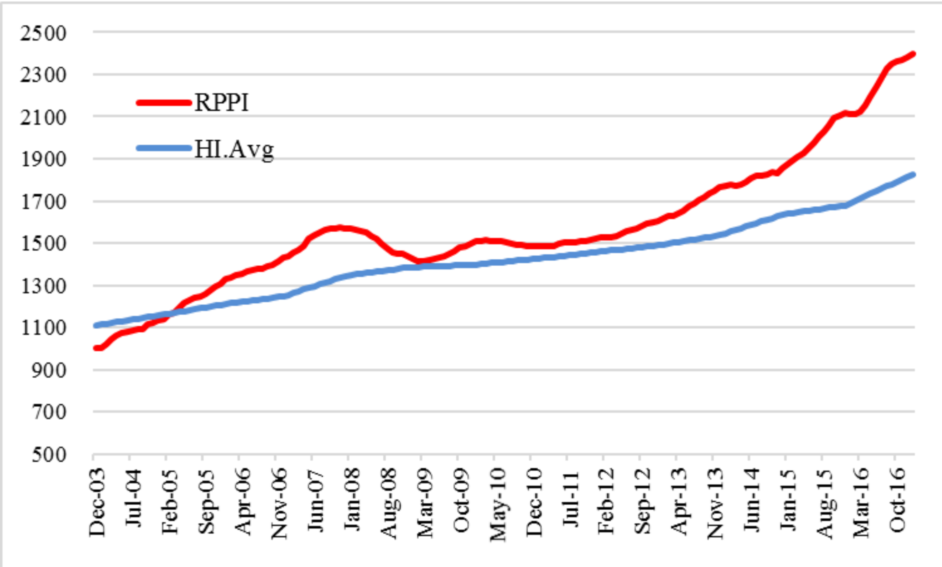



Figure 7. Regional Average Household Income

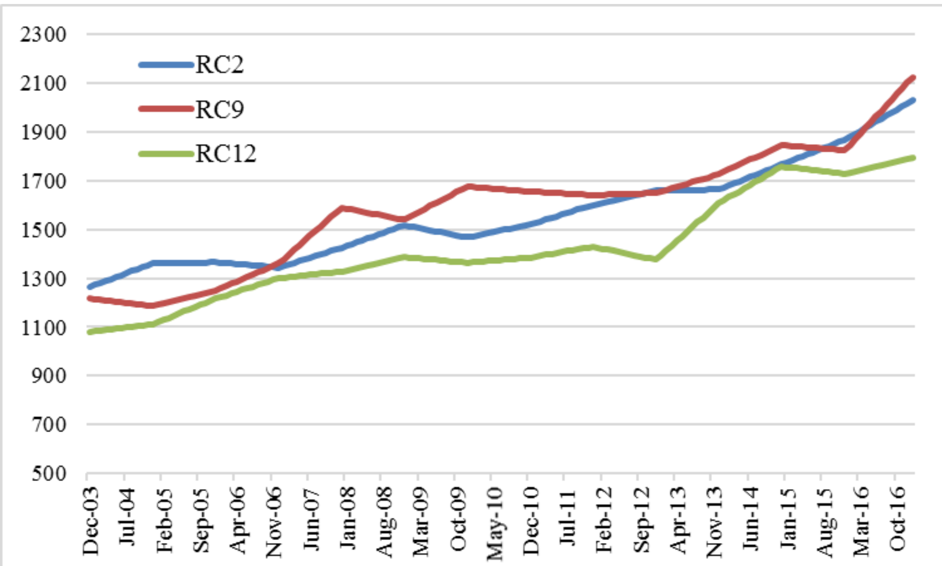
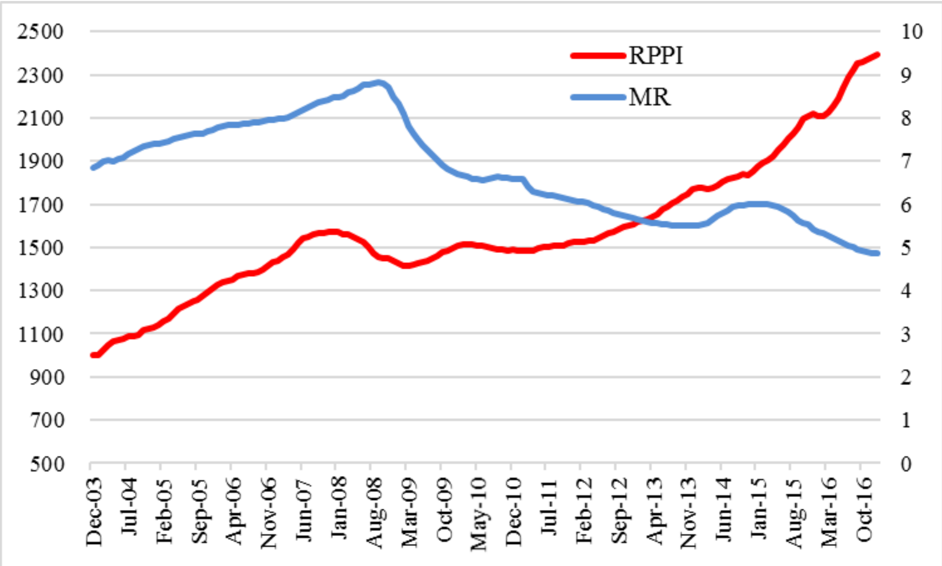


Figure 6 shows that since the late 2012s there has been a growing gap between the housing price index and average household income. By itself this gap would have made housing less affordable. However, this would have been offset, at least to some extent, by the general decline in nominal interest rates over the same period. Lower interest rates would have affected the level of mortgage payments, thereby making housing more affordable than it would otherwise have been (Briggs & Ng, 2009). As shown in Figure 6 and Figure 7 average household income constantly grows between the end of 2003 and the beginning of 2017. At the regional level the increase is particularly strong in Wellington (RC9), up 74%.

Figure 8 shows the 2 year fixed mortgage interest rate and national residential property price index. As can be seen from the Figure 8, the 2 year fixed mortgage interest rate is relatively high and constantly grows between December 2003 and September 2008. However, the Reserve Bank lowered the mortgage interest rate from the level of 8.82% to 7.64% over the period from September 2008 to the end of April 2009 as a response to the global financial crisis. For the period from 2009 onwards, the mortgage rates remain low reaching a record low of 4.85% in January of 2017. Meanwhile, the residential property price index constantly grows after the global financial crisis (April 2009).

Figure 8 National Residential Property Price Index and 2 Year Fixed Mortgage Interest Rate




Prior research (for example, IMF (2003) which is done for the U. K. data) found that real house prices are in a long-run relationship with real interest rates and real income per household. For the case of New Zealand’s housing market, we observe similar dynamics, which are particularly strong after the GFC period. In view of this, average household disposable income and the 2 year fixed mortgage interest rate are prime candidates for the trend equation in our error correction model.

Figure 9 and Figure 10 show the net permanent and long-term migration at national and regional levels, which is the balance of all migrants coming into New Zealand less those that have departed (regardless of citizenship).

Figure 9 National Residential Property Price Index and Net Permanent & Long-Term Migration

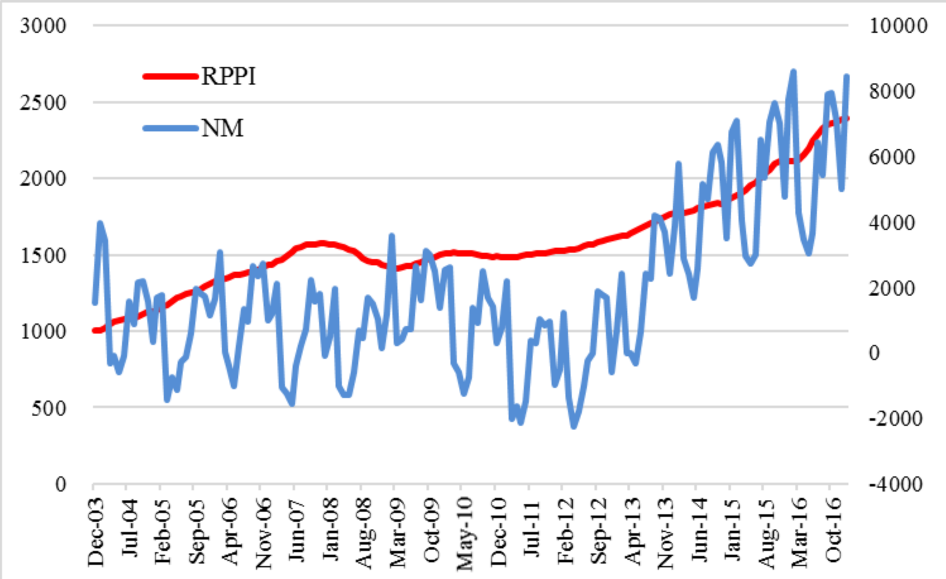



Figure 10 Regional Net Permanent & Long-Term Migration

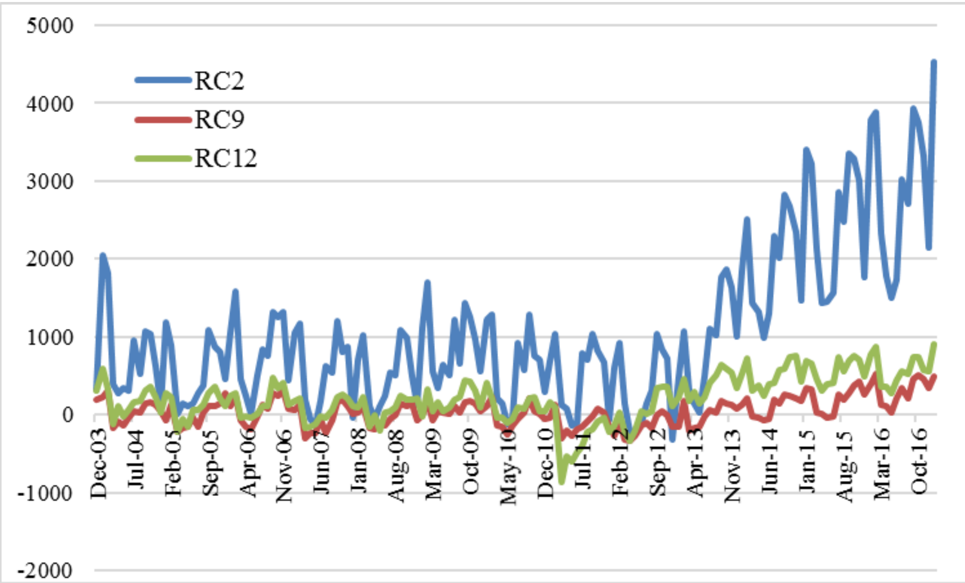
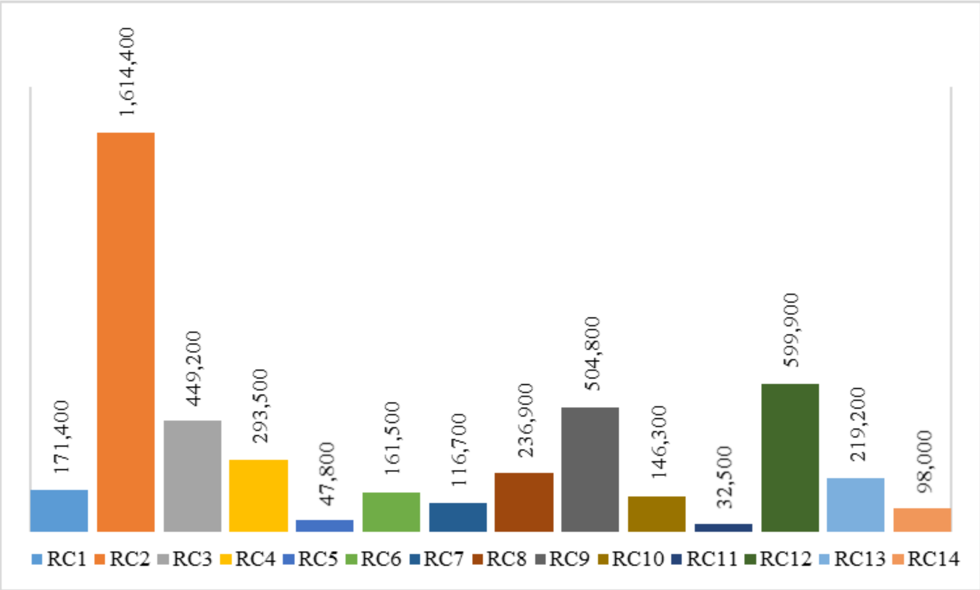



Figure 11 represents estimated annual resident population for RC areas, the latest available at 30 June 2016. The estimated resident population is based on the census "usually resident" population count, updated for residents missed or counted more than once by the census (net census undercount); residents temporarily overseas on census night; and births, deaths, and net migration between census night and the date of the estimate (Statistics NZ, 2017).

Figure 11 Annual Regional Estimated Resident Population for 30 June 2016




Over the last two decades, the total number of people migrating to and from New Zealand fluctuated greatly from year to year. The estimated resident population of New Zealand was 4,692,700 at 30 June 2016. Auckland is the most populous city with up to 34.4% of New Zealand's population. Moreover, around half of all permanent and long-term arrivals in New Zealand are to the Auckland region, so the pattern of net migration there on its own tends to mirror the pattern of net migration to New Zealand, the latter trend being particularly noticeable after 2013 with the surge growth in net migration. Wellington (RC 9) shows a modest net permanent and long-term inflow of migrants with a stronger increase after 2013 similarly to Auckland. Canterbury ranks second in population size out of all regions and has the second largest net gain of migrants, behind Auckland. On Figure 10 we observe the considerable drop in the Christchurch area (RC 12) between 2010 and 2011 due to the high number of permanent and long-term migrant departures. This reflects the significant earthquakes in the region in 2010 and 2011 (Statistics NZ, 2014; MBIE, 2016).

To accurately estimate the impact of migration on regional house prices, we consider the relative growth in migration rather than using raw net permanent and long-term migration data. As such, Figure 12 shows that an identical increase in migrant numbers adjusted by the number of resident population shows a relatively smaller increase in

Auckland compared to that of Canterbury, as Auckland is the most populous city in New Zealand.

For our model, we estimate the net migration rate ($NMR_i^n$) for each region $i$ which defines as follows:

$$NMR_i^n = \left(\frac{E_i^n - I_i^n}{POP_i^n}\right) *1000, \tag{3.2}$$

where $E_i^n$ and $I_i^n$ are number of people emigrating out of the region $i$ and immigrating into the region $i$ at years $n$, respectively; $POP_i^n$ is the estimated mid-year population in the region $i$ at years $n$.

The net migration rate for New Zealand is 2.2 per 1,000 people as estimated for 2016 (CIA World Factbook, 2017). This means that for every 1,000 people in New Zealand at the beginning of the year 2016, 2.2 will have immigrated to the country by the end of the year 2016. This number (2.2) numerically shows the impact of migration on the country's population. The net migration rate for the region numerically shows the impact of migration on the region's population.

Figure 12 Regional Net Migration Rate

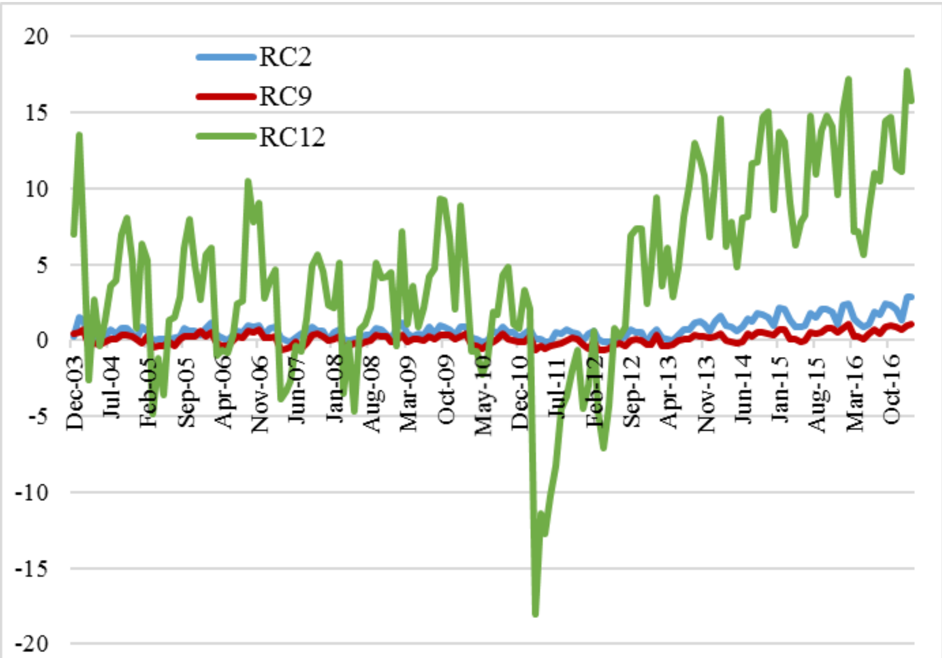



Table 2 provides summary statistics on the data series at the national level. Specifically, information on the mean, maximum and minimum, median, standard deviation, skewness and kurtosis coefficients, and the Jarque-Bera normality test are presented.

Table 2 Summary Statistics of the Data Series at the National Level

| | RPPI | HI | MR | NM |
|---|---|---|---|---|
| Mean | 1575 | 1420 | 6.75 | 1858 |
| Median | 1512 | 1412 | 6.62 | 1567 |
| Maximum | 2395 | 1825 | 8.82 | 8581 |
| Minimum | 1000 | 1110 | 4.85 | -2262 |
| Std. Dev. | 310.05 | 180.46 | 1.11 | 2473.26 |
| Skewness | 0.71 | 0.21 | 0.20 | 0.81 |
| Kurtosis | 3.40 | 2.32 | 1.83 | 3.17 |
| Jarque-Bera | 14.22 | 4.14 | 10.13 | 17.57 |
| Probability | 0.0008 | 0.1262 | 0.0063 | 0.0002 |
| Sum | 248852 | 224396 | 1065.89 | 293582 |
| Sum Sq. Dev. | 1.5E+07 | 5.1E+06 | 1.9E+02 | 9.6E+08 |
| **Correlation** | **RPPI** | **HI** | **MR** | **NM** |
| **RPPI** | 1.00 | | | |
| **HI** | 0.96<br>(0.000) | 1.00 | | |
| **MR** | -0.66<br>(0.000) | -0.76<br>(0.000) | 1.00 | |
| **NM** | 0.67<br>(0.000) | 0.62<br>(0.000) | -0.49<br>(0.000) | 1.00 |
| Observations | 158 | 158 | 158 | 158 |

Note: The p-value is reported in parentheses below the correlation coefficient.

