Essays on Dynamics of The Housing Market

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Abstract

As the largest proportion of a household's wealth is invested in houses, a household's saving and consumption is highly likely to be affected by the movement of housing markets. Economists are also very interested in housing price movements, due to its significant impact on general economic wellbeing and business cycles. The US housing collapse is commonly referred to as the trigger of the global financial crisis (GFC), leading to stronger demand from both the public and policymakers for in-depth analysis of housing markets. This thesis provides three empirical studies that aim to explore the dynamics of housing markets.

The first essay analyses the relationship between immigration and housing markets with a focus on the regional differences within a country. Among the three housing market indicators studied (prices, rents, and price-to-rent ratios), the impact of immigration is found to be most strongly associated with rents and most weakly associated with prices. A negative relationship is reported between immigration and price-to-rent ratios, implying that in an overvalued housing market, the extent of deviation from equilibrium would have been even greater without immigration.

Increased global financial integration as a result of improvements in the specification of trade, innovations in finance, and advances in information technology has led to increased connectedness between financial markets. Against this backdrop, the second essay measures the equicorrelation and connectedness between housing and oil markets. The results provide robust evidence of the existence of strong connectedness between these markets. The results also indicate that the connectedness is time variant, reaching its peak during the financial crisis. Among the studied markets, the US housing market is found to be the dominant shock transmitter, spreading shocks to the other markets. During the GFC period, the oil market operated as an information transmission mediator, conveying shocks from the US housing market to other OECD housing markets, particularly in the net oil importing OECD countries.

The third essay focuses on whether capital gain in housing markets smooths consumption. The results indicate that the appreciation of house prices is an effective channel of risk sharing. Furthermore, the analysis of the consumption response to long-run output shocks in three developed countries (Australia, Canada, and New Zealand) provides evidence that Canadian residents are the most sensitive to permanent domestic output shocks and that the consumption patterns of Australian residents remain unchanged.

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I would like to dedicate this thesis to my parents, my husband Tom, and my little son Michael, for their unconditional love and encouragement. To my wonderful parent who always loves and has faith in me, one of the hardest things I have encountered through this PhD journey is being far away from them. Thanks to them, I have had the freedom to make my own decisions and feel confident in achieving every milestone. My heartfelt thanks are also due to my thoughtful sister, my brother-in-law, and my nephew who have helped me take good care of our parents. To my husband, who has been ready to leave everything behind to go with me through the ups and downs, his love and care have helped me to overcome every challenge and have fueled my journey to the end. Because of him, I have had the strength and belief to make this journey possible. To my wee boy, having him when doing my PhD was unplanned, but has become the most beautiful thing that has happened to me. Being a first-time mother and doing a PhD at the same time is not an easy task, yet it has been totally worth it. His little love and smile have always given me happiness every day.

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CHAPTER 1 Introduction

This chapter provides a snapshot of the three essays included in this thesis. Each essay's primary motivation, objective, and contribution to the literature on housing market dynamics is given accordingly. The organisation of the thesis is outlined at the end of the chapter.

1.1 Background of the study

There is an ever-increasing demand for understanding the housing market's dynamics due to the significant role of housing from a variety of perspectives. Regarding the household aspect, according to Englund and Ioannides (1997); Hossain and Latif (2009); Nneji, Brooks, and Ward (2013); Tsatsaronis and Zhu (2004), a major component of private-sector wealth is housing investment. The share of property in total assets is becoming higher over time due to impressive house price growth rate (Campbell & Cocco, 2007). Through the wealth effect, the performance of the housing markets consequently tends to drive household saving and consumption (Englund & Ioannides, 1997; Granziera & Kozicki, 2015; Hossain & Latif, 2009; Nneji et al., 2013; Poterba, Weil, & Shiller, 1991).

This understanding becomes even more critical once we consider the significance of housing on general economic wellbeing. In particular, the volatility of the housing market is believed to have a considerable impact on closely related financial markets, due to its effect on the profitability and soundness of financial institutions (Hossain & Latif, 2009; Nneji et al., 2013; Tsatsaronis & Zhu, 2004). Take the banking sector as an example. A drop in house prices is highly likely to drive up the mortgage default rate, pulling down the bank's profit. Reduced profitability, in turn, may trigger bank failure as well as having adverse effects on other real estate lenders (Wheelock, 2006).

Prominently, the uncertainty in housing markets is noted as one of the fundamental causes of recessions, as identified by Breitenfellner, Cuaresma, and Mayer (2015); Dufrénot and Malik (2012); Granziera and Kozicki (2015). This is evident in the context of the recent 2007-2009 Global Financial Crisis, since the burst of the US housing bubble is normally believed to be a trigger of the deep global recession (Glindro, Subhanij, Szeto, & Zhu, 2008). The plummet in house prices left financial institutions holding worthless subprime mortgage-backed securities, causing devastating, and far-reaching consequences not only for the US but also for the rest of the world economies. Real estate is further emphasised as a driver of business cycles by Leamer (2007, 2015), considering that eight out of ten post-war recessions in the US follow shocks in the housing market. In the same manner, the empirical studies by Dufrénot and Malik (2012); Ghent and Owyang (2010) highlight that significant information content in modelling business cycles can be provided by housing variables. According to Breitenfellner et al. (2015), this housing influence on the business cycle was even found to be stronger than that of the stock market.

The importance of the housing market along with house prices' enormous swings in the last few decades has bred a rich literature on the determinants of its movement. Previous studies identify numerous factors influencing house prices, demonstrating that they are most closely related to a common set of macroeconomic variables (Adams & Füss, 2010; Bouchouicha & Ftiti, 2012; Clapp & Giaccotto, 1994; Nneji et al., 2013; Tsatsaronis & Zhu, 2004). Interest and inflation, for instance, are usually recognised as the key house price explanatory variables by an emerging strand of literature (Abraham & Hendershott, 1992; Adams & Füss, 2010). As noted by Himmelberg, Mayer, and Sinai (2005), the housing cost appears to increase as the result of an unexpected rise in real interest rates, which consequently leads to lower housing demand and a decline in house prices. Likewise, the rationale of the relationship between house prices and inflation is due to the position of residential real estate as both a consumption good and an investment asset. Also, the fact that inflation impacts on mortgage financing cost results in a negative response of house prices to inflation.

Another strand of the literature highlights other factors driving the uncertainty of the housing markets. Adams and Füss (2010); Hossain and Latif (2009) document the explanatory power of the gross domestic product (GDP) growth rate on house price volatility. Glindro et al. (2008) report the association between the housing market and bank lending, given the fact that the housing market is heavily financed through mortgages. Other house price dynamics' factors can include money shock (Lastrapes, 2002), stock prices (Kakes* & Van Den End, 2004; Sutton, 2002), unemployment rates (Adams & Füss, 2010; Clapp & Giaccotto, 1994), changes in local institutional features (Glindro et al., 2008), and so on.

Interestingly, in some papers, they draw a distinction between demand and supply factors, based on the neoclassical economics framework (Chen & Patel, 1998). According to Chen and Patel (1998), the demand for housing is a function of demographic factors, income, interest rates, and features of the tax system that might encourage homeownership, whereas the availability and cost of land, the cost of construction and investments, and the availability of credit are defined as determinants of housing supply (Tsatsaronis & Zhu, 2004). As such, Chen and Patel (1998), examining dynamic causal relationships between house prices and the five determinants, suggest that both supply and demand-side factors should be responsible for house price dynamics.

Despite having extensive studies on the subject, many unsolved questions still remain. Contributing to the understanding of house price dynamics, this essay focuses on two fundamental driving forces that explain the housing boom and bust. Particularly, the first essay offers a deeper understanding of the relative response of house prices and rents to changes in immigration, considering immigration as one of the key demographic factors altering housing demand. The heterogeneity in the relationships between immigration and three housing market indicators (prices, rents, and price-to-rent ratios) is captured through the Granger causality test and Wavelet coherence approach. The second essay investigates the dynamic connectedness between oil and housing markets. Indeed, the swing of oil prices can be considered as both a housing demand and supply-side factor, given the fact that oil price movement can translate to a change of household income, interest rates, and construction costs. It also provides a valuable research topic that not only documents the dynamics of the housing market due to the variation in the oil market but also considers the spillover of shocks from the former to the latter. Concurrently, bearing in mind the increasing trend in the residential housing prices across the world, albeit with great variation, there is a growing interest in unveiling its role as a consumption smoothing channel. Even housing is considered as an illiquid asset, households might handle negative income shocks and stabilize their consumption via their home equity. The third essay, correspondingly, tackles the question of how capital gains in housing markets finance income loss, which in turn smooths consumption. Overall, the thesis is a rigorous examination of housing market dynamics, which contributes to the literature both theoretically and practically.

The following section outlines some key related literature and research objectives for the individual essays. The main contributions of the three essays to the present body of knowledge are also discussed. Section 1.5 lists the research outputs of the thesis. The structure for the remainder of the thesis is given in section 1.6.

1.2 Essay one

Immigration and housing have always been key considerations in politics and economic policymaking. In recent years, due to high immigration flows around the world and increasing concerns around housing affordability, these issues have become more pressing. Theoretically, the inflow of migrants boosts the number of houses demanded in an economy, putting pressure on house prices and rents for a given supply of houses (Braakmann, 2019; Nygaard, 2011; Sá, 2015). Empirical research, such as studies by Accetturo, Manaresi, Mocetti, and Olivieri (2014); Akbari and Aydede (2012); Moallemi and Melser (2020); Saiz (2007) provide strong evidence of the causal relationship between immigration and housing market.

The majority of empirical studies examining the impact of immigration on housing markets focuses on house prices, rather than other housing market indicators (e.g., rents and price-to-rent ratios). The first strand of the literature, generally, documents immigration upward pressure on house prices. Among them, papers by Gonzalez and Ortega (2013) in Spain, Mussa, Nwaogu, and Pozo (2017) in the US, Elíasson (2017) in Iceland, Degen and Fischer (2009) in Switzerland, Moallemi and Melser (2020) in Australia, and McDonald (2013) in New Zealand, find the significant impact between the two series. However, Akbari and Aydede (2012) in Canada, Braakmann (2019) in England and Wales, Cochrane and Poot (2016) in New Zealand, and Barbu, Strachinaru, and Cioaca (2017) in a 21-country cross-country study, all found a negligible effect.

Against the findings of a positive relationship, another strand of literature, using the disaggregated geographical data of smaller regions, records the decrease of house prices given the growth of immigration (Accetturo et al., 2014; Braakmann, 2019; Sá, 2015; Saiz & Wachter, 2011; Zhu, Pryce, & Brown, 2019). According to Braakmann (2019); Sá (2015), the inflow of migration may induce locals to move away because of increased pressure on amenities and public goods, resulting in a large fall in housing demand and subsequently leading to a fall in house prices. As stated by Sá (2015); Zhu et al. (2019), the size of studied regions has an impact on the direction of the relationship, as bigger regions appear to experience a positive effect whereas a negative effect is witnessed in smaller regions.

The use of house prices to test for the impact of immigration in the housing market is common in prior studies, yet only a handful of papers have accounted for the impact of immigration on both house prices and rents. Saiz (2007), focusing on metropolitan statistical areas (MSAs) in the US, finds that a migration inflow of 1% of the local population leads to rent and price increases of 1% and 2.9–3.4%, respectively, while Saiz and Wachter (2011), when considering neighbourhoods *within* metropolitan areas, demonstrate a negative association between immigration and the changes in housing rents and prices. Mussa et al. (2017) provide empirical evidence that an immigration increase of 1% in an MSA triggers a 0.8% increase in property prices and rents in that MSA. The impact even spills over to surrounding areas as their regions' prices are increased by 10%, whereas rents are increased by 1.17%. In the context of New Zealand, Hyslop, Le, Maré, and Stillman (2019) report a strong positive relationship between immigration and house prices at the national level, but a weak relationship with little systematic effect between immigration and house prices at a narrowly defined local area level.

The relative response of house prices and rents to changes in immigration, however, has not been sufficiently captured and that is a gap this essay aims to fill. The essay's primary contribution is to test the relationship between immigration and housing markets based on three housing market indicators; prices, rents, and price-to-rent ratios. More specifically, the essay studies whether the impact on house prices is larger or smaller than the impact on rents, and how this relative response impacts house prices vis-à-vis the equilibrium prices of the market, and whether the impacts of immigration on house prices and rents vary over time and across frequencies.

Our paper distinguishes itself from other papers by utilising the wavelet coherence approach together with the Granger causality test, soundly capturing the scenario, where two variables may be related to each other at different frequencies and different periods (Ben-Salha, Hkiri, & Aloui, 2018; Cai, Tian, Yuan, & Hamori, 2017; Nagayev, Disli, Inghelbrecht, & Ng, 2016; Ramsey & Lampart, 1998; Schleicher, 2002). The use of wavelet analysis in the area of housing and urban economics has been limited, with the exceptions of Flor and Klarl (2017) and Fan, Yang, and Yavas (2019). The housing cycle synchronisation (co-movement and lead-lag) across 40 of the largest Metropolitan Statistical Areas (MSAs) in the US, and the house price synchronisation of 5 major cities in China are investigated, respectively. Nevertheless, to the best of our knowledge, this paper is the first to use wavelet coherence analysis to examine the relationship between immigration and housing markets.

Regarding the time domain, the question of whether the immigration–housing market relationship is sporadic or persists consistently during a sample period is tested. At one point these two variables may be strongly related to each other, while at another point they may not be related at all. In other words, instead of calculating a single elasticity measure that covers the whole sample period, it might be that the impact of immigration on the housing market may vary across different sub-periods. In terms of the frequency domain, two variables may be closely related at high frequencies, where the two variables, matching each other's movement, closely follow each other. Alternatively, the two variables may be related at low frequencies such that their short-run movements are not synchronised, but common trends can be visualised over the long-run. It is well known that the frequency matters because some decisions are taken in respect to different time horizons, which has led economists to explore short- and long-term relationships between economic variables (Ramsey & Lampart, 1998).

Unlike a conventional regression analysis which generally explains the relationship by postulating that immigration impacts housing markets through changes in the demand side of the market (Akbari & Aydede, 2012; Mussa et al., 2017; Sá, 2015), the Wavelet method analyses the bivariate relationship between two variables, where the two variables are treated symmetrically. When using a regression technique, the literature shows that identification of the impact of immigration on housing markets depends on how potential endogeneity with regard to immigration is addressed, and what control variables are included in the regression models. By incorporating the simultaneity in the relationship in its calculation of coherence between the two variables and including the indirect impact originating from variables that are related to immigration and/or housing markets, Wavelet analysis, thus, is in many ways an effective alternative empirical strategy to explore the relationship between immigration and housing markets.

In addition, our work also complements related literature by covering different regions in New Zealand. New Zealand is known to be one of the top migrant destination countries in the world, especially from 2003 to 2016, when the country's immigration to population ratio always ranked among the highest figures. However, its housing market's price-to-rent ratio was ranked fifth in the world in 2017 (among 37 comparison countries) and its price-to-income ratio was ranked fourth in the world in 2017 (among 32 comparison countries), implying that New Zealand' housing market is one of the most unaffordable housing markets in the world. Thus, the exploration of the New Zealand context is critical. It further suggests potential lines of research that replicate our study. The essay mainly uses generally available immigration, price, and rent data aggregated at the regional level, so it is easy to collect the data required to explore other countries where the immigration-housing interdependence is of interest.

1.3 Essay two

Triggered by the collapse of the US housing market bubble, the Global Financial crisis (GFC) of 2007-2009 marks the darkest time in the global economy since the Great Depression. A downturn in the US financial market is first witnessed, which is followed by the financial meltdown across the rest of the world. Interconnection in the global financial systems is, therefore, suggested by extensive literature.

Several studies provide evidence of the housing market connectedness at both national and international levels. The robust association across the regional housing market is first emphasised by Miao, Ramchander, and Simpson (2011) in the US, Antonakakis, Chatziantoniou, Floros, and Gabauer (2018b) in the UK, and D. Zhang and Fan (2018) in China. In particular, as stated by Antonakakis et al. (2018b), the interregional property return shock transmission plays a critical role in explaining the fluctuation of property returns. Likewise, despite the fact that properties are relatively difficult to trade across borders, the connectedness's significance is documented at the international level. H. S. Lee and Lee (2018), for instance, studying the topic across G7 countries from 1970–2014, suggest the presence of connectedness, notwithstanding a time-varying feature of connectedness over the business cycle. Noticeably, the presence of housing markets' comovement is not only found when the actual transaction prices are used, it is also apparent when the securitised real estate markets are employed (Liow, 2013, 2015; Liow & Angela, 2017; Michayluk, Wilson, & Zurbruegg, 2006). Liow and his co-authors, utilising a dataset of securitised real state, reports a significant interaction of housing markets across Europe (Liow, 2013); across the US, Canada, the UK, France, Australia, Japan, Hong Kong, and Singapore (Liow, Zhou, & Ye, 2015); across the US, the UK, Japan, Hong Kong, and Singapore (Liow & Angela, 2017); and across the US, Europe and developed Asian markets (Liow & Ye, 2018).

While the connectedness across housing markets is clearly demonstrated by the prior work, a cross-market connectedness between the real estate market and other financial markets has not been sufficiently captured. The primary aim of this essay, therefore, is to investigate the dynamic connectedness between residential housing markets and the oil market, suggested by the increasing integration of the global financial markets (H. S. Lee & Lee, 2018; Liow, 2013; Liow et al., 2015; Vansteenkiste & Hiebert, 2011). The essay is of great interest since both classes of assets are recognised as useful alternative investments (Brown & Matysiak, 2000; Kat & Oomen, 2007; Liow & Angela, 2017).

In related research, studies by Magnusson and Makdessi (2019) and Yiqi (2017), indicate the considerable influence of oil movement on the housing markets of OECD countries (Finland, Denmark, Norway, and Sweden), justified by the fact that an increase in oil prices leads to higher construction costs, which in turns lower housing supply and increases house prices. In addition, the oil price increase is highly likely to be linked with a higher inflation rate. To hedge against the higher inflation, investors appear to express stronger interest in the housing market, initiating the growth of house prices. The movement of macroeconomic factors in an economy—e.g. economic growth and the business cycle— may also result in movements in both housing and oil markets, indicating their interrelationships (Vansteenkiste and Hiebert (2011).

When the prior studies normally investigate the fluctuation of housing markets as the result of oil price changes (Antonakakis, Gupta, & Mwamba, 2016; Beltratti & Morana, 2010; Breitenfellner et al., 2015), none of them study the connectedness between two markets. This essay, thus, adds to the existing body of knowledge by investigating the presence and magnitude of housing-oil connectedness. We not only test the housing market fluctuation due to the change in the oil market but also document the spillover of shocks from housing markets to the oil market, providing a more comprehensive picture of the relationship between them.

The use of equicorrelation methodology by Engle and Kelly (2012) and connectedness analysis by Diebold and Yilmaz (2012), enables the identification of the dynamics of housing and oil market connectedness, as well as revealing the dominant shock transmitter/receiver. The first technique of the dynamic equicorrelation (DECO) model is to determine comovement across markets over time, given the fact that the dramatic increase of comovement across markets during the financial crises has been noted in the literature (Balli, de Bruin, Chowdhury, & Naeem, 2019; Diebold & Yılmaz, 2014; Kang, McIver, & Yoon, 2017; H. S. Lee & Lee, 2018; Tsai, 2014, 2015; D. Zhang & Fan, 2018). Moreover, since the essay's examination period of 1970 – 2019 covers from the first oil crisis of 1973 to the most recent financial crises of the GFC and the European sovereign debt crisis (ESDC), the relationship in both tranquil and turmoil phases is examined. Then, the pattern and trend of connectedness across markets through time can be restated by connectedness analysis developed by Diebold and Yilmaz (2012). Prominently, by evaluating the net connectedness and pairwise connectedness, the second approach easily detects the source and recipients of shocks, tackling the question of shock transmission flow.

The empirical analysis is performed by utilising the dataset of 18 OECD countries, combining both net oil importers and net oi exporters. It is noted that the relationship between oil and housing markets appears to be asymmetric regarding net oil-exporting countries and net oil-importing countries (Agnello, Castro, Hammoudeh, & Sousa, 2017; Grossman, Martínez-García, Torres, & Sun, 2019). Therefore, having these countries in the analysis is necessary. Moreover, considering the OECD countries' advanced finance markets and their robust linkage in trade, financial markets, and the general economy, they are a good testing ground for investigating housing-oil connectedness.

1.4 Essay three

The topic of hedging risk and consumption smoothing has attracted a great deal of academic research in the economics and finance literature (Asdrubali, Sørensen, & Yosha, 1996; Balli & Balli, 2011; Balli, Basher, & Balli, 2013; Balli & Rana, 2015; Sørensen, Wu, Yosha, & Zhu, 2007; Sørensen & Yosha, 1998). Based on the theory of full consumption smoothing, there are identical consumption growth rates across individuals, regions, and countries, regardless of the nature of the shocks to production (Asdrubali et al., 1996; D. Kim & Sheen, 2007; Sørensen et al., 2007). The hypothesis, however, is always rejected by empirical studies (Asdrubali et al., 1996; Balli & Balli, 2011; Balli, Basher, & Louis, 2013; Scorcu, 1998; Sørensen & Yosha, 1998) due to the existence of non-traded goods, weak goods and financial market integration, and high transaction costs (Balli & Rana, 2015).

Realising that the level of risk sharing is imperfect and consumption smoothing may promote the welfare and enhance economic efficiency, Balli and Balli (2013); Balli, Basher, and Louis (2013) suggest that further welfare development is possible through a variety of consumption smoothing channels. One of the earliest studies by Asdrubali et al. (1996) reports three risk sharing mechanisms; combing of capital markets, the federal government, and the credit market. Among them, the capital market is generally noted as the key channel to smooth consumption in the United States (Asdrubali et al., 1996), in Australia (D. Kim & Sheen, 2007), in Canada (Balli, Basher, & Louis, 2012), and across OECD countries (Balli, Kalemli-Ozcan, & Sørensen, 2012).

Rather than paying attention to the conventional risk sharing channels, another strand of literature focuses on other alternatives. Xu (2008) argues that non-fiscal channels (such as migration and remittance of migrant wages) are of more importance to smooth risk across provinces in comparison with the capital market. Similarly, labour movements among countries of the group, interlinkages through political relations, and remittances (Balli & Balli, 2011; Balli, Basher, & Balli, 2013; Balli & Rana, 2015) are found to be the significant strategies in buffering the output shocks across various areas, such as Pacific Island countries - PICs, MENA countries, and 86 developing countries.

Abundant studies have been conducted on the mechanism to optimize consumption smoothing and diversify risk (Asdrubali et al., 1996; Balli & Balli, 2011; Balli, Basher, & Louis, 2013; Scorcu, 1998; Sørensen & Yosha, 1998), yet only a few studies document the consumption smoothing's potential of housing capital gains. While some papers report that consumption should be unaffected by the movement of illiquid assets, such as housing (Cho, 2011; Phang, 2004), most prior studies provide evidence of a significant impact of property gains on consumption. According to Hryshko, Luengo-Prado, and Sørensen (2010), in the circumstance of income shock, household consumption could remain steady due to the appreciation of house prices. The relationship is partly explained by the wealth effect, credit constraints (collateral effect), and common factors (Aruoba, Elul, & Kalemli-Ozcan, 2019; Attanasio, Blow, Hamilton, & Leicester, 2009).

Taken together, given the increasing importance of housing wealth and a lack of consensus on the consumption smoothing role of capital gains from the real estate market, this essay addresses the gap in the literature by focusing on a distinct channel coming from housing capital gains. At the first stage, the hypothesis of full risk sharing and perfect consumption smoothing is tested by employing a method first proposed by Asdrubali et al. (1996); Sørensen and Yosha (1998), and further developed by Balli and Rana (2015); Sørensen et al. (2007). The essay then focuses on the consumption smoothing possibility of capital gains coming from the property markets. Along with alternative well-known channels for sheltering consumption against output shocks, capital gains derived from housing markets are expected to act as a good shock absorber.

Last but not least, it is noticeable that despite the popularity of papers investigating the topic at the international and individual levels, there is a lack of empirical research on the possibility of consumption smoothing via the housing market at the national level. In particular, because the nature of housing markets across regions appears to be heterogeneous, hedging against regional output shocks is promising. With the bulk of work focusing on the only case in the US due to data availability, this essay further contributes to the literature by studying, in particular, the three countries of Australia, Canada, and New Zealand. These housing markets' high volatility with a dramatic increase is valuable in analysing the effect on consumption. Also, attention is paid to the developed countries as it is well noted that the house prices - consumption correlation was found to be much stronger in these countries as the result of more open and developed financial and housing markets (Buch & Yener, 2010; Ciarlone, 2011; Slacalek, 2009). By employing the most up-to-date and broad dataset, the essay, thus, revisits the theory of perfect consumption smoothing and is a perfect complement to the existing literature.

1.5 Research outputs from the thesis

Essay one

The first essay contained in this thesis has been submitted to a journal for publication and is currently under R&R.

Essay two

The second essay contained in this thesis is published in Energy Economics:

Nguyen, T. T. H., Naeem, M. A., Balli, F., Balli, H. O., & Syed, I. (2021). Information transmission between oil and housing markets. *Energy Economics*, *95*, 105100. https://doi.org/10.1016/j.eneco.2021.105100

Essay three

The third essay contained in this thesis is published in Applied Economics:

Balli, F., Nguyen, T. T. H., Balli, H. O., & Syed, I. (2020). Consumption smoothing and housing capital gains: evidence from Australia, Canada, and New Zealand. *Applied Economics*, *52*(56), 6145-6161.

To this date, the essays have been presented at the following conferences:

Nguyen, T. T. H., Balli, F. Balli, H. O., & Syed, I. (2019). *Immigration Rollercoaster: Dynamic impact on Housing and Rental market* [Paper presentation]. 25th Pacific Real Estate Society Conference, Melbourne, Australia.

Nguyen, T. T. H., Balli, F. Balli, H. O., & Syed, I. (2019). *Immigration Rollercoaster: Dynamic impact on Housing and Rental market* [Paper presentation]. 23rd Annual New Zealand Finance Colloquium, Lincoln, New Zealand.

1.6 Organisation of the thesis

The remaining chapters of this thesis are structured as follows. The main body of this thesis embraces three essays, which are shown in three independent chapters. Chapter 2 focuses on the relationship between immigration and housing market indicators, comprising prices, rents, and price-to-rent ratios. Chapter 3 explores information transmission (connectedness) between oil and housing markets. Chapter 4 deals with the response of consumption smoothing to housing capital gains. Finally, the summary of the three essays' key findings, contributions, and implications for market participants and regulators is stated in Chapter 5. The agenda for future studies are also suggested in the last chapter.

CHAPTER 2 Immigration and regional housing markets: prices, rents, price-to-rent ratios, and disequilibrium

As pointed out in the introduction to the thesis, since understanding the housing market's dynamics has become increasingly important, it is necessary to investigate its driving factors. The first essay, thus, examines one of the key housing market's determinants, namely immigration. The relationship between immigration and regional housing markets in New Zealand is investigated, using Wavelet coherence in conjunction with the Granger Causality test.

2.1 Introduction

This paper examines the relationship between immigration and housing markets with regard to house prices, rents, and price-to-rent ratios. Across New Zealand as a whole and its top four immigrant-attracting regions, we look at: (1) whether the impact on house prices is larger or smaller than the impact on rents, and how this relative response impacts house prices vis-à-vis the equilibrium prices of the market, and (2) whether the impacts of immigration on house prices and rents vary in different periods depending on the length of the period of analysis (short to medium to long run) and the state of the housing market. The methods—wavelet coherence in conjunction with Granger causality—used in this paper enables us to capture the heterogeneity of the relationship between immigration and the housing market variables. The paper finds that while there is important heterogeneity in the relationships, the findings can nevertheless be generalised, providing important information for a better theoretical understanding of the subject and for policymaking.

Understanding the relative response of house prices and rents to changes in immigration is important for policy purposes. In a housing market, for example, equilibrium is attained when actual rental yields, i.e. the reciprocal of price-to-rent ratios, match the user cost of owner-occupying (Himmelberg et al., 2005). This means that if the rental yield in a given housing market is lower than the user cost, the housing market is overvalued, and if the rental yield is higher than the user cost, the market is undervalued. Now consider an overvalued housing market in a given region; in this region, there has been a surge in the number of migrants that has resulted in an increase in the demand for both owner-occupied and rental housing. For a given time horizon, if these increases in demand result in house prices growing faster than rents, thus *lowering* the rental yield, the housing market will move further away from equilibrium (Hill & Syed, 2016). On the contrary, if these increases in demand result in house rents growing faster than house prices, thus *increasing* the rental yield, the housing market will move towards equilibrium. These two potential outcomes have contrasting policy implications: while the former suggests adopting policies that will dampen the demand in the housing market, the latter suggests adopting policies that will increase investment in the housing market.

The paper uses wavelet coherence analysis in order to ascertain the dynamic relationship between immigration and housing market variables. An important advantage of wavelet analysis is that it allows the investigation of the association between two variables in both time and frequency domains (Crowley, 2007; Flor & Klarl, 2017; Ramsey, 2002). In the short run, immigration and housing market variables may be closely related at high frequencies (i.e. high fluctuations), and in the long run, the two variables may be related at low frequencies (i.e. low fluctuations) exhibiting common trends. This scenario, where two variables may be related to each other at different frequencies at different time periods, is a relationship that could be well captured using wavelet analysis (Fan et al., 2019; Schleicher, 2002).

Furthermore, at a given frequency and time horizon, wavelet analysis output (a wavelet coherence scalogram) provides estimates of the number of periods of displacement between the two variables at which the association between the two variables is the strongest. In this study we conduct Granger causality tests in order to understand what the data reveals regarding which variable leads in the relationship between the two variables. Combining these two identifications—one that identifies the leading variable and the other that identifies the period of displacement—enables us to interpret the results in terms of the responsiveness of one variable to the changes in the other variable. That is, at a given frequency and time horizon, how many periods does one variable take to respond to changes in another variable, and in what direction this response takes place? To the best of our knowledge, this paper is the first to use wavelet coherence analysis to examine the relationship between immigration and housing markets.[1]

[1] Some excellent discussions of the application of wavelet analysis in economics and social sciences can be found in Crowley (2007); Flor and Klarl (2017); Ramsey (2002); Schleicher (2002).

The data used in this paper covers a period of 21 years, 1996–2017, for four different regions in New Zealand and New Zealand as a whole. In terms of the immigration-to-population ratio, New Zealand has been consistently one of the top migrant destination countries of the world. Furthermore, house prices in New Zealand have gone up steadily in the last two decades (see figure 2.6(c)), resulting in New Zealand's housing market being one of the most unaffordable housing markets in the world.[2] Given that the significance of the housing and immigration situation in New Zealand is reflected in many other countries, the findings that we get from this study may be generalised to places where these issues are similarly important.