We use a New Zealand data series that comprises 4 variables sampled monthly from 2003:M12 to 2017:M1. Each variable contains 158 observations. The variables are: Residential Property Prices Index (RPPI), Average Household Income (HI), Mortgage Interest Rate (MR) and Net Migration (NM). By observing the minimum and maximum values of the series in our sample, we can conclude that the observed series show a significant variation in their values over time. Mortgage interest rates in New Zealand averaged 6.75% from 2003 until 2017, reaching an all-time high of 8.82% in September 2008 and a record low of 4.85% in January 2017. Meanwhile, changes in population due to the net migration (arrivals less departures) vary throughout the period the most (standard deviation is equal 2473.26) from its mean value (1858).

For all observed variables, median is not equal to mean, and therefore their distributions are asymmetric. Moreover, skewness different from zero and positive means that the distributions of observed variables have long right tails. Interestingly, kurtosis which measures the peakedness or flatness of the distribution of the series is less than 3 for interest rate and household income: the distribution is flat (platykurtic) relative to the normal, while the residential property price index and net migration are leptokurtic, exhibiting kurtosis more than 3. The normality is uniformly rejected for all variables based on the Jarque-Bera (JB) test. The results show that the data do not support the null hypothesis that each variable has a normal distribution, since p-values of JB tests are close to zero.

For better prediction of causal relationships between data series, we next check the correlation of our variables. Since the observed correlation of pairs RPPI and HI, RPPI and NM, HI and NM is positive, it can be concluded that those pairs of the variables have a significant positive correlation with a p-value = 0.000. Meanwhile, all pairs with mortgage rate (MR and RPPI, HI, NM) have significant negative correlation with a p-value = 0.000, moving in the opposite directions. Another important examination based on correlation is to investigate if the problem of multicollinearity presents in our data. Looking at correlations among pairs of predictors in our sample, we suggest that the predictors are, at least, moderately marginally correlated. Therefore, we use Variance Inflation Factors (VIF) to detect the level of collinearity between the regressors. We first run an ordinary least square regression at national level for all the explanatory variables. Then, we calculate the VIF factor (Table 3).

Table 3 Model Summary with Variance Inflation Factors

| **Variable** | **Coefficient** | **Std. Error** | **t-Statistic** | **Prob.** | **VIF** |
|---|---|---|---|---|---|
| C | -1207 | 131.2 | -9.20 | 0.000 | |
| HI | 1.72 | 0.060 | 28.63 | 0.000 | 2.91 |
| MR | 46.5 | 8.814 | 5.28 | 0.000 | 2.39 |
| NM | 0.02 | 0.003 | 5.25 | 0.000 | 1.62 |
| $R^2$ = 0.93 | | | | | |

Note: $R^2$ is the adjusted-$R^2$

Three of the variance inflation factors - 2.91, 2.39, and 1.62 – are between 0 and 5. This indicates that the level of collinearity between the regressors is moderate. Since the VIFs are relatively low, we could assume that there is little multicollinearity among these variables and multicollinearity is not a problem for our model.

Table 4 presents the results on the Augmented Dickey-Fuller (ADF) tests for unit root in the time series. The null hypothesis for this test is that there is a unit root. The alternative is that the time series is stationary. We find non-stationary behaviour for residential property price index, household income and mortgage rate, while net migration rate time series are stationary. In order to receive consistent, reliable results, the non-stationary data needs to be transformed into stationary data. The non-stationary process is a random walk with a drift so it is transformed to stationary process by differencing.

Table 4 Augmented Dickey Fuller Tests

| Region | RPPI | HI | MR | NMR |
|---|---|---|---|---|
| RC1 | 0 | 0 | 0 | 1 |
| RC2 | 0 | 0 | 0 | 1 |
| RC3 | 0 | 0 | 0 | 1 |
| RC4 | 0 | 0 | 0 | 1 |
| RC5 | 0 | 0 | 0 | 1 |
| RC6 | 0 | 0 | 0 | 1 |
| RC7 | 0 | 0 | 0 | 1 |
| RC8 | 0 | 0 | 0 | 1 |
| RC9 | 0 | 0 | 0 | 1 |
| RC10 | 0 | 0 | 0 | 1 |
| RC11 | 0 | 0 | 0 | 1 |
| RC12 | 0 | 0 | 0 | 1 |
| RC13 | 0 | 0 | 0 | 1 |
| RC14 | 0 | 0 | 0 | 1 |
| NZ | 0 | 0 | 0 | 1 |

Notes: 0 – accept $H_{0:}$ the time series are non-stationary;
1 – reject $H_{0:}$ the time series are stationary.

### 3.2 Empirical Models

This chapter addresses the methodology used to answer the research questions. First, it discusses the Error Correction Model (ECM). The ECM is a model for estimating long run (cointegration) relationships between house prices and macroeconomic variables; specifically, household income and mortgage interest rate. Then we estimate the respond of house prices to short-run movements in lagged changes of economic variables from long-run estimation, and exogenous variable – net migration rate. Cointegration means house prices across regions share the same stochastic trend so that even if they deviate from each other in the short run; they tend to adjust to their long-run equilibrium.

Second, to undertake the Auckland spillover analysis, we employ Vector Autoregressive model to measure how price fluctuation in Auckland City affects other regions and main cities of New Zealand. Then using the VAR model we conduct a Granger causality test, which investigates whether house prices in Auckland contain useful information for predicting house prices in other regions. Before conducting Granger causality test we select the optimal lag lengths for the VAR models. There are two further methods to determine the spillover effect based on VAR, which are the impulse response function and the variance decompositions. Impulse response functions show the responses of the different regions to a one unit shock to housing prices in one of the regions. The variance decomposition analysis helps to answer the question of whether price fluctuations in one region mainly come from its own fluctuation or are impacted by fluctuations in other regions.

### *3.2.1 The Error Correction Model*

As housing price fluctuations in a given region might heavily depend on the characteristics that are unique to that region, we first estimate long-run (cointegration) relationships and short-run (error correction) relationships for each of the variables across 14 RCs within New Zealand. Models of New Zealand house prices that are based on this approach can be found in O'Donovan and Rae (1997), Briggs and Ng (2009), and Grimes and Hyland (2013).

We first establish the following error correction model in accordance with our research variables for the country level:

$$\Delta ln(RPPI_t) = \alpha_1 \Delta ln(RPPI_{t-1}) + \alpha_2 \Delta X_{t-1} + \alpha_3 NMR_{t-1} + \alpha_4 resid_{t-1} + \varepsilon_t, \quad (3.3)$$

where $resid_{t-1}$ is the lagged residual from long-term Equation 3.4:

$$RPPI_t = \beta_0 + \beta_1 HI_t + \beta_2 MR_t + \varepsilon_t \ , \quad (3.4)$$

where $\Delta RPPI_t$ is the residential property prices index of New Zealand in time (month) $t$; the set of independent variables in time $t$ are mortgage rate ($MR_t$), household income ($HI_t$), net migration rate ($NMR_t$); $\Delta X$ is the set of the endogenous variables, which enter the long-term equation: $MR_t$ and $HI_t$ in time $t$. $\alpha = (\alpha_1, \dots, \alpha_4)'$, $\beta = (\beta_0, \beta_1, \beta_2)'$ *are* the parameters to be estimated and $\varepsilon_t$ is the error term in time $t$.

This specification implies that regional house prices adjust to their long-run equilibrium while responding to short-term movements in house prices in the previous periods, lagged changes of economic variables entering long-run equation, and exogenous variable – net migration rate.

Equation 3.3 is known as an error-correction representation of the cointegrated system. Equation 3.4 aims to identify the cointegrating relationship between the residential property price index, average household income and mortgage interest rate. If the system of those variables is cointegrated, then we expect the residuals of Equation 3.4 to be stationary. The coefficient $\alpha_4$ in Equation 3.3 is called the speed of adjustment coefficient. The error-correction mechanism works in the following way: in case $\alpha_4 < 0$

and $[RPPI_t - \beta_0 - \beta_1 HI_t - \beta_2 MR_t]>0$, we expect residential property price index to drop at time $t+1$.

The approach would be to estimate the aggregate model altogether and to estimate a model of similar form for each region. Hence, we model each region's house prices relative to the combination of variables at the RC level:

$$\Delta ln(RPPI_{i,t}) = \alpha_1 \Delta ln(RPPI_{i,t-1}) + \alpha_2 \Delta X_{i,t-1} + \alpha_3 NMR_{i,t-1} + \alpha_4 resid_{i,t-1} + \varepsilon_t, \quad (3.5)$$

where $resid_{t-1}$ is the lagged residual from long-term Equation 3.5:

$$RPPI_{i,t} = \beta_0 + \beta_1 MR_{i,t} + \beta_2 HI_{i,t} + \varepsilon_t \quad (3.6)$$

where $\Delta RPPI_{i,t}$ is residential property price index of region $i$ in time $t$; the set of the exogenous variables of region $i$ in time $t$ are household income ($HI_{i,t}$), net migration rate ($NMR_{i,t}$); $\Delta X$ is the set of the endogenous variables: $MR_{i,t}$ and $HI_{i,t}$ of region $i$ in time $t$.

The estimation is conducted in two steps. Firstly, we estimate a long-run relationship between housing prices and macroeconomic variables, where we consider several possible economic variables, such as mortgage rates and household income as in Briggs and Ng (2009), nominal interest rate (proxied by the 90-day bill rate) and household income, and choose the model which performs the best. Secondly, we use stationary residuals of the long-run equation and incorporate them in the short-run model, where we include lagged economic variables from the long-term equation as well as the exogenous variable, such as regional net migration rate.

We choose not to use household disposable income, as it is only available on the national level, while household income is available on regional level and is shown to enter long-run relationship at conventional significance level together with real interest rates (IMF, 2003).

### *3.2.2 The Vector Autoregressive Model*

To measure how price fluctuation in Auckland City affects other regions, we implement the multivariate Vector Autoregressive model for the property indices. To analyse whether the movement of price in Auckland spillover to the neighbouring Auckland cities and main cities of New Zealand, we will estimate multivariate VAR models and then conduct a Granger causality test, Impulse response functions and Variance Decomposition. In choosing the cities to analyse for spillover effects we follow Greenaway-McGrevy and Phillips (2015). Firstly, we apply the econometric methods on main TLAs within the broader Auckland metropolitan area (Auckland, Manukau, North Shore and Waitakere) and then on main cities (Auckland, Hamilton and Wellington)[4].

Several recent studies analyse a degree of spillover between regions in China and Korea. For example, Choi et al. (2013) consider spillover effect in the Seoul market. First, they conduct a Granger causality test using the bivariate VAR model between North and South Seoul and six metropolitan cities. Secondly, they use a volatility spillover index which is based on the variance decomposition of the forecast error from the VECM model. The volatility spillover index allows them to identify whether volatility in one market impact other regions, or the prices in the region are largely dependent on the characteristics which are unique to that region. Zhang, Shao and Wang (2015) conduct research on a house prices spillover effect for the Chinese market. Similarly, they use the Granger causality test, variance decomposition and, additionally, impulse response analysis. The variance decomposition analysis helps to answer the question of whether price fluctuations in Shanghai mainly come from its own fluctuation or are impacted by fluctuations in Hefei, Hangzou or Nanjing. The advantage of this approach is that it does not require any information about the macroeconomic variables and would allow us to fully employ high frequency of residential price index published by SIRCA. As for New Zealand, to our knowledge, the only study which considers spillover from the Auckland property market to the other metropolitan centres is done by Greenaway-McGrevy and Phillips (2016). They use recently developed methodology which aims to detect the existence of asset bubbles. They show that a housing bubble emerged in 2003 in Auckland, Wellington, Christchurch and Hamilton and collapsed in 2007. What is particularly interesting is the contagion effect of the Auckland City housing bubble on Christchurch, Hamilton and other TLAs that comprise the Auckland metro area. They also document that the second bubble emerged in 2013; however, they do not find any evidence of the bubble spreading to other main centres or other TLAs. As an extension of their research, we conduct a spillover analysis, similar to Choi et al. (2013) and Zhang et al. (2015).

The vector autoregressive model with 1 lag for the main TLAs within the Auckland region is as follows:

[4] We drop Christchurch due to the seismic activity in the area in the past 6 years, which led to the significant and long lasting effect on housing market outcomes.

$$\begin{bmatrix} P_t^{AUKL} \\ P_t^{MANU} \\ P_t^{NOSH} \\ P_t^{WTKR} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} P_{t-1}^{AUKL} \\ P_{t-1}^{MANU} \\ P_{t-1}^{NOSH} \\ P_{t-1}^{WTKR} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{bmatrix} \quad (3.7)$$

where $P_t^i$ is the residential property price index of city *i* in time *t; $a = (a_{11}, \ldots , a_{44})'$*, $c = (c_1,c_2,c_3,c_4)'$ *are* the parameters to be estimated and $\varepsilon = (\varepsilon_1,\varepsilon_2,\varepsilon_3,\varepsilon_4)'$ is the error term. The abbreviations used: Auckland (*AUKL*), Manukau (*MANU*), North Shore (*NOSH*) and Waitakere (*WTKR*).

For the main New Zealand cities, the vector autoregressive model with 1 lag is as follows:

$$\begin{bmatrix} P_t^{AUKL} \\ P_t^{HAMI} \\ P_t^{WELL} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} P_{t-1}^{AUKL} \\ P_{t-1}^{HAMI} \\ P_{t-1}^{WELL} \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix} \quad (3.8)$$

where $P_t^i$ is the residential property price index of city *i* in time *t*; $a = (a_{11}, \ldots , a_{33})'$, $c = (c_1,c_2,c_3)'$ are the parameters to be estimated and $\varepsilon = (\varepsilon_1,\varepsilon_2,\varepsilon_3)'$ is the error term. The abbreviations used: Auckland (*AUKL*), Hamilton (*HAMI*) and Wellington (*WELL*).

### 3.3 The Hypotheses

There are many fundamental variables that could lead to an increase in house prices. We use three major explanatory variable that could drive house prices in New Zealand as follows (expected sign of regression coefficients is in brackets):

[+] Average Weekly Household Income: Household income acts as a proxy for capacity of individual in the economy. The higher the income, the higher the borrowing capacity is, leading to increased demand, leading, in turn, to driving up of house prices.

[-] 2 Year Fixed Mortgage Interest Rate: The mortgage interest rate acts as a proxy for opportunity costs for demand of housing in New Zealand. If the mortgage interest rate increases then the demand for housing decreases leading to decreasing house prices.

[+] Net Migration Rate: Net migration rate acts as a proxy for the number of potential buyers in the market. A greater number of migrants entering the country indicates that the demand for housing increases thereby leading to an increase in house prices.

Next, we hypothesise that a strong housing price increase in Auckland can spillover to other regions. First, the ‘Auckland spillover effect’ spreading values to the main TLAs within the Auckland metropolitan area: North Shore, Manukau and Waitakere. Second, a housing price fluctuation in Auckland affects the central TLAs in the most populous metropolitan areas: Wellington and Hamilton.

# CHAPTER 4: EMPIRICAL ANALYSIS AND RESULTS

Our empirical results are developed into two stages. Firstly, based on the Error Correction model, Equation 3.3 and Equation 3.5, we estimate the effect of selected fundamental variables that could drive house prices in New Zealand. Secondly, to analyse whether the movement of price in Auckland spillover to the neighbouring Auckland cities and main cities of New Zealand, we will estimate multivariate VAR models Equation 3.7 and Equation 3.8 and then conduct a Granger causality test, Impulse response functions and Variance Decomposition.

The regression analysis estimation is conducted in two steps. Firstly, we estimate the long-run price relationship between the residential property price index and household income as well as mortgage rate at national and regional levels. Secondly, we estimate the short-run dynamic of the relationship between the variables, where the stationary residuals[5] of the long-run equation and exogenous variables such as regional net migration rate are added to the model. In short-run, each model runs for 6 lags. Furthermore, the regression analysis is done for the full sample data first (Dec2003 - Jan2017). Then we split it for three subperiods: before the global financial crisis (Dec2003 - Jan2008); during crisis (Feb2008 - Apr2009); and post crisis (May2009 - Jan2017)[6].

## 4.1 The Error Correction Model Estimates

### *4.1.1 The Long-Run Relationship Results*

Based on a sample of monthly data from December 2003 to January 2017, it is found that there is a long-run equilibrium (co-integrating) relationship among residential property price indices, household income and mortgage rate. The estimated results[7] of the long-run equilibrium model of residential property price indices at national and

[5] The Augmented-Dickey-Fuller Unit Root test has been used to check the stationarity of residuals of the long-run regressions. Available upon request.

[6] The New Zealand economy entered recession in early 2008, before the effects of the global financial crisis were felt later in the year. Economic activity fell sharply following the intensification of the global financial crisis in September 2008 with continuous decline till the March quarter 2009. Renewed optimism in the economy drove consumer and business confidence higher in the June quarter 2009. (The New Zealand Treasury, 2010).

[7] The estimated results of the long-run equilibrium model and short-term relationships between changes in RPPIs and their determinants at national and regional levels for the sub period during the crisis are not included in this paper. We do not include these results because it is not meaningful due to the insufficient number of observations.

regional levels for full period and sub periods before and after crisis are summarised in Table 5, Table 6 and Table 7.

The estimated trend equation for the national level is:

$$\underset{}{ln(RPPI)} = \underset{(32.9)}{1.64}\, ln(HI) + \underset{(5.35)}{0.03}\, MR - \underset{(-12.14)}{4.74}\ , \qquad (4.1)$$

where t values are in brackets..

For the full period we find that the regressors such as household income and mortgage rate used to have a significant effect on the residential property price index in long run. The estimated coefficients from Equation 4.1 are statistically significant at the 1% level at both national and regional levels and, for household income, are of the expected positive signs. For the national level a one percent increase in average weekly household income will lead to a 1.64% increase in the residential property price index. The observed impact is higher compared to finding of Briggs and Ng (2009), where a 1% increase in household disposable income per household tended to increase house prices at 1.171%.

Meanwhile, the results show that changes in mortgage rate positively led to house price index changes (at 1% significance level)[8]. This finding does not support our hypothesis and available international evidence. However, based on previous studies for New Zealand's housing market this finding does not seem unique. The New Zealand housing market was found to be exceptional because real interest rates were positively correlated with house price growth rather than negatively related as commonly seen in other countries. Our findings are similar to Shi, Jou and Tripe (2013), who investigates how changes in central bank policy and retail mortgage rates affected real housing prices in New Zealand during the period 1999-2009 and find that real fixed interest rates are positively related to real housing prices. They provide a possible explanation of their findings: New Zealand is a small country with an economy that is largely oriented to tourism and trade. Moreover, the country is viewed as an attractive migration destination. Those could result in a more resilient domestic demand for housing, while the long term interest rates are more affected by global factors. Furthermore, until 2015 New Zealand had consistently offered favourable taxation treatment for housing with no taxes on capital gain at sale. As a consequence, long term real interest rates could afford to increase in exchange for no capital gains tax at future sales.

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[8] We have also tested the alternative model with household income and 90-day bill rate as proxied for interest rate in the study conducted by O'Donovan and Rae (1997). We replace 2 year fixed mortgage interest rate with a 90-day bill rate in a robustness check. The results are very similar.

Next, we compare results after separating our sample for before and after crisis subperiods. For household income, when comparing subperiods, we find similar outcomes as for the full sample. Notably interesting is the impact of the mortgage rate which has changed a sign at regional level. Before the crisis we observe a positive significant impact of mortgage rate on the housing price index, while after the crisis for half of the regions the mortgage rate has become negative and significant at 1% level. Those regions are, from the North Island, Taranaki and Wellington, and all regions from the South Island. This fact could be explained by the fact that the period of strong economic growth between December 2001 and June 2007 has been associated with rising employment and increased income. A lower unemployment rate is likely to have increased people's confidence about future income and therefore their willingness to take on higher levels of debt, while rising real income has increased the amount of money that people have for spending on houses and for servicing mortgage debt (DPMC House Prices Unit, 2008). Nonetheless, the global financial crisis followed by a recession in the New Zealand economy made a shift in consumer confidence forcing people to re-evaluate their personal and household finances.

Table 5 Long Run Equations for the Full Sample

| Region / Variable | | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HI** | | 1.64*** | 1.65*** | 2.27*** | 1.74*** | 1.19*** | 1.45*** | 1.07*** | 1.49*** | 2.29*** | 1.03*** | 0.68*** | 1.70*** | 1.44*** | 0.91*** | 1.59*** |
| | | (32.92) | (25.32) | (26.60) | (32.04) | (15.26) | (20.06) | (22.45) | (23.02) | (22.68) | (33.96) | (19.45) | (21.99) | (30.81) | (19.61) | (21.05) |
| **MR** | | 0.03*** | 0.10*** | 0.03*** | 0.10*** | 0.10*** | 0.12*** | 0.09*** | 0.08*** | 0.14*** | 0.04*** | 0.02*** | 0.08*** | 0.02*** | 0.04*** | 0.07*** |
| | | (5.35) | (16.24) | (3.57) | (16.19) | (10.44) | (15.21) | (16.47) | (8.83) | (15.44) | (8.60) | (5.61) | (8.65) | (3.55) | (6.35) | (8.54) |
| **$R^2$** | | 0.93 | 0.80 | 0.91 | 0.88 | 0.60 | 0.72 | 0.76 | 0.80 | 0.77 | 0.91 | 0.74 | 0.77 | 0.91 | 0.77 | 0.78 |

Notes: The t-Statistic is reported in parentheses below the regression coefficient. The significance is indicated to the right of the coefficient (*** significant at 1%, ** significant at 5%, * significant at 10%). $R^2$ is the adjusted-$R^2$.

Table 6 Long Run Equations for the Period before Crisis

| Region / Variable | | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HI** | | 0.72. | 1.38*** | -1.01*** | 0.08 | -1.39*** | 0.97** | 0.23 | 0.67* | -2.59*** | 0.43*** | 1.39*** | 2.92*** | 1.00*** | 0.41* | 0.80*** |
| | | (1.87) | (4.39) | (-6.97) | (0.10) | (-5.46) | (3.22) | (1.04) | (2.37) | (-4.78) | (4.60) | (4.27) | (4.27) | (6.17) | (2.41) | (4.86) |
| **MR** | | 0.23*** | 0.21** | 0.29*** | 0.47** | 0.67*** | 0.41*** | 0.34*** | 0.45*** | 0.77*** | 0.25*** | -0.04 | 0.02 | 0.24*** | 0.25*** | 0.32*** |
| | | (4.64) | (3.44) | (34.88) | (3.30) | (15.82) | (8.38) | (9.41) | (8.15) | (15.45) | (12.18) | (-0.69) | (0.15) | (8.75) | (7.80) | (16.52) |
| **$R^2$** | | 0.98 | 0.95 | 0.99 | 0.94 | 0.94 | 0.95 | 0.94 | 0.95 | 0.97 | 0.97 | 0.95 | 0.96 | 0.98 | 0.96 | 0.96 |

Notes: The t-Statistic is reported in parentheses below the regression coefficient. The significance is indicated to the right of the coefficient (*** significant at 1%, ** significant at 5%, * significant at 10%). $R^2$ is the adjusted-$R^2$.

Table 7 Long Run Equations for the Period after Crisis

| Region / Variable | | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HI** | | 1.92*** | 0.88*** | 2.82*** | 1.88*** | 1.17*** | 0.55*** | 0.74*** | 0.26*** | 0.44** | 0.88*** | 0.60*** | -0.29*** | 0.74*** | 0.35*** | 0.11* |
| | | (35.53) | (6.46) | (24.88) | (15.55) | (6.66) | (8.26) | (16.72) | (3.89) | (3.29) | (16.97) | (9.47) | (-6.44) | (30.46) | (5.36) | (2.21) |
| **MR** | | 0.003 | -0.01 | 0.05** | 0.10*** | 0.06** | 0.06*** | 0.03*** | -0.03*** | 0.02. | -0.01** | -0.03*** | -0.03*** | -0.07*** | -0.07*** | -0.03*** |
| | | (0.41) | (-0.49) | (3.08) | (6.40) | (2.77) | (6.92) | (5.46) | (-3.62) | (1.67) | (-2.39) | (-4.64) | (-5.33) | (-15.66) | (-7.87) | (-4.00) |
| **$R^2$** | | 0.98 | 0.50 | 0.96 | 0.84 | 0.42 | 0.43 | 0.80 | 0.49 | 0.11 | 0.89 | 0.76 | 0.31 | 0.98 | 0.71 | 0.50 |

Notes: The t-Statistic is reported in parentheses below the regression coefficient. The significance is indicated to the right of the coefficient (*** significant at 1%, ** significant at 5%, * significant at 10%). $R^2$ is the adjusted-$R^2$.

### *4.1.2 The Short Run Dynamic Results*

The estimates of short-term relationships between changes in residential property price indices and their determinants are presented in Table 8, Table 9 and Table 10.

An Augmented-Dickey-Fuller Unit Root Test was also conducted on the trend Equation 4.1. The value of test-statistic is -2.71 which is lower than the critical values for test statistics -2.6 at the 10% significance level. Hence the null hypothesis that the equation's residuals have a unit root is rejected at the 10% level. The result of the test suggests that the residential property price index at national level is cointegrated with disposable income and the 2 year fixed mortgage rate.

Following the existing literature (O'Donovan & Rae, 1997; Briggs & Ng, 2009) we consider the ECM with 3 month lagged variables and, alternatively, 6 month lagged variables. [9] A short-run equation that we estimated for national level is:

$$\Delta ln(RPPI) = \underset{(4.55)}{0.38}\, \Delta ln(RPPI)_{-3} + \underset{(1.71)}{0.64}\, \Delta ln(HI)_{-3} - \underset{(-2.008)}{0.02}\, \Delta MR_{-3} + \underset{(2.2)}{0.0022}\, NMR_{-3}$$

$$+ \underset{(0.53)}{0.007}\, resid_{-3} + \underset{(0.14)}{0.0002} \quad (4.2) \qquad (4.2)$$

where $resid_{-3}$ is the lagged residual from long-term Equation 4.1.[10] The sample period is December 2003 to January 2017. $R^2 = 0.28$ and t values are in brackets.

The coefficient on the lagged residual from the short-run Equation 4.2 is not statistically significant. The t values for all estimated variables are statistically significant; moreover, the signs are as expected. Average household income has a strong positive influence, with a 1% rise leading to a 0.64% rise in housing index. The mortgage rate appears to be significant and has the expected negative sign. The coefficient implies that a 1-percentage point rise in the 2 year fixed mortgage rate will lower relative house prices by 0.02%. Population growth has the expected positive influence on the residential property index. If population density increases by 100 people per 1,000 people in New Zealand, then the residential property price index will tend to increase after three months by 0.22%.

[9] Previous research have been conducted using quarterly data. Additionally, we report the results for the models which include the variables with lags from one to six. The analysis shows that the best results are obtained with 3 month lagged variables.

[10] $Resid_{-3}$ is equal to $[ln(RPPI) - 1.64\, ln(HI) + 0.03\, MR – 4.74]_{-3}$

Table 8 Short Run Equations for the Full Sample

| Variable | Region / Lag | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Δln(PI)** | 1 | 0.75*** | 0.28*** | 0.73*** | 0.46*** | 0.31*** | 0.2* | 0.07 | 0.5*** | 0.57*** | 0.55*** | -0.18* | 0.2* | 0.53*** | 0.51*** | 0.25** |
| | | (12.52) | (3.61) | (12.46) | (6.19) | (3.91) | (2.59) | (0.83) | (7.05) | (8.21) | (7.81) | (-2.24) | (2.51) | (7.91) | (7.35) | (3.05) |
| | 2 | 0.59*** | 0.22** | 0.50*** | 0.40*** | 0.26** | 0.25** | -0.03 | 0.42*** | 0.50*** | 0.35*** | 0.07 | 0.1 | 0.46*** | 0.43*** | 0.28*** |
| | | (7.94) | (2.81) | (6.65) | (5.42) | (3.23) | (3.12) | (-0.39) | (5.57) | (6.81) | (4.68) | (0.92) | (1.24) | (6.45) | (6.21) | (3.57) |
| | 3 | 0.38*** | 0.16* | 0.38*** | 0.37*** | 0.1 | 0.11 | -0.15. | 0.29*** | 0.42*** | 0.25** | -0.05 | -0.02 | 0.44*** | 0.31*** | 0.13 |
| | | (4.56) | (2.01) | (4.6) | (4.7) | (1.23) | (1.37) | (-1.83) | (3.76) | (5.53) | (3.31) | (-0.61) | (-0.22) | (6.2) | (4.27) | (1.63) |
| | 4 | 0.27** | 0.31*** | 0.3*** | 0.39*** | 0.16* | 0.17* | 0.20* | 0.31*** | 0.53*** | 0.31*** | 0.07 | 0.19* | 0.43*** | 0.35*** | 0.16* |
| | | (3.05) | (3.93) | (3.45) | (5.24) | (2) | (2.09) | (2.51) | (4.01) | (7.12) | (3.98) | (0.82) | (2.42) | (6.06) | (4.92) | (2.02) |
| | 5 | 0.17. | 0.28*** | 0.25** | 0.35*** | 0.29*** | 0.12 | 0.28*** | 0.35*** | 0.58*** | 0.31*** | 0.04 | 0.12 | 0.43*** | 0.28*** | 0.15. |
| | | (1.84) | (3.45) | (2.7) | (4.58) | (3.93) | (1.49) | (3.51) | (4.61) | (8.04) | (3.6) | (0.43) | (1.49) | (6.04) | (3.58) | (1.88) |
| | 6 | 0.2* | 0.25** | 0.21* | 0.43*** | 0.26** | 0.16. | 0.04 | 0.37*** | 0.52*** | 0.29** | 0.02 | 0.28*** | 0.44*** | 0.33*** | 0.05 |
| | | (2.11) | (2.96) | (2.28) | (5.72) | (3.31) | (1.98) | (0.5) | (4.68) | (6.66) | (3.24) | (0.22) | (3.63) | (6.2) | (4.38) | (0.59) |
| **Δln(HI)** | 1 | 0.59. | 0.42* | -0.12 | 0.54** | -0.04 | 0.46 | 0.69. | -0.07 | 0.18 | 0.27* | 0.48 | 0.35 | 0.09 | -0.06 | 0.12 |
| | | (1.93) | (2.54) | (-0.73) | (2.8) | (-0.08) | (1.32) | (1.77) | (-0.35) | (0.77) | (2.31) | (1.06) | (0.78) | (0.65) | (-0.47) | (0.55) |
| | 2 | 0.65. | 0.44* | -0.3 | 0.57** | 0.29 | 0.37 | 0.51 | -0.14 | 0.14 | 0.38** | 0.43 | 0.67 | 0.12 | -0.07 | -0.07 |
| | | (1.85) | (2.6) | (-1.45) | (2.93) | (0.63) | (1.03) | (1.29) | (-0.67) | (0.55) | (3.08) | (0.95) | (1.5) | (0.81) | (-0.57) | (-0.33) |
| | 3 | 0.64. | 0.63*** | -0.38. | 0.56** | 0.38 | 0.15 | 0.51 | -0.38. | 0.12 | 0.43** | 0.42 | 0.4 | 0.06 | -0.1 | -0.31 |
| | | (1.71) | (3.72) | (-1.69) | (2.75) | (0.79) | (0.4) | (1.29) | (-1.73) | (0.45) | (3.35) | (0.92) | (0.89) | (0.42) | (-0.73) | (-1.51) |
| | 4 | 0.49 | 0.37* | -0.32 | 0.52** | 0.06 | 0.3 | 0.23 | -0.52* | -0.01 | 0.35** | 0.03 | 0.56 | -0.01 | -0.09 | -0.43* |
| | | (1.26) | (2.25) | (-1.31) | (2.64) | (0.14) | (0.78) | (0.61) | (-2.42) | (-0.04) | (2.75) | (0.06) | (1.29) | (-0.04) | (-0.65) | (-2.19) |
| | 5 | -0.1 | 0.27 | -0.08 | 0.63** | -0.2 | 0.46 | 0.32 | -0.61** | 0.01 | 0.29* | 0.32 | 0.58 | -0.05 | -0.08 | -0.45* |
| | | (-0.25) | (1.58) | (-0.32) | (3.07) | (-0.46) | (1.18) | (0.84) | (-2.83) | (0.04) | (2.05) | (0.68) | (1.34) | (-0.3) | (-0.56) | (-2.32) |
| | 6 | -0.44 | 0.21 | -0.27 | 0.52* | -0.07 | 0.64. | 0.32 | -0.54* | -0.07 | 0.14 | 0.19 | 0.29 | -0.09 | 0.01 | -0.46* |
| | | (-1.11) | (1.2) | (-1.01) | (2.53) | (-0.16) | (1.66) | (0.79) | (-2.44) | (-0.25) | (0.92) | (0.4) | (0.69) | (-0.58) | (0.08) | (-2.33) |
| **ΔMR** | 1 | -0.01 | 0.03* | -0.001 | 0.02. | 0.02 | 0.06* | 0.06* | 0.01 | 0.01 | -0.003 | 0.004 | 0.05* | 0.01 | 0.01 | 0.01 |
| | | (-0.8) | (1.99) | (-0.13) | (1.74) | (0.86) | (2.47) | (2.25) | (0.86) | (0.83) | (-0.4) | (0.17) | (2.03) | (1.15) | (0.53) | (0.52) |
| | 2 | -0.01 | 0.02 | -0.01 | 0.02. | 0.01 | 0.03 | 0.03 | 0.01 | 0.003 | -0.01 | -0.01 | 0.03 | -0.0001 | 0.01 | 0.01 |
| | | (-1.43) | (1.4) | (-0.73) | (1.85) | (0.56) | (1.3) | (1.12) | (0.85) | (0.25) | (-0.58) | (-0.62) | (1.33) | (-0.01) | (0.57) | (0.47) |
| | 3 | -0.02* | 0.02 | -0.01 | 0.01 | -0.003 | 0.02 | 0.03 | 0.03 | 0.01 | -0.01 | -0.03 | 0.06* | 0.002 | 0.01 | 0.01 |
| | | (-2.01) | (1.48) | (-0.77) | (0.45) | (-0.17) | (0.75) | (0.96) | (1.63) | (0.85) | (-1.19) | (-1.15) | (2.49) | (0.16) | (0.61) | (0.67) |
| | 4 | -0.02* | 0.004 | -0.01 | -0.01 | 0.01 | 0.003 | -0.01 | 0.03* | -0.0004 | -0.01 | -0.01 | 0.03 | -0.001 | 0.001 | 0.02 |
| | | (-2.27) | (0.28) | (-1.22) | (-0.6) | (0.55) | (0.12) | (-0.59) | (1.98) | (-0.03) | (-1.43) | (-0.26) | (1.19) | (-0.14) | (0.05) | (1.29) |
| | 5 | -0.01 | 0.01 | -0.02 | 0.01 | 0.01 | -0.01 | 0.01 | 0.04* | -0.005 | -0.02. | -0.03 | 0.03 | -0.01 | -0.003 | 0.03. |
| | | (-1.36) | (0.46) | (-1.6) | (0.65) | (0.39) | (-0.26) | (0.47) | (2.18) | (-0.38) | (-1.71) | (-1.2) | (1.21) | (-0.59) | (-0.29) | (1.81) |
| | 6 | -0.01 | -0.002 | -0.01 | 0.001 | 0.02 | -0.01 | 0.01 | 0.03 | -0.01 | -0.02. | -0.03 | 0.02 | -0.01 | -0.01 | 0.04* |
| | | (-0.96) | (-0.09) | (-1.09) | (0.11) | (0.73) | (-0.5) | (0.27) | (1.6) | (-0.92) | (-1.9) | (-1.08) | (1.06) | (-0.72) | (-1.15) | (2.13) |