The estimates of wavelet coherence and Granger causality between immigration and the three examined housing market variables demonstrate that immigration leads the housing market generally by less than a year. Among these variables, the relationship with immigration across regions and New Zealand as a whole is strongest with rents, still strong with price-to-rent ratios, and weakest with prices. While the relationships between immigration and prices and between immigration and rents are both positive, the relationship between immigration and price-to-rent ratios is negative across all regions. Immigration's relatively dominant role in the movement of rents can be explained by the fact that when immigrants move they tend to rent rather than purchase (Saiz, 2007). While there are different factors that affect how long a new immigrant tends to live in a rented house, it could be expected that, *ceteris paribus*, the more expensive or overvalued a housing market is, the more time an immigrant would take to buy a property (Akbari & Aydede, 2012). This time lag allows housing market supply to respond to changes in housing demand, thus dampening immigration's impact on observed transaction prices (Braakmann, 2019; Nygaard, 2011).

2.2 Literature review

There has been a modest amount of research examining the impact of immigration on housing markets. Most of the studies examine the impact of immigration on house prices, rather than on rents, price-to-rent ratios or other housing market indicators. These studies, most of which focus on broad regions, generally find that immigration exerts upward

[2] According to the OECD, New Zealand's average annual immigration-to-population ratio between 2003 and 2016 was 1.14%. This ratio for other top-ranked countries of the world for these years was: Australia (0.93%), Canada (0.76%), UK (0.55%), Italy (0.49%) and Germany (0.45%) (see Appendix). The OECD also reports that the New Zealand housing market's price-to-rent ratio was ranked 5 in the world in 2017 (among 37 comparison countries) and its price-to-income ratio was ranked 4 in the world in 2017 (among 32 comparison countries).

pressure on house prices due to an increase in the number of households in the economy (Akbari & Aydede, 2012; Cochrane & Poot, 2016; Elíasson, 2017; Gonzalez & Ortega, 2013; McDonald, 2013; Mussa et al., 2017). In recent years, a number of studies in which the analysis uses disaggregated geographical data that focuses on the impact on smaller regions find that immigration causes house prices to fall (Accetturo et al., 2014; Braakmann, 2019; Saiz & Wachter, 2011). Sá reports that the inflow of migration may induce locals to move out because of increased pressure on amenities and public goods, resulting in a large fall in demand leading to a fall in house prices.

Only a small number of studies have looked at both house prices and rents while investigating the impact of the inflow of migrants on housing markets. Saiz (2007), looking at broad regions such as metropolitan statistical areas (MSAs) in the US, finds that a migration inflow of 1% of the local population results in an increase in rents and prices by 1% and 2.9–3.4%, respectively. However, Saiz and Wachter (2011), looking at neighbourhoods *within* metropolitan areas, find a negative association between immigration and the changes in housing rents and prices. In the context of New Zealand, Hyslop et al. (2019) report a strong positive relationship between immigration and house prices at the national level, but a weak relationship with little systematic effect between immigration and house prices at a narrowly defined local area level. They do not find any systematic relationship between immigration and rents at either local or national levels. Mussa et al. (2017) find that, in the US, a 1% increase in immigration in an MSA results in a 0.8% increase in property prices and rents in that MSA; however, when the surrounding areas are considered, the impacts are much higher for prices (10%) than for rents (1.17%).

Compared to previous studies, our study examines the relationship between immigration and housing markets from a different perspective. Instead of focussing on the impact of immigration on prices and rents separately, our study focuses on the *relative* impact of immigration on regional house prices and rents, and the implications of the deviation of housing markets from user cost equilibrium. Additionally, the paper examines the time horizon, i.e. the length of period, of the impact of immigration on house prices and rents, and whether there is any asymmetry between these prices and rents in terms of the length of this period (i.e. in the short, medium or long run). Furthermore, the paper examines the above relationships separately for different regions and sample periods, investigating whether the immigration–housing market relationship is sporadic or persists consistently across regions and over our sample period.

2.3 Empirical strategy

2.3.1 Wavelet coherence analysis

The writing of this section has been built on Cazelles et al. (2008); Crowley (2007); Ramsey and Lampart (1998); Schleicher (2002).[3]

2.3.1.1 Definitions and basics

Wavelets are, by definition, wavelike functions that begin at a particular point in time with the functional value of 0, oscillate with a certain shape depending on the type of the wavelet function, and then return to 0 at another point in time. While retaining the same wavelike shape, wavelets can be stretched, which makes the gap between the beginning and end points larger; or can be squeezed, which makes the gap between the beginning and end points smaller. As shown in the three wavelets in figure 2.1, stretched wavelets approximate the low frequency contents of a variable and squeezed wavelets approximate the high frequency content of a variable (Crowley, 2007). This is an efficient way of localising the time-frequency analysis of a shock's impact, where the duration of the localisation can vary from very short to long periods (Schleicher, 2002). Further to this localisation property, the position of the wavelet can be shifted along the full sample, meaning all the wavelets covering the whole sample may mimic a particular time series.

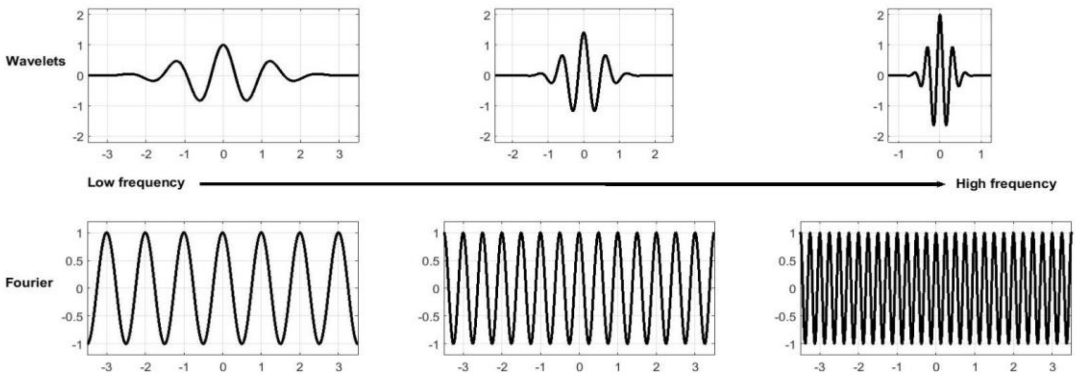

Figure 2. 1 Wavelet and Fourier series

[3] Readers who see a use for wavelets in regional and urban economics and would like to obtain more insights of its use in economics are encouraged to look at Crowley (2007), which in addition to being an excellent review paper, has a very good list of economics application references.

2.3.1.2 Fourier and wavelets

When explaining the usefulness of wavelets, many have used Fourier analysis as the starting point (Crowley, 2007; Ramsey & Lampart, 1998). Both procedures involve projection of a signal (in our case, time series variables) onto an orthonormal set of components—trigonometric in the case of Fourier series representations and wavelets in the case of wavelet analysis. The key differences between Fourier and wavelets is that Fourier series have infinite energy (they do not die out) and finite power (they cannot change over time) while wavelets have finite energy and infinite power (Daubechies, 1992; Ramsey, 2002). As shown in figure 2.1, Fourier's finite power means that a single shock to a variable affects the variable at all frequencies (without any variations in the impact) and its infinite energy means that the effect of that shock is carried over to the entire sample (with no localisation of the impact). These are the two properties of Fourier that makes Fourier transformation inadequate for our study (Cazelles et al., 2008; Crowley, 2007).

Wavelets, on the other hand, with their finite energy, have compact support and within this compact support approximate the frequency content of a variable. The support is squeezed when approximating the high frequency content of a variable and the support is stretched when approximating the low frequency content of a variable. This is an efficient way of localising the time-frequency analysis of a shock's impact where the duration of the localisation can vary from very short to long periods. Furthermore, the ability of wavelet to cut up the data into different frequency components makes the stationarity assumption within these windows plausible, even when the data may well be non-stationary having different frequencies over the sample (Daubechies, 1992; Fan et al., 2019; Ramsey, 2002).

2.3.1.3 Scaling and dilution

The following sequence of functions captures the time-frequency contents of *x(t)*, where *x(t)* is our variable of interest covering the sample period $t=1,\dots,T$:

$$\psi(u,s) = \frac{1}{\sqrt{s}}\psi * \left(\frac{t-u}{s}\right) \tag{2.1}$$

The basis function $\psi(.)$ depends on s and u, implying that it's a double sequence, rather than a single sequence of function. Here, s refers to the scales defining the width of the wavelet $\psi(.)$, u refers to the centre of $\psi(.)$ thus defining the location of the wavelet, $1/\sqrt{s}$ maintains the norm of $\psi(.)$ at 1. Hence, as s is increased, the length of the support of $\psi(.)$ in terms of t is increased. In figure 2.1, s is the highest for the leftmost wavelet and the lowest for the rightmost wavelet. In wavelet language, it is said that the energy of $\psi(.)$ is concentrated in the neighbourhood of u with size proportional to s. Lastly, if a wavelet is shifted on the timeline, this is referred to as translation or a shift of u.

Scaling is particularly useful in the time domain, as the choice of scale indicates the 'packets' used to represent any given variable or signal. A broad support wavelet yields information on variables or signal variations on a large scale, whereas a narrow support wavelet yields information on signal variations on a small scale. The scale size is obtained by 2^n, $n=1,\dots N$, where the larger the value of n, the greater the division of the sample period into smaller sub-periods (Crowley, 2007; Ramsey & Lampart, 1998). The important point here is that, as projections are orthogonal, wavelets at one scale (e.g. a long scale) are not affected by features of a signal at other scales that require narrower support.

2.3.1.4 Wavelet transform

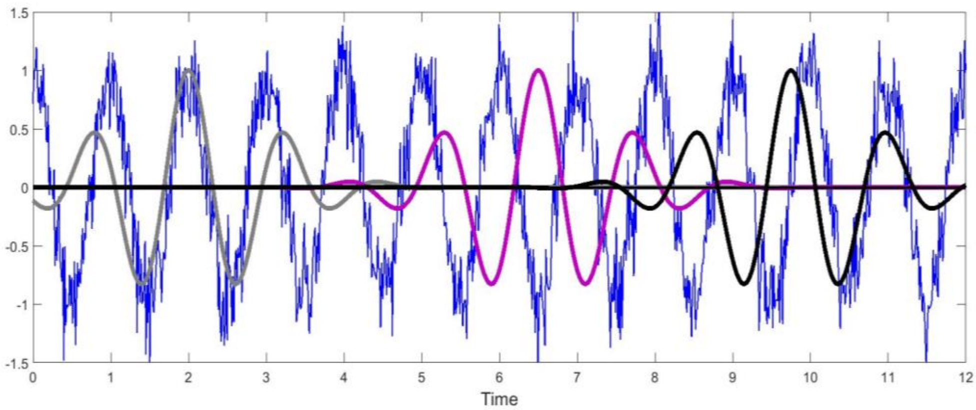

Figure 2. 2 Large and small wavelet transformations

If the wavelet and time series follow a similar pattern at a specific temporal location and scale, then a large transform value is generated. If the wavelet function is applied in a continuous fashion, which is what we did in this study, this is referred to as a continuous wavelet transform. The continuous wavelet transform is defined as:

$$W_x(u,s) = \int x(t)\,\frac{1}{\sqrt{s}}\psi * \left(\frac{t-u}{s}\right) dt \qquad (2.2)$$

where $u*$ is the complex conjugate of u. In figure 2.2, the wobbly (uneven) curve is the data and the smooth curves are Morlet wavelets. The three wavelets have the same scale, s, but are centred in three different positions: u_1, u_2 and u_3. In the leftmost section of the figure, the matching between the data and wavelet is high, which results in a high value of the real part of the wavelet transform, $R(W_x(u_1,s))$. In the rightmost section of the figure, the matching is weak and the value of $R(W_x(u_3,s))$ is low. In the middle part, the data and wavelet are in the perfect opposite phase, resulting in a high negative value for $R(W_x(u_2,s))$.

Following the literature, we use Morlet wavelets in this study (see figure 2.3), which are most commonly used for approximating economic and financial time series data (Fan et al., 2019; Flor & Klarl, 2017).[4]

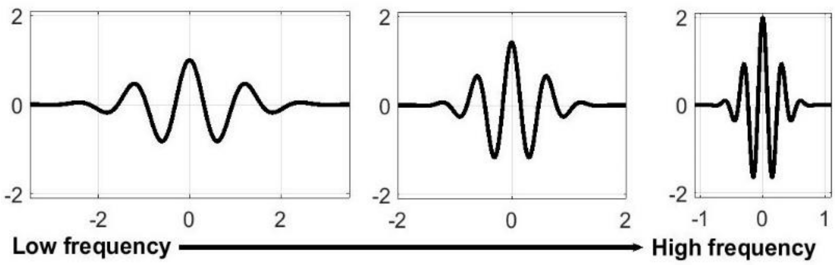

Figure 2. 3 Morlet wavelets

Crowley (2007) reports in his review that the choice of the type of wavelet function does not make a significant difference to the decomposition of the variable into its different frequency components. The Morlet wavelet is defined as follows:

$$\psi^M(t) = \frac{1}{\pi^{1/4}} e^{iw_o t} e^{-t^2/2} \qquad (2.3)$$

where $\pi^{1/4}$ is a normalising factor ensuring that the wavelet has unit variance, w_0 is the central frequency of the wavelet and $e^{iw_o t}$ indicates a complex sinusoid and $e^{-t^2/2}$ is a Gaussian envelope with a standard deviation equal to 1. Hence, a Morlet wavelet is essentially a sine wave multiplied point by point by a Gaussian distribution.

2.3.1.5 Wavelet coherence

Turning now from a single time series to two time series, $x(t)$ and $y(t)$, the association between these two series can be obtained from cross-wavelet transforms. Similar to the continuous wavelet transform $x(t)$, $W_x(u,s)$, the continuous wavelet transform for $y(t)$ can be defined by $W_y(u,s)$, then the wavelet cross-spectrum is given by:

$$W_{xy}(u,s) = W_x(u,s)\, W_y^*(u,s) \qquad (2.4)$$

[4] Crowley (2007) reports in his review that the choice of the type of wavelet function does not make a significant difference to the decomposition of the variable into its different frequency components.

where * denotes the complex conjugates. Large cross-wavelet power $|W_{xy}(u,s)|$ will be obtained in the regions where the values of both continuous wavelet transforms are high, and small cross-wavelet power $|W_{xy}(u,s)|$ will be obtained in the regions where the values of both continuous wavelet transforms are low. For our purpose, rather than using cross-spectrums, it is more useful to use wavelet coherence as a measure of association between two wavelet transforms.

The wavelet coherence is obtained by normalising the cross-spectrum by the spectrum of each series as follows:

$$R^2(u,s) = \frac{\left|S(s^{-1})W_{xy}(u,s)\right|^2}{S(s^{-1}|W_x(u,s)|^2)S(s^{-1}\left|W_y(u,s)\right|^2)} \tag{2.5}$$

where S denotes a smoothing operator in both time and scale. The coherence is bounded between 0 and 1. As can be seen from the above equation, wavelet coherence is the ratio of the cross-wavelet power to the product of individual wavelet power and therefore is comparable to the squared correlation coefficient. Hence, the wavelet coherence provides a measure of whether the two series are linearly correlated with each other at a particular frequency and time in the time-frequency domain. The wavelet coherence can also be interpreted as the fractional portion of power of *x(t)* that is common with that of *y(t)* at a particular frequency and time and which therefore provides a measure of whether the two time series co-move localised at a particular frequency and time. Furthermore, for a given frequency, the coherence measure is allowed to change over the time domain, which may be a lot more informative than having only one correlation measure for the full sample.

2.3.1.6 Periods of displacement or lead-lag relationships

Another question that is of interest is whether there is any period of displacement or lead-lag in the relationship between the two time series. That is, at a given time and frequency, is coherence observed at a particular period of displacement between the two variables indicating lead-lag in their relationship? A measure of the displacement period (lead-lag) in the relationship can be obtained by calculating the phase difference as follows:

$$\phi_{x,y} = tan^{-1}\frac{I\{W_{xy}(u,s)\}}{R\{W_{xy}(u,s)\}}, \phi_{x,y} \in [-\pi,\pi] \tag{2.6}$$

where *I* and *R* are the equation’s imaginary and real parts, respectively, of the smooth power spectrum. If the distribution of the phase difference is found to be unimodal for a given time and frequency, the two time series are said to be locked in a relationship at a particular phase and a period of displacement. Conversely, if the distribution of the phase difference is found to be uniform for a given time and frequency then there is a lack of association of the phase of the two time series and no particular displacement period (lead-lag) is dominant in the relationship.

2.3.1.7 Identification of lead-lag relationship

In order to understand the period of displacement and the lead-lag relationship between two variables, let us look at figure 2.4. There are two time series, M and H where *H* refers to the changes in the housing market variable and *M* refers to changes in the immigration, and a full cycle for both series comprises of 4 periods. The figure shows that while the period of displacement between M and H is fixed, there are two possibilities with regard to which variable leads the relationship (the lead-lag relationship): (1) M leads H by one period and (2) H leads M by three periods (a full cycle of four periods minus one period). This situation, where every relationship is characterised as bidirectional, is problematic for our purpose because: (1) this would not allow us to make a definitive statement with regard to their relationship that would be useful for policymaking and (2) this may not even be a correct depiction of the relationship, i.e. the relationship may in fact be unidirectional. This situation arises when working with sample data where the beginning period of the sample is arbitrary, unlike data collected through experiments where the period of initiation (i.e. period 0) of signals (variables) is known.

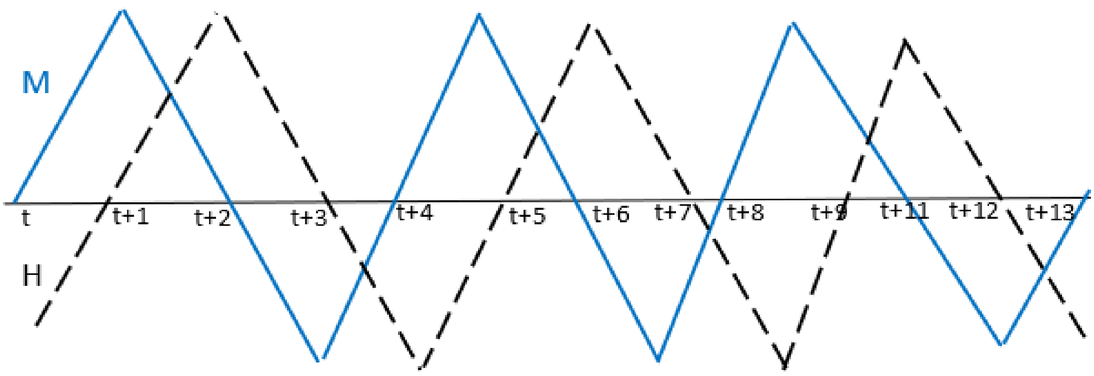

Figure 2. 4 Sample starting point, displacement periods and lead-lag relationships between two variables

One way to address this situation, perhaps the only way, is to specify which variable leads the relationship a priori when interpreting the wavelet coherence results. This pre-specified relationship can be based on the theoretical understanding of the relationship or conventional wisdom in the literature, or it could be obtained directly from using the same sample data but using a different empirical tool. In our case, along with literature, Granger causality tests is employed to investigate the lead-lag relationship before interpreting the wavelet coherences.

With this in mind, let's look at figure 2.5 for the interpretation of the arrows (i.e. estimates of equation 2.6) in wavelet coherence scalograms. Arrows pointing directly to the right indicate that two variables are perfectly positively correlated with each other (no lead-lag) and arrows pointing directly to the left indicate that two variables are perfectly negatively correlated with each other (no lead-lag). Now, an arrow pointing straight down indicates that the period of displacement between the two variables is one-quarter of a cycle. If we pre-specify that *M* leads *H*, and if the wavelet coherence indicates that the full cycle is, say, 12 months (i.e. the scale of the wavelet is 12 months), then the arrow pointing straight down indicates that the movement of *M* leads the movement of *H* by a period of 1/4 X 12 = 3 months. An arrow pointing straight up indicates that the period of displacement between *M* and *H* is three-quarters of the cycle. Given the pre-specification that that *M* leads *H* and the finding that the wavelet cycle is 12 months, an arrow pointing straight up indicates that the movement of *M* leads the movement of *H* by a period of 3/4 X 12 = 9 months.

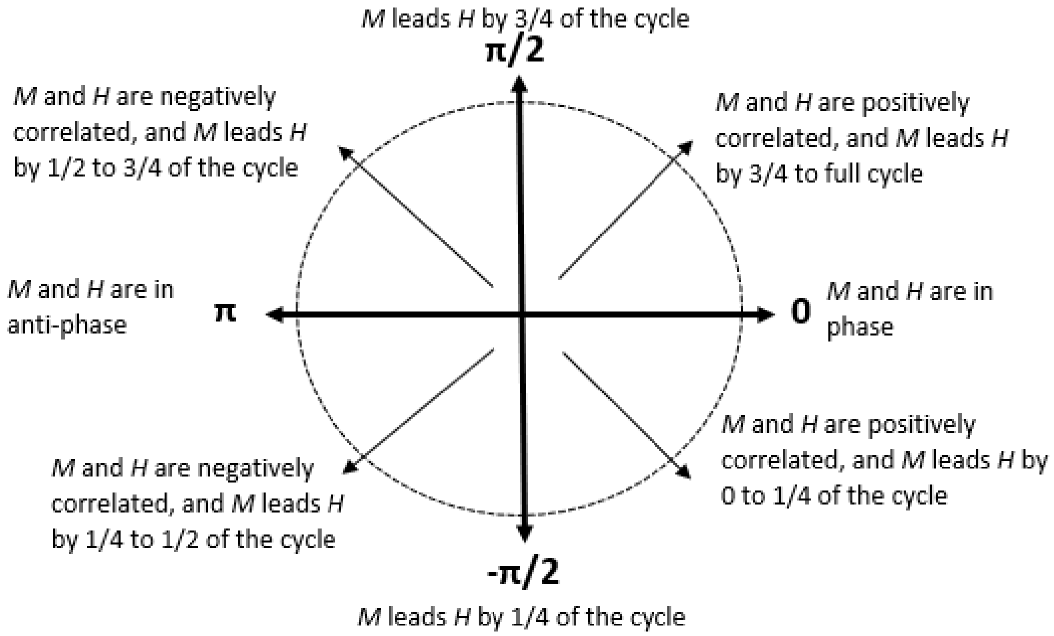

Figure 2. 5 Interpretation of arrows in wavelet coherence scalograms given that M leads H

The arrows, in most cases, will not all point directly right or left, or straight down or straight up, but will point down and to the right (southeast), down and to the left (southwest), up and to the left (northwest) and up and to the right (northeast). An arrow pointing southeast indicates that the movement of M leads the movement of H in the same direction (positive correlation) by a period between 0 and one-quarter of the full wavelet cycle. Given a 12-month wavelet cycle, this means that M leads H by 0–3 months (not inclusive). An arrow pointing southwest indicates that the movement of M leads the movement of H in the opposite direction (negative correlation) by a period between one-quarter and one-half of the full wavelet cycle. An arrow pointing northwest indicates that M leads the movement of H in the opposite direction (negative correlation) with a lead-lag period between one-half and three-quarters of the full cycle. An arrow pointing northeast indicates that M leads the movement of H in the same direction (positive correlation) with a lead-lag period between three-quarters and the full wavelet cycle (i.e. given a 12-month cycle, M leads H by 9–12 months).

While the Wavelet analysis is a powerful tool for assessing the relationship at both time and frequency domains as previously mentioned, it needs to be handled properly for accurate results. According to González-Concepción, Gil-Fariña, and Pestano-Gabino (2012), the weakness of Wavelet analysis is associated with the sample characteristics and potential numerical instabilities. It is based on equally spaced data, which might not apply in certain economic and financial time series. Also, the approach assumes dyadic samples and a certain number of initial values to start the estimation. The process of decomposing a signal which employs very high-order polynomials may lead to specific instabilities. Leise and Harrington (2011) mention another drawback of the Wavelet transform, namely the edge effects. As a response, the results below the cone of influence should be explained carefully.

2.3.2 Granger causality test

We undertake Granger causality tests in order to determine what the data reveals about leads or lags in the relationship between immigration and our three housing market variables. The theories explaining the relationship between immigration and house prices/rents support the proposition that immigration is one of the fundamental determinants of house prices and rents. In principle, the increase of immigrants would increase the demand for housing. Combined with an upward sloping housing supply, this would lead to an increase in house prices and rents (Sá, 2015). Therefore, when we apply

Granger causality tests to the data, our a priori expectation is that immigration would lead the housing market variables.

The Granger causality tests are performed on the first difference of both immigration and the housing market variables. The unit root tests—Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests—are conducted on all of these variables and we find that the variables in their levels are integrated of order 1, which is the reason we used the variables in the first differences (see Appendix). The equations for the Granger causality tests are as follows:

$$H_t = a_1 + \sum_{i=1}^{k} \alpha_i H_{t-\mathrm{i}} + \sum_{i=1}^{k} \beta_i M_{t-\mathrm{i}} + \varepsilon_{1t} \qquad (2.7)$$

$$M_t = a_2 + \sum_{i=1}^{k} \gamma_i M_{t-\mathrm{i}} + \sum_{i=1}^{k} \delta_i H_{t-\mathrm{i}} + \varepsilon_{2t}$$

where *H* refers to the changes in the housing market variable and *M* refers to changes in immigration. The subscript *t* refers to the time period which runs from period 1 to period *k*. The lags, as preferred by *k*, are selected using Akaike information criterion (AIC), Schwarz information criterion (SIC), and Hannah-Quinn information criterion (HQ). Our test results strongly support that immigration Granger causes the housing market variables. These results are discussed in detail in section 2.5.

2.4 Data

This study uses monthly data sets of house prices, rents, and net immigration in New Zealand at both nationwide and regional levels covering the period between July 1996 and June 2017. The regions that are included in the paper are Auckland, Canterbury, Waikato, and Wellington. These four regions contain around two-thirds of the population of New Zealand and include the largest four cities in New Zealand (in terms of population) - Auckland, Christchurch, Hamilton, and Wellington.[5] During the sample period, around three-quarters of net immigration to New Zealand was to these four regions. Of these four regions, Auckland and Waikato share a common boundary, the other regions are geographically separate. The paper uses monthly indexes of median house prices and median house rents (July 1996 = 100), where the median house prices

[5] In 2017, the populations of these four cities were: Auckland (1,660,000), Christchurch (381,500), Hamilton (165,400) and Wellington (212,700).

are collected from the Real Estate Institute of New Zealand (REINZ) and the median house rents are collected from the Ministry of Business, Innovation and Employment's (MBIE) tenancy bond database. For information on immigration, the paper uses monthly changes of (net) immigration-to-population ratios in New Zealand and our four regions, where data on both net immigration and population are collected from Statistics New Zealand (StatsNZ).[6]

Figure 2.6(a) shows the monthly net immigration-to-population ratio for New Zealand as a whole and our four regions during 1996–2017. The figure shows that there are large variations in the ratios for all regions over the sample period. While we use monthly ratios for our wavelet and Granger causality analysis, the large variations in the *monthly* data mask systematic patterns that are present in their movements, patterns that become clear when we look at the *annual* net immigration-to-population ratios for our regions, shown in figure 2.6(b). The figure shows that there are two periods when there were major increases in immigration (2002–2003 and 2014–2016), and two periods with large drops (1999–2000 and 2011–2012). Overall, the figure shows that while there were large fluctuations in immigration in New Zealand and the regions, there were also noticeable co-movements and heterogeneity across the regions. Among these regions, there appears to be maximum variation in immigration-to-population ratios in Auckland and minimum in Waikato.

[6] Net immigration is calculated as the difference between the arrivals into and departures from New Zealand for people whose movements are deemed as permanent and long term, i.e. 12 months or more.

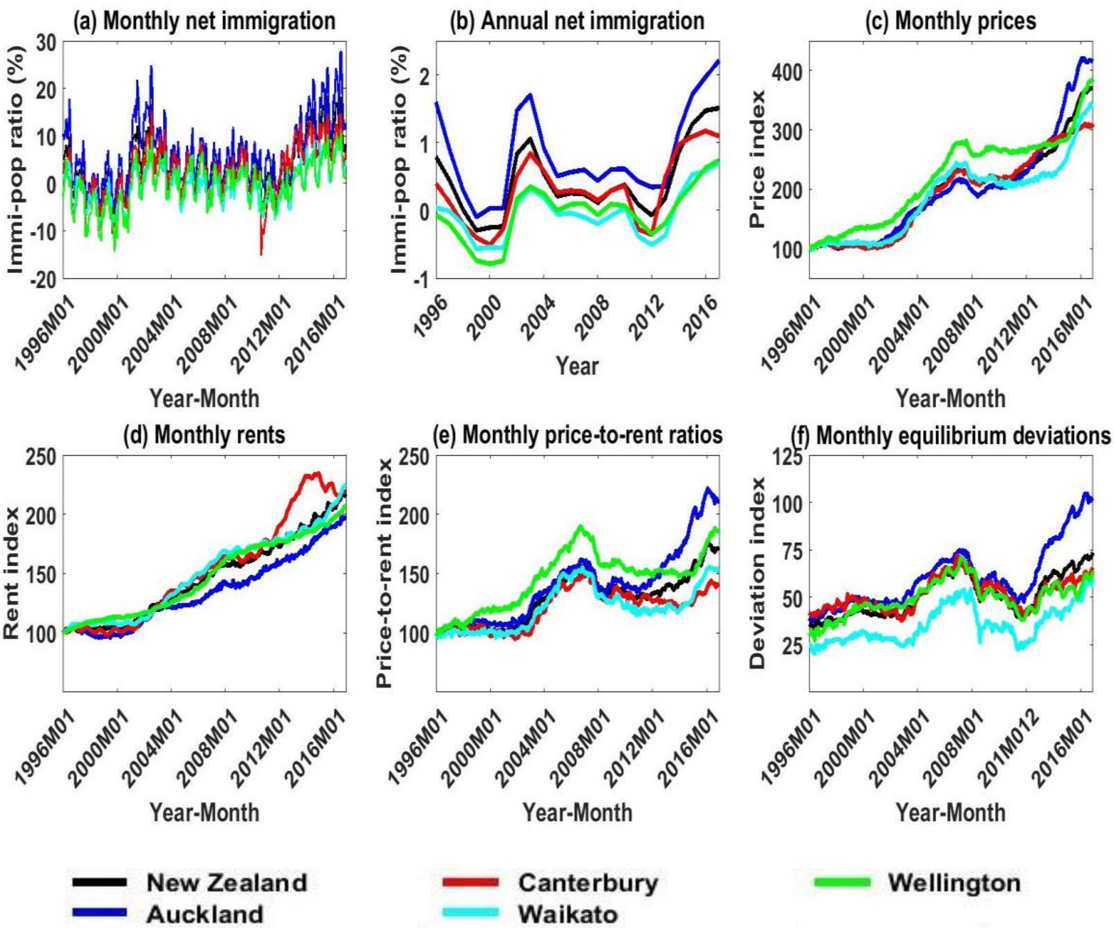

Figure 2. 6 Net immigration and housing market data by region, 1996–2017

Figure 2.6(c) and 2.6(d) show the price indexes and rent indexes, respectively, for New Zealand as a whole and our four regions between 1996 and 2017. While there are similarities in the overall dynamics of the price indexes, there are variations in the price changes across regions and different intervals of the sample period. Overall, during the sample period the house prices in New Zealand grew on average by 6.42% per year; the largest growth is seen in Auckland with an average growth of 7.01% per year and the smallest is seen in Canterbury with an average growth of 5.44% per year.[7] The growth of rent was slow during 1996–2002, then from 2002 onwards, the rents grew at a higher rate which remained steady until the end of the sample period. The exception is Canterbury where rent growth was very high during 2012–2014 followed by a fall during 2015–2017.[8]

[7] The growth of property prices in Canterbury has been relatively subdued since the earthquake that took place in Christchurch on 22 February 2011.
[8] Hyslop et al. (2019); Saiz (2007); Shi, Young, and Hargreaves (2009) have documented large differences in regional house prices and rents.

Figure 2.6(e) shows the indexes for price-to-rent ratios for New Zealand as a whole and our four regions between 1996 and 2017. When we compare the price indexes and the rent indexes in figures 2.6(c) and 2.6(d), respectively, we can see that the price movements exhibit more variation, more ups, and downs,-than the rent movements in the sample period. These relative changes of these two indexes are reflected in the indexes of price-to-rent ratios. These price-to-rent ratio indexes increased substantially in the first half of the sample, with most of the increases taking place between 2002 and 2008 due to large increases in prices. During the post-GFC period, while rents continued to increase at a steady rate, prices remained relatively flat, resulting in a decrease in the price-to-rent ratios. Price increases outweighed rent increases from 2012–2013, resulting in the price-to-rent ratio increasing further. The largest increase is seen in Auckland, indicating that the Auckland housing market can be expected to be more overvalued (or less undervalued) than the other regional markets studied in the paper.

Figure 2.6(f) shows the deviations from the equilibrium of our regional housing markets and New Zealand as a whole. These deviations are calculated by taking the difference between the actual price-to-rent ratio and the reciprocal of the user cost of housing ownership (Hill & Syed, 2016; Himmelberg et al., 2005). A positive deviation indicates that the market is overvalued and a negative deviation indicates that the market is undervalued. The user cost consists of the interest rate (r_t), running and transaction costs (ω_t), the depreciation rate (δ_t), the risk premium (γ_t), and the negative of expected capital gain (g_t) (Nygaard, 2011). Following Hill and Syed (2016); Himmelberg et al. (2005), we set: r_t = simple average of mortgage interest rates of residential properties and the interest rates of the 10-year government bond, ω = 2.0%, δ = 2.5%, γ = 1.0%, and g = moving average of actual nominal capital gain over the preceding 10 years. The actual price-to-rent ratios are adjusted downward by a factor of 0.8 in order to control for the quality difference between sold and rented houses (Hill & Syed, 2016). The figure shows that the deviations are positive, indicating that all of the examined regional markets were consistently overvalued during the sample period, although there were substantial changes over time in the extent of the deviation.[9]

[9] Note that these deviations were only calculated in order to understand whether the regional markets were overvalued or undervalued; deviations were not included as one of the housing market variables in our wavelet analysis. For a detailed discussion on the extent of overvaluation of regional housing markets in New Zealand, see Appendix.

Table 2. 1 Descriptive statistics of housing market variables and immigration

Regions	Variables	Mean§ (% growth per month)	Standard deviation	JB test
New Zealand	Price	0.52	0.97	0.76
	Rent	0.30	1.17	1.21
	Price-to-rent ratio	0.22	1.36	1.54
	Immigration	0. 01	3.40	22.31***
Auckland	Price	0.57	1.41	2.00
	Rent	0.27	1.32	2.80
	Price-to-rent ratio	0.30	1.72	2.45
	Immigration	0.01	4.54	5.69*
Canterbury	Price	0.44	1.70	30.77***
	Rent	0.30	2.33	8.72***
	Price-to-rent ratio	0.14	2.74	0.61
	Immigration	0.02	3.56	87.14***
Waikato	Price	0.49	1.96	0.80
	Rent	0.32	1.95	1.95
	Price-to-rent ratio	0.17	2.71	1.35
	Immigration	0.02	2.91	47.65***
Wellington	Price	0.54	1.37	0.19
	Rent	0.29	4.55	160.00***
	Price-to-rent ratio	0.25	4.79	115.21***
	Immigration	0.02	3.25	33.11***

Note: JB test refers to the Jargue-Bera test, which is used to test the hypothesis for normality. ** and *** indicate that the null hypothesis has been rejected at the 5% and 1% levels, respectively. §The figures refer to the monthly mean growth rate of the variable over the sample period. For example, the price of houses grew by 0.52% per month in New Zealand during July 1996–June 2017.

Table 2.1 contains descriptive statistics for the main variables of analysis. As shown in the table, the monthly growth rate of immigration is generally lower than that of the housing market variables, whereas its volatility appears to be higher, reflected by the higher standard deviation. Among the three housing market variables, house prices have a higher growth rate in comparison with rents. On average, in New Zealand, the growth rate of immigration is recorded at 0.01%, while the growth rate of housing market variables, including prices, rents, and price-to-rent ratios, accounts for 0.51%, 0.3%, and 0.22%, respectively. Regarding the housing markets across four regions, the highest monthly house price growth rate is found in Auckland (0.52%). It is Canterbury, on the other hand, has the lowest figure (0.44%). In terms of rents, Waikato records the highest monthly rent growth, which is 0.32% in contrast to 0.27% in Auckland. The distributions of housing market variables in some regions seem to be against normality as examined by the Jarque-Bera (JB) test.

2.5 Results

2.5.1 Granger causality tests

Table 2.2 shows the results of the Granger causality tests which are conducted using the monthly changes in the immigration-to-population ratios and the monthly percentage changes of the housing market variables (number of lags are selected using AIC criteria).

Table 2. 2 VAR Granger causality Wald tests between immigration and the housing market variables

Regions	Housing market variables	H_o: M does not Granger cause H		H_o: H does not Granger cause M	
		F statistics	p values	F statistics	p values
New Zealand	Price	36.96***	0.0007	28.40**	0.0126
	Rent	64.48***	0.0000	30.71***	0.0096
	Price-to-rent ratio	38.64***	0.0032	39.00***	0.0028
Auckland	Price	39.28***	0.0003	33.85***	0.0022
	Rent	49.35***	0.0000	30.31**	0.0108
	Price-to-rent ratio	31.64***	0.0045	29.45***	0.0091
Canterbury	Price	45.33***	0.0001	8.08	0.9463
	Rent	35.39***	0.0007	23.05**	0.0411
	Price-to-rent ratio	31.15***	0.0008	12.00	0.5274
Waikato	Price	11.06	0.6812	10.86	0.6971
	Rent	50.10***	0.0001	45.79***	0.0005
	Price-to-rent ratio	42.19***	0.0001	23.87**	0.0475
Wellington	Price	33.01***	0.0010	12.39	0.4105
	Rent	34.24*	0.0805	34.49*	0.0764
	Price-to-rent ratio	32.52***	0.0034	14.48	0.4145

Note: *M* and *H* refer to the change in the immigration-to-population ratio and the change in the housing market variables, respectively. The symbols ***, **, and * denote the statistical significance at 1%, 5%, and 10%, respectively. The lag lengths in the equations are selected by the AIC criteria.

Out of 15 hypothesis tests with the null hypothesis that H_o: *M* does *not* Granger cause *H*, where *M* refers to immigration and *H* refers to housing market variables, 13 are rejected at the 1% significance level. In contrast, out of 15 hypothesis tests with the null hypothesis that H_o: *H* does *not* Granger cause *M*, 5 are rejected at the 1% level—2 relationships for New Zealand, 2 for Auckland, and 1 for Waikato. For these 5, the relationship is found to be bidirectional. Overall, these results are strongly supportive of the proposition that the movement of immigration Granger causes, i.e. leads the movement of housing market variables.[10]

[10] The Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests for unit root indicate that most, if not all, of these variables are integrated of order 1 and their first differences are integrated of order 0. The Granger causality tests that use the number of lags selected by SIC and HQ criteria provide results similar to the test results shown in table 2.1, which use the number of lags selected by AIC criteria. ADF and PP unit root test results and SIC and HQ results are provided in Appendix.

2.5.2 Wavelet coherence analysis

The outputs from wavelet analysis are typically shown in a wavelet coherence scalogram (see figures 2.7–2.9). The horizontal axis of the scalogram shows time, which is in months. The vertical axis shows the scale (in months) of the wavelets, where lower or squeezed scales (higher frequencies) are shown near the top and higher or stretched scales (lower frequencies) are shown near the bottom of the vertical axis. In this time-frequency domain, the strength or weakness of wavelet coherence measures is expressed using colours, with warmer colours indicating higher coherence between the two variables. The colours range from blue to red, with blue indicating low coherence and red indicating high coherence. The coherences bounded by black borders are statistically significant at the 5% level.

It should be noted that the results are reliable only in the zone above the cone in the scalogram, also known as the cone of influence. The calculation of coherence at each point requires using the data in the neighbourhood of that point. Since data is finite, there will not be enough data around the starting point and the end point for calculating the coherences. In order to address this issue, the zero-padding technique is commonly used, which means that the unavailable data in the neighbourhood are filled in with zeros. While this method lets us calculate the coherences, they may not be reliable (Cazelles et al., 2008; Schleicher, 2002). Therefore, the coherence results below the cone of influence should be interpreted with caution.

The scalograms in figures 2.7–2.9 also include arrows at some time-frequency points. Let us suppose that the two variables are *M* and *H* where *M* leads *H*. The arrows display two things: (1) whether the coherence between *M* and *H* are in phase (positive correlation) or are in anti-phase (negative correlation), and (2) what the period of displacement (lead-lag) in terms of the number of months is between *M* and *H*.

2.5.2.1 Prices

Figure 2.7 shows the wavelet coherence between immigration and house prices for New Zealand as a whole and our four regions.

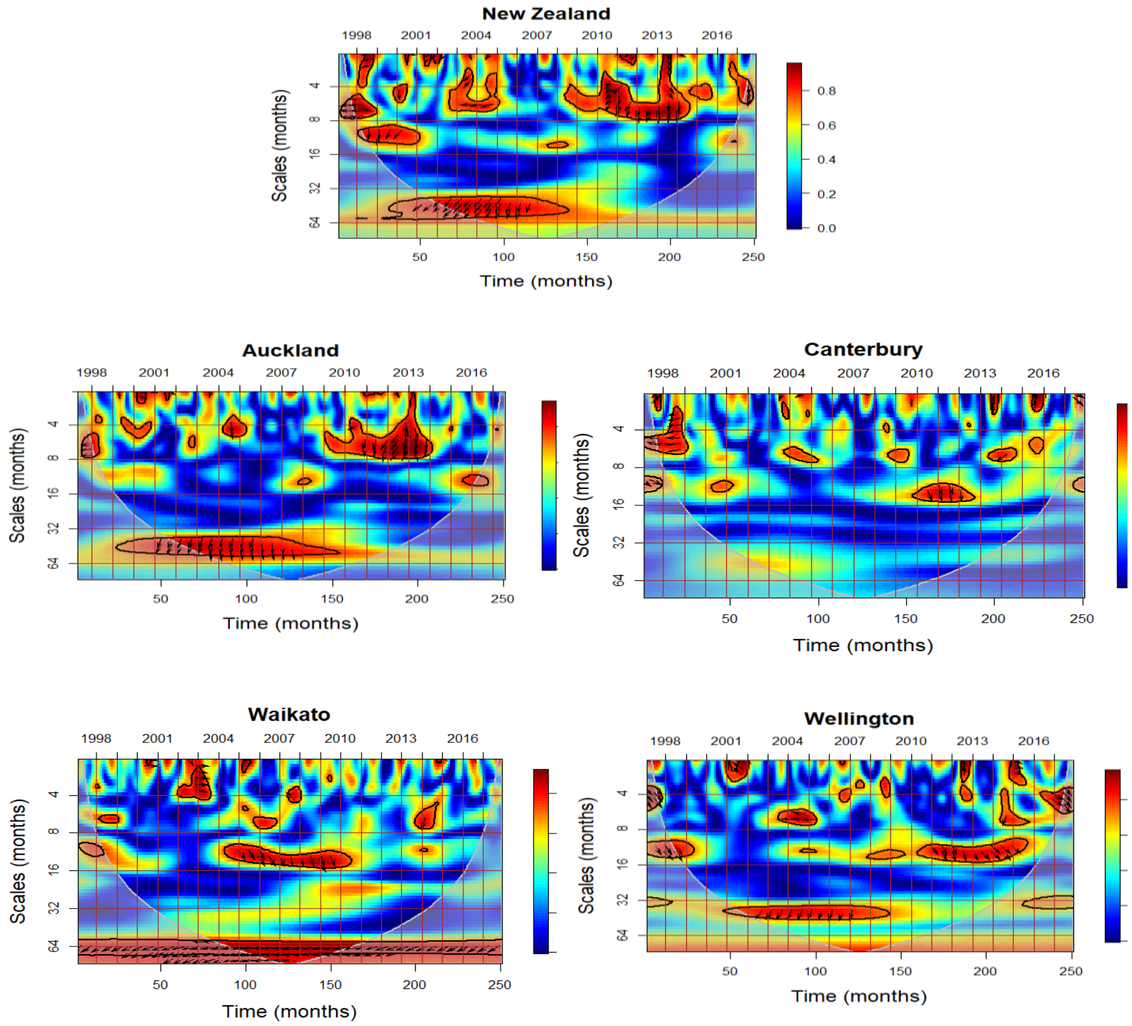

Figure 2. 7 Wavelet coherence between immigration and house prices

Focussing first on New Zealand as a whole, the figure provides evidence of the existence of coherence between immigration and house prices. Out of the full sample period of 21 years, in more than 80% of the periods, the coherence was very high, 0.8, and these estimates are statistically significant at the 5% level. The results show that the relationship between immigration and house prices is mostly confined to frequencies that correspond to scale bands of one year or less (mostly 4–8 months), implying that the relationship mostly holds over short-term periods. Most of the arrows are pointing down and to the right, indicating that immigration and houses prices are in phase, and that the movement of immigration leads the movement of house prices in the same direction with a delay of 1–2 months (1/4 x 4 – 1/4 x 8 = 1–2 months). Notably, there are two time intervals where the relationship is the strongest: 2002–2004 and 2008–2014. These two intervals also roughly align with the time periods 2001–2004 and 2013–2017, when there was a surge in immigration in New Zealand (see figure 2.6(b)).

Moving now from New Zealand as a whole to the regions in the country, we find that in each of the regions there were some periods where the coherence between immigration and house prices had a high value, of 0.8 or above, and where these estimates are statistically significant at the 5% level. However, with the exception of the Wellington region, these meaningful coherences only occur over short periods compared to the full sample period, indicating generally weak relationships between immigration and house prices.

2.5.2.2 Rents

The coherence scalograms in figure 2.8 show the relationship between immigration and housing rents. Starting with New Zealand as a whole, we see evidence of very strong correlation between immigration and housing rents covering almost the entire sample period (with the exception of the first 3 years between 1996 and 1999). The coherence indicates that the relationship holds over a short to medium-term period corresponding to a wavelet scale of around one year, and that the two variables are positively correlated, with immigration leading the housing rents by 2–8 months (1/4 x 8 – 1/2 x 16 = 2–8 months). Moving now to the four regional markets, with the exception of the Auckland region, the relationship between immigration and housing rents is as strong as we found it for New Zealand as a whole.[11] The commonality in the coherence reveals a very systematic relationship between immigration and housing rents.

Comparing the results between prices and rents, i.e. between figures 2.7 and 2.8, there is clear evidence that immigration leads changes in both house prices and rents in the same direction by a period of between one-quarter and one-half of a year. However, the relationship is much stronger and more consistent for rents than for prices for all the examined regions. In the case of rents, the relationship is consistent across regions in both time and frequency domains; the relationship not only covers the whole sample period but also holds at the same frequencies (same cycle) with the arrows pointing in roughly the same southwest direction (same lead-lag relationship).

[11] Auckland has a very large and heterogeneous rental market and, therefore, may have the ability to absorb fluctuating numbers of immigrants.

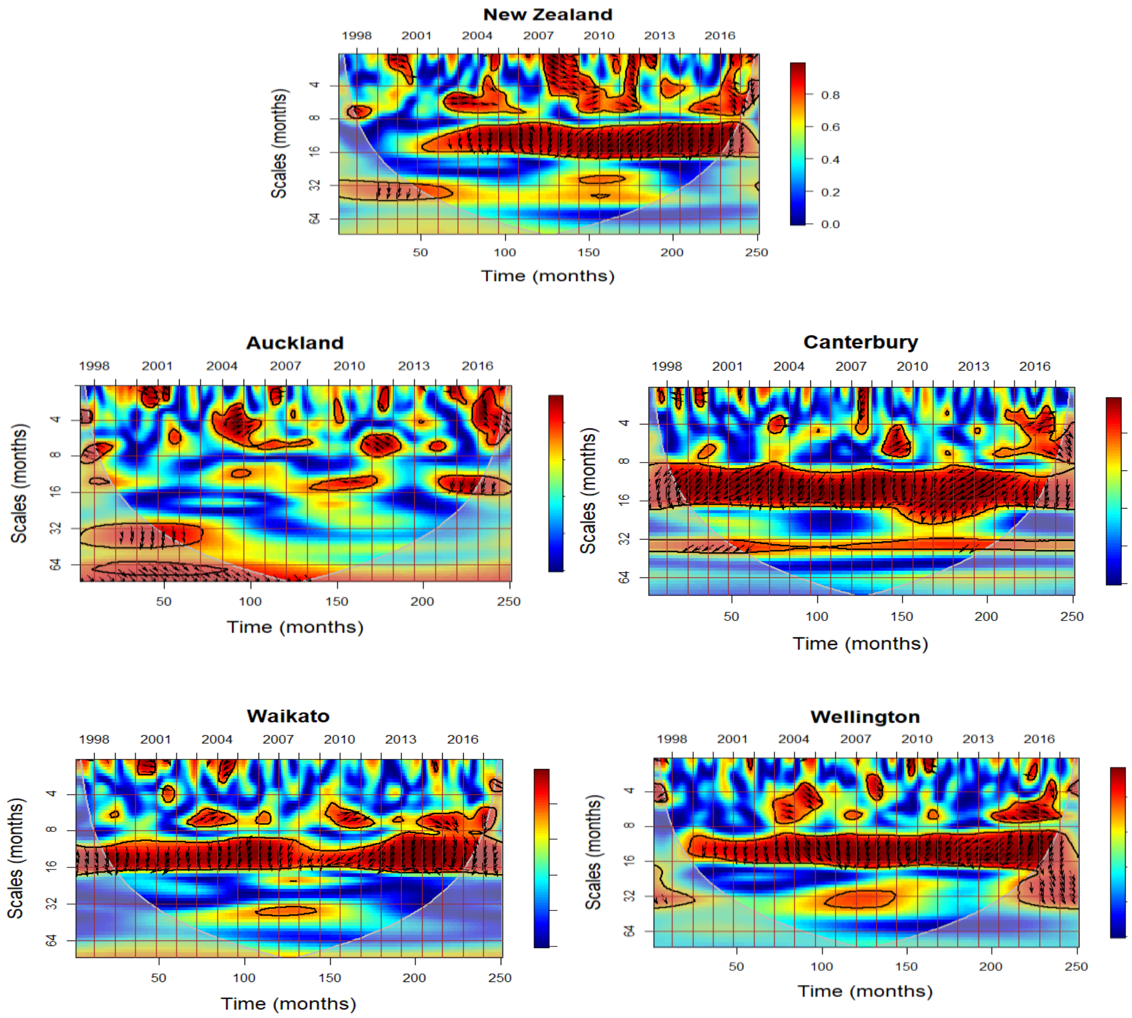

Figure 2. 8 Wavelet coherence between immigration and housing rents

The delayed response of prices to changes in immigration may be occurring, because immigrants tend to rent for a period of time before they buy (Saiz, 2007). This delay in purchase also allows housing market supply to respond to changes in demand, dampening the impact of immigration on house prices (Akbari & Aydede, 2012). It could be expected that the more expensive or overvalued a housing market is, the more time an immigrant would take to buy a property, allowing more time for the housing market to respond (Braakmann, 2019). The delayed response in rents to immigration may be due to stickiness in the rental market. Rental markets are relatively sticky because of rental contracts—nominal contracts typically last at least a year, and implicit contracts discourage owners from increasing rents due to the high transaction costs of finding another renter (Genesove, 2003). All of this means that when there is an increase in immigration, only a small portion of the rental market responds contemporaneously (and the magnitude of this change is also curtailed because of market rigidity), with the result that the immediate effect of immigration on average changes in rents in a region remains negligible or small, changes are staggered over a longer period of time, and any larger changes are delayed.

2.5.2.3 Price-to-rent ratios

Figure 2.9 shows the coherence scalograms for immigration and price-to-rent ratios for New Zealand as a whole and four regional markets within New Zealand.

In the case of New Zealand as a whole, a strong relationship over a short- to a medium-term period (8–16 months period) can be seen during 2011–2017. The arrows indicate that there is a negative coherence between immigration and price-to-rent ratios with immigration leading price-to-rent ratios by 6–14 months. At high frequencies or very short-term periods, a high coherence can be seen during 2001–2005, indicating a negative relationship with a lead-lag of less than a quarter of a year.

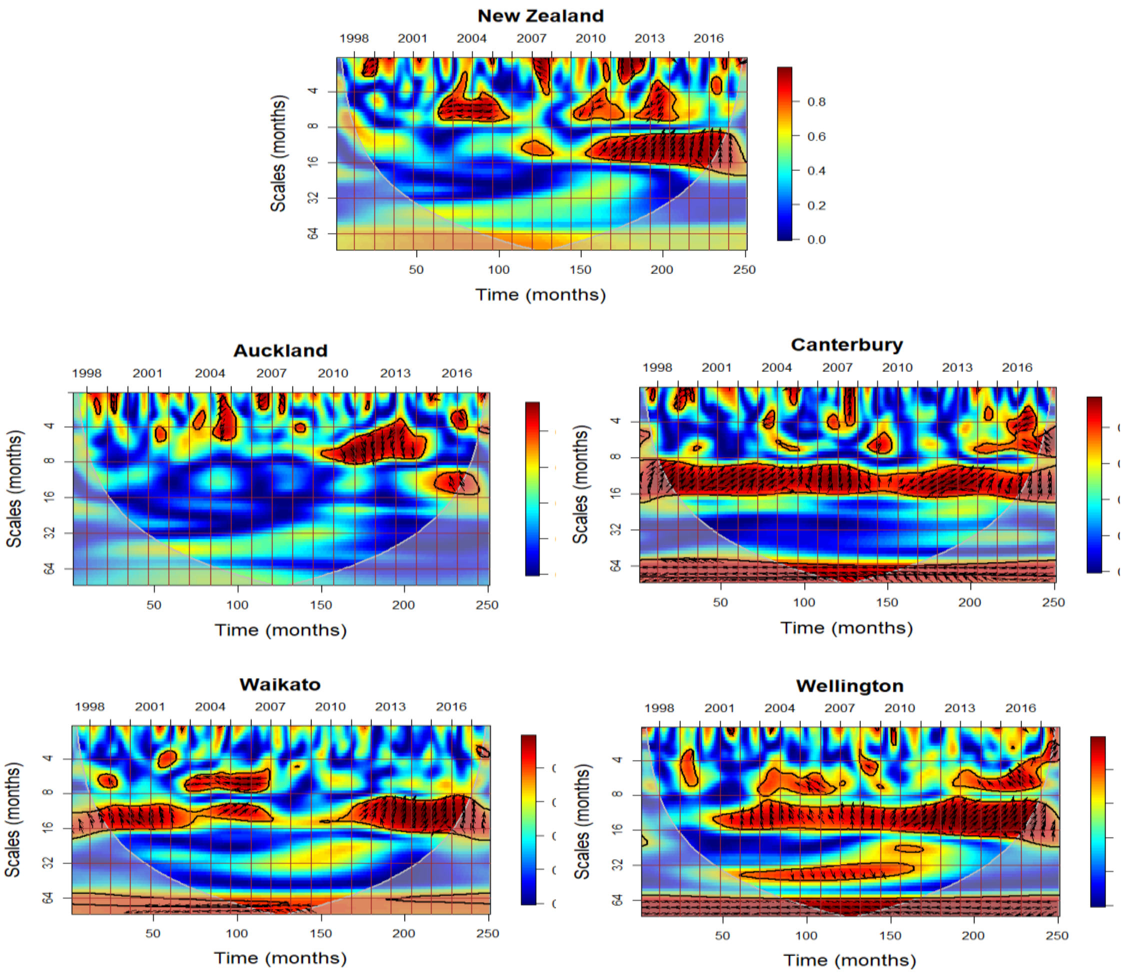

Figure 2. 9 Wavelet coherence between immigration and price-to-rent ratios

Moving to the four regional markets, in the case of Auckland there is a strong coherence between immigration and price-to-rent ratios during 2010–2014 at frequencies that correspond to a low- to medium-range relationship and the coherence indicates that immigration leads changes to house price-to-rent ratios by 2-3 months. In other three regional markets, in line with the findings for New Zealand as a whole, we find strong coherences between immigration and price-to-rent ratios covering a large period (70–100%) of the sample. Moreover, these coherences correspond to the same frequencies in each region, showing that in these regions the relationship holds for a medium-range period. In addition, for each region, the movement of immigration leads price-to-rent ratios by 6–14 months in the negative direction.

2.6 Conclusion

The paper examines the relationship between immigration and housing markets using wavelet coherence analysis in conjunction with Granger causality tests as its main analytical tool and monthly data sets from four regions in New Zealand and New Zealand as a whole (1996–2017). To the best of our knowledge, this paper is the first empirical paper studying the impact of immigration on regional prices, rents, *and* price-to-rent ratios within the same framework of analysis, which enables us to ascertain the relative response of these prices and rents to changes in immigration. Other studies in the literature which examine both prices and rents do not combine the two to form a single series and their methods do not allow quantitative comparisons of the responses of prices and rents to immigration. Our paper mainly uses immigration, price and rent data aggregated at the regional level, which are generally available in many countries, making possible a straightforward replication of our study.

Our results show that in New Zealand's housing markets the movement of immigration leads the movement of prices and rents in the same direction by 1–2 quarters of a year. The duration of impact is short to medium term for both prices and rents, with an average duration of around one year. The results further show that the impact on house rents is more pronounced than the impact on house prices, and this holds consistently for different time intervals and different regions. This may be because immigrants tend to rent for a period of time before they buy, which increases rental prices but also allows housing market supply to respond to changes in housing demand. It could be expected that the more expensive or overvalued a housing market is, the more time an immigrant would take to buy a property, allowing more time for the housing market to respond.

Furthermore, we find strong evidence from all our examined regions that an increase in immigration results in a decrease in price-to-rent ratios. From a policymaker’s perspective, particularly when there are concerns about further overheating an overvalued housing market, it may be useful to know that increases in immigration would not make the situation worse but, on the contrary, would contribute towards a gradual correction of a housing market towards equilibrium.

CHAPTER 3 Information transmission between oil and housing markets

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As described in the previous essay, while there are some regional differences in the relationship between immigration and housing markets, the movement of the housing market is significantly triggered by the change of immigration. What follows is an account of the association between oil and housing markets, given the fact that their integration is also partially responsible for the fluctuation of the housing markets. By adapting the methodology of DECO-GARCH and the connectedness index and OECD dataset, the equicorrelation and connectedness among oil and housing markets are documented accordingly.

3.1 Introduction

Originating from the subprime mortgage crisis in the US, the Global Financial Crisis (hereafter GFC) of 2007–2009 is well known as the most severe and widespread financial crisis since the Great Depression. Soon after the crisis in the US financial system began, the spillover to other financial markets had a catastrophic impact, leading to a severe slump in the global economy. Due to this, empirical studies have paid attention to the possibility of information transmission across a wide variety of financial markets. Studying the connectedness among markets has brought several advantages, such as delivering an 'early warning system' for a growing crisis (Diebold & Yilmaz, 2012) and revealing some predictability of markets in response to shocks (Teye, Knoppel, de Haan, & Elsinga, 2017). Furthermore, studying the connectedness among markets has the potential to provide insights into the individual characteristics of different markets (Tsai, 2018).

The existence of connectedness across housing markets at both national and international levels has been demonstrated by many in the literature. At the national level, the high magnitude of cross-region housing connectedness in the US, the UK, and China was reported by Miao et al. (2011), Antonakakis, Chatziantoniou, Floros, and Gabauer (2018a) and Dayong Zhang and Fan (2019). Some papers that indicated the presence of connectedness at the international level include Liow (2013), across European real estate securities markets; Liow et al. (2015), across eight developed securitized real estate markets (the US, Canada, the UK, France, Australia, Japan, Hongkong, and Singapore); Liow and Angela (2017), across three Asian public real estate markets; K.-H. Kim and Park (2016), across the direct real estate markets of East Asia; and H. S. Lee and Lee (2018), across G7 private real estate markets. Regardless of whether the studies investigate securitized real estate or direct real estate markets, the peak of market connectedness generally occurs during periods of financial and market disruption (H. S. Lee & Lee, 2018; Miao et al., 2011).

While the connectedness across housing markets is supported by prior literature, cross-market connectedness between real estate markets and other financial markets remains a largely unexplored area. In fact, higher connectedness across markets can be explained by the acceleration of international financial integration (H. S. Lee & Lee, 2018; Liow, 2013; Liow et al., 2015; Vansteenkiste & Hiebert, 2011). The trend toward the integration of global financial markets has been inevitable in recent years due to increases in the specialization of trade, innovations in finance, which have generated a great range of available derivative instruments, and advances in information technology. Furthermore, in the context of OECD countries, due to the presence of robust linkages in trade, financial markets, and general economic conditions, a higher degree of cross-market connectedness is expected.