Table 8 Short Run Equations for the Full Sample (continued)

| Variable | Region / Lag | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NMR | 1 | 0.00026 | 0.00537* | 0.00176* | 0.00261 | 0.00329 | 0.00176 | 0.00288 | -0.00104 | 0.00019 | 0.00213 | 0.01356 | 0.00003 | -0.00005 | 0.00063. | -0.00133 |
| | | (0.32) | (2.37) | (2.09) | (1.35) | (1.27) | (0.60) | (0.74) | (-0.38) | (0.09) | (1.47) | (1.19) | (0.01) | (-0.51) | (1.96) | (-1.6) |
| | 2 | 0.00101 | 0.0065** | 0.00262* | 0.0053** | 0.004 | 0.00215 | 0.00565 | 0.00017 | 0.00413. | 0.006*** | 0.0223. | -0.00649 | -0.00003 | 0.001*** | -0.00117 |
| | | (1.09) | (2.75) | (2.50) | (2.72) | (1.52) | (0.72) | (1.40) | (0.06) | (1.81) | (3.60) | (1.97) | (-1.32) | (-0.29) | (3.40) | (-1.42) |
| | 3 | 0.0022* | 0.00448 | 0.00274* | 0.00543* | 0.00576* | 0.00507 | 0.00415 | 0.00084 | 0.00542* | 0.007*** | 0.01546 | -0.00311 | 0.00007 | 0.001*** | -0.00028 |
| | | (2.2) | (1.88) | (2.41) | (2.60) | (2.11) | (1.63) | (1.03) | (0.27) | (2.30) | (4.12) | (1.33) | (-0.64) | (0.67) | (3.71) | (-0.32) |
| | 4 | 0.00179. | 0.00608* | 0.00213. | 0.0057** | 0.0071** | 0.00374 | 0.00898* | 0.0008 | 0.00085 | 0.007*** | 0.00802 | 0.00135 | 0.00002 | 0.001** | 0.00087 |
| | | (1.7) | (2.58) | (1.75) | (2.80) | (2.63) | (1.20) | (2.29) | (0.27) | (0.38) | (4.01) | (0.67) | (0.28) | (0.21) | (2.84) | (1.00) |
| | 5 | 0.00215. | 0.00619* | 0.00135 | 0.00522* | 0.009*** | 0.00426 | 0.0047 | -0.00253 | 0.00435* | 0.00328. | -0.004 | -0.0022 | 0.00003 | 0.00033 | 0.0024** |
| | | (1.96) | (2.55) | (1.05) | (2.52) | (3.55) | (1.35) | (1.21) | (-0.85) | (2.01) | (1.81) | (-0.34) | (-0.46) | (0.30) | (0.89) | (2.80) |
| | 6 | 0.00226* | 0.00618* | 0.00283* | 0.00368. | 0.0083** | 0.00556. | 0.00826* | -0.00233 | 0.00149 | 0.00214 | -0.004 | 0.00276 | 0.000003 | 0.00026 | 0.00149. |
| | | (2.06) | (2.45) | (2.19) | (1.78) | (3.10) | (1.80) | (2.05) | (-0.77) | (0.64) | (1.12) | (-0.33) | (0.58) | (0.03) | (0.73) | (1.70) |
| Resid | 1 | -0.01 | | -0.005 | | | -0.043* | -0.071* | -0.017 | -0.008 | | | | -0.027** | | -0.034* |
| | | (-1.12) | | (-0.73) | | | (-2.35) | (-2.19) | (-1.59) | (-0.87) | | | | (-2.82) | | (-2.53) |
| | 2 | -0.01 | | -0.002 | | | -0.034. | -0.039 | -0.017 | -0.006 | | | | -0.025* | | -0.021 |
| | | (-0.52) | | (-0.23) | | | (-1.79) | (-1.18) | (-1.40) | (-0.57) | | | | (-2.38) | | (-1.54) |
| | 3 | 0.01 | | -0.001 | | | -0.029 | -0.026 | -0.014 | -0.003 | | | | -0.019. | | -0.015 |
| | | (0.53) | | (-0.08) | | | (-1.43) | (-0.78) | (-1.08) | (-0.27) | | | | (-1.71) | | (-1.03) |
| | 4 | 0.02 | | 0.004 | | | -0.027 | -0.016 | -0.011 | -0.009 | | | | -0.019 | | -0.002 |
| | | (1.39) | | (0.33) | | | (-1.32) | (-0.52) | (-0.85) | (-0.84) | | | | (-1.61) | | (-0.15) |
| | 5 | 0.04* | | 0.010 | | | -0.017 | -0.038 | -0.017 | -0.008 | | | | -0.018 | | 0.011 |
| | | (2.38) | | (0.86) | | | (-0.80) | (-1.22) | (-1.24) | (-0.77) | | | | (-1.48) | | (0.71) |
| | 6 | 0.04* | | 0.005 | | | -0.011 | -0.016 | -0.018 | -0.012 | | | | -0.018 | | 0.011 |
| | | (2.49) | | (0.41) | | | (-0.51) | (-0.48) | (-1.27) | (-0.99) | | | | (-1.45) | | (0.65) |
| $R^2$ | 1 | 0.56 | 0.24 | 0.56 | 0.37 | 0.10 | 0.11 | 0.04 | 0.25 | 0.35 | 0.43 | 0.02 | 0.09 | 0.37 | 0.30 | 0.12 |
| | 2 | 0.39 | 0.21 | 0.33 | 0.37 | 0.08 | 0.09 | 0.01 | 0.17 | 0.27 | 0.36 | 0.02 | 0.06 | 0.25 | 0.28 | 0.12 |
| | 3 | 0.28 | 0.19 | 0.22 | 0.30 | 0.03 | 0.02 | 0.02 | 0.10 | 0.22 | 0.32 | 0.00 | 0.05 | 0.22 | 0.20 | 0.03 |
| | 4 | 0.22 | 0.23 | 0.16 | 0.32 | 0.06 | 0.03 | 0.06 | 0.13 | 0.27 | 0.32 | -0.02 | 0.07 | 0.20 | 0.19 | 0.05 |
| | 5 | 0.18 | 0.18 | 0.11 | 0.30 | 0.16 | 0.02 | 0.07 | 0.17 | 0.34 | 0.19 | -0.02 | 0.05 | 0.18 | 0.07 | 0.08 |
| | 6 | 0.19 | 0.14 | 0.12 | 0.32 | 0.12 | 0.05 | 0.01 | 0.15 | 0.23 | 0.11 | -0.02 | 0.10 | 0.19 | 0.10 | 0.04 |

Notes: The t-Statistic is reported in parentheses below the regression coefficient. The significance is indicated to the right of the coefficient (*** significant at 1%, ** significant at 5%, * significant at 10%). $R^2$ is the adjusted-$R^2$.

Table 9 Short Run Equations for the Period before Crisis

| Variable | Region / Lag | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Δln(PI)** | 1 | 0.44** | 0.3. | 0.41** | 0.23 | -0.06 | 0.02 | -0.07 | 0.39* | 0.39* | 0.2 | 0.31* | 0.2 | 0.38* | 0.39** | 0.1 |
| | | (3.03) | (1.96) | (2.88) | (1.54) | (-0.39) | (0.1) | (-0.46) | (2.55) | (2.63) | (1.33) | (2.19) | (1.37) | (2.56) | (2.91) | (0.63) |
| | 2 | 0.23 | -0.12 | -0.04 | 0.43** | 0.06 | 0.13 | 0.12 | 0.42** | 0.24 | -0.08 | 0.08 | -0.03 | 0.28. | 0.26. | 0.28. |
| | | (1.43) | (-0.76) | (-0.2) | (2.95) | (0.4) | (0.79) | (0.63) | (2.76) | (1.36) | (-0.55) | (0.46) | (-0.19) | (1.85) | (1.9) | (1.9) |
| | 3 | 0.15 | -0.05 | 0.05 | 0.25 | 0.01 | -0.01 | -0.01 | 0.25 | 0.14 | -0.28. | 0.03 | -0.03 | 0.32* | 0.14 | 0.07 |
| | | (1.07) | (-0.3) | (0.32) | (1.55) | (0.06) | (-0.04) | (-0.06) | (1.56) | (0.75) | (-1.89) | (0.16) | (-0.16) | (2.22) | (0.98) | (0.46) |
| | 4 | 0.01 | 0.12 | 0.002 | 0.37* | -0.03 | -0.07 | -0.35. | 0.24 | 0.16 | 0.06 | 0.06 | -0.02 | 0.17 | 0.16 | 0.06 |
| | | (0.04) | (0.77) | (0.01) | (2.45) | (-0.17) | (-0.4) | (-1.86) | (1.53) | (0.88) | (0.42) | (0.39) | (-0.13) | (1.09) | (0.98) | (0.37) |
| | 5 | -0.14 | 0.12 | -0.28. | 0.27 | 0.03 | 0.01 | 0.06 | 0.21 | 0.29 | 0.03 | -0.04 | 0.1 | 0.17 | -0.06 | 0.16 |
| | | (-0.93) | (0.71) | (-1.88) | (1.66) | (0.17) | (0.09) | (0.32) | (1.37) | (1.63) | (0.19) | (-0.26) | (0.61) | (1.1) | (-0.36) | (1.18) |
| | 6 | 0.16 | -0.03 | -0.14 | 0.49** | -0.24 | 0.03 | -0.14 | 0.32* | 0.38* | -0.12 | -0.05 | 0.29. | 0.31* | 0.14 | -0.18 |
| | | (1.03) | (-0.18) | (-0.99) | (3.24) | (-1.52) | (0.15) | (-0.7) | (2.04) | (2.07) | (-0.65) | (-0.28) | (1.79) | (2.14) | (0.84) | (-1.12) |
| **Δln(HI)** | 1 | -0.23 | 0.19 | 0.06 | -2.28* | -2.62*** | 0.83 | -0.7 | -0.45 | 0.37 | -0.22 | 1.33 | 0.22 | 0.03 | -0.21 | -0.01 |
| | | (-0.37) | (0.55) | (0.18) | (-2.16) | (-4.27) | (0.61) | (-0.7) | (-1.12) | (0.8) | (-0.98) | (1.19) | (0.15) | (0.05) | (-0.4) | (-0.01) |
| | 2 | -0.31 | 0.49 | -0.12 | -1.03 | -2.26*** | 0.15 | -0.75 | -0.48 | 0.24 | -0.11 | 0.68 | -0.23 | -0.18 | -0.31 | -0.01 |
| | | (-0.46) | (1.4) | (-0.28) | (-1) | (-3.56) | (0.11) | (-0.72) | (-1.19) | (0.5) | (-0.49) | (0.54) | (-0.16) | (-0.32) | (-0.56) | (-0.02) |
| | 3 | 0.12 | 0.47 | -0.2 | -2.26* | -2.20** | -1.66 | -1.14 | -0.71. | 0.26 | 0.1 | 0.55 | -0.72 | 0.03 | 0.28 | -0.24 |
| | | (0.2) | (1.31) | (-0.54) | (-2.0)9 | (-3.39) | (-1.24) | (-1.08) | (-1.72) | (0.54) | (0.43) | (0.44) | (-0.51) | (0.06) | (0.5) | (-0.61) |
| | 4 | -0.41 | 0.44 | -0.05 | -1.23 | -2.29** | -1.48 | -1.23 | -1.14** | 0.23 | 0.03 | -0.01 | -0.1 | -0.22 | 0.01 | -0.14 |
| | | (-0.62) | (1.28) | (-0.17) | (-1.2) | (-3.4) | (-1.06) | (-1.24) | (-2.85) | (0.47) | (0.14) | (-0.01) | (-0.07) | (-0.38) | (0.01) | (-0.31) |
| | 5 | -1.16. | 0.14 | -0.04 | -1.68 | -2.03** | -2.27. | -1.04 | -1.17** | 0.42 | -0.15 | 0.09 | -0.33 | -0.45 | -0.28 | -0.09 |
| | | (-1.7) | (0.4) | (-0.16) | (-1.51) | (-3.02) | (-1.74) | (-1.04) | (-2.95) | (0.82) | (-0.56) | (0.07) | (-0.23) | (-0.8) | (-0.44) | (-0.24) |
| | 6 | -1.88* | 0.17 | -0.19 | -1.08 | -3.04*** | -1.51 | -1.27 | -1.32** | 0.75 | -0.29 | -0.85 | -1.77 | -0.23 | -0.34 | 0.09 |
| | | (-2.7) | (0.47) | (-0.66) | (-1.03) | (-4.34) | (-1.13) | (-1.26) | (-3.37) | (1.37) | (-1.04) | (-0.65) | (-1.28) | (-0.44) | (-0.54) | (0.21) |
| **ΔMR** | 1 | 0.01 | 0.04 | 0.05 | 0.05 | -0.09 | 0.02 | 0.02 | -0.07 | -0.12. | -0.06 | 0.18 | -0.02 | 0.02 | 0.01 | 0.01 |
| | | (0.30) | (0.41) | (1.31) | (0.79) | (-0.99) | (0.12) | (0.12) | (-0.7) | (-1.91) | (-1.00) | (1.67) | (-0.12) | (0.31) | (0.16) | (0.05) |
| | 2 | -0.01 | 0.05 | -0.01 | 0.08 | -0.04 | -0.04 | -0.05 | -0.06 | -0.06 | -0.07 | -0.05 | -0.02 | -0.03 | 0.002 | -0.13 |
| | | (-0.13) | (0.57) | (-0.2) | (1.31) | (-0.47) | (-0.17) | (-0.33) | (-0.57) | (-0.72) | (-1.3) | (-0.42) | (-0.13) | (-0.53) | (0.04) | (-1.28) |
| | 3 | -0.06 | 0.02 | -0.05 | 0.09 | -0.1 | -0.18 | -0.11 | 0.04 | -0.02 | -0.07 | -0.11 | 0.04 | -0.01 | 0.1 | -0.29** |
| | | (-1.52) | (0.27) | (-1.13) | (1.36) | (-1.13) | (-0.85) | (-0.71) | (0.4) | (-0.23) | (-1.28) | (-0.92) | (0.31) | (-0.21) | (1.56) | (-2.94) |
| | 4 | -0.06 | 0.02 | -0.09* | -0.01 | -0.06 | -0.21 | -0.22 | -0.08 | 0.04 | -0.08 | 0.01 | -0.09 | -0.03 | -0.00004 | -0.1) |
| | | (-1.61) | (0.2) | (-2.22) | (-0.1) | (-0.63) | (-0.98) | (-1.48) | (-0.87) | (0.47) | (-1.65) | (0.1) | (-0.69) | (-0.54) | (-0.001) | (-0.93) |
| | 5 | -0.04 | 0.1 | -0.08* | 0.03 | 0.08 | -0.53* | -0.21 | 0.01 | 0.04 | -0.07 | -0.16 | -0.11 | -0.08 | 0.03 | -0.08 |
| | | (-1.13) | (1.16) | (-2.15) | (0.52) | (0.84) | (-2.62) | (-1.38) | (0.14) | (0.61) | (-1.16) | (-1.34) | (-0.85) | (-1.25) | (0.39) | (-0.89) |
| | 6 | -0.03 | 0.17. | -0.06 | 0.02 | -0.11 | -0.42. | -0.17 | -0.08 | -0.07 | -0.07 | -0.06 | -0.03 | -0.08 | -0.11 | 0.07 |
| | | (-0.88) | (1.89) | (-1.36) | (0.33) | (-1.1) | (-1.97) | (-1.13) | (-0.81) | (-0.96) | (-1.15) | (-0.51) | (-0.27) | (-1.39) | (-1.62) | (0.65) |

Table 9 Short Run Equations for the Period before Crisis (continued)

| Variable | Region / Lag | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NMR | 1 | 0.00164 | 0.00139 | 0.00311 | -0.00371 | -0.00732 | -0.00954 | -0.00497 | 0.00381 | 0.0034 | -0.0021 | -0.0393. | 0.00002 | 0.0018 | 0.00125 | -0.00234 |
| | | (0.62) | (0.26) | (1.39) | (-0.75) | (-1.21) | (-0.76) | (-0.52) | (0.58) | (0.81) | (-0.6) | (-1.88) | (0) | (0.59) | (1.61) | (-0.79) |
| | 2 | 0.00213 | 0.00826 | 0.00206 | 0.00631 | -0.0038 | -0.00282 | 0.00352 | 0.00268 | 0.00636 | 0.00467 | 0.01033 | 0.00896 | 0.0003 | 0.00129 | 0.00004 |
| | | (0.76) | (1.48) | (0.82) | (1.32) | (-0.61) | (-0.22) | (0.35) | (0.40) | (1.41) | (1.34) | (0.43) | (0.76) | (0.90) | (1.63) | (0.01) |
| | 3 | 6.56* | 0.00723 | 0.00151 | 0.00392 | 0.00522 | 0.01978 | 0.00058 | 0.00749 | 0.01* | 0.009** | 0.00928 | 0.00861 | 0.0006* | 0.0016* | 0.00374 |
| | | (2.57) | (1.24) | (0.71) | (0.79) | (0.81) | (1.6) | (0.06) | (1.05) | (2.22) | (2.83) | (0.37) | (0.75) | (2.14) | (2.03) | (1.44) |
| | 4 | 0.00252 | 0.011. | 0.00073 | 0.00329 | 0.00239 | 0.00297 | 0.00126 | 0.00652 | -0.00041 | 0.011** | 0.02028 | 0.00621 | 0.00044 | 0.00045 | 0.00399 |
| | | (0.96) | (1.96) | (0.34) | (0.72) | (0.35) | (0.23) | (0.13) | (0.93) | (-0.09) | (3.25) | (0.77) | (0.54) | (1.46) | (0.54) | (1.4) |
| | 5 | 0.00034 | 0.00767 | -0.00063 | -0.00196 | 0.00734 | 0.01224 | -0.00074 | -0.00748 | 0.00327 | 0.00313 | 0.01207 | -0.00646 | 0.0006* | -0.00006 | 0.0107*** |
| | | (0.13) | (1.31) | (-0.3) | (-0.4) | (1.07) | (1.01) | (-0.08) | (-1.06) | (0.72) | (0.81) | (0.45) | (-0.56) | (2.06) | (-0.07) | (4.48) |
| | 6 | 0.00057 | 0.00058 | -0.00039 | 0.00336 | -0.00627 | 0.01961 | 0.00106 | -0.0078 | 0.00029 | 0.00059 | 0.00344 | -0.01178 | 0.0007* | -0.00023 | 0.00363 |
| | | (0.22) | (0.1) | (-0.18) | (0.74) | (-0.91) | (1.56) | (0.11) | (-1.11) | (0.06) | (0.15) | (0.12) | (-1.05) | (2.57) | (-0.28) | (1.29) |
| Resid | 1 | | | -0.08 | | | | | | 0.004 | | -0.53*** | | | | |
| | | | | (-0.91) | | | | | | (0.09) | | (-4.21) | | | | |
| | 2 | | | 0.04 | | | | | | 0.03 | | -0.31. | | | | |
| | | | | (0.34) | | | | | | (0.58) | | (-2.01) | | | | |
| | 3 | | | 0.05 | | | | | | 0.05 | | -0.28* | | | | |
| | | | | (0.53) | | | | | | (0.81) | | (-2.2) | | | | |
| | 4 | | | 0.04 | | | | | | 0.09 | | -0.31* | | | | |
| | | | | (0.49) | | | | | | (1.6) | | (-2.53) | | | | |
| | 5 | | | 0.13. | | | | | | 0.1. | | -0.29* | | | | |
| | | | | (1.71) | | | | | | (1.9) | | (-2.32) | | | | |
| | 6 | | | 0.09 | | | | | | 0.10* | | -0.30* | | | | |
| | | | | (1.22) | | | | | | (2.08) | | (-2.27) | | | | |
| $R^2$ | 1 | 0.11 | 0.02 | 0.19 | 0.12 | 0.29 | -0.07 | -0.06 | 0.08 | 0.15 | -0.01 | 0.24 | -0.05 | 0.08 | 0.18 | -0.05 |
| | 2 | -0.03 | 0.01 | -0.10 | 0.19 | 0.25 | -0.07 | -0.06 | 0.10 | 0.02 | -0.001 | 0.04 | -0.07 | -0.004 | 0.09 | 0.03 |
| | 3 | 0.09 | -0.02 | -0.03 | 0.12 | 0.26 | -0.003 | -0.06 | 0.07 | 0.06 | 0.15 | 0.04 | -0.07 | 0.09 | 0.10 | 0.12 |
| | 4 | 0.02 | 0.06 | 0.06 | 0.13 | 0.22 | -0.06 | 0.02 | 0.14 | 0.01 | 0.19 | 0.04 | -0.08 | -0.02 | -0.06 | -0.03 |
| | 5 | 0.09 | 0.01 | 0.17 | 0.05 | 0.26 | 0.08 | -0.03 | 0.17 | 0.09 | -0.03 | 0.06 | -0.06 | 0.04 | -0.09 | 0.29 |
| | 6 | 0.13 | 0.01 | 0.05 | 0.19 | 0.27 | 0.03 | -0.05 | 0.22 | 0.12 | -0.03 | 0.03 | 0.04 | 0.13 | -0.02 | 0.03 |

Notes: The t-Statistic is reported in parentheses below the regression coefficient. The significance is indicated to the right of the coefficient (*** significant at 1%, ** significant at 5%, * significant at 10%). $R^2$ is the adjusted-$R^2$.