In this regard, there has been increasing interest in investigating the association between housing and oil markets. Both of these asset markets are recognized as useful alternative avenues for investment (Brown & Matysiak, 2000; Kat & Oomen, 2007; Liow & Angela, 2017), although the understanding of the impact of financial crises on their comovement is limited by the lack of available literature. The strong empirical evidence of housing–oil interdependence was reported in Breitenfellner et al. (2015) and Rehman, Ali, and Shahzad (2019), who highlighted the impact of oil prices on residential prices in OECD countries. Nevertheless, while researchers have traditionally investigated the fluctuation of housing markets in response to changes in oil prices (Antonakakis et al., 2018a; Beltratti & Morana, 2010; Breitenfellner et al., 2015), none have investigated the *connectedness* between these markets, although such investigation has become increasingly important with the growth of financialization in both property and commodity markets.

With this backdrop, the primary aim of this paper is to investigate the dynamic connectedness between oil and housing markets by capturing the presence and intensity of the dynamic interdependence between them. Not only do we review housing market fluctuations due to changes in oil markets, but we are also interested in the spillover of shocks from housing markets to oil markets, providing a more comprehensive picture of the relationship between these two markets. Furthermore, our paper investigates the time-varying feature of connectedness, especially during periods of financial turmoil. Prior studies have found that extreme economic events usually result in a sharp rise in volatility and an increase in connectedness across markets (Balli, de Bruin, Chowdhury, & Naeem, 2020; Diebold & Yılmaz, 2014; Kang et al., 2017; H. S. Lee & Lee, 2018; Tsai, 2015). Having both tranquil and tumultuous phases in our analysis enables us to investigate whether different financial states play significantly different roles in the connectedness between housing and oil markets. Accordingly, our attention is focussed on exploring which of the two markets is a net shock transmitter and which is a receiver. Through our examination of the periods of financial distress, we attempt to identify the key market that provides leadership in the price discovery process and that transmits the risk to other markets.

In our study, we use the quarterly dataset of 18 OECD countries. Given their advanced financial markets and economy, the OECD is a good testing ground for investigating the connectedness between oil and housing markets. The sample period running from 1970Q1 to 2019Q3 covers important events, from the first oil crisis of 1973 to the most recent financial crises of the GFC and the European sovereign debt crisis (ESDC). Empirical findings are developed by utilizing the methodologies of equicorrelation advanced by Engle and Kelly (2012) and the connectedness analysis developed by Diebold and Yilmaz (2012). Such methodologies perfectly complement each other, allowing us to identify systematic information transmission between housing and oil markets. More specifically, the first technique of the dynamic equicorrelation (DECO) model is to determine comovement across markets. According to Kang et al. (2017), this model is an extreme case of a dynamic conditional correlation model in which correlations are equal across all pairs, but the common equicorrelation changes over time. Second, the pattern and trend comovement over time across markets can be investigated by the connectedness analysis developed by Diebold and Yilmaz (2012). Additionally, by evaluating the net connectedness and pairwise connectedness, this second technique detects the source and recipients of shocks, addressing the question of the flow of shock transmission.

The key results are as follows. Despite the highly dynamic nature of the relationship, our first finding indicates the presence of strong integration between housing and oil markets. In line with prior studies, we also find that connectedness tends to be more intensive during negative shock events. A closer look at net connectedness across these markets reveals that, rather than always being a net transmitter or a net receiver of a shock, either of the markets can switch its role between net shock receiver and transmitter, depending upon time and events (Antonakakis et al., 2018a). Meanwhile, we find the US and UK housing markets to have the highest net connectedness, signifying their contribution to the variations of other markets. While our result is generally consistent with the literature that suggests the variation in oil markets is one of the determinants in housing market fluctuations, we also find that the housing market influenced the oil market during the GFC period. Indeed, our findings reveal that during the GFC period the US housing market played a leading role, transmitting risk to oil markets. The study indicates the role of oil as a mediating factor, spreading shocks from the US housing market to other housing markets. Finally, we also notice the difference in the magnitude of connectedness between net oil-importing and net oil-exporting countries, where the net oil-importing countries appear to be significantly impacted by oil price fluctuations, while this is not observed in the net oil-exporting countries.

The rest of our paper proceeds as follows. Section 3.2 provides a brief literature review. Section 3.3 explains our methodology. Section 3.4 describes the data used in the paper. Section 3.5 discusses the results of our empirical analysis. Finally, section 3.6 presents our conclusion and policy implications.

3.2 Literature review

While our study is the first to employ the DECO-GARCH methodology in order to examine the connectedness between housing markets and the oil market, there are a number of studies that examine the relationships using different methodologies and data sets. Magnusson and Makdessi (2019), utilizing a linear regression model to study the relationship between Brent crude oil prices and housing markets of four OECD countries (Finland, Denmark, Norway, and Sweden) for the period 1990–2018, find that oil price changes impact positively on housing prices. An increase in oil prices leads to higher construction costs, resulting in a decrease in housing supply and an increase in house prices as a consequence. Also, oil price rises might contribute to increases in the general inflation of an economy, which in turn motivate investors to invest in the housing market in order to hedge against this higher inflation, again causing house prices to rise. Yiqi (2017), who focusses on the case of Norway, where oil exports accounted for nearly 50% of the country's exports in 2016, reports that oil price movements exert a positive influence on the housing market. Yiqi finds further that the impact is more pronounced in oil-dependent regions than in other regions.

The above papers generally indicate a positive relationship between oil prices and housing prices, whereas Beltratti and Morana (2010), using an F-VAR model and data from G7 countries, report a negative relationship (with the exception of Japan). They point out that oil price shocks appear to trigger house price variations of 1–7 percent, with an increase in oil prices resulting in a significant contraction in house prices. Antonakakis et al. (2016), using a dynamic conditional correlation GARCH model in order to examine time-varying linkages between housing and oil market returns in the United States over the period 1859–2013, emphasize that the co-movements between housing and oil market returns are consistently negative over time, apart from several periods in the 19th century when the US economy experienced recessions.

Several studies investigate the asymmetry in the impact of oil price changes on housing prices in terms of (1) short-run versus long-run impact, (2) oil price increases versus oil price decreases, (3) net oil-exporting countries versus net oil-importing countries, and (4) more oil-dependent region versus less oil-dependent region of an oil-exporting country. Yeap and Lean (2017) adopt a non-linear autoregressive distributed lag model (NARDL) to examine possible asymmetric effects in the short run and the long run. Considering the Malaysian housing markets for the period 1999Q1–2015Q4, they discover that an increase in oil prices negatively impacts housing market returns in the long run, while in the short run both increases and decreases in oil prices have a negative effect on the housing market returns. Rehman et al. (2019), running a similar NARDL model, highlight the asymmetric nonlinear impact of oil prices on residential housing markets of the US, the UK, and Canada. The authors note that, in the short run, both the UK and Canadian residential housing prices are negatively impacted by oil prices. In the long run, however, a positive oil price component positively affects the US and Canadian house prices while a negative oil price component negatively affects the UK residential house prices. Agnello et al. (2017), using duration models and the dataset of 20 net oil-exporting and net oil-importing industrial countries, report that the housing booms when oil prices increase are shorter than the housing busts when oil prices decrease. Grossman et al. (2019), using a panel VARX model and Texas housing data for the period 1975–2016, find that oil price shocks have a limited impact on house prices, although the impact is significantly larger in oil-dependent urban areas than the impact in less oil-dependent urban areas.

The literature investigating the interdependence between oil and housing markets advances five key reasons for this relationship (Agnello et al., 2017; Antonakakis et al., 2016; Breitenfellner et al., 2015; Magnusson & Makdessi, 2019). First, the linkage between two markets might be because an increase in oil prices will generally have a detrimental effect on household income and expenditure, which in turn lowers a country's growth rate and reduces housing demand and house prices. Second, the increase in construction and building operation costs associated with rising oil prices will result in a fall in housing supply and a consequent increase in housing prices (Magnusson & Makdessi, 2019). Third, an increase in oil prices may lead to an increase in inflation, resulting in the central banks tightening monetary policy and a consequent withdrawal of liquidity from the housing market, reducing housing demand and prices. Fourth, the movement of macroeconomic factors in an economy, including economic growth and the business cycle, may prompt movements in both housing and oil markets, indicating the relationship between them (Vansteenkiste & Hiebert, 2011). Fifth, the profound trend towards the globalization of financial markets due to the development of technology and financial innovation is one of the keys to the interrelationship of housing markets and oil markets (H. S. Lee & Lee, 2018; Liow, 2013; Vansteenkiste & Hiebert, 2011). Technological development and financial innovation have enabled the more rapid and reliable exchange of information leading to global financial liberalization (Issing, 2001). The introduction of advanced financial products of derivative instruments enabled financial market participants to customize their risk exposures and to adjust them over time by selecting alternative investment options, making it easier to trade across different categories of assets. There has been a massive influx of investors attracted to commodity derivative trading, and Basu and Gavin (2010) explain that this is because investors are attempting to hedge against other financial market risks. In fact, these investors are looking for higher yields in a low-interest-rate environment and, given the difference in the returns derived from the oil and housing markets, the preference of investors to invest more in one market alters the other market's price.

In related research, some studies have explored the connectedness amongst housing markets, with some using house price indexes constructed from actual transaction prices of houses and others using movements of securitized real estate markets based on the stock price movements of real estate investment trusts (REITs). In terms of actual transaction price indices, robust evidence of direct housing market connectedness can be found at both the national and international levels. There are some papers examining the connectedness of housing markets across regions within a country, Miao et al. (2011) for the US, Antonakakis et al. (2018a) for the UK, and Dayong Zhang and Fan (2019) for China. Miao et al. (2011), examining the dependency across 16 metropolitan housing markets in the US from 1989 to 2006, demonstrates a robust association during the active phase of the real estate market. Likewise, applying the Diebold and Yılmaz (2014) approach, Antonakakis et al. (2018a), in their study of UK regional property connectedness, report the importance of interregional property return shock transmission in explaining the fluctuation of property returns.

Although it is relatively difficult to trade properties across borders, several papers discuss the significance of the connectedness of house prices across different countries. Vansteenkiste and Hiebert (2011), using a global VAR model and quarterly house price data from seven Euro area countries for the period 1971–2009, identify substantial heterogeneity in the relationship across countries although there is a limited relationship in aggregate. H. S. Lee and Lee (2018), using OECD real house price indexes of G7 countries from 1970–2014, report that connectedness varies substantially over the business cycle, reaching a peak during the GFC. They also report that the United States and Italy were major net transmitters of housing market volatility shocks to other countries during the GFC and ESDC, respectively. H. S. Lee and Lee (2018) could be thought of as the closest to our study as both studies use the same connectedness methodology and OECD quarterly real house price data. However, the focus of the two studies is different as H. S. Lee and Lee (2018) focus on the connectedness between housing markets and we focus on the connectedness between housing markets and the oil market.

Research using data from securitized real estate markets in order to study the connectedness across the real estate markets of different countries include papers by Liow and his co-authors, which find strong relationships across Europe (Liow, 2013); across the US, Canada, the UK, France, Australia, Japan, Hong Kong and Singapore (Liow et al., 2015); across the US, the UK, Japan, Hong Kong, and Singapore (Liow & Angela, 2017); and across the US, Europe and developed Asian markets (Liow & Ye, 2018).

Michayluk et al. (2006) also find a significant interaction between US and UK real estate markets.

Generally, the literature related to housing market connectedness is large whereas cross-market connectedness between real estate and oil markets remains a largely unexplored area of research. Recent decades have witnessed increasing connectedness across markets, partly due to financial market innovations, enhanced financial liberalization, and global financial market integration (H. S. Lee & Lee, 2018; Liow, 2013; Vansteenkiste & Hiebert, 2011). Among OECD countries, given the high linkages in trade, in financial markets, and in general economic conditions, one would expect stronger connectedness across markets. A number of studies report that the connectedness across different markets is stronger during periods of financial turmoil (Bouri, Vo, & Saeed, 2020; Diebold & Yilmaz, 2012; Kang et al., 2017; Kenourgios, 2014; Mensi, Boubaker, Al-Yahyaee, & Kang, 2018). Our paper gives special attention to the effect of financial distress when documenting the dynamics of equicorrelation and connectedness among oil and housing markets across OECD countries using the DECO-GRACH and connectedness index frameworks.

3.3 Methodology

To detect the comovement across housing and oil markets, this paper follows closely the methodology of dynamic equicorrelation developed by Engle and Kelly (2012), and the connectedness index proposed by Diebold and Yilmaz (2012). The first method finds the magnitude and dynamic feature of equicorrelation between these markets, and the second method finds the intensity and direction of connectedness between these markets. Furthermore, while the equicorrelation method is generally suggested as having a backward-looking at the relationship, the connectedness index offer a forward-looking, depending on the forecasting horizon used in obtaining the Forecast Error Variance Decomposition.

3.3.1 The dynamics equicorrelation (DECO-GARCH) model

In this section, we describe in brief the key features of the DECO-GARCH model. As Kang et al. (2017) and Bouri et al. (2020) describe, this approach removes the calculation and presentational complication of high dimension systems and, hence, can be used to measure large covariance matrices. This fits our paper's objective perfectly.

Suppose r_t represents a normally distributed $n \times 1$ vector of asset returns, $r_t = [r_{1t}, r_{2t}, \dots, r_{nt}]$.

$$r_t | I_{t-1} \sim N\,(0, X_t) \qquad (3.1)$$

Conditional covariance matrix X_t is defined by Engle (2002) as:

$$X_t = C_t C_t C_t \qquad (3.2)$$

$$\mu_t = X_t^{1/2} z_t \qquad (3.3)$$

$$R_t = [diag\,(P_t)^{-1/2}]\,P_t\,[diag\,(P_t)^{-1/2}] \qquad (3.4)$$

Here, C_t denotes a diagonal matrix consisting of standard deviations of univariate GARCH, R_t represents the time-varying conditional correlation matrix, μ_t denotes $n \times 1$ vector of residuals, which is dependent on the information set at $t-1$, z_t denotes $n \times 1$ vector of standardized residuals, and P_t represents the conditional correlation matrix of standardized residuals.

The univariate GARCH (1,1) model that is used to derive the components of X_t is as follows:

$$x_{i,t} = \theta_i + \alpha_i \mu_{i,t-1}^2 + \beta_i x_{i,t-1} \qquad (3.5)$$

In the above equation, X_t is the conditional variance of the return series, θ_i is the constant term, α_i captures the ARCH effect, and β_i represents the persistence of the volatility process. The conditional correlation parameters are estimated using standardized residuals z_t.

Following the dynamic conditional correlation (DCC) process, the dynamics of P are defined as:

$$P_t = (1 - \omega_1 - \omega_2)\bar{P} + \omega_1 z_{t-1} z'_{t-1} + \omega_2 P_{t-1} \qquad (3.6)$$

In equation (6), $\omega_{1,}\, \omega_2$ and ω_3 denote parameter matrices, the indicator function $\eta_t = I(z_t < 0) \circ z_t$ takes the value of 1 if the argument is true, otherwise, it takes the value of 0. Also, $\circ$ represents the Hadamard product. Unconditional correlation matrices of z_t and η_t are represented by $\bar{P}_j = E[z_t, z'_t]$ and $\bar{N}_j = E[\eta_t, \eta'_t]$, respectively. The conditional correlation matrix is given as:

$$R_t = P_t^{*-1} P_t P_t^{*-1} \qquad (3.7)$$

In the above equation, P_t^* is a diagonal matrix with a square root of the i^{th} diagonal of P_t at its i^{th} diagonal position.

In order to overcome the limitation of a large number of assets, the DECO model is estimated in two stages. The model assumes that at a given time, the correlation between the assets is equal, but it can vary over time. Moreover, to further simplify, the DECO model estimates only two equicorrelation parameters, α and β. Following the estimations, the unconditional correlation matrix is defined as:

$$R_t = \begin{bmatrix} 1 & \bar{\lambda}_t & \cdots & \bar{\lambda}_t \\ \bar{\lambda}_t & 1 & \cdots & \vdots \\ \vdots & \vdots & \ddots & \bar{\lambda}_t \\ \bar{\lambda}_t & \ldots & \bar{\lambda}_t & 1 \end{bmatrix}$$

$$R_t = (1 - \bar{\lambda}_t)I_n + \bar{\lambda}_t J_n \qquad (3.8)$$

Here, I_n represents n-dimensional identity matrices, and J_n is $n \times n$ matrices of ones.

Equicorrelation $\bar{\lambda}_t$ is defined as:

$$\bar{\lambda}_t = \frac{2}{n(n-1)} \sum_{i \neq j} \lambda_{ij,t} = \frac{2}{n(n-1)} \sum_{i \neq j} \frac{p_{ij,t}}{\sqrt{p_{ij,t} p_{jj,t}}} \qquad (3.9)$$

Finally, the scalar DECO model is given as:

$$P_t = (1 - \alpha_2 - \beta_2)\, \bar{P} + \alpha_2 e_{t-1} e'_{t-1} + \beta_2 P_{t-1} \qquad (3.10)$$

3.3.2 Connectedness index

Having measurements to disclose the existence of dynamic connectedness as well as the direction of connectedness across markets, the connectedness approach built on the variance decomposition matrix can be utilized for discovering the source (net transmitters) and recipients of shocks.

Suppose there is the covariance stationary N-variance vector autoregressive lag of p, VAR(p) as follows:

$$x_t = \sum_{i=1}^{p} \varphi_i x_{t-i} + \varepsilon_t \qquad (3.11)$$

Here, x_t is a N x 1 vector of endogenous variables, t denotes time, and $\varepsilon_t \sim (0, \Sigma)$ is the vector of the disturbances distributed independently and identically. It is problematic to read the estimated coefficients because of the complexity of the interaction of the variables and because they are generally over parameterized (Yang, Yu, & Deng, 2018).

Thus, to understand the dynamics of the system, the moving average form of the above model is used and calculated as:

$$x_t = \sum_{i=0}^{\infty} A_i \, \varepsilon_{t-1} \tag{3.12}$$

Here, A_i is N x N matrices following the rule: $A_i = \varphi_1 A_{i-1} + \varphi_2 A_{i-2} + \varphi_3 A_{i-3} + \cdots + \varphi_n A_{i-n}$ and for i<0, A_i = 0.

To understand the dynamics of the system, it is worth noticing the moving average coefficients. From these, we find the variance decomposition, disclosing the percentage contribution of each variable to other variables. In other words, this measures the portion of the H step-ahead error variance in forecasting x_i that is due to shocks to x_j, with $i \neq j$ for each i. Notably, the result from variance decomposition appears to be responsive to the order of variables in the system. Utilizing the generalized VAR framework, first proposed by Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998), Diebold and Yilmaz (2012)'s methodology can correct the issue. In particular, as denoted by θ_{ij}^{g}, the H step-ahead forecast error variance for $H = 1, 2, \ldots$, is measured as follows:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \Sigma e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_h \Sigma A_h' e_i\right)} \tag{3.13}$$

Where:

- Σ is the variance matrix for the error vector ε,
- σ_{jj} is the standard deviation of the disturbance of the j^{th} equation (standard deviation of ε_j)
- e_i is the selection vector, which is equal to 1 for the i^{th} element and 0 for the others.

Since the total variance decomposition in each row is different from 1, and given the need for calculating the connectedness index, it is advisable to normalize each entry.

$$C_{i\leftarrow j}(H) = \tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \tag{3.14}$$

$\tilde{\theta}_{ij}^{g}(H)$ shows the pairwise directional connectedness from market j to market i. For simplification, it is denoted as $C_{i\leftarrow j}(H)$. The total variance decomposition of each row or across a particular housing market should be equal to 1 after normalization: $\sum_{j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H) = N$.

Given our paper's aim, a key to understanding the connectedness is to look at total connectedness value. Using the error variance decomposition, total connectedness (TC) is constructed as:

$$TC(H) = \frac{\sum_{i,j=1(i\neq j)}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \times 100 = \frac{\sum_{i,j=1(i\neq j)}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \times 100 \quad (3.15)$$

The index thus indicates the impact of connectedness across markets on the total forecast error variance. The next interesting step is to find the direction of the ripple effect to discover which markets are transmitting a shock to others and which are receiving a shock from others. With regard to directional connectedness from all other markets *j* to market *i* is:

$$C_{i\leftarrow\blacksquare}(H) = \frac{\sum_{j=1(i\neq j)}^{N} \tilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ij}^{g}(H)} \times 100 = \frac{\sum_{j=1(i\neq j)}^{N} \tilde{\theta}_{ij}^{g}(H)}{N} \times 100 \quad (3.16)$$

The directional connectedness transmitted by market *i* to all other markets *j*, is calculated as:

$$C_{\blacksquare\leftarrow i}(H) = \frac{\sum_{j=1(i\neq j)}^{N} \tilde{\theta}_{ji}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{\theta}_{ji}^{g}(H)} \times 100 = \frac{\sum_{j=1(i\neq j)}^{N} \tilde{\theta}_{ji}^{g}(H)}{N} \times 100 \quad (3.17)$$

After estimating the directional connectedness and the net total directional connectedness, we address the question of whether markets are net transmitters or receivers of shocks when the value is positive and when it is negative. Net total connectedness from market *i* to all other markets *j* is found as the difference between the total directional connectedness from market *i* transmitted to other markets and the total directional connectedness to market *i* received from other markets:

$$NC_i(H) = C_{\blacksquare\leftarrow i}(H) - C_{i\leftarrow\blacksquare}(H) \quad (3.18)$$

To conclude, for a closer look into specific markets, it might be of interest to analyse the net pairwise directional connectedness between two markets *i* and *j*, which is obtained by

$$C_{ij} = C_{j \leftarrow i}(H) - C_{i \leftarrow j}(H) \quad (3.19)$$

and tells us how much each market affects another specific market.

3.4 Data description

3.4.1 Data

In order to estimate the connectedness between the housing markets and the oil market, we use house price data from the OECD and the West Texas Intermediate (WTI) crude oil prices from the US Energy Information Administration. The house price data that we use are quarterly indexes of real house prices of new and existing dwellings, where the OECD calculates the real house prices by deflating the nominal house prices by each country's consumer expenditure deflator.[12] Most of the house price data start from 1970 (with the exception of a few countries); and, for all countries, the data is only available at quarterly frequencies. This availability has determined the period this paper covers, 1970Q1 to 2019Q3, and the use of quarterly frequency data in the analysis. The use of quarterly house price data in a similar context can be found in Agnello et al. (2017); Breitenfellner et al. (2015); Magnusson and Makdessi (2019).[13]

Our period of coverage includes important financial market events: the oil price crisis (1973), the GFC (2007–2009), and the ESDC (2010–2012). Of the 18 OECD countries covered in the analysis, there are both net oil-exporting and net oil-importing countries. It should be noted that the US and the UK, while they are net oil-importing countries, they also produce large amounts of oil (Ali, 2016; Van Eyden, Difeto, Gupta, & Wohar, 2019).

Our connectedness analysis is conducted using the housing and oil markets' returns calculated by taking the difference of the natural logarithm of the prices between time *t*

[12] Eurostat (2013) reports that there are differences in the way house price indexes are constructed in different European Union countries, which could create issues when comparing these indexes across countries. These differences arise from: different data sources and methodologies, and different revision policies used to compile national indexes. The collection of data from one platform (the OECD), rather than from each country's national statistics agency, is likely to provide the best comparable house price indexes across countries.

[13] We follow H. S. Lee and Lee (2018); Hahn Shik Lee and Lee (2020) in using house price indexes that reflect the price movements of real properties, rather than securitized real estate indexes. Mühlhofer (2013) argues that since a financial market crisis may originate from a real estate market, as happened in the GFC, using the former type of house price index in the analysis of the interrelationship between markets may be more informative for investors and policy makers than using the latter. Nevertheless, securitized real estate indexes have been used to study connectedness across housing markets (Liow, 2015; Liow & Ye, 2018; Liow et al., 2015).

and time t–1 (equation 3.20). The realized volatility of the markets is measured using the square root of the variance of the calculated returns (equation 3.21).

$$r_{i,t} = \ln\left(\frac{p_{i,t}}{p_{i,t-1}}\right) \times 100 \qquad (3.20)$$

$$RV = r_{i,t}^{2} \qquad (3.21)$$

Figure 3.1 shows the movements of the oil prices and the house prices of the 18 OECD countries studied in the paper.

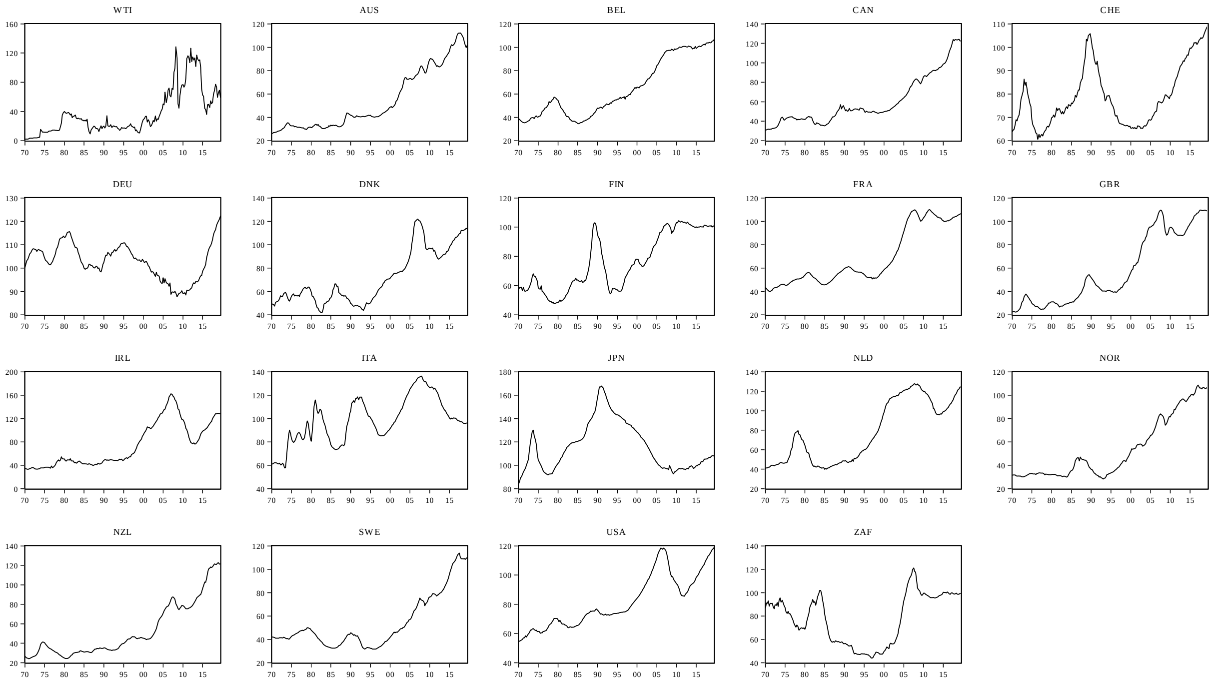


Figure 3. 1 Evolution of WTI oil prices and house prices in 18 OECD countries

Note: The vertical axis shows the price indexes in oil and housing markets. WTI, AUS, BEL, CAN, CHE, DEU, DNK, FIN, FRA, GBR, IRL, ITA, JPN, NLD, NOR, NZL, SWE, USA, ZAF and WTI refer to Crude oil WTI, Australia, Belgium, Canada, Switzerland, Germany, Denmark, Finland, France, Great Britain, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Sweden, United States, and South Africa, respectively

With the exception of Germany and Japan, the house prices exhibit positive trends during the sample period, particularly during 2005–2019.[14] However, in each country, there are wide fluctuations within this generally positive trend. The figure also shows that there are large disparities in house price movements across countries, with a tendency to move closer together during periods of financial crisis. For example, during the GFC most

[14] House prices in Germany fell during 1970–2010 and then experienced sharp increases in the last decade; house prices in Japan reached a peak in 1990 and have fallen consistently since then with some sign of stabilisation in recent years.

countries in the sample experienced a drop in house prices, including Germany (DEU), Denmark (DNK), Ireland (IRL), Italy (ITA), Netherlands (NLD), New Zealand (NZL), the US (USA), and South Africa (ZAF).

The movement of oil prices has also been generally positive; however, both the rate of increase and the volatility differ substantially across the sample period. The greatest volatility occurred in the last 20 years of the sample period. The oil price peak was recorded in the first half of 2008 when the price reached USD128.57 per barrel. The high oil price during that period can be explained by surging demand due to the rapid expansion of emerging economies (for example, China), and falling supply due to a decline in the output of OPEC producers (Carlin & Soskice, 2014). In 2009, the global financial crisis saw the fall in demand largely outweighing the fall in supply, and oil prices dropped by more than 60 percent to USD 44.56 per barrel.

3.4.2 Descriptive statistics

Table 3.1 and Table 3.2 provide descriptive statistics of market returns and realized volatility of all variables examined in the study, respectively.

Table 3. 1 Descriptive statistics of returns in oil and housing markets (in percent per quarter)

	Mean	Std. Dev.	Skewness	Kurtosis	J-B	ADF
Crude oil WTI	1.650	18.362	0.863	13.564	945.209***	-13.71***
Australia	0.690	2.034	0.455	3.793	12.016***	-6.503***
Belgium	0.509	1.719	-0.323	3.841	9.274***	-4.104***
Canada	0.696	2.214	-0.604	5.226	52.936***	-9.377***
Switzerland	0.271	1.892	-0.101	5.198	40.198***	-3.891***
Germany	0.101	1.014	-0.629	6.217	98.444***	-3.158**
Denmark	0.418	2.662	-0.128	4.667	23.456***	-7.464***
Finland	0.285	2.508	-0.184	5.131	38.591***	-4.395***
France	0.457	1.342	-0.126	2.489	2.678	-3.984***
Great Britain	0.800	2.689	0.328	4.367	18.977***	-5.401***
Ireland	0.655	3.203	-0.102	3.580	3.117	-4.395***
Italy	0.230	3.043	1.732	8.500	348.554***	-5.265***
Japan	0.127	1.622	0.253	7.590	175.940***	-5.248***
Netherlands	0.564	2.357	-0.094	5.670	59.110***	-3.604***
Norway	0.617	2.247	0.156	4.354	15.923***	-5.467***
New Zealand	0.765	2.372	0.454	4.157	17.842***	-5.104***
Sweden	0.488	1.949	-0.736	3.896	24.512***	-4.274***
United States	0.391	1.163	-1.106	4.228	49.542***	-3.186**
South Africa	0.070	2.790	0.025	3.556	2.573	-7.43***

Note: ABB refers to country abbreviations, Std. Dev. refers to the standard deviation, J-B refers to the Jarque-Bera test of normality and ADF refers to the Augmented Dicky-Fuller test of stationarity. ** and *** indicate the statistical significance at 5% and 1%, respectively.

The standard deviation reveals that small countries, such as Ireland and Italy, appear to have the highest volatility in house price returns. Similarly, we find Ireland and Italy have the highest realized volatility, at 10.63 and 9.27, respectively. The standard deviation of the returns of the oil market is significantly higher than the standard deviations of the returns of the housing markets. Furthermore, the average of the realized volatility of the oil market's returns is extremely high at 338.2. This can be expected given the oil market's higher liquidity and higher degree of leverage as well as the impact on the oil market of geopolitical factors and the business cycles of economies. Finally, the Jarque-Bera (J-B) and the Augmented Dickey-Fuller (ADF) tests provide sufficient evidence that all our examined variables are normally distributed.

Table 3. 2 Descriptive statistics of realized volatility of oil and housing markets (in percent per quarter)

	Mean	Std. Dev.	Skewness	Kurtosis	J-B	ADF
Crude oil WTI	338.201	1208.309	9.482	107.346	92792.980***	-13.601***
Australia	4.593	8.124	4.272	26.643	5213.780***	-7.100***
Belgium	3.201	4.943	2.895	13.073	1113.717***	-12.463***
Canada	5.361	9.607	3.161	14.022	1331.984***	-7.962***
Switzerland	3.635	7.337	5.062	34.787	9181.712***	-13.350***
Germany	1.033	2.294	9.067	106.254	90670.140***	-12.666***
Denmark	7.225	13.569	3.403	16.814	1956.440***	-10.901***
Finland	6.340	12.704	3.560	17.532	2160.563***	-8.011***
France	2.000	2.397	1.920	6.607	228.927***	-3.982***
Great Britain	7.835	14.631	4.257	24.745	4498.818***	-8.919***
Ireland	10.634	16.700	3.219	16.274	1795.408***	-10.402***
Italy	9.269	26.209	4.884	28.749	6256.953***	-6.314***
Japan	2.634	6.790	6.498	52.234	21391.340***	-2.177***
Netherlands	5.844	12.150	4.344	26.786	5290.262***	-5.260***
Norway	5.406	9.858	4.215	27.814	5666.003***	-3.33988
New Zealand	6.182	11.447	5.560	47.081	17050.940***	-7.648***
Sweden	4.018	5.881	3.928	26.053	4893.530***	-7.380***
United States	1.499	2.026	3.302	18.096	2239.691***	-7.235***
South Africa	7.752	12.429	2.350	8.649	445.444***	-7.851***

Note: ABB refers to country abbreviations, Std. Dev. refers to the standard deviation, J-B refers to the Jarque-Bera test of normality and ADF refers to the Augmented Dicky-Fuller test of stationarity. ** and *** indicate the statistical significance at 5% and 1%, respectively.

3.5 Empirical findings

3.5.1 Dynamic return equicorrelation

In order to show the integration between housing and oil markets, the first part of the empirical study evaluates the equicorrelation using the DECO-GARCH model. Figure 3.2 describes the evolution of return equicorrelation among studied markets. As shown, equicorrelation is time-varying, with figures ranging from 0.02 to 0.15. While the large variations are apparent, its value remains positive, strongly indicating the contagion effect across markets.

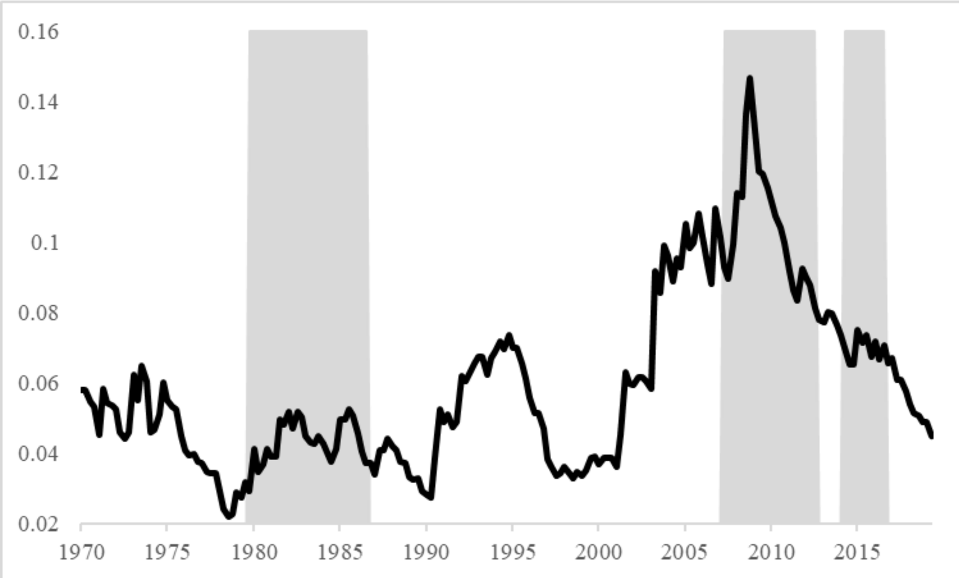


Figure 3. 2 Dynamic equicorrelation between oil and housing market returns estimated using the DECO-GARCH of Engle and Kelly (2012)

Note: The shaded areas indicate the oil glut of 1980–1986, GFC of 2007–2009, ESDC of 2009–2012 and shale-oil revolution of 2014–2016.

Furthermore, we notice the dramatic increase of equicorrelation under periods of financial crises. The correlation between housing and oil markets appears to be more pronounced during some critical events, including the oil crisis of 1973, the oil collapse of 1986, the GFC of 2007–2009, ESDC of 2009–2012, and the shale-oil revolution of 2014–2016. The jump in equicorrelation between oil and housing markets was first recorded in 1973 when the first oil crisis was caused by the oil restriction announcement by members of the Organization of the Petroleum Exporting Countries (OPEC). Consequently, the increase of crude oil prices globally during this shock badly affected some OECD net oil-importing countries. Then, in 1986 we witnessed the oil price collapse in response to the decision by Saudi Arabia, one of the most important oil exporters, and some oil-exporting countries to increase their oil production and market share. Since the oil shock of 1986 only lasted for a short period of 9 months with less extreme volatility in oil prices, the equicorrelation value between oil and housing markets was found to be stronger than the calm period, but not quite as high as that in the 1973 oil price crisis (0.06 in 1986 compared to 0.065 in 1973).

The recent GFC resulted in an unprecedented equicorrelation peak of 0.147. Originating from the subprime mortgage crisis as the US housing bubble burst in 2007, the GFC triggered global panic and transmitted risks to other financial markets. Shortly after that, oil prices plummeted, indicating strong integration between the housing and oil markets. From the end of 2009, the European sovereign debt crisis (ESDC) had an adverse impact on the housing markets of several eurozone member states (e.g. Greece, Portugal, Ireland, Spain, and Cyprus). The equicorrelation between housing and oil markets remained high during the peak of the crisis (2010–2011). This strong magnitude of equicorrelation between housing and oil markets continued until recent years as a result of the shale-oil revolution, which put downward pressure on the global price of oil. Overall, our findings indicate more robust integration across markets when there is financial turmoil, and are fully in line with the findings reported in the literature (Bouri et al., 2020; Diebold & Yilmaz, 2012; Kang et al., 2017; Kenourgios, 2014; Mensi et al., 2018).

3.5.2 Static connectedness

Having discussed the correlation between the housing and oil markets using the DECO-GARCH approach, the next part of our analysis addresses the connectedness between these two markets using the method of Diebold and Yilmaz (2012). We first look at the connectedness of the markets by considering the static indexes, which are calculated by using a four-quarter step-ahead forecast error variance decomposition.

Table 3. 3 Full-sample return connectedness

	AUS	BEL	CAN	CHE	DEU	DNK	FIN	FRA	GBR	IRL	ITA	JPN	NLD	NOR	NZL	SWE	USA	ZAF	WTI	FROM
AUS	59.17	0.32	4.95	2.03	0.04	0.64	3.46	0.08	13.38	0.15	1.14	0.00	1.15	0.88	4.89	3.04	2.58	1.23	0.86	2.15
BEL	0.52	62.17	1.22	0.44	0.22	1.03	1.13	7.16	0.46	0.56	1.23	1.35	11.36	2.01	0.17	4.39	2.36	1.22	0.98	1.99
CAN	5.84	0.54	62.63	1.97	2.57	2.00	0.71	3.48	5.35	0.34	3.88	0.25	0.07	2.43	3.36	1.79	2.15	0.47	0.18	1.97
CHE	0.60	0.43	1.36	55.38	0.64	1.42	4.68	0.97	10.70	0.38	3.12	5.41	3.35	1.16	1.61	2.58	2.20	0.38	3.64	2.35
DEU	0.98	0.43	2.34	0.60	78.11	0.06	3.31	0.16	0.45	0.22	1.18	3.97	0.92	1.01	1.16	0.32	3.75	0.34	0.69	1.15
DNK	1.19	0.42	3.57	1.13	0.37	61.20	1.09	0.11	2.91	0.38	5.99	1.60	1.57	3.47	1.06	1.65	10.28	1.47	0.54	2.04
FIN	3.16	0.39	0.58	6.35	0.30	0.76	52.84	0.26	16.55	0.04	3.93	1.46	1.40	2.11	1.55	3.02	1.31	3.43	0.53	2.48
FRA	1.39	7.39	0.97	0.49	0.05	1.23	1.34	62.33	4.97	1.72	0.67	0.07	0.22	1.36	0.04	6.29	8.59	0.33	0.57	1.98
GBR	2.87	1.22	1.08	9.93	0.14	3.76	4.62	0.62	51.37	0.29	3.70	2.30	0.51	1.36	0.02	3.81	11.39	0.29	0.73	2.56
IRL	0.15	0.73	0.31	1.31	1.62	3.75	0.47	3.14	0.66	58.84	1.23	0.42	3.85	1.00	0.27	1.39	15.05	4.36	1.44	2.17
ITA	4.72	0.21	9.64	1.75	1.08	4.61	0.89	5.22	2.22	0.21	66.44	0.19	0.18	0.21	0.78	0.22	0.36	0.61	0.47	1.77
JPN	0.03	0.48	0.88	8.77	3.80	0.17	0.41	0.34	14.51	0.24	1.79	61.08	1.67	0.06	3.20	0.41	1.76	0.18	0.21	2.05
NLD	1.25	3.27	0.04	5.55	0.29	3.75	0.20	0.11	0.50	0.51	0.25	1.81	76.15	0.86	0.11	1.10	2.93	0.68	0.64	1.26
NOR	0.83	0.21	0.26	0.79	0.61	4.11	1.82	0.88	0.84	0.86	3.19	2.81	0.56	73.64	4.84	2.29	1.40	0.03	0.01	1.39
NZL	5.03	0.19	1.99	1.78	0.50	0.44	1.93	0.01	2.25	0.11	0.57	2.17	0.11	0.56	67.64	0.69	8.04	4.76	1.22	1.70
SWE	1.01	4.30	0.17	2.78	0.07	1.31	9.13	3.84	3.51	0.28	0.15	1.00	0.62	3.82	0.69	58.80	5.24	1.54	1.74	2.17
USA	0.22	1.02	1.13	5.61	1.56	4.99	0.25	0.16	5.95	0.28	0.62	0.61	1.95	0.05	0.75	0.88	64.89	2.67	6.42	1.85
ZAF	2.87	1.34	0.11	0.55	0.09	0.50	4.63	3.03	2.33	0.01	0.50	0.60	2.47	0.80	4.12	0.77	5.57	68.89	0.81	1.64
WTI	0.44	0.67	1.56	5.19	0.70	0.19	0.83	0.68	0.82	0.74	2.47	1.26	0.17	0.01	0.78	0.16	6.53	0.98	75.82	1.27
TO	1.74	1.24	1.69	3.00	0.77	1.83	2.15	1.59	4.65	0.39	1.87	1.44	1.69	1.22	1.55	1.83	4.81	1.32	1.14	Total
NET	-0.41	-0.75	-0.27	0.65	-0.38	-0.21	-0.33	-0.39	2.09	-1.78	0.11	-0.61	0.44	-0.17	-0.16	-0.34	2.97	-0.32	-0.13	35.93%

Note: This table reports the return connectedness between oil and housing markets from 1970Q1-2019Q3. FEVD is based on a 19-variate VAR with one lag and 4 quarters predictive horizons, delivers pair-wise directions of spillovers (19 × 19 submatrix). 'FROM' denotes total directional connectedness from all others i.e., off-diagonal row sums, whereas 'TO' denotes total directional spillovers to all others i.e., off-diagonal column sums. 'NET' spillovers are the difference between the contribution to others and the contribution from others. AUS, BEL, CAN, CHE, DEU, DNK, FIN, FRA, GBR, IRL, ITA, JPN, NLD, NOR, NZL, SWE, USA, ZAF and WTI refer to Australia, Belgium, Canada, Switzerland, Germany, Denmark, Finland, France, Great Britain, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Sweden, United States, South Africa, and Crude oil WTI, respectively.

Table 3. 4 Full-sample realized volatility connectedness

	AUS	BEL	CAN	CHE	DEU	DNK	FIN	FRA	GBR	IRL	ITA	JPN	NLD	NOR	NZL	SWE	USA	ZAF	WTI	FROM
AUS	66.69	0.14	1.10	0.36	0.22	1.05	10.08	0.11	13.98	0.48	0.53	0.99	0.10	1.55	0.09	0.21	0.33	1.12	0.85	1.75
BEL	0.48	65.15	1.03	0.98	0.25	1.65	3.04	2.66	0.41	0.98	5.30	1.08	9.09	1.03	3.37	0.39	0.32	1.28	1.50	1.83
CAN	13.97	2.24	57.75	1.59	0.54	1.72	7.15	0.06	5.35	0.28	0.12	0.75	0.63	0.66	4.21	0.05	0.78	0.47	1.68	2.22
CHE	4.18	0.30	1.30	44.14	0.39	0.52	9.19	0.58	12.95	0.18	1.91	19.56	1.45	0.23	0.59	0.54	0.88	0.05	1.07	2.94
DEU	0.89	0.04	0.08	1.95	88.41	0.66	0.65	1.98	1.47	0.21	0.58	1.12	0.51	0.07	0.17	0.46	0.33	0.20	0.20	0.61
DNK	0.40	1.26	2.02	0.66	0.46	73.14	0.09	1.42	0.34	0.38	1.43	0.56	0.28	4.75	0.74	2.05	1.93	4.83	3.28	1.41
FIN	7.38	1.87	0.95	9.57	0.12	0.06	58.42	0.50	9.18	0.17	1.24	2.29	1.14	0.38	0.75	4.04	1.34	0.20	0.40	2.19
FRA	0.53	2.93	0.41	1.44	0.55	1.13	0.27	78.75	0.45	0.61	1.88	0.08	0.35	0.15	1.16	0.10	1.68	7.10	0.43	1.12
GBR	6.92	0.03	0.35	1.56	0.82	0.37	0.59	0.40	68.99	1.25	0.40	8.66	0.17	0.11	0.28	1.06	7.86	0.14	0.07	1.63
IRL	0.87	1.31	0.32	0.50	0.48	0.39	0.47	0.15	1.90	81.86	0.22	0.31	4.30	0.46	0.16	0.64	2.52	2.55	0.57	0.95
ITA	6.32	0.71	1.84	1.71	0.15	0.54	2.46	0.18	1.60	1.04	52.72	0.46	2.23	1.58	18.46	1.25	0.20	2.02	4.53	2.49
JPN	0.04	0.41	1.25	4.93	0.59	0.10	2.19	1.14	14.53	0.39	1.32	66.41	0.20	0.32	0.94	1.14	3.64	0.21	0.26	1.77
NLD	0.71	1.02	0.73	3.28	1.45	0.32	1.21	0.25	0.84	5.60	0.42	0.02	80.81	0.34	0.11	0.13	1.44	1.14	0.19	1.01
NOR	0.63	0.18	0.54	0.01	0.18	10.66	0.57	0.02	0.02	0.47	0.79	0.48	0.45	80.05	0.54	0.52	0.33	3.02	0.55	1.05
NZL	1.74	1.01	5.97	0.62	0.15	0.39	0.78	0.66	0.99	0.34	5.17	3.05	0.09	1.22	59.95	1.30	0.82	0.74	15.00	2.11
SWE	0.20	0.18	1.98	1.89	1.67	1.17	14.26	0.15	0.84	0.06	1.38	0.76	1.11	0.40	0.43	71.25	0.75	1.05	0.47	1.51
USA	0.21	0.51	0.07	1.26	0.18	2.79	3.37	0.74	0.93	1.70	0.09	2.82	1.25	0.52	0.25	2.02	78.29	1.85	1.14	1.14
ZAF	1.17	0.75	1.45	0.22	0.15	1.21	0.55	2.26	0.72	2.10	0.67	0.23	1.19	4.78	1.18	0.80	3.09	75.40	2.09	1.29
WTI	1.11	2.67	2.97	0.55	0.08	1.89	1.23	0.07	0.48	0.40	7.54	0.62	0.17	1.16	20.80	0.84	1.67	0.79	54.99	2.37
TO	2.51	0.92	1.28	1.74	0.44	1.40	3.06	0.70	3.53	0.88	1.63	2.31	1.30	1.04	2.85	0.92	1.57	1.51	1.80	Total
NET	0.76	-0.91	-0.94	-1.20	-0.17	-0.01	0.87	-0.42	1.89	-0.08	-0.86	0.54	0.29	-0.01	0.75	-0.59	0.43	0.22	-0.56	31.41%

Note: This table reports the volatility connectedness between oil and housing markets from 1970Q1-2019Q3. FEVD is based on a 19-variate VAR with one lag and 4 quarters predictive horizons, delivers pair-wise directions of spillovers (19 × 19 submatrix). 'FROM' denotes total directional connectedness from all others i.e., off-diagonal row sums, whereas 'TO' denotes total directional spillovers to all others i.e., off-diagonal column sums. 'NET' spillovers are the difference between the contribution to others and the contribution from others. Boldface values are used for reporting/reference purposes. AUS, BEL, CAN, CHE, DEU, DNK, FIN, FRA, GBR, IRL, ITA, JPN, NLD, NOR, NZL, SWE, USA, ZAF and WTI refer to Australia, Belgium, Canada, Switzerland, Germany, Denmark, Finland, France, Great Britain, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Sweden, United States, South Africa and Crude oil WTI, respectively.

Table 3.3 and Table 3.4 illustrate the static connectedness between housing and oil markets. The results show that the total return and realized volatility connectedness indices are relatively high, at 35.93 percent and 31.41 percent, respectively. This signifies that, on average, more than 30 percent of the forecast error variance is the result of the effect of transmission between these two markets, and the remaining 70 percent of the variance is due to idiosyncratic shocks. While H. S. Lee and Lee (2018), who use the same methodology as Diebold and Yilmaz (2012); Diebold and Yılmaz (2014), find the total connectedness across housing markets in the G7 countries is 10.2 percent, we find the total connectedness across the markets examined in our study to be around 30 percent. This may be because we include a larger number of housing markets in our sample and because we include oil markets, which play a significant role in promoting connectedness between these markets.

We assess net connectedness across all markets in order to identify which markets are net transmitters and which are net receivers. We find that the big countries, the US and the UK, are the two greatest return net transmitters, with net connectedness of 2.97 percent and 2.09 percent, respectively. We find the UK to be the largest source of shock when it comes to net connectedness in realized volatility. The leading role of the US market in causing global fluctuation is not new to the literature (Beltratti & Morana, 2010; Long, Li, Wang, & Cheng, 2012; Rehman et al., 2019). Beltratti and Morana (2010) examine the associations between general macroeconomic developments and housing markets across the G7 countries and find that the US had the most impact on the fluctuation of real housing prices in other countries. Similarly, H. S. Lee and Lee (2018) emphasized the direction of connectedness from the US housing market to other G7 countries, particularly during the 2007–2009 GFC. In their study, they find that the markets of the other 5 countries experienced negative returns and volatility net connectedness, suggesting that they are mainly shock receivers from the housing markets of the US and the UK. The literature therefore indicates that the importance of the US housing market in explaining other markets' variation should be considered.

3.5.3 Dynamic connectedness

The above discussion of static connectedness gives us an overview of the average connectedness across housing markets and the oil market but does not reveal the varying level of connectedness over time. Because certain events have a significant impact on the connectedness of the markets (Diebold & Yilmaz, 2012), we utilize a 40-quarter rolling window dynamic connectedness analysis in order to obtain a more comprehensive picture over time.

3.5.3.1 Total dynamic connectedness

Figure 3.3 describes the total dynamic connectedness in return and realized volatility between housing and oil markets, which demonstrates the time-varying nature of their connectedness. The figure moves around the value of 75 percent, with a lowest value of 67 percent and a highest of 85 percent. Additionally, while total connectedness in return and realized volatility have certain periods of dispersion, they appear to share a common pattern.

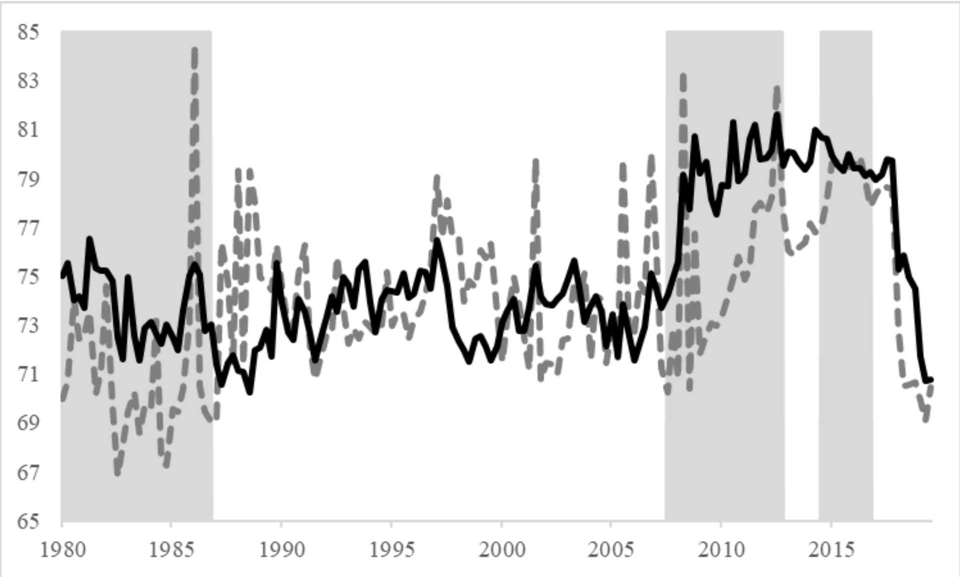


Figure 3. 3 Dynamic returns and realized volatility connectedness between oil and housing markets estimated using Diebold and Yilmaz (2012)

Note: The dynamic returns (black) and realized volatility (dashed grey) connectedness indices are calculated from the forecast error variance decompositions using a rolling window size of 40 quarters and a forecast horizon of H = 4 quarters. The shaded areas indicate the oil glut of 1980–1986, GFC of 2007–2009, ESDC of 2009–2012, and shale-oil revolution of 2014–2016.

What is noticeable is the significant increase in the total connectedness of return and volatility during periods of the financial crisis. As mentioned previously, the oil crisis of 1986, the GFC, the ESDC, and the shale-oil revolution provide opportunities to examine the substantial impact of financial downturns on the connectedness among markets. Total volatility connectedness reached an unprecedented record high of 84.5 percent in 1986, associated with the oil price collapse. After the oil market stabilization, the index started to decline and varied around 70–75 percent. However, from the GFC onwards (including the GFC, the ESDC, and the shale-oil revolution), connectedness rises steeply to a peak of nearly 84 percent and remained high until 2017. The variation in housing and oil market connectedness during this period of crises was due to the risk diffusion effect (Tsai, 2014). This high degree of connectedness has also been reported by various papers investigating the connectedness among commodity markets and across housing markets. For example, Kang et al. (2017) and Balli et al. (2020) find that the dynamic spillover effects among the commodity markets were more pronounced during the crisis period considered. Similar findings were reported by H. S. Lee and Lee (2018) regarding the connectedness among housing markets.

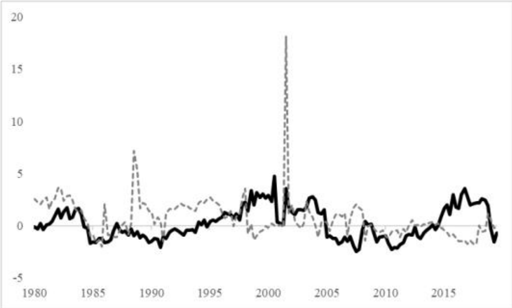
3.5.3.2 Net connectedness

In order to investigate the direction of information flow between housing and oil markets, we estimate the net return connectedness and net realized volatility connectedness. Figure 3.4 provides a detailed exposition of the directional *from* and *to* connectedness. Whenever the figure is more than zero, the market is considered to be the net transmitter of connectedness. Whenever the figure is less than zero, the market is considered to be the net receiver of connectedness.

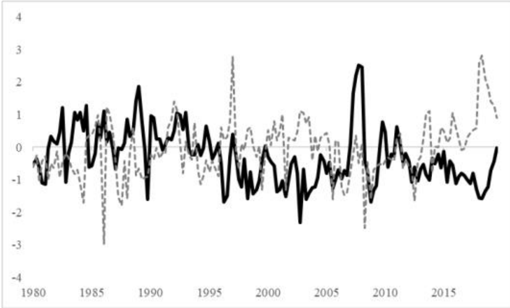
In line with studies by Beltratti and Morana (2010); Kang et al. (2017) and Dayong Zhang and Fan (2019), we find that the connectedness is bidirectional across all markets. In other words, rather than playing one role, a market could change from being a shock transmitter to a shock receiver or vice versa depending on the time period analysed. With regard to Germany, for example, the positive value of return and volatility net connectedness from 1990 to 2000 indicates the German housing market was the source of shocks to other housing markets. Germany's economic growth following reunification in 1990 (Sinn, 2002), resulted in a strong economy that had a dramatic impact on other European nations. However, its role switched to being a recipient of shocks from the GFC onwards, as indicated by Germany's negative net connectedness during and beyond that crisis period.

While some countries switch roles, other countries might be classified as dominant transmitters or receivers. For example, it is clear that the USA, especially during the GFC, played the role of the dominant transmitter. The US housing market proved to be the most influential since its net connectedness remained positive during most of the sample period. The fact that the US subprime mortgage crisis spread across other markets globally, becoming a global financial crisis (Islam & Verick, 2011; Naeem, Peng, Suleman, Nepal, & Shahzad, 2020), reveals the importance of the global influence of the US housing market.