Table 10 Short Run Equations for the Period after Crisis

| Variable | Region / Lag | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Δln(PI) | 1 | 0.68*** | 0.01 | 0.73*** | 0.17 | 0.12 | 0.25* | 0.07 | 0.17 | 0.17 | 0.46*** | -0.07 | 0.03 | 0.22* | 0.15 | 0.07 |
| | | (9.3) | (0.11) | (9.56) | (1.5) | (1.13) | (2.35) | (0.63) | (1.58) | (1.62) | (5.16) | (-0.62) | (0.25) | (2.22) | (1.43) | (0.64) |
| | 2 | 0.48*** | 0.15 | 0.46*** | 0.11 | 0.09 | -0.05 | -0.03 | -0.06 | 0.03 | 0.28** | -0.06 | 0.01 | 0.14 | 0.14 | 0.05 |
| | | (5.49) | (1.53) | (4.55) | (0.98) | (0.87) | (-0.43) | (-0.32) | (-0.56) | (0.34) | (2.98) | (-0.61) | (0.07) | (1.32) | (1.36) | (0.48) |
| | 3 | 0.24* | 0.01 | 0.26* | 0.08 | -0.18. | -0.05 | -0.27** | -0.21. | -0.03 | 0.3** | -0.17 | -0.25* | -0.09 | 0.04 | -0.09 |
| | | (2.36) | (0.09) | (2.39) | (0.78) | (-1.94) | (-0.49) | (-3.2) | (-1.97) | (-0.33) | (3.14) | (-1.61) | (-2.62) | (-0.82) | (0.36) | (-0.9) |
| | 4 | 0.14 | 0.12 | 0.2. | 0.1 | 0.01 | 0.13 | 0.13 | -0.14 | 0.15 | 0.15 | 0.11 | 0.13 | 0.08 | 0.26** | 0.01 |
| | | (1.35) | (1.13) | (1.77) | (0.97) | (0.11) | (1.39) | (1.6) | (-1.3) | (1.52) | (1.48) | (0.99) | (1.37) | (0.77) | (2.64) | (0.15) |
| | 5 | 0.04 | 0.1 | 0.16 | 0.05 | 0.22* | -0.01 | 0.25** | 0.05 | 0.28** | 0.15 | -0.02 | -0.24* | 0.21* | 0.17 | 0.05 |
| | | (0.36) | (0.94) | (1.41) | (0.48) | (2.43) | (-0.14) | (3) | (0.46) | (2.84) | (1.26) | (-0.16) | (-2.47) | (2.08) | (1.59) | (0.51) |
| | 6 | 0.07 | 0.18. | 0.1 | 0.15 | 0.14 | -0.09 | -0.06 | 0.01 | 0.09 | 0.23. | 0.05 | 0.02 | 0.25* | 0.23* | 0.06 |
| | | (0.65) | (1.78) | (0.94) | (1.38) | (1.49) | (-0.99) | (-0.65) | (0.12) | (0.87) | (1.78) | (0.52) | (0.16) | (2.6) | (2.04) | (0.56) |
| Δln(HI) | 1 | 0.68* | -0.41 | 0.04 | 0.57** | 1.5 | 0.37 | 0.73* | -0.11 | 0.34 | 0.4** | 0.12 | -0.14 | 0.18 | -0.13 | 0.23 |
| | | (2.59) | (-1.46) | (0.18) | (2.86) | (1.63) | (1.63) | (2.26) | (-0.47) | (1.34) | (3.04) | (0.31) | (-0.34) | (1.61) | (-1.05) | (1.08) |
| | 2 | 0.96** | -0.49. | -0.15 | 0.64** | 2.11* | 0.57* | 0.69* | -0.24 | 0.25 | 0.47** | 0.35 | 0.35 | 0.14 | -0.18 | 0.1 |
| | | (3.03) | (-1.84) | (-0.48) | (3.23) | (2.38) | (2.41) | (2.12) | (-1.04) | (1.01) | (3.37) | (0.96) | (0.88) | (1.22) | (-1.56) | (0.48) |
| | 3 | 1.02** | -0.32 | -0.32 | 0.62** | 2.86** | 0.73** | 0.94** | -0.27 | 0.27 | 0.46** | -0.003 | 0.18 | 0.13 | -0.27* | -0.18 |
| | | (2.87) | (-1.14) | (-0.87) | (3.06) | (3.29) | (3.12) | (3.26) | (-1.17) | (1.08) | (3.07) | (-0.01) | (0.45) | (1.13) | (-2.4) | (-0.85) |
| | 4 | 1.15** | -0.46. | -0.33 | 0.59** | 1.53. | 0.79*** | 0.26 | -0.22 | 0.18 | 0.57*** | -0.12 | 0.59 | 0.07 | -0.27* | -0.37. |
| | | (3.01) | (-1.68) | (-0.84) | (2.93) | (1.67) | (3.44) | (0.87) | (-0.93) | (0.66) | (3.48) | (-0.31) | (1.47) | (0.56) | (-2.47) | (-1.79) |
| | 5 | 0.88* | -0.32 | -0.07 | 0.73*** | 0.45 | 1.02*** | 0.47 | -0.15 | 0.12 | 0.51** | -0.11 | 0.42 | -0.03 | -0.27* | -0.22 |
| | | (2.19) | (-1.28) | (-0.19) | (3.59) | (0.52) | (4.34) | (1.45) | (-0.61) | (0.45) | (2.9) | (-0.29) | (1.01) | (-0.29) | (-2.23) | (-1.11) |
| | 6 | 0.56 | -0.36 | -0.37 | 0.68** | 1.11 | 1.13*** | 0.63. | 0.01 | 0.18 | 0.32 | 0.01 | 0.51 | -0.1 | -0.2 | -0.29 |
| | | (1.38) | (-1.54) | (-0.94) | (3.16) | (1.28) | (4.85) | (1.84) | (0.06) | (0.67) | (1.74) | (0.02) | (1.19) | (-0.89) | (-1.65) | (-1.52) |
| ΔMR | 1 | -0.03** | -0.01 | -0.01 | -0.01 | -0.04 | -0.02 | -0.01 | -0.03 | -0.04* | -0.03* | -0.04. | 0.03 | -0.02 | -0.03. | -0.04. |
| | | (-2.96) | (-0.55) | (-0.95) | (-0.37) | (-1.18) | (-1.02) | (-0.41) | (-1.26) | (-2.12) | (-2.63) | (-1.68) | (1.02) | (-1.57) | (-1.79) | (-1.72) |
| | 2 | -0.04*** | -0.03. | -0.01 | -0.001 | -0.05* | -0.03. | -0.04 | -0.03 | -0.04** | -0.02** | -0.05* | 0.01 | -0.01 | -0.02. | -0.03 |
| | | (-3.78) | (-1.77) | (-0.66) | (-0.05) | (-2.08) | (-1.75) | (-1.37) | (-1.43) | (-3.07) | (-2.73) | (-2.16) | (0.35) | (-1.21) | (-1.83) | (-1.31) |
| | 3 | -0.04*** | -0.03 | 0.004 | -0.02 | -0.05* | -0.04* | -0.07** | -0.03 | -0.03* | -0.02* | -0.03 | 0.02 | -0.01 | -0.02. | -0.01 |
| | | (-3.84) | (-1.35) | (0.3) | (-1.02) | (-2.08) | (-2.49) | (-3.08) | (-1.63) | (-2.62) | (-2.57) | (-1.5) | (0.69) | (-0.73) | (-1.69) | (-0.5) |
| | 4 | -0.03** | -0.02 | 0.01 | -0.02 | -0.02 | -0.04* | -0.09*** | -0.01 | -0.03* | -0.02* | -0.02 | 0.03 | -0.01 | -0.01 | 0.003 |
| | | (-3.2) | (-1.18) | (0.87) | (-1.33) | (-0.62) | (-2.19) | (-3.94) | (-0.52) | (-2.01) | (-2.34) | (-1.09) | (1.17) | (-1.01) | (-1.32) | (0.18) |
| | 5 | -0.03* | -0.005 | 0.01 | 0.01 | -0.03 | -0.02 | -0.03 | -0.002 | -0.02. | -0.03** | -0.02 | 0.02 | -0.005 | -0.02 | -0.01 |
| | | (-2.29) | (-0.28) | (0.74) | (0.69) | (-1.18) | (-1.51) | (-1.14) | (-0.12) | (-1.72) | (-2.67) | (-1.05) | (0.99) | (-0.52) | (-1.5) | (-0.36) |
| | 6 | -0.02* | -0.02 | 0.01 | 0.01 | -0.005 | -0.03. | -0.03 | -0.01 | -0.02. | -0.03** | -0.03 | 0.01 | -0.002 | -0.02 | -0.002 |
| | | (-2.13) | (-1.41) | (1.1) | (0.62) | (-0.21) | (-1.73) | (-1.29) | (-0.84) | (-1.89) | (-2.81) | (-1.47) | (0.68) | (-0.27) | (-1.44) | (-0.1) |

Table 10 Short Run Equations for the Period after Crisis (continued)

| Variable | Region / Lag | NZ | RC1 | RC2 | RC3 | RC4 | RC5 | RC6 | RC7 | RC8 | RC9 | RC10 | RC11 | RC12 | RC13 | RC14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **NMR** | 1 | -0.0003 | 0.01*** | 0.0009 | 0.0054* | 0.0035 | 0.0028 | -0.0015 | 0.0011 | 0.0026 | 0.003* | 0.026** | -0.0018 | 0.00003 | 0.0008* | 0.0008 |
| | | (-0.42) | (3.78) | (0.9) | (2.46) | (1.13) | (1.38) | (-0.4) | (0.41) | (1.12) | (2.34) | (2.8) | (-0.38) | (0.36) | (2.44) | (1.1) |
| | 2 | 0.0003 | 0.01*** | 0.0024. | 0.006** | 0.0035 | 0.0027 | 0.0004 | 0.0029 | 0.007** | 0.005*** | 0.025** | -0.01** | 0.00002 | 0.001*** | 0.0004 |
| | | (0.34) | (3.93) | (1.93) | (2.94) | (1.16) | (1.26) | (0.11) | (1.06) | (2.88) | (3.78) | (2.64) | (-2.73) | (0.22) | (3.87) | (0.59) |
| | 3 | 0.002. | 0.009** | 0.0031* | 0.0063** | 0.0036 | -0.0002 | -0.0015 | 0.0021 | 0.006** | 0.0046** | 0.0122 | -0.0111* | 0.00003 | 0.001*** | 0.0007 |
| | | (1.89) | (3.28) | (2.2) | (2.81) | (1.21) | (-0.12) | (-0.47) | (0.79) | (2.64) | (3) | (1.24) | (-2.48) | (0.33) | (4.38) | (0.98) |
| | 4 | 0.0017 | 0.0094*** | 0.0025. | 0.0072** | 0.0059. | -0.0006 | 0.0053 | 0.0007 | 0.0019 | 0.0045* | 0.0083 | -0.0073 | -0.0001 | 0.0012*** | 0.0012. |
| | | (1.54) | (3.46) | (1.77) | (3.24) | (1.88) | (-0.29) | (1.55) | (0.26) | (0.82) | (2.57) | (0.82) | (-1.58) | (-0.07) | (3.69) | (1.79) |
| | 5 | 0.0028* | 0.009*** | 0.0018 | 0.008*** | 0.008** | -0.0016 | -0.0001 | 0.0009 | 0.0046* | 0.0035 | 0.0005 | -0.0046 | -0.0003 | 0.0007. | 0.0014* |
| | | (2.43) | (3.47) | (1.21) | (3.44) | (2.69) | (-0.8) | (-0.04) | (0.32) | (2.03) | (1.88) | (0.05) | (-0.98) | (-0.42) | (1.97) | (2.09) |
| | 6 | 0.0033** | 0.0086** | 0.0036* | 0.0045. | 0.0078* | -0.0009 | 0.0033 | 0.0031 | 0.0025 | 0.0027 | 0.0009 | 0.001 | -0.06 | 0.0006. | 0.0014* |
| | | (2.82) | (3.29) | (2.49) | (1.9) | (2.53) | (-0.47) | (0.9) | (1.11) | (1.05) | (1.38) | (0.09) | (0.21) | (-0.79) | (1.7) | (2.04) |
| **Resid** | 1 | -0.06** | | -0.02* | | | | -0.27** | | | | | -0.23** | | | |
| | | (-3.23) | | (-2.02) | | | | (-3.27) | | | | | (-3.29) | | | |
| | 2 | -0.08*** | | -0.04* | | | | -0.24** | | | | | -0.24*** | | | |
| | | (-3.71) | | (-2.43) | | | | (-3.04) | | | | | (-3.53) | | | |
| | 3 | -0.08** | | -0.04* | | | | -0.22** | | | | | -0.22** | | | |
| | | (-3.09) | | (-2.31) | | | | (-3.34) | | | | | (-3.35) | | | |
| | 4 | -0.07* | | -0.04. | | | | -0.29*** | | | | | -0.29*** | | | |
| | | (-2.27) | | (-1.95) | | | | (-3.93) | | | | | (-4.4) | | | |
| | 5 | -0.06. | | -0.03 | | | | -0.27** | | | | | -0.27*** | | | |
| | | (-1.79) | | (-1.38) | | | | (-3.3) | | | | | (-3.89) | | | |
| | 6 | -0.06. | | -0.04. | | | | -0.25** | | | | | -0.27*** | | | |
| | | (-1.97) | | (-1.79) | | | | (-3.11) | | | | | (-3.72) | | | |
| **$R^2$** | 1 | 0.60 | 0.12 | 0.56 | 0.28 | 0.09 | 0.17 | 0.14 | 0.03 | 0.10 | 0.63 | 0.07 | 0.09 | 0.07 | 0.13 | 0.01 |
| | 2 | 0.44 | 0.19 | 0.26 | 0.29 | 0.16 | 0.10 | 0.14 | 0.01 | 0.14 | 0.57 | 0.09 | 0.16 | 0.01 | 0.21 | -0.02 |
| | 3 | 0.32 | 0.09 | 0.11 | 0.26 | 0.19 | 0.13 | 0.34 | 0.04 | 0.11 | 0.51 | 0.02 | 0.19 | -0.02 | 0.22 | 0.00 |
| | 4 | 0.24 | 0.14 | 0.04 | 0.28 | 0.09 | 0.17 | 0.27 | -0.01 | 0.04 | 0.40 | -0.01 | 0.17 | -0.02 | 0.26 | 0.04 |
| | 5 | 0.18 | 0.12 | 0.02 | 0.28 | 0.18 | 0.17 | 0.20 | -0.04 | 0.13 | 0.30 | -0.03 | 0.16 | 0.01 | 0.12 | 0.03 |
| | 6 | 0.15 | 0.14 | 0.06 | 0.22 | 0.15 | 0.22 | 0.15 | -0.02 | 0.02 | 0.23 | -0.02 | 0.10 | 0.04 | 0.10 | 0.04 |

Notes: The t-Statistic is reported in parentheses below the regression coefficient. The significance is indicated to the right of the coefficient (*** significant at 1%, ** significant at 5%, * significant at 10%). $R^2$ is the adjusted-$R^2$.

Next, we turn to the 14 regions' model estimations for the period between December 2003 and January 2017. When estimating the short-term equations for the full time period we observe that household income has a significant positive impact on property indices, but only in Northland, Waikato, Bay of Plenty, Gisborne, Hawke's Bay and Wellington.

The net migration rates affect residential property price indices in most of the regions, although the effect is smaller than one would expect. For the period between 2003 and 2017 the coefficients are generally positive, as would be expected, and significant, except three regions (Taranaki, West Coast, and Canterbury). Most of the impact of net migration on the house price index seems to appear after the third month. The population growth highly affects two main New Zealand cities, Auckland and Wellington. Interestingly, the strongest responses to the population size changes are in Auckland's neighbouring regions (Northland, Waikato and Bay of Plenty).

Our findings for the mortgage rate for the full time period show that 2 year fixed mortgage rate coefficients are not significant or showing positive signs. The only region where the property index is negatively affected by the mortgage interest rate is Wellington and after the fifth month.

After splitting our sample period, similarly to the long-run results, we find evidence that, in the short run before the crisis, mortgage rates generally were positively related to the property indices, while after the crisis for most regions 2 year fixed mortgage rate coefficients in most cases had the expected negative sign and were statistically significant, indicating that lowering of real interest rates is associated with a rising house price index. We do not find any significant impact from mortgage rates for Auckland, Waikato, Taranaki, West Coast and Canterbury.

## 4.2 The Spillover Effect Estimates

### *4.2.1 Auckland Region (Auckland, Manukau, North Shore, Waitakere)*

We start the empirical study on spillover effects by conducting a Granger causality test using the multivariate VAR model for the levels of housing prices for Auckland, Manukau, North Shore and Waitakere. We choose optimal lag length for the VAR model including all four Auckland metropolitan areas and find that it is equal to one.[11]

[11] According to the Akaike Information Criterion, Schwarz Information Criterion and Hannan-Quinn Information Criterion the optimal lag for the VAR model is 1.

A Granger causality test helps to assess how useful housing prices of one of the territorial authorities are for forecasting others. More formally, we say that *y* Granger causes *x* if *y* helps to forecast *x*, given past *x*. The results of the Granger causality test are shown in Table 11. The results suggest that there are strong one-way causality relations between Auckland housing prices and the housing prices of the other three territorial authorities. The housing prices in Auckland Granger-cause the housing prices in Manukau, North Shore and Waitakere at the 1% significance level. At the same time, the housing prices in Manukau, North Shore and Waitakere do not Granger-cause Auckland's housing prices at any conventional significance level. This means that observing a price trend in Auckland helps to predict price trends in Manukau, North Shore and Waitakere, but not the other way around.

Table 11 Granger causality tests for RPPIs

| **Granger-causes** | **Auckland** | **Manukau** | **North_Shore** | **Waitakere** |
|---|---|---|---|---|
| **Auckland** | | 1.41<br>(0.235) | 0.07<br>(0.798) | 0.35<br>(0.553) |
| **Manukau** | 17.84***<br>(0.000) | | 0.62<br>(0.432) | 1.57<br>(0.210) |
| **North_Shore** | 26.04***<br>(0.000) | 0.0002<br>(0.990) | | 0.36<br>(0.548) |
| **Waitakere** | 34.91***<br>(0.000) | 1.01<br>(0.314) | 1.67<br>(0.196) | |

Notes: The row city price index represents dependent variable. The upper value in the table reports the *F*-statistic of a Wald coefficient restriction test on four parameters while the lower value reports the Wald test's associated *p*-value. *** indicates significance at the 1%.

Next, we examine the interaction between the systems of four housing prices by considering the impulse response functions. Table 12 details the generalised impulse response functions (Pesaran and Shin, 1998). It shows the responses of the four different territorial authorities to a one unit shock to housing prices in one of the four cities.

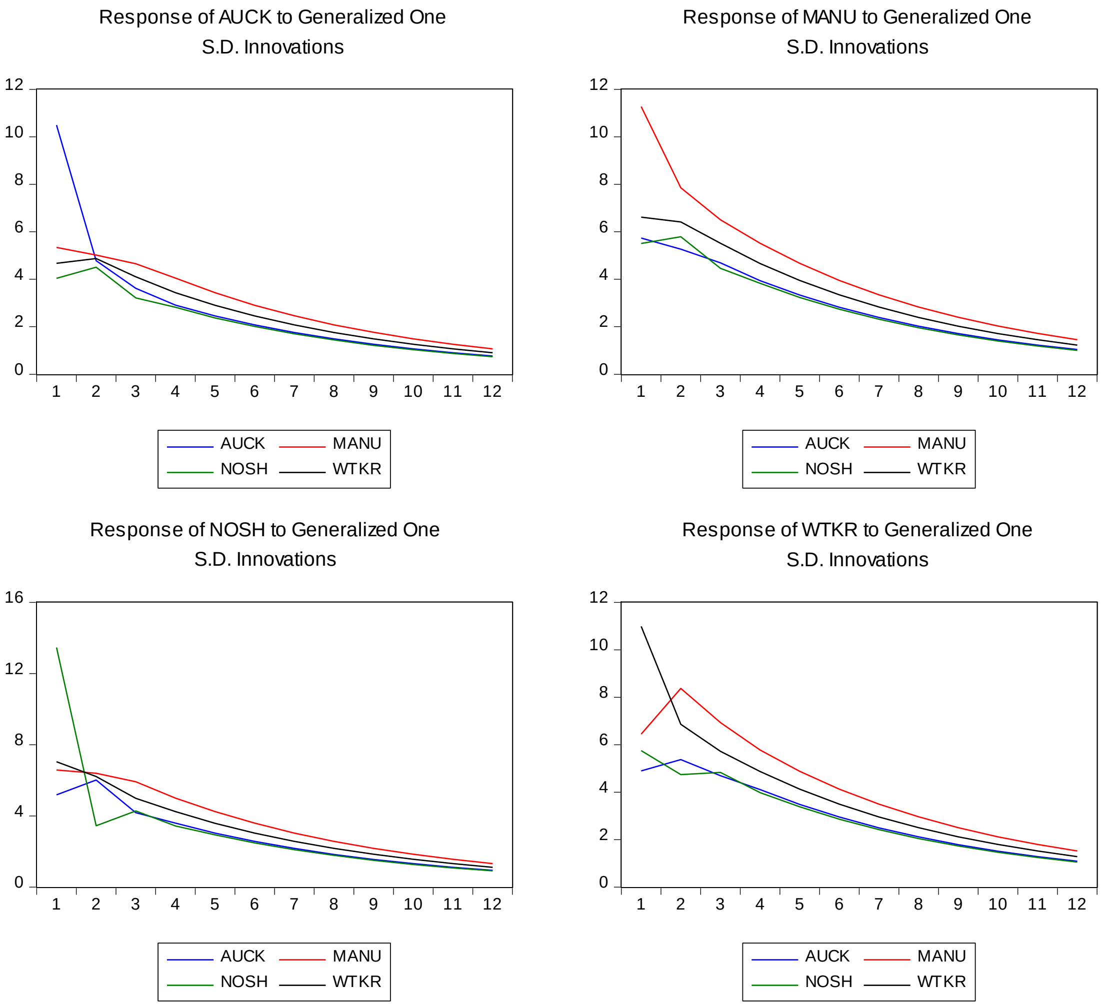
We plot the generalised impulse response functions for 12 steps ahead in Figure 13, where we apply a unit shock to the innovations of each series. The upper-left graph shows the responses to a unit shock in the Auckland's housing prices. As can be seen, this shock leads to an increase in all the other prices. The highest instantaneous impact is observed in Manukau prices, followed by Waitakere and North Shore. After one period, the effect increases for Waitakere and North Shore with the response values of 4.87 and 4.50, which starts to decline after that and dies out slowly. At the same time, Manukau shows a positive reaction which gradually decreases after one month with a contemporaneous response value of 5.34. We can say that a unit shock to Auckland's prices leads to an increase in prices in Waitakere and North Shore by 4.87 and 4.50 units, and leads to an increase in Manukau by 5.34 units.

Table 12 Generalised Impulse Response Functions of RPPIs of Territorial Authorities in the Auckland Metro Area

| Response of AUCK: | | | | | Response of MANU: | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Period** | **AUCK** | **MANU** | **NOSH** | **WTKR** | **Period** | **AUCK** | **MANU** | **NOSH** | **WTKR** |
| 1 | 10.49 | 5.34 | 4.04 | 4.68 | 1 | 5.74 | 11.27 | 5.50 | 6.61 |
| 2 | 4.78 | 5.02 | 4.50 | 4.87 | 2 | 5.27 | 7.86 | 5.79 | 6.41 |
| 3 | 3.62 | 4.66 | 3.21 | 4.10 | 3 | 4.69 | 6.51 | 4.46 | 5.52 |
| 4 | 2.91 | 4.04 | 2.82 | 3.43 | 4 | 3.94 | 5.52 | 3.83 | 4.66 |
| 5 | 2.46 | 3.43 | 2.37 | 2.90 | 5 | 3.33 | 4.67 | 3.23 | 3.95 |
| 6 | 2.08 | 2.91 | 2.01 | 2.46 | 6 | 2.82 | 3.95 | 2.73 | 3.34 |
| 7 | 1.76 | 2.46 | 1.70 | 2.08 | 7 | 2.39 | 3.34 | 2.31 | 2.83 |
| 8 | 1.49 | 2.08 | 1.44 | 1.76 | 8 | 2.02 | 2.83 | 1.96 | 2.39 |
| 9 | 1.26 | 1.76 | 1.22 | 1.49 | 9 | 1.71 | 2.39 | 1.66 | 2.02 |
| 10 | 1.06 | 1.49 | 1.03 | 1.26 | 10 | 1.45 | 2.03 | 1.40 | 1.71 |
| 11 | 0.90 | 1.26 | 0.87 | 1.07 | 11 | 1.22 | 1.71 | 1.19 | 1.45 |
| 12 | 0.76 | 1.07 | 0.74 | 0.90 | 12 | 1.04 | 1.45 | 1.00 | 1.23 |
| **Response of NOSH:** | | | | | **Response of WTKR:** | | | | |
| **Period** | **AUCK** | **MANU** | **NOSH** | **WTKR** | **Period** | **AUCK** | **MANU** | **NOSH** | **WTKR** |
| 1 | 5.18 | 6.57 | 13.46 | 7.04 | 1 | 4.90 | 6.44 | 5.74 | 10.98 |
| 2 | 6.01 | 6.40 | 3.44 | 6.20 | 2 | 5.38 | 8.38 | 4.74 | 6.86 |
| 3 | 4.17 | 5.92 | 4.27 | 4.99 | 3 | 4.69 | 6.93 | 4.83 | 5.72 |
| 4 | 3.59 | 5.00 | 3.43 | 4.24 | 4 | 4.11 | 5.77 | 3.98 | 4.87 |
| 5 | 3.02 | 4.24 | 2.93 | 3.58 | 5 | 3.48 | 4.88 | 3.38 | 4.12 |
| 6 | 2.56 | 3.58 | 2.48 | 3.03 | 6 | 2.95 | 4.13 | 2.86 | 3.49 |
| 7 | 2.17 | 3.03 | 2.10 | 2.56 | 7 | 2.49 | 3.49 | 2.42 | 2.95 |
| 8 | 1.83 | 2.57 | 1.78 | 2.17 | 8 | 2.11 | 2.96 | 2.05 | 2.50 |
| 9 | 1.55 | 2.17 | 1.50 | 1.84 | 9 | 1.79 | 2.50 | 1.73 | 2.11 |
| 10 | 1.31 | 1.84 | 1.27 | 1.55 | 10 | 1.51 | 2.12 | 1.46 | 1.79 |
| 11 | 1.11 | 1.56 | 1.08 | 1.32 | 11 | 1.28 | 1.79 | 1.24 | 1.51 |
| 12 | 0.94 | 1.32 | 0.91 | 1.11 | 12 | 1.08 | 1.52 | 1.05 | 1.28 |

Thus, we conclude that a shock to Auckland housing prices is transmitted to all other areas. The highest response for North Shore and Waitakere occur after one period that is exhibiting a spillover effect, while the highest response for Manukau occurs instantaneously. The upper-right graph demonstrates the dynamics of the system when a unit shock is applied to the Manukau housing prices. The house price impact in Manukau brings a positive response in other cities. Specifically, North Shore shows a highest response after one period, while Auckland and Waitakere exhibit slowly declining response function, without an evidence of a spillover after one period. The highest response value is observed for Waitakere, which reaches 6.61 units, followed by North Shore and Auckland with an increase by 5.79 and 5.27 units, respectively. When a one standard deviation positive shock is given to the house price in North Shore, the response in other cities is of similar magnitude, with the highest response value in Waitakere being 7.04 units. Lastly, when a one standard deviation positive shock is given to the house price in Waitakere, Manukau seems to react the most, showing a significant response in one period with a value of 8.38 units, which gradually stabilises after that.

Figure 13 Generalised Impulse Response Functions of RPPIs of Territorial Authorities in the Auckland Metro Area




Overall, the impulse response analysis shows the high degree of interaction between the housing prices of four territorial authorities showing a spillover effect between four cities. In all the cases, a one unit positive shock in the housing price of one of the suburban areas leads to either a contemporaneous increase in prices of other parts of the city or peaks after one period. In Table 13 we show the cumulated sum of the effects of a unit shock in one city to the other variables. In the last row we show the cumulated effect after 12 periods. Though our analysis does not yield any strong evidence of any particular part of the city having a substantially higher response to the shock in other parts, we can observe that in the long run Manukau has the highest cumulative response to the shocks in prices in other areas. For example, a response to a one unit shock in Waitakere's housing prices leads to a cumulated increase of 35.77 units in Auckland, 35.47 units in North Shore and 50.91 in Manukau.

Table 13 Accumulated Generalised Impulse Response Functions of RPPIs of Territorial Authorities in the Auckland Metro Area

| Response of AUCK: | | | | | Response of MANU: | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Period** | **AUCK** | **MANU** | **NOSH** | **WTKR** | **Period** | **AUCK** | **MANU** | **NOSH** | **WTKR** |
| 1 | 10.49 | 5.34 | 4.04 | 4.68 | 1 | 5.74 | 11.27 | 5.50 | 6.61 |
| 2 | 15.27 | 10.36 | 8.54 | 9.55 | 2 | 11.00 | 19.12 | 11.29 | 13.02 |
| 3 | 18.89 | 15.01 | 11.75 | 13.64 | 3 | 15.69 | 25.63 | 15.74 | 18.54 |
| 4 | 21.80 | 19.06 | 14.57 | 17.08 | 4 | 19.62 | 31.15 | 19.57 | 23.20 |
| 5 | 24.25 | 22.49 | 16.94 | 19.98 | 5 | 22.96 | 35.82 | 22.80 | 27.15 |
| 6 | 26.33 | 25.39 | 18.95 | 22.44 | 6 | 25.78 | 39.77 | 25.53 | 30.49 |
| 7 | 28.08 | 27.85 | 20.65 | 24.52 | 7 | 28.17 | 43.11 | 27.84 | 33.31 |
| 8 | 29.57 | 29.93 | 22.09 | 26.27 | 8 | 30.19 | 45.94 | 29.80 | 35.71 |
| 9 | 30.83 | 31.69 | 23.31 | 27.76 | 9 | 31.90 | 48.33 | 31.46 | 37.73 |
| 10 | 31.89 | 33.18 | 24.34 | 29.02 | 10 | 33.35 | 50.36 | 32.86 | 39.44 |
| 11 | 32.79 | 34.44 | 25.21 | 30.09 | 11 | 34.57 | 52.07 | 34.05 | 40.89 |
| 12 | 33.55 | 35.51 | 25.95 | 30.99 | 12 | 35.61 | 53.53 | 35.05 | 42.12 |
| **Response of NOSH:** | | | | | **Response of WTKR:** | | | | |
| **Period** | **AUCK** | **MANU** | **NOSH** | **WTKR** | **Period** | **AUCK** | **MANU** | **NOSH** | **WTKR** |
| 1 | 5.18 | 6.57 | 13.46 | 7.04 | 1 | 4.90 | 6.44 | 5.74 | 10.98 |
| 2 | 11.19 | 12.97 | 16.90 | 13.24 | 2 | 10.27 | 14.82 | 10.48 | 17.84 |
| 3 | 15.37 | 18.88 | 21.18 | 18.22 | 3 | 14.96 | 21.75 | 15.31 | 23.56 |
| 4 | 18.96 | 23.88 | 24.61 | 22.46 | 4 | 19.07 | 27.52 | 19.29 | 28.43 |
| 5 | 21.98 | 28.11 | 27.55 | 26.04 | 5 | 22.55 | 32.40 | 22.66 | 32.55 |
| 6 | 24.54 | 31.70 | 30.03 | 29.07 | 6 | 25.50 | 36.53 | 25.52 | 36.04 |
| 7 | 26.71 | 34.73 | 32.12 | 31.64 | 7 | 27.99 | 40.02 | 27.94 | 39.00 |
| 8 | 28.54 | 37.30 | 33.90 | 33.81 | 8 | 30.10 | 42.98 | 29.98 | 41.50 |
| 9 | 30.10 | 39.47 | 35.40 | 35.64 | 9 | 31.89 | 45.48 | 31.71 | 43.61 |
| 10 | 31.41 | 41.31 | 36.68 | 37.20 | 10 | 33.40 | 47.60 | 33.18 | 45.40 |
| 11 | 32.52 | 42.87 | 37.75 | 38.51 | 11 | 34.68 | 49.39 | 34.42 | 46.92 |
| 12 | 33.46 | 44.18 | 38.66 | 39.63 | 12 | 35.77 | 50.91 | 35.47 | 48.20 |

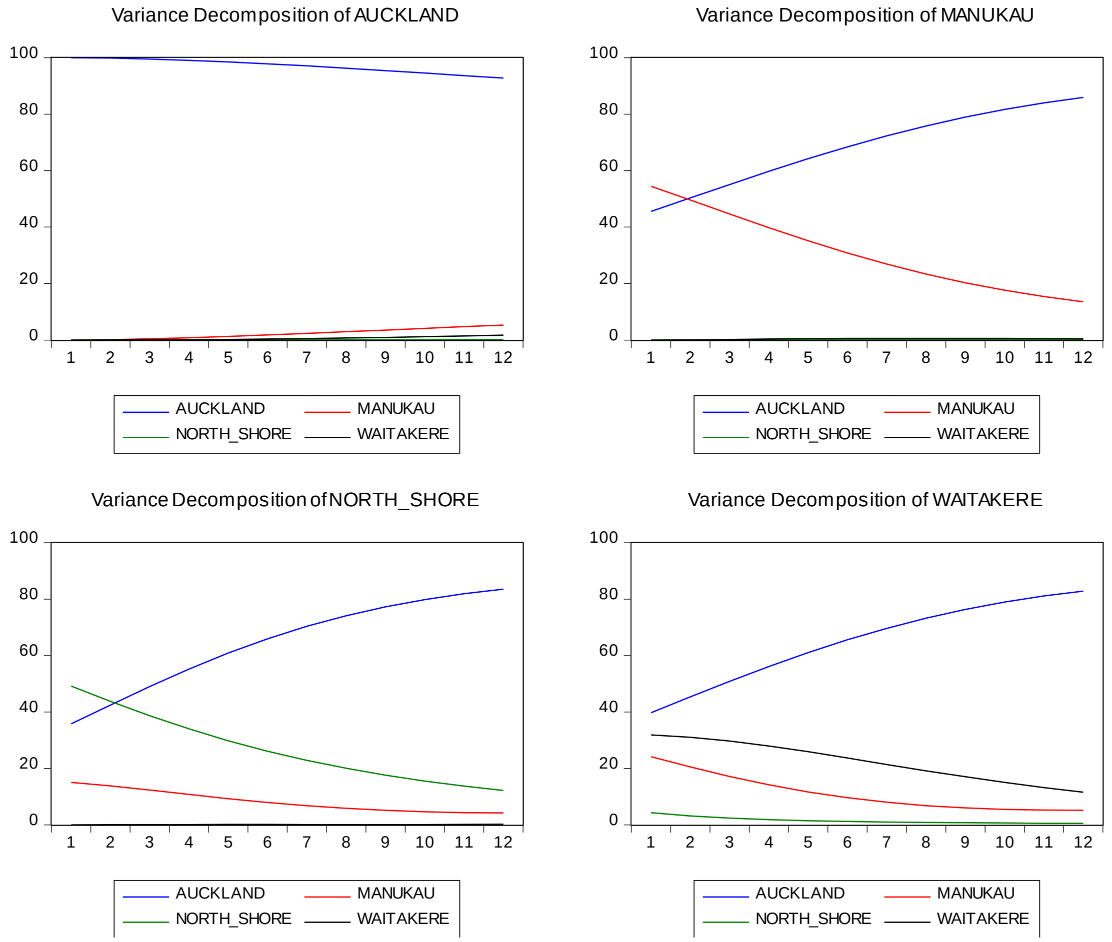
Lastly, we analyse the forecast error variance decomposition. The forecast error variance decomposition tells us the proportion of the movements in a variable due to its "own" shocks versus shocks to the other variables. In Table 14 we report the variance decomposition for Auckland, Manukau, North Shore and Waitakere at various forecasting horizons, from one to ten months. In Figure 14 we plot the variance decomposition.