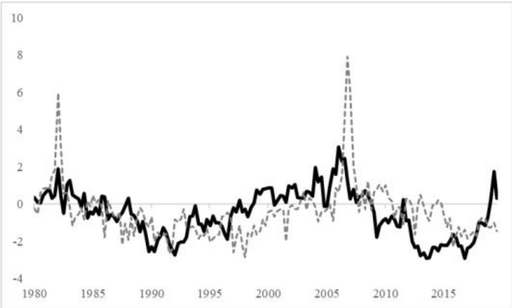
a) Australia



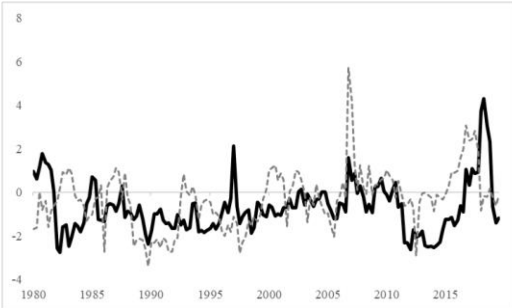
b) Belgium



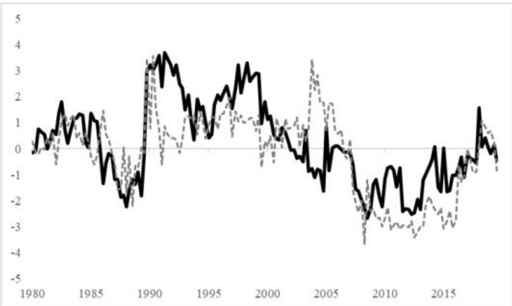
c) Canada



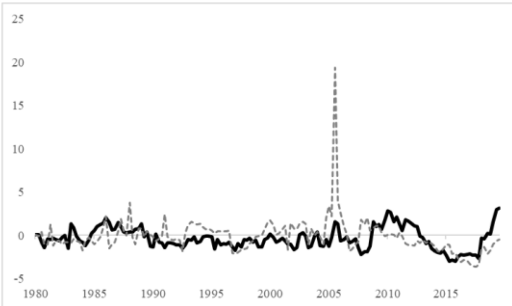
d) Switzerland



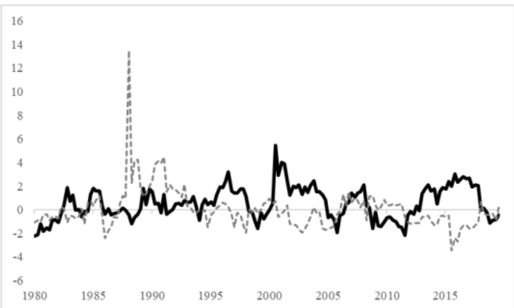
e) Germany



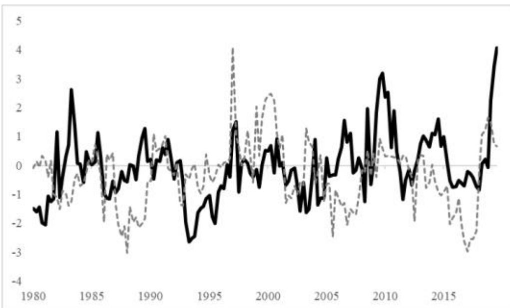
f) Denmark



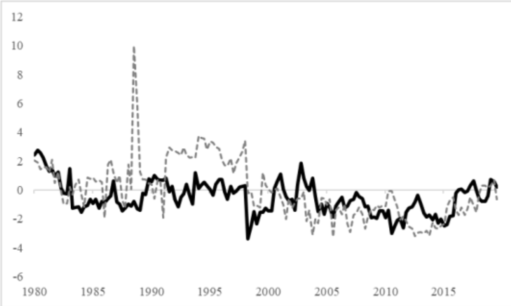
g) Finland



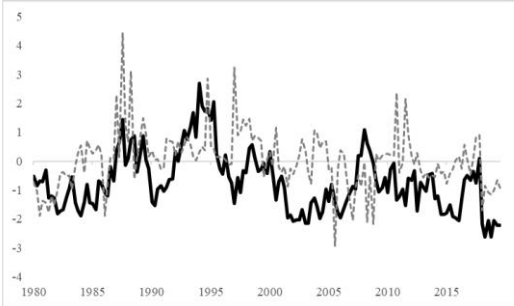
h) France



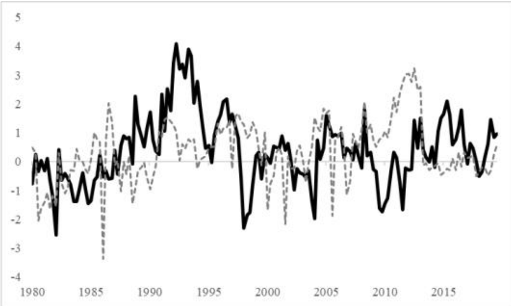
i) Great Britain



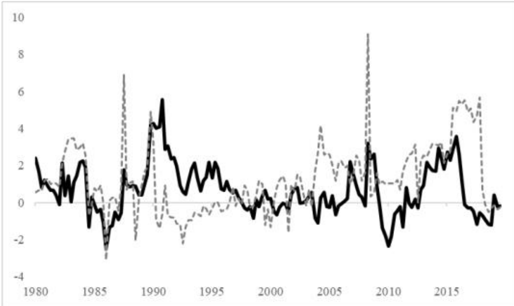
j) Ireland



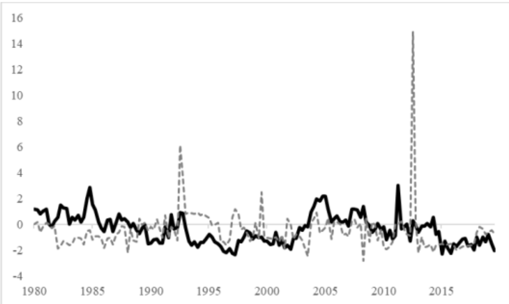
k) Italy



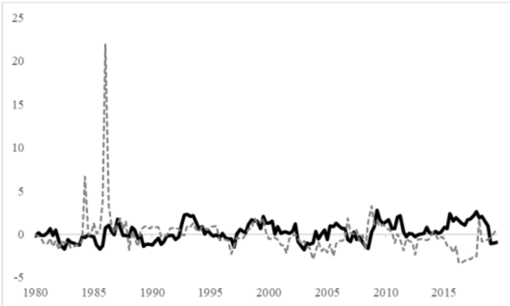
l) Japan



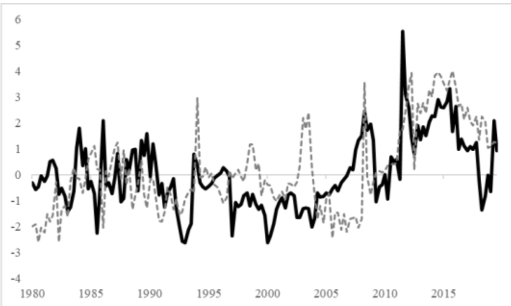
m) Netherland



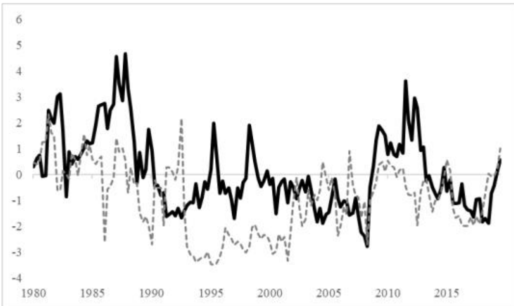
n) Norway



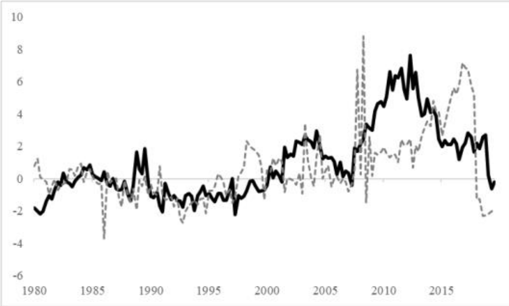
o) New Zealand



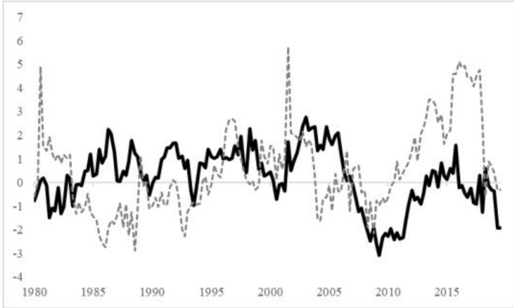
p) Sweden



q) USA



r) South Africa



s) Crude oil WTI

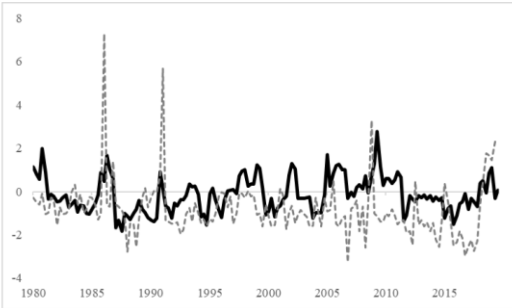


Figure 3. 4 Dynamic net ('to other' less 'from other') connectedness between oil and housing markets

Note: The dynamic returns (black) and volatility (dashed grey) NET connectedness indices are calculated from the forecast error variance decompositions using a rolling window size of 40 quarters and a forecast horizon of H = 4 quarters. Positive (negative) values of spillovers indicate that the corresponding variable is a net transmitter (receiver) of return or volatility spillover effects to (from) all the remaining variables of the system.

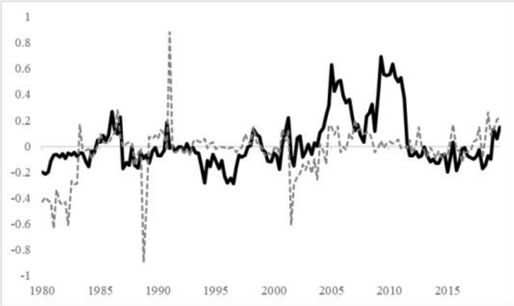
Finally, analyzing the net connectedness of oil, we notice a few sharp jumps, signifying the significant influence of oil price shocks on the housing markets. The first spike indicates the oil price collapse of 1986, the second is linked to the 1991 oil price shocks because of the Gulf War recession, and the third jump is for the duration of the GFC (2007–2009). Therefore, the analysis of net connectedness provides evidence that the oil market has been the significant transmitter of shocks during the period of financial crises. Nevertheless, the question remains, which of the examined housing markets are the key receivers of shocks from the oil market? In the following section, we analyse this using pairwise connectedness between the oil market and each of the housing markets.

3.5.3.3 Net pairwise connectedness between oil and individual markets

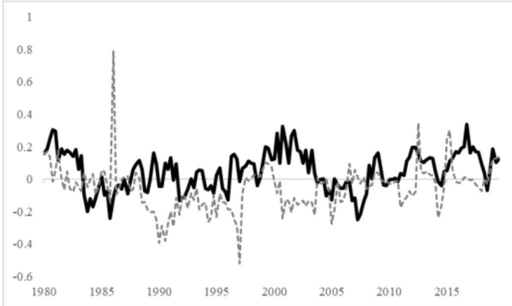
We make use of the pairwise connectedness between oil and housing markets to investigate one of the key aspects of this study, that is, how innovation from one market prompts adjustments in other markets. Figure 3.5 plots the pairwise connectedness between the oil market and the individual housing markets. A positive value signifies the role of the oil market as the information transmitter, a negative value signifies the role of the oil market as the information receiver. As previously mentioned, the impact of financial disturbance is strong; it can be seen that financial distress also influences the pairwise connectedness between oil and housing markets. This is evident because pairwise connectedness values jump across almost all pairwise relationships during the oil crises of 1986 and 1991, and the GFC of 2007–2009. Next, we discuss each of the crises in some detail, providing a higher classification of net receivers and transmitters.

First, with regard to the 1986 oil price collapse, we look at the pairwise connectedness indexes and find that the shocks from the oil market caused a change in the housing markets of many OECD countries, including Belgium (BEL), Switzerland (CHE), Germany (DEU), Ireland (IRL), Italy (ITA), Japan (JPN), Netherlands (NLD), the US (USA), and South Africa (ZAF). We note that these shock recipient countries are mainly net oil-importing nations. As a consequence, their economies in general, and their housing markets in particular, were strongly dependent on oil (Driesprong, Jacobsen, & Maat, 2008; Hamilton, 2009; Naeem, Hasan, Arif, Balli, & Shahzad, 2020). With regard to the US, even though it started to produce more oil during this time, this was not enough to become independent of foreign oil markets. On the other hand, Norway (NOR), a net oil-exporting country, was unaffected by oil fluctuations, which is indicated by the negative pairwise connectedness between its housing market and oil prices. We find the oil price shock of 1986 highlights the channel of shock spreading from the oil market to the housing markets of net oil-importing countries due to their oil reliance, which is consistent with the findings of Grossman et al. (2019) and Agnello et al. (2017).

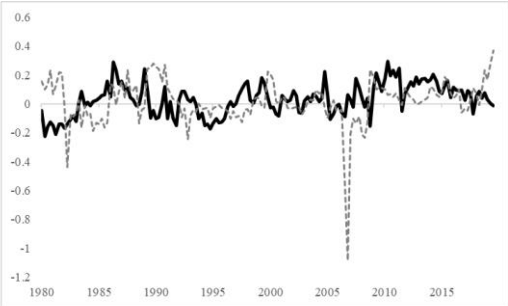
a) Australia



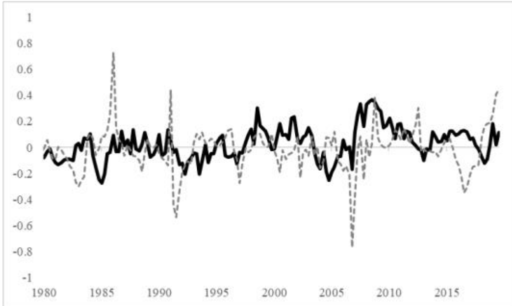
b) Belgium



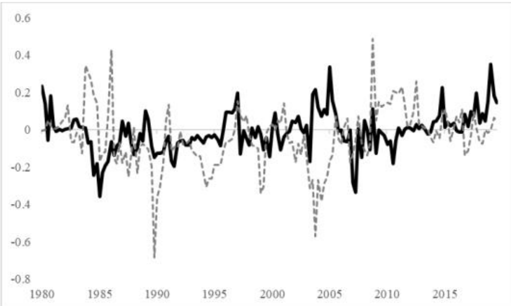
c) Canada



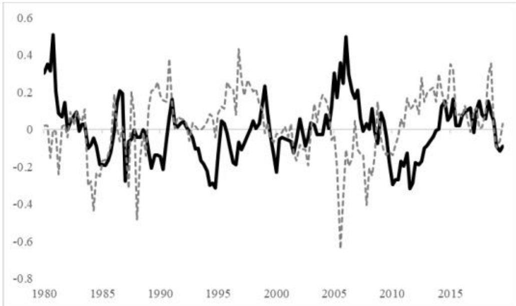
d) Switzerland



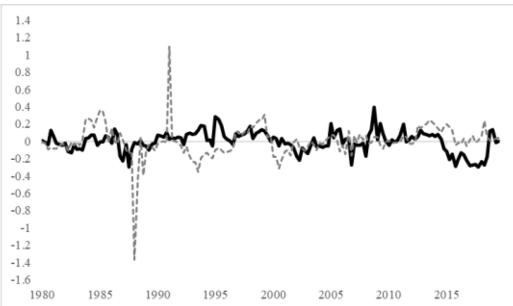
e) Germany



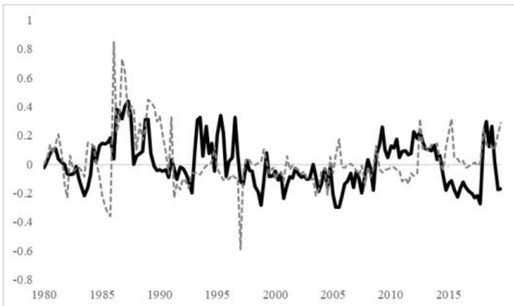
f) Denmark



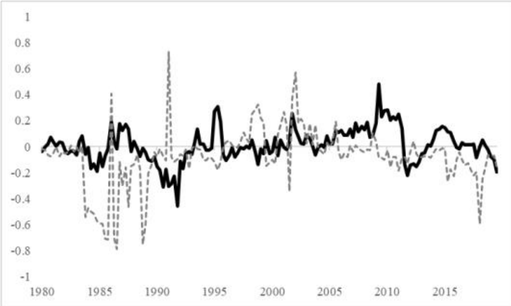
g) Finland



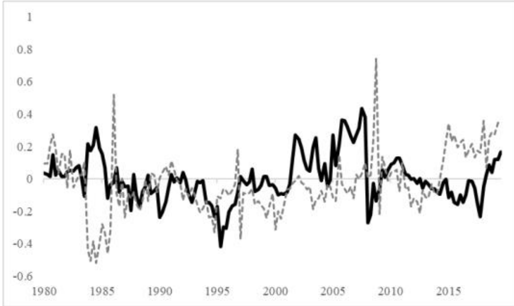
h) France



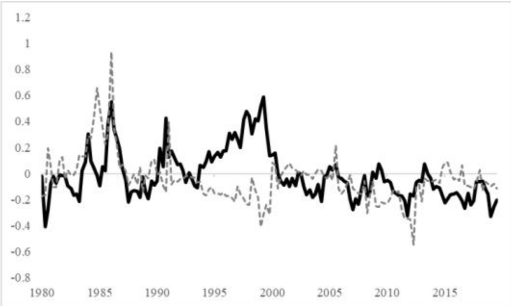
i) Great Britain



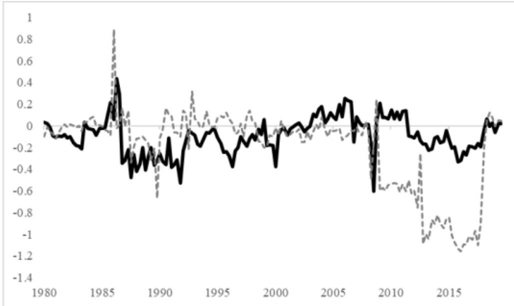
j) Ireland



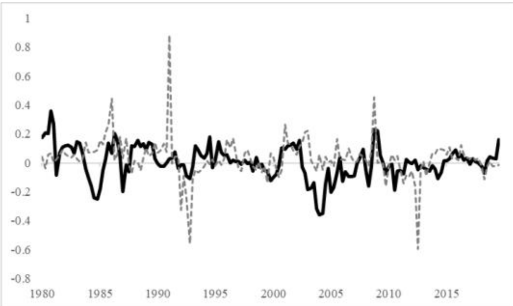
k) Italy



l) Japan

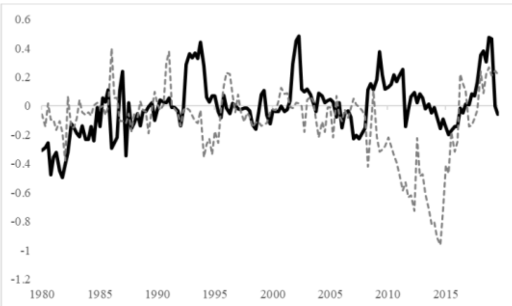


m) Netherland

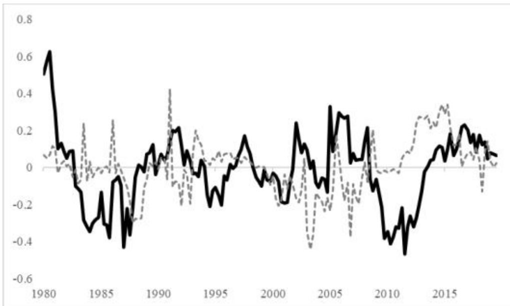


n) Norway

o) New Zealand



p) Sweden



q) USA r) South Africa

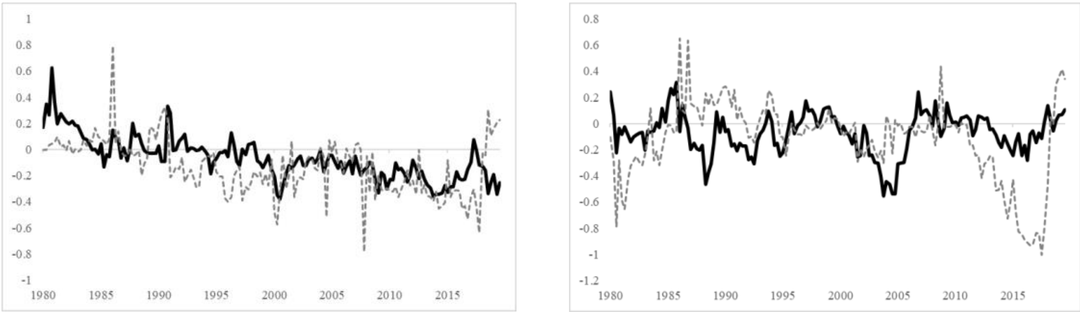


Figure 3. 5 Dynamic pairwise connectedness between oil and housing markets

Note: The dynamic returns (black) and volatility (dashed grey) pairwise connectedness indices are calculated from the forecast error variance decompositions using a rolling window size of 40 quarters and a forecast horizon of H = 4 quarters.

The second jump in pairwise connectedness can be seen during the period of Iraq's invasion of Kuwait. The invasion on 2 August 1990 generated an economic threat to the oil-dependent countries. It can be seen that during this period US pairwise connectedness is negative, which may be because at the time around half of the oil in the US was imported from Persian Gulf countries. Other countries that depended on Persian Gulf imports, such as Australia (AUS), Finland (FIN), Italy (ITA), Japan (JPN), Netherlands (NLD), and Switzerland (SWE), were severely affected by this crisis until the war ended with the surrender of Iraq in 1991. These findings provide strong evidence of the significant impact of the oil market shocks on the housing markets of net oil-importing countries.

Similar to the two oil crises of 1986 and 1991, the US sub-prime mortgage crisis provides the opportunity to observe the vulnerability of housing markets in net oil-importing countries to an oil market crisis. Indeed, the GFC of 2007–2009 provides strong evidence that oil is the source of variation in the housing markets of Germany (DEU), Ireland (IRL), and Netherland (NLD). What is interesting here is that while the US was a net receiver in the wake of previous shocks, it became a net transmitter of shocks during the GFC. In other words, the direction of connectedness from the US *to* other markets is more evident during the GFC (H. S. Lee & Lee, 2018). While the GFC was triggered by the dramatic decline in house prices in the US, it also resulted in oil prices plummeting across the globe. Our finding that the US was a net transmitter of shock during this period sheds light on the role of oil as a global intermediary channel of risk transmission from the United States to other housing markets, especially for net oil-importing countries. Hence, our findings are in line with Breitenfellner et al. (2015), who report the role of oil as a mediating factor of risk transfer to changes in housing prices.

We also note that there is a shift in the US housing market from being a recipient to being a source of shocks during the studied period, as shown by the decreasing value of net pairwise connectedness between oil and housing markets. As previously reported, in net oil-importing countries, the shock is generally spread from the oil market to the housing market because of these countries' oil dependence, whereas the effect is negligible in net oil-exporting countries. The last several decades have seen the movement of the US from a leading oil-importing country to a country that can produce a large share of the oil it consumes. With the recent shale-oil revolution in the US, the import of oil hit a two-decade low in 2014, according to the US Energy Information Administration. As a result, the lowest value of net pairwise connectedness between the US housing and oil market can be observed during this period. Overall, we can attribute the reduced effect of the oil market on the US housing market to the reduced reliance of the US on foreign oil over time.

3.6 Conclusion

Our paper provides a comprehensive analysis of the correlation and connectedness among housing and oil markets in the context of OECD countries, using the approach of dynamic equicorrelation advanced by Engle and Kelly (2012) and the connectedness index developed by Diebold and Yilmaz (2012).

While there is a large body of literature on the connectedness across housing markets, little is known about the cross-market connectedness between housing and other financial markets. To the best of our knowledge, this is the first paper to investigate the connectedness between the oil market and housing markets. These two markets are recognised as being useful investment alternatives as a result of the phenomenon of increasing financial integration, especially in the context of OECD markets. The existing literature exploring the relationship between these two markets analyses one direction in the relationship, that is, how oil price fluctuations lead to changes in housing markets. Our paper, on the other hand, contributes to the literature by analysing the connectedness between these two markets, that is, both directions of the relationship. Furthermore, realizing the direct impact of the GFC on conventional housing markets, we focus on market contagion in the less researched area of the residential real estate market rather than in the securitized real estate market. We also focus on periods of financial disturbance, including the 1973 oil crisis, the 1986 oil price collapse, the 2007–2009 GFC, the 2009–2012 ESDC, and the 2014–2016 shale-oil boom in the US, because the literature generally documents a noticeable jump in connectedness during the financial market's high volatility periods. We provide a comprehensive analysis of the difference in connectedness between these two markets in both tranquil and turmoil periods.

It is important for both investors and policymakers to acknowledge the existence, magnitude, and direction of information flow between markets. Being aware of the degree of connectedness between markets can help investors make strategically sound investment decisions. Since we find the correlation and connectedness between housing and oil markets to be significant, investors should consider whether there is a diversification benefit to including both these two assets in their portfolios. Because of the increased connectedness between these markets during periods of financial turmoil, our findings indicate that the diversification benefit of including assets from both these markets in a portfolio during extreme economic and financial events would be limited.

In terms of policy implications, the presence of correlation and connectedness between housing and oil markets poses challenges due to the impact of external events on domestic housing markets. The finding that house prices in net oil-importing countries are more connected to oil prices than house prices in net oil-exporting countries indicates that if countries want to have greater control over their domestic house prices, they should reduce their oil dependence. There are both short- and long-term policies that can reduce a country's reliance on oil importation. In the short term, more attention could be paid to the exploration of alternative sources of energy, such as natural gas and clean energy. Government policies promoting a shift to electric vehicles from conventional vehicles, for example, could cut oil consumption substantially (Summerton, 2016) and effectively eliminate greenhouse gas emissions at the same time (Newell, Pizer, & Raimi, 2019). In the long term, for some countries, increasing domestic oil production as the US has done may be a solution, but environmental and economic considerations should also be taken into account (Parry & Darmstadter, 2003). Other policies to cut overall oil dependence and have long-term effect could increase support for the development of energy-efficient technologies through R&D.

Importantly, when it comes to the recent financial turmoil of the GFC, our findings demonstrate the risks associated with the dominant shock transmitting role of the US housing market as it shifts from the role of net receiver of return and volatility spillovers (during the oil price crises) to a net transmitter of spillovers (since the GFC). Because the oil market operates as a mediating factor, it channelled risks from the US to the other countries' housing markets, which contributed to the impact of the US financial crisis on the rest of the world. With this in mind, policymakers in net oil-importing countries should closely monitor the US real estate market in order to maintain a stable domestic economy.

Our study examines the connectedness between residential housing markets and the oil market and suggests that financial liberalization and global financial market integration are major candidates driving the relationship. New avenues for future research could include investigating the factors influencing the causal relationship between oil and housing markets, such as household balance sheets and income statements, housing supply, and macroeconomic and demographic factors. Additionally, we find that the role of any given market is bidirectional, depending on the time period analysed and whether it includes periods of financial turmoil that shift the market's position between being a net transmitter and a net receiver of shocks. A promising direction for further research would be an examination of why markets shift their roles from information transmitters to receivers, and vice versa, across sample periods.

CHAPTER 4 Consumption smoothing and housing capital gains: evidence from Australia, Canada, and New Zealand

The previous two essays have analysed the cause of housing market dynamics and the interaction of the housing markets with other markets. The following part of this thesis moves on to consider whether capital gains from housing markets can work as an effective channel for sheltering consumption against output shocks. The essay employs regional level panel data of three developed countries, comprising Australia, Canada, and New Zealand.

4.1 Introduction

Housing is considered as one of the major components of households' asset portfolio. The share of the property to the total asset is getting higher over time due to the impressive house price growth rate (Campbell & Cocco, 2007). Given the coincidence of rising housing prices and strong private consumption has motivated the literature to explore the relationship between them. Indeed, Hryshko et al. (2010) reported that in the circumstance of income shock, household consumption could be sustained due to the appreciation of house prices. The ability to maintain consumption under such negative income shock is defined as consumption smoothing (risk sharing). Building upon the study of Hryshko et al. (2010), our paper's focus is to conduct an empirical investigation into the response of regional consumption risk sharing to gains from housing markets. While the previous paper employed the individual-level data from the Panel Study of Income Dynamics for the US market, we extend the literature by testing the hypothesis at the national level, including the analysis of three developed countries (Australia, Canada, and New Zealand).

Specifically, we first attempt to test the hypothesis of full risk sharing and perfect consumption smoothing by employing a method first proposed by Asdrubali et al. (1996) and Sørensen and Yosha (1998) and then further developed by Sørensen et al. (2007) and Balli and Rana (2015). Since the previous literature always rejects the theory of full consumption smoothing, investigating the mechanism to optimize consumption smoothing and diversifying risk plays a pivotal role (Asdrubali et al., 1996; Balli & Balli, 2011; Balli, Basher, & Louis, 2013; Scorcu, 1998; Sørensen & Yosha, 1998). It is of interest to test whether capital gains coming from the property markets can further smooth consumption. Our conjecture is that together with alternative well-known channels for sheltering consumption against output shocks, capital gains coming from housing markets act as a good shock absorber. Additionally, we assess the sensitivity of our result by comparing the cases of three developed countries, including Australia, Canada, and New Zealand. The variance in results gives us a deeper look into these countries' regional housing market integration and development

Furthermore, to better observe capital gains in housing markets and how it finances for income loss, which in turn smooths consumption, our study has been done in two parts. The first part of the empirical analysis is based on year-to-year changes (k=1) where both good and bad years for the economy may present. As good times generally lead to the jump of housing prices, it might result in a higher degree of consumption smoothed. However, the short-run drop in house prices can be found in the period of the market downturn. Given the fact that house prices may decrease in short-run but increase in the long run,e.g. 5 years, households might use these long-term capital gains in the housing market to insure against the swing of income loss. Therefore, realizing the fluctuation of one-year housing capital gain, we create a longer time interval from 3 to 5 years to demonstrate net positive property gains. Importantly, as higher data's differencing interval length can also be signified for longer-lasting income shocks, varying data frequency further allows us to test the persistence of our findings.

Several contributions are made from our paper. Although alternative mechanisms for smoothing consumption have been investigated, suggesting that capital markets, credit markets, and saving are the key consumption smoothing channels (Asdrubali et al., 1996; Balli, Kalemli-Ozcan, et al., 2012; D. Kim & Sheen, 2007), this paper is one of few studies discovering a distinct channel coming from housing capital gains. Further, we analyse the possibility of consumption smoothing via the housing market at the national level when the literature on consumption smoothing at the international level and individual level is vast. Insuring against regional output shocks is promising since the nature of housing markets across regions appears to be heterogeneous. Additionally, we construct the analysis of inter-regional consumption smoothing by the fact that the regional production per capita is more volatile than the country's production per capita. Take Australia as an example. Calculating the ratio of the standard deviation of the

Australian region's production to that of the country's production, the ratio is ranged from 0.44 to 3.4, with an average of 1.55.

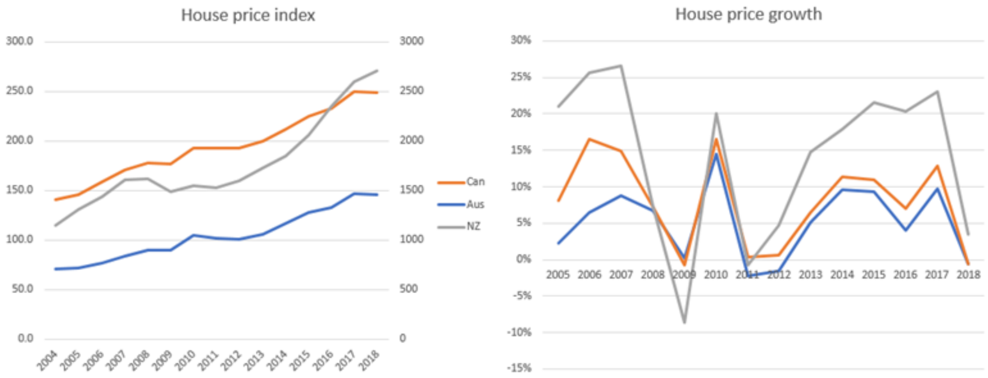


Figure 4. 1 House price index and growth in Australia, Canada, and New Zealand.

Note: The left-handed figure represents the house price indices for three studied countries. Australia and Canada house price indices are shown by the first axis while the secondary axis is for house price index of New Zealand. The house price growth of the three countries is displayed in the right-handed figure.

This paper is a perfect complement to the existing evidence of consumption smoothing as we revisit the theory of full risk sharing and perfect consumption smoothing by employing the most updated sample of Australia, Canada, and New Zealand. These countries are picked owing to several reasons. The housing markets' high volatility with a dramatic increase experienced in these countries is valuable to analyse their effect on consumption. Figure 4.1 indicates the revolution of house price indices and house price growth in the studied countries. As shown, house price growth recorded a marked fluctuation with a sharp decline during the Global Financial Crisis (GFC). Second, we focus on developed countries as it is well noted that house prices - consumption correlation was found much stronger in countries as the result of more opened and developed financial and housing markets (Buch & Yener, 2010; Ciarlone, 2011; Slacalek, 2009). Third, due to data availability, the bulk of work has studied the topic but referring to the only case of the U.S and OECD countries, new evidence by exploring Australia, Canada, and New Zealand is well worth considering.

Our main findings can be summarized as follows. Fully consistent with related work, the empirical result supports the fact that risk sharing is not perfect as only a fraction of income shock is smoothed. Hence, it allows for further risk sharing possibility. Interestingly, when adjusting the frequency of data for longer-lasting shocks, we realize that the amount of consumption smoothing in Canadian housing markets is reduced, whereas consumption smoothing is found unchanged in Australia. Finally, we reveal the unexplored crucial channel of consumption smoothing, which is gains from the housing markets. Also, the response of consumption to housing capital gains is statistically significant across different data frequencies.

The remainder of the paper is organized as follows. Session 4.2 is to provide a brief review of previous related literature. Session 4.3 describes the empirical model for measuring the degree of risk uninsured and the impact of capital gains from the housing markets on consumption smoothing. Coming to session 4.4, it presents data with some key descriptions before obtaining the empirical results in session 4.5. The paper concludes and gives direction for further research in session 4.6.

4.2 Literature review

4.2.1 The theory of perfect consumption smoothing and consumption smoothing channels

The topic of hedging risk (risk sharing) and consumption smoothing have been widely studied in economics and finance literature (Asdrubali et al., 1996; Balli & Balli, 2011; Balli, Basher, & Balli, 2013; Balli & Rana, 2015; Sørensen et al., 2007; Sørensen & Yosha, 1998). Under perfect consumption smoothing, conventional wisdom states that the consumption growth rates in all individuals, regions, and countries should be identical and stable, regardless of the nature of the shocks to production (Asdrubali et al., 1996; D. Kim & Sheen, 2007; Sørensen et al., 2007). In terms of international consumption smoothing, all country-specific output shocks are entirely diversified and the instability of an individual country’s output had no influence on its consumption (Balli & Balli, 2011).