Table 14 Variance Decomposition of RPPIs

| Variance Decomposition of AUCK: | | | | | | Variance Decomposition of MANU: | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Period** | **S.E.** | **AUCK** | **MANU** | **NOSH** | **WTKR** | **Period** | **S.E.** | **AUCK** | **MANU** | **NOSH** | **WTKR** |
| 1 | 13.05 | 100.00 | 0.00 | 0.000 | 0.00 | 1 | 14.93 | 45.55 | 54.45 | 0.00 | 0.00 |
| 2 | 18.93 | 99.85 | 0.13 | 0.001 | 0.02 | 2 | 20.93 | 50.33 | 49.57 | 0.02 | 0.08 |
| 3 | 23.78 | 99.53 | 0.41 | 0.005 | 0.06 | 3 | 25.50 | 55.08 | 44.65 | 0.06 | 0.20 |
| 4 | 28.17 | 99.07 | 0.79 | 0.012 | 0.13 | 4 | 29.42 | 59.74 | 39.81 | 0.11 | 0.35 |
| 5 | 32.33 | 98.49 | 1.26 | 0.022 | 0.23 | 5 | 33.00 | 64.21 | 35.18 | 0.15 | 0.47 |
| 6 | 36.35 | 97.82 | 1.79 | 0.037 | 0.36 | 6 | 36.38 | 68.42 | 30.85 | 0.17 | 0.56 |
| 7 | 40.29 | 97.07 | 2.36 | 0.055 | 0.52 | 7 | 39.69 | 72.30 | 26.90 | 0.19 | 0.61 |
| 8 | 44.21 | 96.27 | 2.94 | 0.078 | 0.71 | 8 | 42.98 | 75.83 | 23.37 | 0.19 | 0.62 |
| 9 | 48.11 | 95.43 | 3.54 | 0.105 | 0.92 | 9 | 46.30 | 78.95 | 20.27 | 0.19 | 0.59 |
| 10 | 52.03 | 94.55 | 4.14 | 0.135 | 1.17 | 10 | 49.70 | 81.67 | 17.62 | 0.18 | 0.54 |
| **Variance Decomposition of NOSH:** | | | | | | **Variance Decomposition of WTKR:** | | | | | |
| **Period** | **S.E.** | **AUCK** | **MANU** | **NOSH** | **WTKR** | **Period** | **S.E.** | **AUCK** | **MANU** | **NOSH** | **WTKR** |
| 1 | 16.33 | 35.81 | 15.01 | 49.18 | 0.00 | 1 | 15.27 | 39.74 | 24.14 | 4.28 | 31.84 |
| 2 | 22.19 | 42.45 | 13.76 | 43.77 | 0.02 | 2 | 21.44 | 45.34 | 20.47 | 3.16 | 31.03 |
| 3 | 26.40 | 48.99 | 12.30 | 38.67 | 0.05 | 3 | 26.21 | 50.83 | 17.11 | 2.38 | 29.68 |
| 4 | 29.92 | 55.18 | 10.76 | 33.99 | 0.07 | 4 | 30.36 | 56.09 | 14.15 | 1.84 | 27.92 |
| 5 | 33.12 | 60.87 | 9.26 | 29.79 | 0.08 | 5 | 34.19 | 61.03 | 11.64 | 1.47 | 25.87 |
| 6 | 36.19 | 65.94 | 7.90 | 26.08 | 0.08 | 6 | 37.88 | 65.56 | 9.59 | 1.19 | 23.66 |
| 7 | 39.24 | 70.35 | 6.74 | 22.84 | 0.07 | 7 | 41.52 | 69.64 | 7.98 | 0.99 | 21.39 |
| 8 | 42.31 | 74.11 | 5.80 | 20.02 | 0.06 | 8 | 45.16 | 73.23 | 6.79 | 0.84 | 19.14 |
| 9 | 45.45 | 77.25 | 5.10 | 17.59 | 0.06 | 9 | 48.86 | 76.33 | 5.96 | 0.72 | 17.00 |
| 10 | 48.68 | 79.82 | 4.61 | 15.49 | 0.07 | 10 | 52.64 | 78.94 | 5.44 | 0.62 | 15.00 |

As can be seen, as the forecasting horizon increases, the variance decompositions converge. We can draw the following conclusions: the Auckland house price explains 94.5% of its forecast error variance, while 4% and 1% are attributable to housing prices in Manukau and Waitakere, respectively. North Shore contributes the least with less than 1%. This means that the fluctuation of Auckland's property price mainly occurs due to its own shocks and not due to the shocks from other nearby territorial authorities. The second largest impact to the house price in Auckland is attributable to Manukau, followed by Waitakere and North Shore. As for the house price in Manukau, it explains about 17% of its forecast error variance after 10 months, while Auckland contributes substantially with the proportion of nearly 82%, followed by Waitakere and North Shore with proportions of less than 1%. This means that the spillover effect between prices in Auckland and Manukau is not equal, with the housing price in Manukau being strongly affected by price fluctuation in Auckland, but not the other way around. The next territorial authority which we consider in our analysis is North Shore. The North Shore house price explains about 15.5% of its forecast error variance, which shows that other cities play a significant role in explaining its forecast error variance. The major contributor is Auckland, with a share of 80%, followed by Manukau with a share of less than 5%, and the smallest impact comes from Waitakere with a share close to zero. The last territorial authority we want to address is Waitakere. The Waitakere house price explains only 15% of its forecast error variance, the smallest number among the system of four considered areas. This indicates that the price movement in Waitakere is greatly affected by the price movements in the nearby cities. The highest spillover effect is observed from Auckland with a share of 79%, followed by Manukau with a share of 5% and the least spillover effect is noticeable from North Shore with a share of less than 1%.

Figure 14 Variance Decomposition of RPPIs.




We can summarise the findings in the following way: First, the Granger causality test indicates that Auckland helps to explain future housing prices in North Shore, Waitakere and Manukau. We do not find any other significant causal relationships. Second, Variance Decomposition Analysis shows that the main contributor to the forecast error of all the cities is Auckland. Its share is equal to 82%, 80% and 79% for Manukau, North Shore and Waitakere, respectively. However, the variance decomposition of Auckland is almost solely explained by the shocks in Auckland, and not by the shocks in other cities. Overall, our findings suggest a spillover effect of housing prices from Auckland to other three cities.

#### *4.2.2 Main Cities (Auckland, Hamilton, Wellington)*

After considering the spillover effect for the cities near the Auckland region we switch our attention to the main cities such as Auckland, Hamilton and Wellington. The idea behind this is that residents living in one of those big cities might be tempted to move to, or invest in, the city which has more affordable housing prices. However, an important factor in making their decision is availability of jobs in their industry. That is why in this part of our analysis we consider only large cities, which have similar infrastructure and job markets.

First, we carry out the Granger causality test and present the results in Table 15. As can be seen, there is a two-way causality relation between the house prices in Wellington and Hamilton. Additionally, there is a one-way causality relation between the house prices in Hamilton and Auckland, where the prices in Auckland help to predict the prices of Hamilton. None of the cities cause the change in the housing prices in Auckland. The housing price change in Hamilton is caused by both Auckland and Wellington. The change in housing price in Wellington is caused by Hamilton. We can imply the indirect influence of prices in Auckland on Wellington, as Auckland causes Hamilton, and Hamilton causes Wellington. Granger causality analysis indicates a high degree of interaction between the housing prices of three main cities.

Table 15 Granger causality tests of RPPIs

| Granger-Causes | Auckland | Hamilton | Wellington |
|---|---|---|---|
| **Auckland** | | 1.44<br>(0.2297) | 0.08<br>(0.7738) |
| **Hamilton** | 22.8***<br>(0.000) | | 57.58***<br>(0.000) |
| **Wellington** | 0.12<br>(0.7223) | 75.69***<br>(0.000) | |

Note: The row city price index represents dependent variable. The upper value in the table reports the F-statistic of a Wald coefficient restriction test on four parameters while the lower value reports the Wald test's associated p-value. *** indicates significance at the 1%.

Next we consider the Impulse Response Functions (IRF), which help us to understand how shocks to house prices in one city spillover to house prices in other cities. IRFs for each lag are presented in Table 16, while accumulated values after 12 months are presented in Table 17. Figure 15 plots the coefficients against the time period.

Table 16 Generalised Impulse Response Functions of RPPIs of the Main Centres

| Response of AUCK: | | | | Response of HAMI: | | | | Response of WELL: | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Period** | **AUCK** | **HAMI** | **WELL** | **Period** | **AUCK** | **HAMI** | **WELL** | **Period** | **AUCK** | **HAMI** | **WELL** |
| 1 | 11.30 | 2.71 | 1.53 | 1 | 3.35 | 13.97 | 2.35 | 1 | 1.12 | 1.39 | 8.28 |
| 2 | 6.67 | 3.71 | 0.86 | 2 | 4.64 | 8.18 | 3.46 | 2 | 1.44 | 3.10 | 4.93 |
| 3 | 4.34 | 3.23 | 0.82 | 3 | 4.29 | 5.81 | 3.11 | 3 | 1.71 | 3.11 | 3.27 |
| 4 | 3.00 | 2.58 | 0.82 | 4 | 3.63 | 4.47 | 2.55 | 4 | 1.74 | 2.72 | 2.30 |
| 5 | 2.16 | 2.02 | 0.76 | 5 | 2.98 | 3.54 | 2.03 | 5 | 1.61 | 2.27 | 1.69 |
| 6 | 1.59 | 1.59 | 0.68 | 6 | 2.41 | 2.82 | 1.62 | 6 | 1.42 | 1.87 | 1.27 |
| 7 | 1.20 | 1.25 | 0.58 | 7 | 1.94 | 2.26 | 1.28 | 7 | 1.20 | 1.51 | 0.97 |
| 8 | 0.92 | 0.98 | 0.48 | 8 | 1.56 | 1.80 | 1.02 | 8 | 1.00 | 1.22 | 0.75 |
| 9 | 0.72 | 0.78 | 0.40 | 9 | 1.25 | 1.44 | 0.81 | 9 | 0.82 | 0.98 | 0.59 |
| 10 | 0.56 | 0.62 | 0.33 | 10 | 1.00 | 1.15 | 0.65 | 10 | 0.67 | 0.79 | 0.46 |
| 11 | 0.44 | 0.49 | 0.26 | 11 | 0.80 | 0.92 | 0.52 | 11 | 0.54 | 0.63 | 0.37 |
| 12 | 0.35 | 0.39 | 0.21 | 12 | 0.64 | 0.74 | 0.41 | 12 | 0.44 | 0.51 | 0.29 |

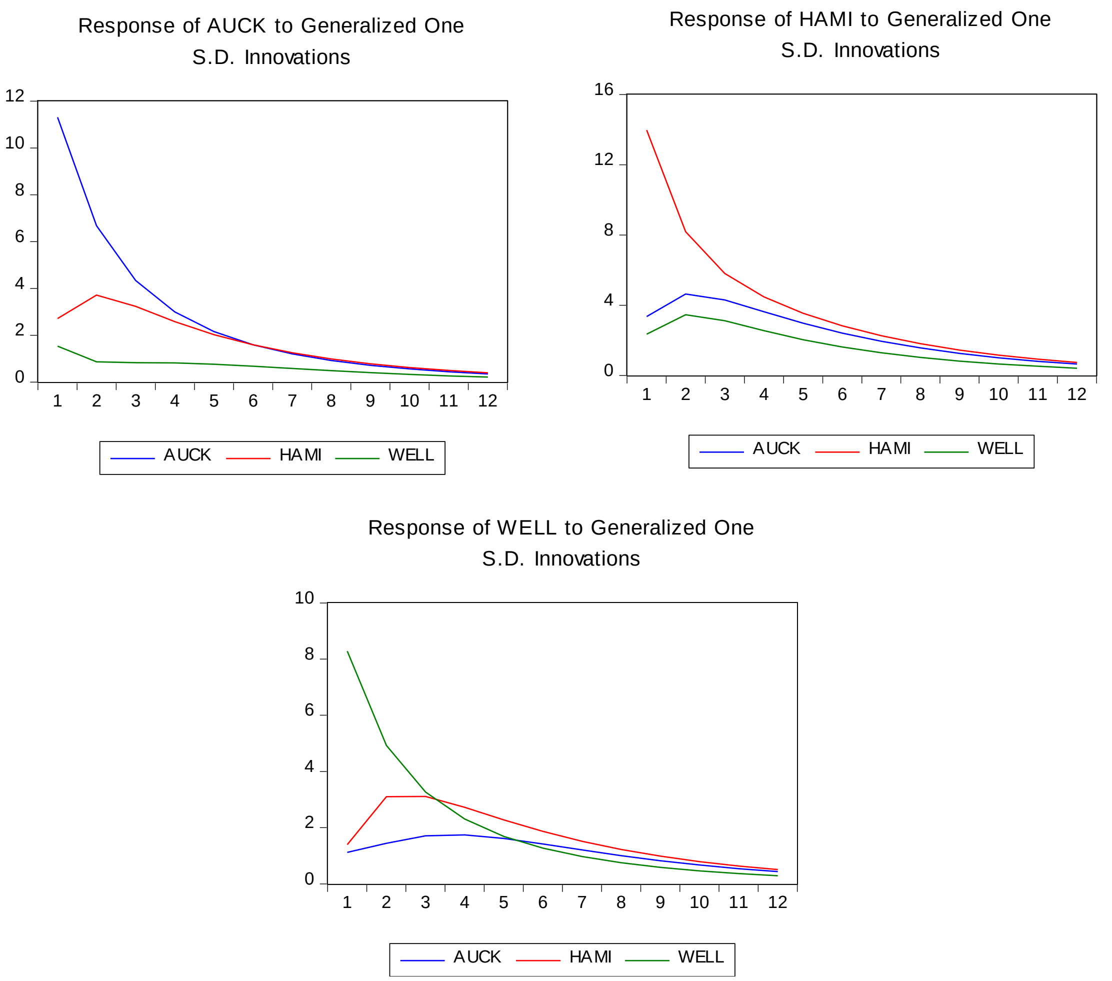
Table 17 Accumulated Generalised Impulse Response Functions of RPPIs of the Main Centres

| Response of AUCK: | | | | Response of HAMI: | | | | Response of WELL: | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Period** | **AUCK** | **HAMI** | **WELL** | **Period** | **AUCK** | **HAMI** | **WELL** | **Period** | **AUCK** | **HAMI** | **WELL** |
| 1 | 11.30 | 2.71 | 1.53 | 1 | 3.35 | 13.97 | 2.35 | 1 | 1.12 | 1.39 | 8.28 |
| 2 | 17.98 | 6.42 | 2.39 | 2 | 7.99 | 22.15 | 5.81 | 2 | 2.57 | 4.49 | 13.21 |
| 3 | 22.32 | 9.65 | 3.22 | 3 | 12.28 | 27.96 | 8.92 | 3 | 4.28 | 7.61 | 16.47 |
| 4 | 25.31 | 12.23 | 4.03 | 4 | 15.91 | 32.44 | 11.47 | 4 | 6.02 | 10.33 | 18.78 |
| 5 | 27.47 | 14.25 | 4.80 | 5 | 18.89 | 35.98 | 13.50 | 5 | 7.63 | 12.60 | 20.47 |
| 6 | 29.06 | 15.84 | 5.47 | 6 | 21.30 | 38.80 | 15.11 | 6 | 9.05 | 14.47 | 21.74 |
| 7 | 30.27 | 17.08 | 6.05 | 7 | 23.24 | 41.05 | 16.40 | 7 | 10.25 | 15.98 | 22.71 |
| 8 | 31.19 | 18.07 | 6.54 | 8 | 24.81 | 42.86 | 17.42 | 8 | 11.25 | 17.21 | 23.46 |
| 9 | 31.91 | 18.85 | 6.94 | 9 | 26.06 | 44.30 | 18.23 | 9 | 12.08 | 18.19 | 24.05 |
| 10 | 32.47 | 19.47 | 7.26 | 10 | 27.06 | 45.46 | 18.88 | 10 | 12.75 | 18.98 | 24.51 |
| 11 | 32.91 | 19.96 | 7.52 | 11 | 27.87 | 46.38 | 19.40 | 11 | 13.29 | 19.61 | 24.87 |
| 12 | 33.26 | 20.35 | 7.74 | 12 | 28.51 | 47.12 | 19.81 | 12 | 13.73 | 20.12 | 25.16 |

We can draw several conclusions. First, a positive unit shock to any city will lead to an increase in prices in all other cities, with the response values ranging between 1.53 and 4.64 units. Second, when a shock is given to Auckland or Hamilton, the highest response value is achieved either contemporaneously or after one period, while a shock to Wellington is transmitted to Auckland and Hamilton with the highest response value in four and three months, respectively. Third, by looking at the Figure 15 one can observe that the impulse response function of Hamilton is always above the other lines, which means that shocks to house prices in other cities spillover to Hamilton the most. We arrive at the same conclusion by looking at the accumulated IRF, where the highest value in the last row of each table is for Hamilton.

Both the Granger causality test and the IRF analysis agree that Hamilton housing prices are highly affected by the price trends and shocks in both Auckland and Wellington.

Figure 15 Generalised Impulse Response Functions of RPPIs of the Main Centres

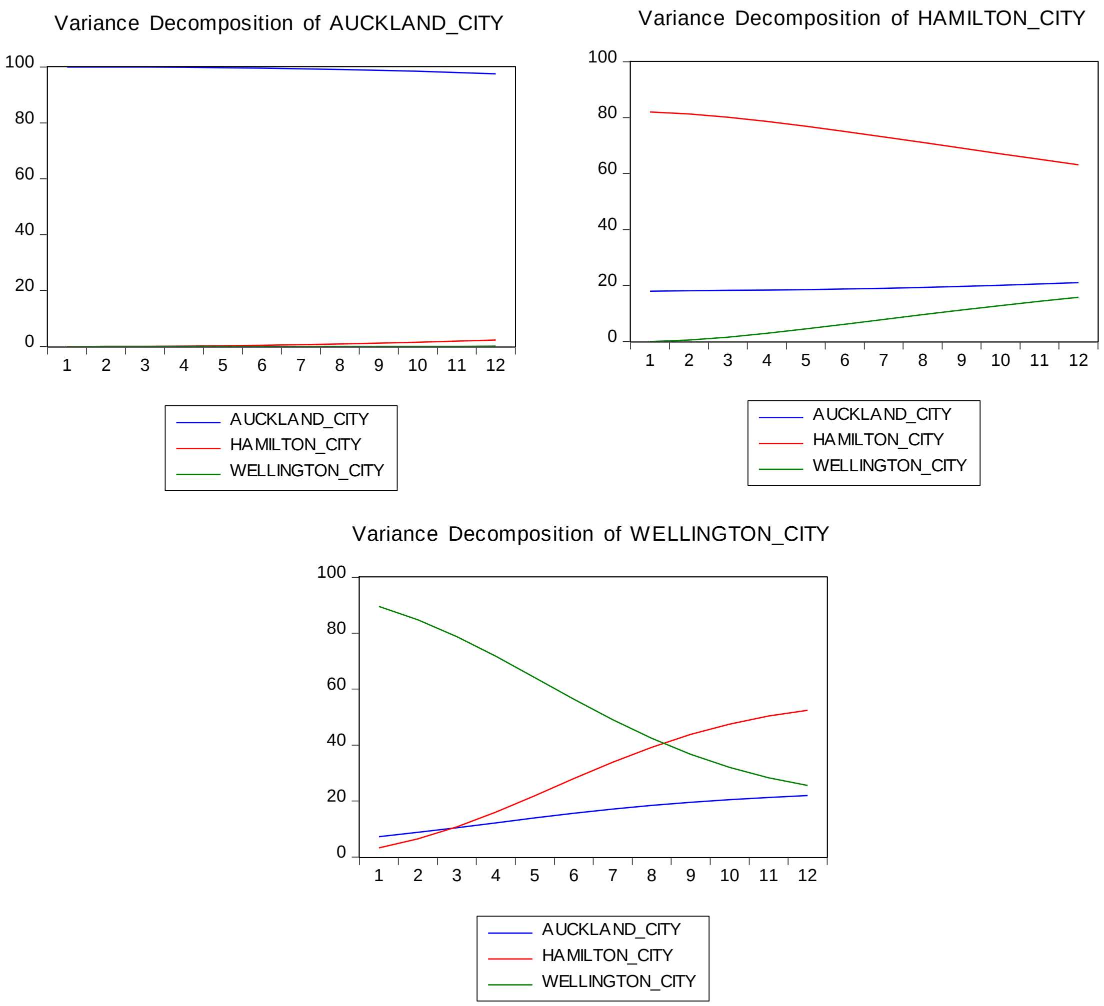



Lastly, Table 18 and Figure 16 present the results of variance decomposition. The forecast error variance decomposition tells us the proportion of the movements in a variable due to its “own” shocks versus shocks to the other variables. The Auckland house price explains about 97.5% of its forecast variance, the highest proportion amongst three considered main cities. Apart from its own shocks, shocks to Hamilton house prices appear to contribute with a share of 2%, and Wellington with a share less than 0.5%. In comparison to Auckland, Hamilton house prices explain less of their forecast error variance, only 63%. The second largest contributor is Auckland with a share of 21%, followed by Wellington with a share of about 16%. Wellington can only explain about 26% of its error forecast variance, which indicates that shocks to the prices of other cities noticeably contribute to the change of house prices in Wellington. The results suggest that 52% comes from Hamilton and about 22% from Auckland.

Table 18 Variance Decomposition of RPPIs

| | Variance Decomposition of AUCK: | | | | Variance Decomposition of HAMI: | | | | Variance Decomposition of WELL: | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Period** | **S.E.** | **AUCK** | **HAMI** | **WELL** | **S.E.** | **AUCK** | **HAMI** | **WELL** | **S.E.** | **AUCK** | **HAMI** | **WELL** |
| 1 | 13.06 | 100.00 | 0.00 | 0.0000 | 15.26 | 18.01 | 81.99 | 0.00 | 8.97 | 7.25 | 3.24 | 89.51 |
| 2 | 18.69 | 99.98 | 0.02 | 0.0008 | 22.30 | 18.14 | 81.34 | 0.52 | 12.14 | 8.79 | 6.44 | 84.77 |
| 3 | 23.17 | 99.93 | 0.07 | 0.0014 | 28.19 | 18.26 | 80.18 | 1.56 | 14.34 | 10.47 | 10.77 | 78.76 |
| 4 | 27.07 | 99.85 | 0.15 | 0.0014 | 33.56 | 18.39 | 78.68 | 2.93 | 16.12 | 12.21 | 16.04 | 71.75 |
| 5 | 30.64 | 99.73 | 0.27 | 0.0011 | 38.62 | 18.56 | 76.94 | 4.50 | 17.71 | 13.95 | 21.92 | 64.13 |
| 6 | 33.97 | 99.56 | 0.43 | 0.0014 | 43.45 | 18.76 | 75.07 | 6.17 | 19.24 | 15.60 | 28.01 | 56.40 |
| 7 | 37.15 | 99.36 | 0.64 | 0.0038 | 48.09 | 19.01 | 73.11 | 7.89 | 20.78 | 17.09 | 33.88 | 49.02 |
| 8 | 40.21 | 99.10 | 0.89 | 0.0101 | 52.57 | 19.31 | 71.11 | 9.59 | 22.39 | 18.41 | 39.22 | 42.37 |
| 9 | 43.20 | 98.79 | 1.18 | 0.0222 | 56.88 | 19.66 | 69.10 | 11.24 | 24.07 | 19.54 | 43.80 | 36.67 |
| 10 | 46.12 | 98.43 | 1.52 | 0.0425 | 61.03 | 20.07 | 67.10 | 12.83 | 25.83 | 20.49 | 47.51 | 32.00 |
| 11 | 49.01 | 98.02 | 1.91 | 0.0730 | 65.01 | 20.54 | 65.13 | 14.34 | 27.66 | 21.30 | 50.36 | 28.34 |
| 12 | 51.88 | 97.55 | 2.34 | 0.1158 | 68.81 | 21.06 | 63.19 | 15.75 | 29.55 | 22.00 | 52.41 | 25.59 |

Figure 16 Variance Decomposition of RPPIs




The results of the variance decomposition support the results on the Granger causality test in that the housing prices in Auckland are relatively independent, while trends in housing prices in Auckland spillover to Hamilton and Wellington.

# CHAPTER 5: CONCLUSION

The aims of this paper have been to describe the broad trends in New Zealand house prices, and to model their key determinants. We conduct our research into two stages. First, we provide a framework to analyse the impacts of fundamental variables on housing market outcomes at both national and regional levels. Second, we analyse the movement of price in Auckland spillover to the neighbouring Auckland cities and main cities of New Zealand.

To examine long- and short-term dynamic relationships between the determinants and housing prices we apply an Error Correction model. Our model focuses upon three key variables: average weekly household income, 2 year fixed mortgage interest rate, and net migration rate. We model house prices at both an aggregate and regional level using monthly data on Residential Property Prices Indices from SIRCA CoreLogic New Zealand Residential Sales Index covering the period from December 2003 to January 2017. Additionally, we run our model for three subperiods: before, during and after the global financial crisis.

In the long run, house prices at national level as well as in 14 regions between 2003 and 2017 are determined by average household income and the 2 year fixed mortgage interest rate (both positively). The higher the income, the higher the borrowing capacity is, leading to increased demand, leading, in turn, to driving up of house prices. Although our findings as regards mortgage rates do not support our hypothesis, they are in line with previous studies for the New Zealand housing market which was found to be exceptional because real interest rates were positively correlated with house price growth rather than negatively.

After separating our sample into before and after crisis subperiods, in the long run, average household income positively affects residential property price indices. This finding is in a line with our hypothesis: the higher the income, the higher the borrowing capacity is, leading to increased demand, leading, in turn, to driving up of house prices. The impact of mortgage rate on housing indices has changed a sign at regional level. Before the crisis we observe a positive significant impact of the mortgage rate on the housing price index, while after the crisis for half of the regions the mortgage rate has become negative and significant at 1% level. Those regions are, from the North Island, Taranaki and Wellington, and all regions from the South Island. We can conclude that the global financial crisis followed by a recession in New Zealand’s economy made a shift in consumer confidence forcing people to re-evaluate their personal and household finances.

The estimates of short-term relationships between changes in residential property price indices and their determinants at national level are as follows:

- Average household income has a strong positive influence, with a 1% rise leading to a 0.64% rise in housing index.
- The mortgage rate appears to be significant and has the expected negative sign. The coefficient implies that a 1-percentage point rise in the 2 year fixed mortgage rate will lower relative house prices by 0.02%.
- Population growth has the expected positive influence on the residential property index. If population density increases by 100 people per 1,000 people in New Zealand, then residential property price index will tend to increase after three months by 0.22%.

The main findings at regional level of the short-term dynamic relationship between the determinants and housing prices are as follows:

- Household income has a significant positive impact between December 2003 and January 2017 in half of the regions (Northland, Waikato, Bay of Plenty, Gisborne, Hawke's Bay and Wellington).
- The net migration rates positively affect residential property price indices in most of the regions between 2003 and 2017, except three regions (Taranaki, West Coast and Canterbury). The population growth highly affects two main New Zealand cities, Auckland and Wellington. Interestingly, the strongest responses to the population size changes are in Auckland's neighbouring regions (Northland, Waikato and Bay of Plenty).
- Similarly to the long-run results, we find evidence that in the short run before the crisis 2 year fixed mortgage rates generally were positively related to the property indices, while after the crisis for most regions mortgage rate coefficients in most cases had the expected negative sign and were statistically significant, indicating that lowering of real interest rates is associated with a rising house price index. We do not find any significant impact by mortgage rates for Auckland, Waikato, Taranaki, West Coast, and Canterbury.

Overall, breaking our entire sample into two subperiods, pre-crisis (2003-2008) and post-crisis (2009-2017), improves our model. This helps our findings to be consistent with international evidence and to indicate that average weekly household income and population growth positively influence residential property price indices, while mortgage interest rate increases lead to a decrease in house prices. Regions differ from one another in the responsiveness to the economic and demographic indicators. Although more long-run co-movement is observed, the results indicate that house prices across RCs exhibit different short-run behaviours across New Zealand, which may indicate that regions within New Zealand are heterogeneous economically and demographically. (The housing prices in New Zealand show different movement, as mentioned earlier, not necessarily cointegrated across regions and depend on the characteristics of specific regional markets).

On the second stage of our research we hypothesise that strong housing price increases in Auckland spillovers to other regions. First, we consider the 'Auckland spillover effect' on the main TLAs within the Auckland metropolitan area, which are North Shore, Manukau and Waitakere. We find strong evidence of the spillover effect between Auckland and other parts of the city. Both the Granger causality test and the variance decomposition suggest that housing price fluctuation in Auckland spillovers to North Shore, Manukau and Waitakere. Furthermore, the impulse response analysis indicates that housing prices in Manukau exhibit the highest response to shocks to the housing prices in other TLAs. Second, we consider the spillover effect between Auckland and the central TLAs in the most populous metropolitan areas, which are Wellington and Hamilton. Combining the results of the three different methods, namely the Granger causality, variance decomposition and impulse response functions, we can conclude that the housing price in Hamilton is strongly affected by the movements in price in Wellington, and, to a larger extent, in Auckland. At the same time, Auckland appears to be 'the least responsive' to the price movements in other main cities. The Granger causality test shows that neither the housing price in Wellington, nor in Hamilton can be useful to predict the housing price in Auckland. The variance decomposition analysis indicates that the housing price in Auckland mainly moves due to its "own" shocks versus shocks in other main cities, while shocks in Auckland greatly contribute to the price fluctuations in other main cities.

In light of this, the results of our study contribute to the knowledge of regional distributional effects of Auckland price growth on neighbouring and regional price growth in two ways. First, to conduct our empirical analysis, we use a unique dataset with Residential Property Prices Indices with monthly frequency from SIRCA: there is greater and more recent availability of data from which to draw conclusions, compared to when the previous studies were conducted. Second, of particular importance from a policy perspective we find that fluctuation in one market impacts other regions as well. For this reason, when implementing housing market policy, both the council and the government must consider its effects on the target region and on other regions.

Finally, in our research, we will draw out the implications of our empirical work for further related research. One of the limitations in this research is the relatively short period studied. This means that we have not seen as much variation in economic conditions as would be desirable to provide more robustness to our spillover analyses. Another aspect could be to break the entire sample into two subperiods: pre-crisis and post-crisis.

Additionally, the methodology of spillover testing may be extended to the construction of the spillover index, similarly to the work by Choi et al. (2013).

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# APPENDIX 1: RC/TLA Correspondence and Name Definitions

| RC Abbreviation | RC Name | TLA Abbreviation | TLA Name |
|---|---|---|---|
| RC01 | Northland Region | FARN | Far North District |
| | | WHAN | Whangarei District |
| | | KAIP | Kaipara District |
| RC02 | Auckland region | RODN | Rodney District |
| | | RODNHC | Rodney - Hibiscus Coast |
| | | RODNN | Rodney - North |
| | | NSHO | North Shore City |
| | | NSHOC | North Shore - Coastal |
| | | NSHOO | North Shore - Onewa |
| | | NSHONH | North Shore - North Harbour |
| | | WTKR | Waitakere City |
| | | AUCK | Auckland City |
| | | AUCKC | Auckland City - Central |
| | | AUCKE | Auckland_City - East |
| | | AUCKS | Auckland City - South |
| | | AUCKI | Auckland City - Islands |
| | | MANU | Manukau City |
| | | MANUE | Manukau - East |
| | | MANUC | Manukau - Central |
| | | MANUNW | Manukau - North West |
| | | PAPA | Papakura District |
| | | FRAN | Franklin District |
| RC03 | Waikato Region | THAM | Thames-Coromandel District |
| | | HAUR | Hauraki District |
| | | WKAT | Waikato District |
| | | MATA | Matamata-Piako District |
| | | HAMI | Hamilton City |
| | | HAMINE | Hamilton - North East |
| | | HAMICN | Hamilton - Central & North West |
| | | HAMISE | Hamilton - South East |
| | | HAMISW | Hamilton - South West |
| | | WAIP | Waipa District |
| | | OTOR | Otorohanga District |
| | | SWKA | South Waikato District |
| | | WTOM | Waitomo District |
| | | TAUP | Taupo District |
| RC04 | Bay of Plenty Region | WBOP | Western Bay of Plenty District |
| | | TAUR | Tauranga City |
| | | ROTO | Rotorua District |
| | | WHAK | Whakatane District |
| | | KAWE | Kawerau District |
| | | OPOT | Opotiki District |
| RC05 | Gisborne Region | GISB | Gisborne District |
| RC06 | Hawke’s Bay Region | WROA | Wairoa District |
| | | HAST | Hastings District |
| | | NAPI | Napier City |
| | | CHAW | Central Hawke's Bay District |
| RC07 | Taranaki Region | NEWP | New Plymouth District |
| | | STRA | Stratford District |
| | | STAR | South Taranaki District |

| RC Abbreviation | RC Name | TLA Abbreviation | TLA Name |
|---|---|---|---|
| RC08 | Manawatu-Wanganui Region | RUAP | Ruapehu District |
| | | WANG | Whanganui District |
| | | RANG | Rangitikei District |
| | | MANA | Manawatu District |
| | | PALM | Palmerston North City |
| | | TARA | Tararua District |
| | | HORO | Horowhenua District |
| RC09 | Wellington Region | KAPI | Kapiti Coast District |
| | | PORI | Porirua City |
| | | UHUT | Upper Hutt City |
| | | HUTT | Lower Hutt City |
| | | WELL | Wellington City |
| | | WELLCS | Wellington - Central & South |
| | | WELLE | Wellington - East |
| | | WELLN | Wellington - North |
| | | WELLW | Wellington - West |
| | | MAST | Masterton District |
| | | CART | Carterton District |
| | | SWRP | South Wairarapa District |
| RC10 | Nelson–Marlborough Region | TASM | Tasman District |
| | | NELS | Nelson City |
| | | MARL | Marlborough District |
| | | KAIK | Kaikoura District |
| RC11 | West Coast Region | BULL | Buller District |
| | | GREY | Grey District |
| | | WEST | Westland District |
| RC12 | Canterbury Region | HURU | Hurunui District |
| | | WMAK | Waimakariri District |
| | | CHRI | Christchurch City |
| | | CHRIE | Christchurch - East |
| | | CHRIH | Christchurch - Hills |
| | | CHRICN | Christchurch - Central & North |
| | | CHRIS | Christchurch - Southwest |
| | | SELW | Selwyn District |
| | | ASHB | Ashburton District |
| | | TIMA | Timaru District |
| | | MACK | MacKenzie District |
| | | WMAT | Waimate District |
| RC13 | Otago Region | WTKI | Waitaki District |
| | | COTA | Central Otago District |
| | | QUEE | Queenstown-Lakes District |
| | | DUNE | Dunedin City |
| | | DUNECN | Dunedin - Central & North |
| | | DUNEPC | Dunedin - Peninsular & Coastal |
| | | DUNES | Dunedin - South |
| | | CLUT | Clutha District |
| RC14 | Southland Region | SOUT | Southland District |
| | | GORE | Gore District |
| RC15 | Invercargill City | INVE | Invercargill City |

Notes: TLAs are generally denoted by the first four letters of their name; TLA names starting with "Wai" have the first 3 letters shortened to W; Directional and spatial epithets (North, East, South, West, Central, Upper) are shortened to N, E, S, W, C, U respectively. The only exceptions to the above naming conventions (to avoid duplication or to use conventional abbreviations) are: Waitakere (WTKR), Western Bay of Plenty (WBOP), Lower Hutt (HUTT), South Wairarapa (SWRP), Waitaki (WTKI).