Indeed, the hypothesis of perfect consumption smoothing is always rejected by empirical studies (Asdrubali et al., 1996; Balli & Balli, 2011; Balli, Basher, & Louis, 2013; Scorcu, 1998; Sørensen & Yosha, 1998). According to Asdrubali et al. (1996), while there were alternative channels to absorb output’s risk across the United States’ regions, it was only 75% of consumption smoothing achieved. Subsequently, the unsmoothed shock was left with 25%. In Canada, the numbers were 80% and 20%, respectively (Balli, Basher, et al., 2012). Regarding Pacific Island countries and OECD members, 43% of shock was found unsmoothed (Balli & Balli, 2011). The extent of unsmoothed consumption across Pacific island countries, the Middle Eastern and North African (MENA) countries, and China was even higher at roughly 60% (Balli & Balli, 2011; Balli, Basher, & Louis, 2013; Du, He, & Rui, 2011; Xu, 2008). As stated by Volosovych (2013) when focusing on 117 countries over the world, there is a large difference in the magnitude of risk sharing across countries. The highest one was at 52% for Switzerland while it was only 2-4% for the case of Brazil or Lithuania. The weak presence of risk sharing (imperfect consumption smoothing) was explained by the existence of non-traded goods, weak goods and financial market integration, and high transaction costs (Balli & Rana, 2015).

Nevertheless, the benefit of consumption smoothing is undeniable as it can noticeably promote welfare and enhances economic efficiency. For instance, during the recession, countries can utilize the capital and credit markets to ease the adverse impact of the recession on consumption. It, then, stabilizes the economic growth of these countries. Large welfare gain can also be achieved via international and inter-region economic integration. It is especially better for countries with higher volatility of output and consumption (Balli & Balli, 2013; Balli, Basher, & Louis, 2013). For instance, as stated by Balli and Balli (2013), the gain for non-GCC (Gulf Cooperation Council) MENA countries (resource-scarce economies) was generated at nearly 4% when full risk sharing was achieved. Meanwhile, the number was recorded at a smaller value of 3% among GCC countries (oil-rich economies). Like the fact that the consumption smoothing theory is far from perfect, it leaves room for further welfare development. Hence, the issue of how to optimize partial consumption smoothing for the higher benefit has brought great concern (Sørensen & Yosha, 1998).

Since the benefit of consumption smoothing is significant, the literature has attempted to identify different channels of consumption smoothing. Depending on risk sharing at a national level or an international level, alternative mechanisms are documented. As one of the first papers analyzing consumption smoothing at the national level, Asdrubali et al. (1996) suggested that there were three channels initiating risk sharing, including capital markets (cross-ownership of productive assets), the federal government (tax, transfer system, and federal grants), and credit market (lending and borrowing). Indeed, transactions in the capital market were also highlighted as the central ways of risk sharing in both studies across states in the United States (Asdrubali et al., 1996) and Australia (D. Kim & Sheen, 2007). Likewise, in other studies for Canadian provinces by Balli, Basher, et al. (2012), the smoothing degree was persistently raised by the capital market while the credit channel appears to be less important over the years. Additionally, the equally prominent roles of capital markets and the federal tax-transfer system were proved in their study. By contrast, in China, Xu (2008) found that interprovincial risk sharing was obtained mostly via non-fiscal channels, which were migration and remittance of migrant wages. Capital markets and financial intermediaries in China played a modest role in consumption risk sharing (Du et al., 2011).

Next, in terms of risk sharing across country borders, European group has received an extensive empirical literature's attention. The influential research was that by Sørensen and Yosha (1998) who focused on consumption smoothing across European community countries and OECD countries from 1966 to 1990. The authors revealed that capital and credit markets in Europe were less integrated compared with these of the US. It was because the factor of income flows did not significantly smooth consumption in there. In these groups, saving was indicated as an important channel to buffer income shocks. On the contrary, the role of capital gain from international asset holding on diversifying shock across European Union countries and OECD countries was continued to be explored by Balli, Kalemli-Ozcan, et al. (2012) for the updated period spanning from 1992 to 2007. Accordingly, starting from zero before 1999 but increasing over time, risk sharing from capital gain (at around 6%) was highlighted to be more stable and higher than risk sharing from factor income flow's channel.

Other alternative channels for smoothing international consumption were then discovered by more papers across various areas, such as Pacific Island countries - PICs, MENA countries, and 86 developing countries. These channels can be range from labor movements among countries of the group to interlinkages through political relations, bilateral as well as multilateral (Balli & Balli, 2011; Balli, Basher, & Balli, 2013; Balli & Rana, 2015). Balli and Balli (2011) also uncovered the significant role of remittances in buffering the output shocks. While the impact of remittances was unstable, it increased significantly in recent years. Foreign aids were also considered as a steady strategy to smooth consumption for PICs (Balli & Balli, 2011; Balli, Pierucci, & Fu, 2019).

4.2.2 The relationship between housing capital gains and consumption smoothing

The last decade records a great deal of attention to studying the missing relationship with consumption derived from the development of the housing markets. There are mixed results across papers due to different methodologies applied and different countries selected as a sample. Negligible relationship between capital gains from housing markets and consumption is found in some while in others, a significant relationship has been proved.

On the one hand, several papers argued that consumption should be affected by the change in the value of high liquidity assets but in terms of illiquidity assets, such as housing, the relationship was absent (Cho, 2011; Phang, 2004). For instance, in Singapore, a study by Phang (2004) reinforced the argument. The liquidity constraints (the difficulty for households to withdraw housing equity to finance consumption) caused the failure of the house price change and consumption relationship. Likewise, studying the case of Korea, Cho (2011) clarified that there was an insignificant relationship between these two variables. The existence of a weak housing wealth effect was merely found in the high-income groups with a high level of homeownership, but not for the lower-income group.

Another strand of the literature has documented the statistically significant impact of property gains on consumption. The wealth effect, credit constraint (collateral effect), and common factors, as suggested by Attanasio et al. (2009) and Aruoba et al. (2019), are three explanations for the housing-consumption association. Indeed, the significant collateral effect justifies the sensitivity of consumption to income due to the fact that a drop of housing value relative to human wealth leads to the decrease of loan collateral and borrowing capacity, which in turn causes increasing consumption sensitivity (Lustig & Van Nieuwerburgh, 2010). The study by Benito and Mumtaz (2009), when documenting the U.K market during 1992-2002, concluded that housing acting as collateral allowing obtaining credit could facilitate consumption plans. Undoubtedly, relaxing borrowing constraints by the appreciation of housing values would result in an increase in consumption smoothing (Campbell & Cocco, 2007). Focusing on emerging economies from Asia and Central Europe, Ciarlone (2011) added that due to the growth in house prices, homeowners might feel wealthier owing to their increased ability to refinance or sell the house. Even if they wished to keep the house, consumption today was highly likely to increase given the higher discounted value of wealth. As mentioned by Hurst and Stafford (2004), despite the fact that households have to pay large pecuniary costs to get access to home equity, the housing capital gains which are associated with the higher home equity is proved to be a tool to smooth their consumption. In particular, in periods of relatively low interest rates, a lower stream of mortgage payments can be made through refinancing. It helps households to have more resources to smooth consumption. In another aspect, the households can refinance to get access to the accumulated home equity, which is referred to as the "consumption-smoothing motivation". The ability to smooth consumption via housing capital gains is more pronounced when households receive negative income shocks and have limited reserves of more liquid assets, everything else being equal. Suggestive evidence is also provided by Peltonen, Sousa, and Vansteenkiste (2012). They documented that the increasing impact from real estate wealth to household consumption was experienced in recent years, especially for Taiwan and Thailand. More recent papers are of interest to compare the effect of housing wealth on consumption with the strongly proved significant effect of financial wealth on consumption (Ciarlone, 2011; Slacalek, 2009). Capital gains from the real estate market and capital gains from financial markets appear to cause diverse reactions from consumers due to several reasons, including liquidity, the utility derived from the property right of an asset as housing services, different distributions of assets across income groups, and psychological reasons (Ciarlone, 2011; Peltonen et al., 2012). The paper by Slacalek (2009) at the country-level for 16 economies stated the fact that although the effect of financial wealth on consumption was found higher than housing wealth's effect, the latter increased sharply since 1988 due to financial infrastructure's development. While Barrell, Costantini, and Meco (2015) found an insignificant impact on consumption by housing wealth in Italy, the significant relationship was emphasized in the UK.

For some papers, it is reported that the effect of housing wealth on consumption is even stronger than that of financial wealth (Sierminska & Takhtamanova, 2012). Two reasons are provided. The first cause is because of the higher number of people owning houses in comparison with the number of people owning stocks. For instance, houses, as identified by Christensen, Corrigan, Mendicino, and Nishiyama (2009) owned by nearly 70% of Canadian households while the proportion of people holding stocks was much lower. Secondly, thanks to recent financial development, it is much easier for people to access capital gains from housing markets. Consequently, Benjamin, Chinloy, and Jud (2004) found that the rise of US consumption due to the appreciation of house wealth was considerably higher than that due to the financial wealth growth. Consequently, the use of real estate to offset the downturn of financial wealth, reducing the instability of the economy and smoothing consumption is potentially achieved.

Overall, a range of studies have searched for the relationship between consumption and housing markets, yet the conclusion drawn has varied. As the most related study to our paper, Hryshko et al. (2010) concluded that followed by the loss of income (job disability), a high level of consumption can be maintained as the result of house price appreciation. As long as the housing equity is higher than the minimum down payment, homeowners can access capital gains either by using equity as collateral or selling the house. We extend the literature by exploring the cases of three developed countries. Given the increasing importance of housing wealth and the lack of consensus on the consumption smoothing role of capital gains from real estate, this paper aims to fill this gap.

4.3 Empirical model

4.3.1 Inter-regional consumption smoothing

To quantify the degree of risk sharing and estimate the deviations from perfect consumption smoothing, we apply the panel regression model proposed firstly by Asdrubali et al. (1996); Sørensen and Yosha (1998) and then developed further by Balli, Basher, and Balli (2013); Balli and Rana (2015). Full detail about the method can be found in the original papers.

In short, the panel regression model for estimating the magnitude of consumption smoothing is applied as follows:

$$\widetilde{CON_{it}} = constant + \beta_u \widetilde{GDP_{it}} + \varepsilon_{it} \quad (4.1)$$

The equation can be re-written as:

$$\Delta \log CON_{i,t} - \Delta \log CON_t = constant + \beta_u\left(\Delta \log GDP_{i,t} - \Delta \log GDP_t\right) + \varepsilon_{it}$$

Where:

- $\widetilde{CON_{it}}$ is the difference between the growth rate of final real consumption per capita in region i at time t and the aggregate growth rate of the country's final consumption per capita at time t ($\Delta \log CON_{i,t} - \Delta \log CON_t$). Particularly, $CON_{i,t}$ is the region i's real consumption per capita at time t and CON_t stands for the country's time t real per capita final consumption.
- In a similar manner, $GDP_{i,t}$ is real GDP per capita of region i at time t. The country aggregate real GDP per capita at time t is shown as GDP_t. Therefore, $\widetilde{GDP_{it}}$ is calculated as the difference between the growth rate of real GDP per capita in region i at time t and the aggregate growth rate of the country's real GDP growth

rate per capita at time t. $\left(\Delta \log GDP_{i,t} - \Delta \log GDP_t\right)$. It represents the idiosyncratic part of the output.

- ε_{it} is defined as the error term.

In this regression, subtracting from each variable the aggregate value is crucial since aggregate fluctuation cannot be eliminated by the sharing of risk (Sørensen et al., 2007). In other words, It is to isolate the aggregate income and eventually consumption from output fluctuation (Balli & Rana, 2015). Additionally, it is worth noticing that as the aggregate values of the variables have been subtracted, adding a time-fixed effect, according to Sørensen et al. (2007), brings very little change in the results.

The coefficient β_u, thus, is to assess the average co-movement of the region's idiosyncratic consumption growth with its idiosyncratic output growth over the sample period. The smaller β_u means the smaller extent of the co-movement between consumption and output and confirms the higher magnitude of consumption buffered against GDP fluctuation. Correspondingly, β_u can be defined as the unsmoothed amount (fraction of GDP shock that is not smoothed) when its value is greater than 0. In contrast, full consumption smoothing which implies that idiosyncratic shocks to GDP and consumption are uncorrelated advises the zero value of β_u.

Accordingly, it is more instructive to look at the corresponding series of (1-β_u), which demonstrates the amount of consumption smoothing. In particular, the high value of the metric (1-β_u) as corresponding to small β_u provides strong evidence of a high degree of consumption smoothing and risk sharing. Again, full risk sharing or perfect consumption smoothing is achieved when β_u is equal to 0 and the value of (1-β_u) approaches 1.

4.3.2 Consumption smoothing via capital gains in the housing markets

Although different strategies to stimulate consumption smoothing have been largely explored by a growing body of literature, the link between housing capital gains and consumption smoothing is still missing. Motivated by the limited number of studies on this topic, after calculating the deviation from perfect consumption smoothing, we focus on quantifying the increase of consumption smoothing especially gained through capital gains in the housing markets. We use the following panel regression equation:

$$\widetilde{CON}_{it} = constant + \beta_0\,\widetilde{GDP}_{it} + \beta_1\,\widetilde{GDP}_{it} * \widetilde{HP}_{it} + \gamma * \widetilde{HP}_{it} + \varepsilon_{it} \qquad (4.2)$$

Where:

- $\widetilde{HP_{it}}$ is the house price in region i (normalized to CPI) at time t minus the aggregate country's house price. It therefore reflects the idiosyncratic part of capital gains in the housing market. Again, we deduct aggregate value at time t from house price in region i, time t since the aggregate price of the group is not insurable (Sørensen et al., 2007).
- γ is a linear term which specifies whether HP has an impact on the average growth difference between consumption and output. Since the term is not the study's focus, it is included to ensure that the estimated coefficient on the interaction term is not affected by the exclusion of a significant linear term (Demyanyk, Ostergaard, & Sørensen, 2007)

Additionally, from equation (4.2), we are interested to measure β as follows:

$$\beta = \beta_0 + \beta_1 \widetilde{HP_{it}} \tag{4.3}$$

Similarly, we further run the analysis using house price growth as the additional proxy for capital gains in the housing market.

$$\widetilde{CON_{it}} = constant + \beta_0 \widetilde{GDP_{it}} + \beta_1 \widetilde{GDP_{it}} * \widetilde{HPG_{it}} + \gamma * \widetilde{HPG_{it}} + \varepsilon_{it} \tag{4.4}$$

$$\beta = \beta_0 + \beta_1 \widetilde{HPG_{it}} \tag{4.5}$$

Where: $\widetilde{HPG_{it}}$ is the idiosyncratic part of capital gains in the housing market, which is calculated by deducting aggregate value at time t from house price growth in region i time t.

As seen in equation (4.3) and (4.5), β illustrates the response of consumption smoothing to capital gains in the housing markets. Specifically, the value of (1-β_0) represents the average degree of consumption smoothing within the group when β_1 is zero. Statistically significant β_1 with the value different from zero indicates that HP (HPG) has an impact on consumption smoothing. It assesses how much higher than average HP (HPG) lowers the amount of consumption smoothing obtained. Also, β_1 can be seen as a translation of HP (HPG) to percentage points of idiosyncratic shocks absorbed via consumption smoothing. Then, the value of (1-β_0-$\beta_1 \widetilde{HP_{it}}$) and (1-$\beta_0$-$\beta_1 \widetilde{HPG_{it}}$) demonstrate how much consumption is smoothed in region i and period t via capital gains in the housing markets during the period considered. Altogether, the negative sign of β_1 is anticipated as the negative value of β_1 increases the value of (1-β_0-β_1 $\widehat{HP_{it}}$) and (1-β_0-β_1 $\widehat{HPG_{it}}$). [15]

Following Sørensen and Yosha (1998) and Balli and Rana (2015), we use the regression method of two-step Generalized Least Square (GLS). It is assumed that an error term in each equation/region follows an AR(1) process to address autocorrelation in the residuals. Autocorrelation parameter is assumed to be equal across regions because of a short sample period. Additionally, country-specific variances in the error terms are allowed.

In terms of two-step GLS, as described in Asdrubali et al. (1996); Sørensen and Yosha (1998), ordinary least squares were firstly used to estimate the panel. Then, the residuals were found to compute the variance and correct for heteroscedasticity (Balli & Rana, 2015).

4.4 Data and descriptive statistics

The paper uses a broad data set consisting of Australia, Canada, and New Zealand. The availability of data allows us to provide empirical evidence on consumption smoothing through housing capital gains at a regional level. Detail about data sources can be found in Table A.4.1 (Appendix) and the period of analysis varies depending on the country of selection. We use annual data for the cases of Australia and Canada while quarterly data is available for New Zealand.

For Australia, the panel data set consists of all Australian states. The database is taken from the Australian Bureau of Statistics (ABS) National account. Both consumption and gross state product are calculated in chain volume. A measure via chain volume is considered to be more accurately reflect volume changes over time (ABS, 2003). Statistics Canada is the key data source for Canada, which provides national account data by provinces. All major variables are collected for 10 Canadian provinces. Regarding New Zealand, major variables such as consumption, population, and consumer price index (CPI) are taken from Statistics New Zealand. It is also noted that since data for household final consumption is unavailable, for the best availability as stated by Asdrubali et al. (1996), a retail sale is obtained as a proxy for private consumption. Measurement errors in retail sales, in fact, lead to higher standard deviation but do not

[15] Following Asdrubali et al. (1996), we also control for time trend, inflation, and population growth for robustness check, but those coefficients are not reported for the purpose of brevity.

cause biased estimates. For gross regional product, it is drawn from Infometrics. The house price index is collected from The Real Estate Institute of New Zealand (REINZ).

Following previous papers, GDP and consumption series are converted into "real per capita" terms (Asdrubali et al., 1996; Balli & Balli, 2011; Balli, Basher, & Louis, 2013; Sørensen & Yosha, 1998). First, these variables are expressed in per capita terms by normalizing over the regional population. Then, after deflating by CPI, we have figures in real terms. For simplicity, the term "real per capita" is often omitted in this paper. Growth rates of real per capita GDP and consumption are calculated by taking the difference of log of real per capita GDP and consumption, respectively. Further details regarding the data source are provided in the Appendices.

Table 4.1 reports the descriptive statistics for our key variables, including the growth rate of real GDP per capita (GDP), the growth rate of real consumption per capita (CONS), house price index (HP) and house price growth (HPG) across areas in Australia, Canada, and New Zealand.

Generally, there is a substantial variation in GDP and consumption real growth rate per capita across countries and regions. Particularly, Australia records the annual growth rate of GDP at 1.86% over the sample period whereas the real consumption per capita growth rate is lower at 1.58% on average. The annual GDP growth rate in Canada is 1.55% and is subject to a large standard deviation of 2.83%. The Canadian growth rate of consumption is quite high, at 2.05% while its variation is low (1.08%). Regarding New Zealand, the quarterly data reveals the average growth rate of GDP and consumption at 0.35% and 0.44%, respectively. We document a substantial deviation in the growth rate of consumption, as the standard deviation of consumption is twice as much as that of GDP in there (7.55% compared with 3.9%).

When it comes to the house price index, in Australia, New South Wales - the most populated state - records the highest cost of buying houses with a mean of 113.31. The highest variation in the house price index is also found there. The most affordable place to stay in Australia is found in the smallest and least populated state- Northern Territory (89.85). For Canada, the cost of housing seems to be higher in big cities and big provinces than that in rural and remote areas. Severe weather and the long distance from major markets usually leads to low house prices. For instance, property prices are found cheapest in Manitoba and Saskatchewan. Meanwhile, British Colombia (BC) is observed as one of the most expensive states to buy houses. The HP index in BC is 88.43 while the national index is merely 71.96. In New Zealand, over the sample period from 1992 to 2018, Auckland experiences the largest house price volatility. Regarding house price growth, the highest growth rate is normally found in the big urban areas, e.g., Victoria in Australia, Alberta in Canada, and Auckland in New Zealand.

Table 4. 1 Descriptive statistics of real GDP per capita growth, real consumption per capita growth, and house price index

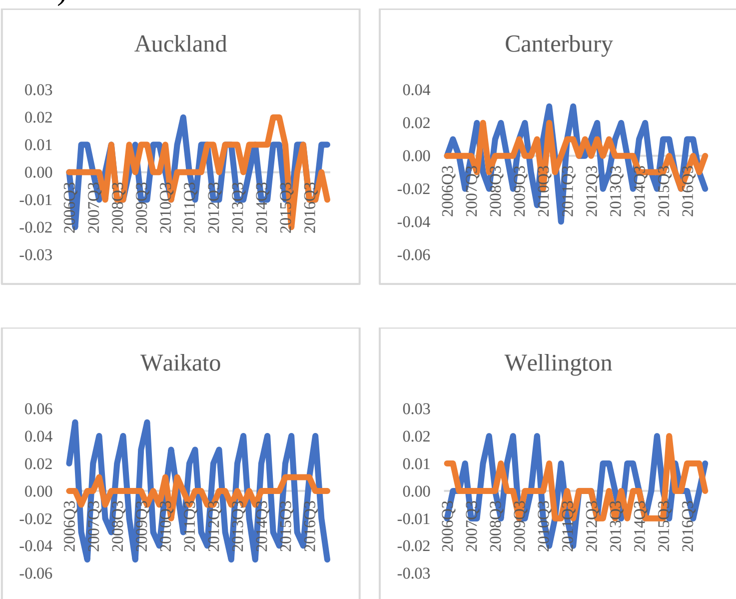
Countries and regions	GDP		CONS		HP		HPG	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Australia	1.86	2.18	1.58	1.19	104.39	25.01	5.17	5.05
Australian Capital Territory	1.69	1.41	1.02	1.54	96.37	17.28	4.14	4.36
New South Wales	1.66	1.54	1.60	1.23	113.31	33.56	4.99	7.08
Northern Territory	3.45	5.24	2.12	2.80	89.85	21.44	5.23	9.15
Queensland	2.07	3.81	1.74	2.05	100.89	16.72	3.92	5.33
South Australia	1.22	1.68	1.53	1.43	96.73	17.01	4.30	4.57
Tasmania	1.94	2.28	1.84	1.86	100.49	17.90	4.97	4.96
Victoria	1.15	1.65	1.36	1.49	101.05	28.74	6.54	6.50
Western Australia	3.75	6.64	2.03	2.24	97.08	17.51	4.71	10.46
Canada	1.55	2.83	2.05	1.08	74.97	15.83	3.06	2.63
Alberta	1.85	8.91	2.13	2.18	71.40	25.46	4.86	9.09
British Columbia	1.61	2.76	1.99	1.46	88.00	9.21	0.95	3.52
Manitoba	1.79	2.12	1.88	1.07	65.28	20.88	4.52	3.44
New Brunswick	1.86	2.20	2.39	0.98	88.37	8.31	1.24	1.47
Newfoundland and Labrador	3.97	9.93	3.19	1.21	70.12	21.65	4.08	5.15
Nova Scotia	1.61	2.15	2.33	0.89	79.31	14.43	2.76	2.43
Ontario	1.27	2.05	1.87	1.12	71.73	13.74	3.01	1.25
Prince Edward Island	1.61	2.86	2.28	1.16	92.29	7.32	1.12	1.78
Quebec	1.61	2.04	2.04	1.01	77.20	17.53	3.32	2.19
Saskatchewan	3.02	7.56	2.34	1.35	66.41	26.41	5.21	7.29
New Zealand	0.35	3.90	0.44	7.55	1812.02	356.22	1.34	2.08
Auckland	0.30	3.03	0.52	8.46	1826.93	534.87	1.76	2.79
Canterbury	0.46	4.65	0.36	8.22	2005.43	280.18	0.95	2.37
Waikato	0.22	6.32	0.03	7.90	1830.76	292.83	0.99	2.83
Wellington	0.34	3.10	0.12	8.17	1695.38	201.62	1.18	2.18

Note: GDP and CONS represents growth rate of GDP per capita and growth rate of consumption per capita, respectively. HP and HPG stand for house price index and house price growth, respectively. Mean and standard deviation (Std. Dev.) of GDP, CONS, and HPG are in percentage.

Before going to the main empirical analysis, looking at the idiosyncratic part of income and housing markets gives us an intuition of the correlation between them. Figure 4.2 presents the evolution of idiosyncratic output growth (GDP) and idiosyncratic capital gains in the housing markets (HP) across countries' regions. As shown, the GDP fluctuation is considerably wilder than that of HP. We further observe that when there is a drop in the former, the latter appears to remain stable or moving in the opposite direction, suggesting the potential benefit of the housing market as a hedge against the swing of income, facilitating risk sharing and consumption smoothing.

A) Australia

B) New Zealand



C) Canada

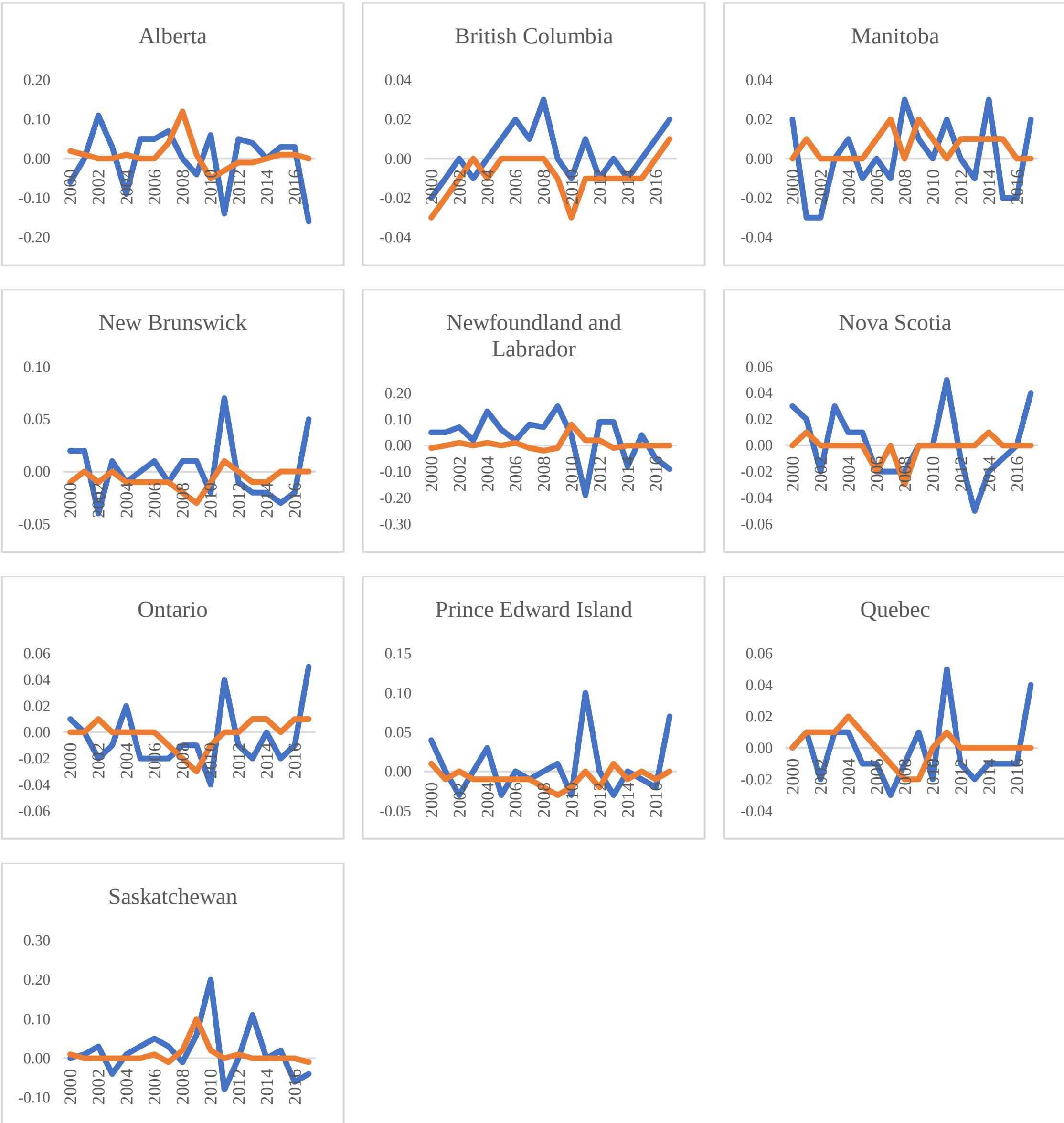


Figure 4. 2 Evolution of idiosyncratic output growth (GDP) and idiosyncratic capital gains in the housing markets (HP)

Note: The blue line and the red line represents GDP and HP, respectively. The annual data is employed for the cases of Australia and Canada while quarterly data is available for New Zealand

4.5 Empirical results

This session first reports the patterns of national consumption smoothing across regions in our three studied countries. It is to assess the magnitude of unsmoothing consumption. After that, we provide insight into the contribution of housing capital gains in buffering output shocks.

4.5.1 The pattern of consumption smoothing

Table 4.2 displays results of unsmoothed consumption degree across states of Australia, provinces of Canada, and regions of New Zealand. These primary findings are corresponding to the Eq.(4.1) $\widehat{CON_{it}} = constant + \beta_u \widehat{GDP_{it}} + \varepsilon_{it}$

As shown by the table, the amount of unsmoothed output shocks is measured by the coefficient β_u. As such, the value of (1-β_u) displays the extent of consumption which is smoothed. The first remark point to note is that the coefficient β_u, representing for the co-movement of idiosyncratic output and consumption, is statistically significant and less than one. It indicates that only a fraction of shocks to gross state product is absorbed. Consistent with the literature, the hypothesis of perfect consumption smoothing, therefore, is strongly rejected.

Table 4. 2 National consumption smoothing across states of Australia, provinces of Canada, and regions of New Zealand.

	Australia	Canada	New Zealand
Not smoothed (β_u)	0.60***	0.28***	0.18**
	(0.03)	(0.04)	(0.09)

Note: The table shows the panel estimation results corresponding to the Eq.(4.1) $\widehat{CON_{it}} = constant + \beta_u \widehat{GDP_{it}} + \varepsilon_{it}$. The coefficient β_u indicates the unsmoothed fraction of shocks to gross state product. The numbers in parentheses are standard errors. *, **, and *** indicates statistical significance at 10%, 5%, and 1% level, respectively.

A closer examination reveals that the extent of consumption smoothing appears to vary across countries, ranging from 40% to 82%. Indeed, Australia has the highest unsmoothed degree in comparison with others. The results of Australia show that its consumption smoothing degree stands at approximately 40%, leaving the substantial proportion of shocks unsmoothed at 60%. By contrast, the paper by D. Kim and Sheen (2007) and Rana and Balli (2016) found a larger proportion of consumption smoothing across states of Australia, at 90% and 74%, respectively. The differences among studies are likely to arise from different periods covered as our paper utilized the most updated available period for analyzing.

Concerning Canada and New Zealand, the lower magnitude of unsmoothed consumption smoothing is observed. There is 28% of shocks remained unsmoothed in Canada, as opposed to 18% for the case of New Zealand. A fairly similar conclusion of consumption smoothing's magnitude among Canadian provinces was found by Balli, Basher, et al. (2012). Accordingly, most Canadian output shocks were smoothed by two key channels of capital markets and the federal tax system rather than the credit market.

Generally, since consumption smoothing is imperfect, there is substantial scope for increasing welfare by stimulating risk sharing across regions. As one of the potential consumption smoothing channels, capital gains from the housing markets is added and investigated in the next part.

4.5.2 The extent of consumption smoothing via capital gains in the housing markets

In this part, we explore the position of property capital gains in smoothing consumption and facilitating risk sharing. The empirical results of consumption smoothing via real estate gains are given in Table 4.3, which correspond to Eqs. 4.2, 4.3 (Panel A) and Eqs. 4.4, 4.5 (Panel B).

Table 4. 3 Consumption smoothing via capital gains in the housing market across states of Australia, provinces of Canada, and regions of New Zealand

A) House prices

	Australia	Canada	New Zealand
β_0	0.68***	0.06***	0.19***
	(0.04)	(0.01)	(0.03)
β_1	-11.35***	1.14	-7.72***
	(1.18)	(2.62)	(1.21)

B) House price growth

	Australia	Canada	New Zealand
β_0	0.48***	0.08***	0.14***
	(0.05)	(0.02)	(0.05)
β_1	-3.04***	-0.54**	-12.12
	(0.73)	(0.27)	(13.34)

Note: The coefficients in Panel A are estimated from the regression Eq.(4.2) $\widetilde{CON_{it}} = constant + \beta_0\, \widetilde{GDP_{it}} + \beta_1\, \widetilde{GDP_{it}} * \widetilde{HP_{it}} + \gamma * \widetilde{HP_{it}} + \varepsilon_{it}$ and Eq.(4.3) $\beta = \beta_0 + \beta_1\, \widetilde{HP_{it}}$. The coefficients in Panel B are estimated from the regression Eq.(4.4) $\widetilde{CON_{it}} = constant + \beta_0\, \widetilde{GDP_{it}} + \beta_1\, \widetilde{GDP_{it}} * \widetilde{HPG_{it}} + \gamma * \widetilde{HPG_{it}} + \varepsilon_{it}$ and Eq.(4.5) $\beta = \beta_0 + \beta_1\, \widetilde{HPG_{it}}$. The value of (1-$\beta_0$) represents the average degree of consumption smoothing within the group. The value of (1-β_0-$\beta_1\, \widetilde{HP_{it}}$) in Panel A and (1-$\beta_0$-$\beta_1\, \widetilde{HPG_{it}}$) in Panel B demonstrate how much consumption is smoothed in region i and period t via capital gains in the housing markets. The numbers in parentheses are standard errors. *, **, and *** indicates statistical significance at 10%, 5%, and 1% level, respectively. We also employ control variables including trend, square of trend, and population growth.

At first glance, the statistically significant negative coefficient β_1 is observed. Negative β_1 consequently lowers the value of β and increases (1-β_0-$\beta_1\, \widetilde{HP_{it}}$). In other words, whenever we add property capital gains, the co-movement of idiosyncratic output and consumption decreases. The appreciation of housing prices thereby serves as an effective buffer against output shocks and raising the consumption smoothing.

Specifically, the analysis across Australian states highlights the highly statistically significant coefficient β_1 at -11.35 (house price) and -3.04 (house price growth). For

Canada, though the housing market and consumption smoothing are found weakly connected when house price is employed, it turns to be significant regarding house price growth. Nevertheless, as it will be discussed in the next session, after controlling the frequencies of data to reflect more permanent output shocks, the role of the housing market in smoothing consumption in Canada is strongly pronounced. Considering New Zealand, that β_1 (Panel A) is documented at -7.72 indicates the impact of housing capital gains against the oscillation of consumption. However, the relationship is negligible when house price growth is employed (Panel B).

Even though New Zealand housing markets appear to have a weak impact on consumption smoothing, the findings generally demonstrate the important position of capital gains against the movement of consumption in other countries. Ignoring the impact of housing capital gains might result in a potentially serious underestimating of risk sharing across regions.

4.5.3 Consumption smoothing with longer-lasting shocks

At this stage, there is strong evidence that capital gains coming from housing markets can promote consumption smoothing, yet empirical studies show that consumption smoothing is likely to be affected by various differencing frequencies (Asdrubali et al., 1996; Balli, Basher, & Louis, 2013; Sørensen & Yosha, 1998). Thus, this session varies data's differencing interval length to get longer-lasting shocks. Normally, the analysis is based on data differenced at a 1-year frequency (k=1) (except for New Zealand, its frequency is based on quarter). To estimate the changes of consumption smoothing to longer-lasting shocks to GDP, data differencing interval of 2, 3, and 5 will be employed.

Table 4.4 shows the extent of the consumption smoothing degree when applying k-differenced data. Running the framework using k year frequency of data reveals several main points. First and foremost, consistent with findings in the previous session, even though the different frequency of data is applied, an unsmoothed fraction of output shock is found highest in Australia whilst New Zealand is the country where regional specific output shocks are strongest buffered. Additionally, within Australia, the magnitude of consumption smoothing remains unchanged when we modified the frequency of data. Approximately 50% of shocks to production on average is insured. A similar pattern was also found across OECD countries when increasing k (Sørensen & Yosha, 1998).

Table 4. 4 Consumption smoothing across states of Australia, provinces of Canada, and regions of New Zealand, k-year frequency of data.

Not smoothed (β_u)	K=2	K=3	K=5
Australia	0.59***	0.65***	0.47***
	(0.04)	(0.05)	(0.04)
Canada	0.14***	0.20***	0.28***
	(0.03)	(0.03)	(0.04)
New Zealand	0.04	0.08**	0.01
	(0.05)	(0.03)	(0.04)

Note: The table shows the panel estimation results corresponding to the first equation $\widehat{CON}_{it} = constant + \beta_u \widehat{GDP}_{it} + \varepsilon_{it}$. The coefficient β_u indicates the unsmoothed fraction of shocks to gross state product. The numbers in parentheses are standard errors. *, **, and *** indicates statistical significance at 10%, 5%, and 1% level, respectively.

On the other hand, in response to longer-lasting shocks across Canada provinces, consumption smoothing declines considerably from 85% to 72%. To some extent, when dealing with more permanent shocks, Canadian residents might feel riskier and more reluctant to consume, thus increasing unsmoothed fraction. Likewise, the sharp decline in consumption smoothing is also found across U.S states in the papers by Asdrubali et al. (1996); Sørensen and Yosha (1998). In fact, the permanent income theory suggests the decrease of smoothing via saving behavior when shocks to the product are more persistent (Balli, Basher, & Louis, 2013). Generally, the results suggest that unlike Australia, Canada residents are more sensitive to long-lasting shocks, then changing their consumption behavior consequently. Meanwhile, as quarterly data is used for analyzing the case of New Zealand, increasing k from 1 to 5 has little effect on consumption smoothing. The term is too short to record any big difference. Slight fluctuation in consumption smoothing, thereby, is experienced.

Table 4.5 displays results of consumption smoothing as a function of housing capital gains corresponding to the difference in frequencies of data. As shown, a significant and negative coefficient of housing capital gains is reconfirmed when the differing interval is getting higher (i.e., k increases from 1 to 2, 3, and 5). Noticeably, the negative β_1 with significant t-statistic for Australia and Canada is demonstrated whereas the effect of New Zealand house price growth on consumption smoothing appears to be insignificant. It can be justified by the fact that New Zealand is the country recording the highest degree of consumption smoothed given income shock in comparison with the other countries. Adding capital gains in the housing market brings little effect to the consumption movement. Also, in order to observe the effect on consumption, the change in housing wealth should be in the long run or permanent rather than the short term (Dvornak & Kohler, 2007). It thereby possibly explained the weak response of consumption smoothing to the appreciation of house price growth in New Zealand, where the data frequency is available on a quarterly basis (short term) rather than an annual basis (long term).

Table 4. 5 Consumption smoothing via housing capital gains across states of Australia, provinces of Canada, and regions of New Zealand, k-year frequency of data.

A) House prices

		K = 2	K = 3	K = 5
Australia	β_0	0.50***	0.70***	--
		(0.04)	(0.04)	
	β_1	-8.74***	2.54	--
		(2.48)	(2.04)	
Canada	β_0	0.19***	0.25***	0.32***
		(0.03)	(0.04)	(0.06)
	β_1	-9.56***	-44.5**	-21.80**
		(3.20)	(20.45)	(10.23)
New Zealand	β_0	0.12***	0.41***	0.62***
		(0.03)	(0.08)	(0.19)
	β_1	-46.78***	-15.17**	-12.85**
		(14.68)	(7.78)	(5.26)

B) House price growth

		K = 2	K = 3	K = 5
Australia	β_0	0.58***	0.60***	--
		(0.06)	(0.09)	
	β_1	-30.67***	-20.45**	--
		(8.77)	(10.45)	
Canada	β_0	0.08***	0.15***	0.19***
		(0.03)	(0.08)	(0.08)
	β_1	-67.67***	-71.46*	-58.12**
		(28.76)	(37.45)	(27.44)
New Zealand	β_0	0.16***	0.21**	0.62***
		(0.05)	(0.10)	(0.19)
	β_1	-12.45	-40.43*	-30.23
		(10.45)	(22.34)	(26.25)

Note: The coefficients in Panel A are estimated from the regression Eq.(4.2) $\widehat{CON}_{it} = constant + \beta_0\, \widehat{GDP}_{it} + \beta_1\, \widehat{GDP}_{it} * \widehat{HP}_{it} + \gamma * \widehat{HP}_{it} + \varepsilon_{it}$ and Eq.(4.3) $\beta = \beta_0 + \beta_1\, \widehat{HP}_{it}$. The coefficients in Panel B are estimated from the regression Eq.(4.4) $\widehat{CON}_{it} = constant + \beta_0\, \widehat{GDP}_{it} + \beta_1\, \widehat{GDP}_{it} * \widehat{HPG}_{it} + \gamma * \widehat{HPG}_{it} + \varepsilon_{it}$ and Eq.(4.5) $\beta = \beta_0 + \beta_1\, \widehat{HPG}_{it}$. The value of (1-$\beta_0$) represents the average degree of consumption smoothing within the group. The value of (1-β_0-$\beta_1\, \widehat{HP}_{it}$) in Panel A and (1-$\beta_0$-$\beta_1\, \widehat{HPG}_{it}$) in Panel B demonstrate how much consumption is smoothed in region i and period t via capital gains in the housing markets. The numbers in parentheses are standard errors. *, **, and *** indicates statistical significance at 10%, 5%, and 1% level, respectively. We also employ control variables including trend, square of trend, and population growth. The result of Australia with k=5 is not included due to data limitation.

Our findings of the determinant role of housing capital gains on smoothing consumption are consistent with those reported in the literature. The papers for the U.K market and the U.S market by Aron, Duca, Muellbauer, Murata, and Murphy (2012), and Hurst and Stafford (2004) found comparable results. Especially, studying the subject for Australia, the effect of housing wealth on consumption expenditure of households was also indicated by Dvornak and Kohler (2007). As identified by the study, a permanent $A1 increase in housing wealth caused an increase of approximately 3 cents in annual consumption. Regarding Canada, the responsiveness of consumption on property gains is found statistically significant by Christensen et al. (2009), Sierminska and Takhtamanova (2012), and Kichian and Mihic (2018).

While there are alternative theories to explain for the observed significant house price - consumption relationship, for the case of our studied countries, the main determinants for the correlation are highly likely because of housing collateral (Atalay, Whelan, & Yates, 2016; Lustig & Van Nieuwerburgh, 2010). Exploring the mechanism linking consumption and house prices especially for the cases of Australia and Canada, Atalay et al. (2016); Sierminska and Takhtamanova (2012) discovered that borrowing constraint was the key driver. The rise of house value induces the relaxation of collateral constraints or improves the borrowing capacity of borrowers. It, consequently, leads to higher consumption. A further review in Canada by Kichian and Mihic (2018) uncovered the fact that the impact was associated with the easiness of accesses to credit (mortgage loan). In other words, in conjunction with the increase in house prices, residents increased their consumption when credit condition was easier. Nevertheless, it is also important to note that the difference in regulatory in different countries (i.eg., refinance home loans) might explain the diverse results obtained for each country.

In a nutshell, housing capital gains are demonstrated its ability as a good shock absorber as the response of consumption smoothing through this channel is robust to higher frequencies. When there is the existence of more permanent shocks, property gains would still be a vital factor in smoothing consumption.

4.6 Conclusion

This paper explores the potential channel of consumption smoothing associated with capital gains via the housing markets, using the methodology generated by Asdrubali et al. (1996) and Balli and Rana (2015). Drawing upon empirical analysis, there are several key results provided. In line with the literature, the first result generally rejects the perfect consumption smoothing hypothesis. The disapproval of full risk sharing is indicated by the proportion of consumption smoothing in response to output shocks, at roughly 40% across states in Australia, 72% across provinces in Canada, and 82% across regions in New Zealand. Consequently, it specifies the enormous potential of further risk sharing via capital gains in housing markets. Indeed, the results confirm that the heterogeneity in the housing prices across areas plays an influential role to remain the individual consumption's stability since the rising of consumption is generated after the appreciation of house prices. For robustness checks by means of using higher differing intervals, the ability to buffer output fluctuation and smoothing consumption by property gains is restated. Additionally, the existence of between-country differences also suggested as the response of consumption smoothing to longer-lasting shocks is diverse across countries. Unlike the case of Australia where we observe negligible effect, more persistent shock, in fact, appears to lower the degree of consumption smoothed within provinces of Canada.

Our findings have macroeconomic implications. As the fact that we reject the hypothesis of full risk sharing, it suggests ample scope for further risk sharing by considering alternative channels. Especially, countries' larger welfare gains can be achieved thanks to housing capital gain's ability to hedge the consumption from output fluctuation. As a result, the regulation toward real estate gains as one source of sustainable economic growth and macroeconomic stabilization should be monitored carefully. Further, given the fact that more persistent income shocks result in the lower consumption smoothed (higher consumption sensitivity) in Canada in comparison with the other countries, it advises the higher attention of Canadian policymakers to control for the effect.

While the main contribution of this paper is to fill the literature gap on the significant role of capital gains from the housing market on stabilizing consumption, its focus is on three economically developed countries. Employing the analytical framework used in this paper, a broader examination of housing capital gain's impact on consumption smoothing across emerging economies is an interesting topic for further research.

CHAPTER 5 Conclusion

This final chapter concludes the thesis by giving a summary of the main findings. The implications are then discussed. Limitations of the thesis and some intended agendas for future research are provided at the end of the chapter.

5.1 Summary of contribution

The dynamics of the housing market have been a major topic of discussion over the years, given its significant position in household wealth and consumption, financial markets, and the general economy. Three housing dynamics related topics are, therefore, explored in this thesis. Firstly, it is of importance to understand the sources of house price variation. The conventional wisdom maintains that immigration is one of the critical factors affecting the housing market when examining the relationship between immigration and house prices, rather than other housing market indicators. As a response, the first essay fills the gap in the literature by studying the impact of immigration on three housing variables: prices, rents, and price-to-rent ratios. In particular, understanding the relative response of prices and rents to changes in immigration is crucial for policy purposes. Moreover, the use of wavelet coherence analysis further allows for exploration of the association at both time and frequency domains, providing a more comprehensive picture of the relationship.

In the last decades, the phenomenon of financial integration is becoming more apparent, triggering cross-market connectedness. The second essay, thus, focuses on the potential connectedness between two critical alternative investment assets of property and oil. Their connectedness remains questionable, even though abundant studies document a significant impact of the housing market's movement on oil price fluctuation. The second essay, examining both directions of the relationship, addresses this omission in the literature. Additionally, as most prior studies exploring the market contagion use a dataset of securitised real estate markets, our work adds to the literature by employing residual property indices. Taking into account that a financial market crisis may originate from a real estate market, as happened in the GFC, the use of residential housing price indices in the analysis may be more informative for investors and policymakers. Finally, as the studied period covers the oil crisis of 1973, the oil price collapse of 1986, the GFC of

2007-2009, and the shale oil revolution of 2014-2016, the true time-varying nature of the housing-oil relationship during both tranquil and crisis periods is fully captured.

Given the apparent dynamics of the housing market and their increasing tendency, the third essay tackles the question of whether property capital gains can smooth consumption. There are alternative channels suggested to smooth consumption, yet a distinct channel of housing capital gains has not been fully investigated. The essay is one of few studies working on the national level, whereas there have been abundant papers at the international level and the individual level. Additionally, we complement the prior literature using the most up-to-date sample of three developed countries, comprising Australia, Canada, and New Zealand. As most prior studies concentrate on the context of the US and OECD countries, it is worthwhile to investigate these countries, which have housing markets that have experienced wild fluctuation with an increasing trend in the last decade.

Taken together, this thesis fills three voids in the housing market dynamics literature, representing a variety of new results on the determinants of house price dynamics and the impact of housing capital gains on consumption. The first essay adds evidence on the important contributory role of immigration, significantly explaining the housing market's movement. Among housing market variables, the reaction to immigration is strongest with rents and weakest with prices, implying that the degree of deviation from housing market equilibrium would be lower thanks to immigration. Within the context of financialization, the second essay stresses the presence of strong connectedness between housing and oil markets, despite their highly dynamic relationship. Confirming other empirical studies, the essay emphasises the oil market as one of the housing market movement's determinants. It further underscores the impact of the housing market on the oil market, especially during the recent GFC. The oil market's position as a mediator that spreads shocks from the US housing market to other housing markets is explicitly indicated. The third essay provides strong support for the hypothesis of imperfect consumption smoothing. Prominently, it highlights that a significant degree of consumption is smoothed via capital gains from the housing market. Property gains would still a vital factor in smoothing consumption when alternative data frequencies are applied to represent more permanent shocks. The asymmetry in the behaviour of residents in the three countries is also noted when dealing with longer-lasting shocks.

The following sub-sessions embrace each of the empirical studies' findings and implications. The limitations and intended agenda for future research are also given.

5.2 Essay one

Employing the wavelet coherence analysis and Granger causality test, the first essay documents immigration-housing market interaction in the context of New Zealand. New Zealand has been consistently ranked as one of the top countries in terms of immigration, whereas its housing market appears to make it one of the most unaffordable places in the world. The studied period runs from 1996 to 2017, covering 21 years at monthly frequency.

The potential heterogeneity in the relationship between immigration and housing markets in terms of the housing market variables, the duration of the relationship, different time intervals of the sample period, and different regions in the country, is recognised. Nonetheless, the conclusion that the housing market is generally led by immigration is strongly indicated. Notably, comparing the response of prices and rents to immigration variation, the result is more pronounced regarding rents. The finding can be justified because immigrants are highly likely to rent for a period of time before buying a house, which first leads to higher rental prices and then allows the housing market to have more time to adjust to increased housing demand. That the change in immigration causes variation in price to rent ratios in the opposite direction is also suggested.

The research findings, thus, have important policy implications. The housing market equilibrium is attained when actual rental yields (the reciprocal of the price to rent ratio) match the user cost of owner-occupation. Consequently, in an overvalued housing market, given that an increase in immigration causes higher demand in house rents than house prices, the housing market will move towards equilibrium. The paper's finding advises on how to correct an overvalued housing market towards equilibrium through immigration. Given the increase of immigration, the extent of overvaluation in the housing market can be expected to decrease.

Our essay mainly uses immigration, price, and rent data aggregated at the regional level, which are generally available in many countries. Therefore, it is worthwhile to further investigate other countries by straightforward replication of the study. In addition, exploring the interaction between house prices and rents in one system will be an interesting topic for future research. Not but not least, we believe that apart from documenting the immigration-housing market relationship via the Wavelet analysis, future research should look for other decomposition frameworks. Particularly, the analysis using the time difference approach will be helpful in future research.

5.3 Essay two

The second essay, using the method of dynamic equicorrelation developed by Engle and Kelly (2012) and the connectedness index proposed by Diebold and Yilmaz (2012), demonstrates the correlation and connectedness between housing and oil markets. The sample comprises 18 OECD countries from 1970 to 2019. Given their advanced financial markets and economies, OECD countries are a good testing ground to investigate the relationship. Furthermore, higher connectedness across markets is expected in the context of OECD countries due to their robust linkage in trade, financial markets, and general economic conditions.

The finding first highlights the strong integration between the two markets, despite their dynamics across time and countries. In line with the literature, the connectedness increases sharply due to the effect of negative shocks events. Prominently, instead of maintaining their position over time, the studied markets appear to take interchangeable roles, indicating that they can switch their positions between shock net receivers and net transmitters. The US and the UK housing markets, however, tend to transmit shocks and cause the variation of other markets, given their highest levels of net connectedness. Similar to the majority of the literature, the essay documents oil as a housing market fluctuation determinant. Nevertheless, during the GFC, the leading role of the US housing market is revealed due to its ability to transfer shocks to the oil market. The oil market, in turn, appears to be the information mediator, spreading shocks from the US housing market to the other countries' housing markets. Finally, we notice the discrepancy in terms of net oil-importing and exporting countries. Oil-dependent countries are normally impacted by the oil fluctuation, whereas the effect is not observed in the net oil-exporting countries.

The detected connectedness between housing and oil markets has several implications. In terms of the investment perspective, on account of the high magnitude of correlation and connectedness between housing and oil markets, along with their increased integration during extreme economic and financial events, there is limited diversification benefit from combining them in the portfolios. The essay also draws a clear picture for policymakers. A close watch on these two markets should be kept to foster financial stability. A key element of crisis prevention is better surveillance of the swing of the oil market to avoid its adverse effect on the real estate market. Due to the fact that housing prices in net oil-importing countries are more vulnerable to shifts in oil prices than in net oil-exporting countries, countries are advised to reduce their oil dependence. The dominant role of the US housing market as the shock transmitter during the recent financial distress of the GFC also requires policymakers to increase their attention to the US housing market's movement.

The significance of housing - oil connectedness poses the question of which specific elements establish the causal relationship between them. Further research is warranted to consider some connectedness drivers, such as household balance sheets, income statements, and macroeconomic and demographic factors. Furthermore, given the bidirectional role of any market that is time-dependent, another possible venue of research would be to explore the factors explaining market role variation across sub-periods. Apart from looking at the general oil shocks, future research could decompose oil price shocks into supply and demand shocks to gain additional insight into the dynamic connections between the two studied markets. Future studies could fruitfully explore the topic further by adopting regional data due to the potential divergence in terms of oil-housing market connectedness at the regional level.

5.4 Essay three

The third essay analyses the potential role of housing capital gains in smoothing consumption, using the methodology generated by Asdrubali et al. (1996) and further developed by Balli and Rana (2015). The most up-to-date dataset including the three developed countries of Australia, Canada, and New Zealand is utilised.

Consistent with the literature, the result first rejects the theory of full risk sharing since only a fraction of income is smoothed. In particular, the proportion of consumption smoothed in response to output shocks accounts for roughly 40% across states in Australia, 72% across provinces in Canada, and 82% across regions in New Zealand. Noticeably, there is heterogeneity in the degree of consumption smoothed given the presence of longer shocks across countries. A lower degree of consumption is smoothed in Canada, while the consumption pattern remains unchanged in Australia. In other words, in comparison with Australian residents, Canadian residents tend to be more sensitive to permanent domestic output shocks

Given the fact that there is ample scope for a further risk sharing possibility due to imperfect consumption smoothing, capital gains from the housing market are specifically examined as an alternative channel. The essay states the gains in the housing markets to be an important factor in maintaining the stability of consumption, as an increase in consumption is generally found given the appreciation of house prices. Moreover, the response of consumption to housing capital is still pronounced when adjusting the data frequency for more permanent shocks.

There are a number of important macroeconomic implications arising from the essay's findings. Owing to the fact that the output shocks can be hedged partially thanks to capital gains in the housing market, the countries' welfare can be promoted through this channel. The regulation toward real estate as one source of sustainable economic growth and macroeconomic stabilization should be carefully monitored. Furthermore, the finding of more persistent income shocks causing a lower level of consumption smoothed (higher consumption sensitivity) in Canada in comparison with the other countries suggests the higher attention of Canadian policymakers on controlling for the effect.

The essay emphasizes the significant role of capital gains from the housing market on stabilizing consumption by employing the data of three economically developed countries. This recommends further investigation employing the same analytical framework for other countries. A broader examination of the impact of housing capital gains on consumption smoothing across emerging economies deserves exploration. Also, further research is warranted to carry out extensive exploration of channels that one can exploit the house price appreciation to smooth consumption. Additionally, apart from looking at the capital gains from housing markets, investigating alternative smoothing channels used to cope with adverse income shocks in smoothing consumption, especially via more liquid assets might prove an important area for future direction.

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Appendices

Essay One

The housing market's deviation from equilibrium

User cost equilibrium condition in housing

The present value of buying a durable good—in this case, a house—using it for one period and then selling it is known as that good's user cost (Hicks, 1946). When the housing market is in equilibrium, user cost should equal the cost of renting the house for one period. The equilibrium condition for housing, following Girouard, Kennedy, Van Den Noord, and André (2006); Himmelberg et al. (2005), can be written as follows:

$$R_t = v_t P_t \quad \text{(A.1)}$$

where R_t is the period t rental price, P_t the purchase price, $v_t P_t$ is user cost, and v_t the per dollar user cost. In a housing market, per dollar user cost can be calculated as follows:

$$v_t = r_t + \omega_t + \delta_t + \gamma_t - g_t \quad \text{(A.2)}$$

where r is an appropriate interest rate, ω is the average running cost and transaction cost combined, δ is the housing market's depreciation rate, γ is the risk premium of owning rather than renting, and g is the expected capital gain. That is, an owner-occupier foregoes interest on the market value of the house, incurs running costs, transaction costs and depreciation, incurs risk (mainly because of the uncertainty of future price and rent movements in the housing market) and benefits from any capital gains on the house.[16]

Owner-occupying becomes more attractive if $R_t > v_t P_t$ and this should exert upward pressure on P and downward pressure on R until the market returns to equilibrium (Beracha & Johnson, 2012; Hill & Syed, 2016). Assuming households are not credit constrained, if $R_t < v_t P_t$, the opposite should occur.[17] Rearranging equation A.1, we obtain that in equilibrium the price-to-rent ratio should be equal to the reciprocal of per dollar user cost (i.e., $P_t/R_t = 1/v_t$. If the actual price-to-rent ratio differs from our estimate of the reciprocal of per dollar user cost it follows that the housing market is not in equilibrium, and Dev_t in equation A.3 will be different from zero.

[16] Owner-occupiers in some countries, but not New Zealand, benefit from tax deductions on mortgage interest payments, in which case r_t should be adjusted to include the tax offset (see Girouard et al. 2006 for a list of such countries in the OECD).

[17] Where houses are credit constrained, rent may be more than user cost (Duca, Muellbauer, & Murphy, 2011). Also, the housing market may be slow to move to equilibrium due to the high transaction costs.

$$Dev_t = P_t/R_t - 1/v_t \quad \text{(A.3)}$$

More specifically, the housing market is overvalued if the actual price-to-rent ratio is greater than the reciprocal of the per dollar user cost (Dev_t>0), and undervalued if the actual price-to-rent ratio is smaller than the reciprocal of the per dollar user cost (Dev_t<0).

Measurement issues related to equilibrium deviations

There are two problems preventing the application of this approach to the housing market from being straightforward. First, the equilibrium condition in equation A.1 implicitly assumes that P_t and R_t refer to houses of the same quality. The median rental house will tend to be of inferior quality to the median owner-occupied house (Fox & Tulip, 2014; Hill & Syed, 2016). By implication, observed price-to-rent ratios calculated from unmatched medians, i.e. the ratio of the median (or mean) house price to the median (or mean) rent, should be higher than matched price-to-rent ratios. This means that a housing market analysis based on comparisons of unmatched price-to-rent ratios and per dollar user costs will be subject to systematic bias towards a finding that the market is overvalued when it is not.

This problem can be addressed in two ways. First, by adjusting for the quality difference between owner-occupied and rented houses. This quality adjustment could be achieved by applying hedonic methods to actual transaction-based price and rent data that contain detailed information on the attributes of the transacted houses. Hill and Syed (2016) calculate the quality-adjustment factor using housing data for New South Wales, Australia and this adjustment factor has been used in this paper.[18] Second, depending on the purpose of the study, by using the changes in price-to-rent ratios rather than their levels. The changes in price-to-rent ratios can be obtained by taking the difference between price and rent indexes. While the houses in price indexes would not match the houses in rent indexes, the idea is that the quality difference would not cause any systematic differences in the direction of their movements (Smith & Smith, 2006). This approach has been followed in many studies, including Beracha and Johnson (2012); Duca et al. (2011); Gallin (2008); Himmelberg et al. (2005). In our case, while we need price-to-rent ratio levels in order to know whether the market is overvalued or

[18] Our paper uses data sets on prices and rents aggregated at the regional level and that do not include detailed hedonic characteristics of houses.

undervalued, our main analyses (wavelet coherence and Granger causality testing) use price and rent indexes and indexes of price-to-rent ratios.

The second problem with this user-cost approach is that the expected capital gain g is not directly observable and obtaining a measure of it is problematic. A standard approach is to assume that the expected capital gain is extrapolated from the past performance of the housing market. But then the question is how far back into the past households look in order to extrapolate future prices. Evidence based on household surveys in the US indicates that households extrapolate over a relatively short horizon (Case & Shiller, 2006). By implication g and hence the equilibrium price-rent ratio $1/v$ may fluctuate a lot over time, thus potentially seriously undermining the usefulness of this particular application of the user-cost approach (Diewert, 2009; Verbrugge, 2008). However, Diewert (2009), citing evidence on the length of booms and busts from Girouard et al. (2006), argues that market participants are more likely to use a longer time horizon to form their expectations. These studies suggest that the housing market performance of the past 10–20 years should be used for extrapolation of future capital gains. Using these longer time horizons substantially reduces the volatility of expected capital gain and results in the user-cost equilibrium approach being more likely to be practically applicable in the housing context. In our study, we calculated expected capital gains using time horizons of 5, 10 and 15 years. In line with our expectation, the expected capital gains and the resulting measures of a housing market's deviation from equilibrium becomes smoother with the increases in the time horizons.

Deviation of New Zealand's housing markets from equilibrium

The deviation of the housing market from its equilibrium is calculated by taking the difference between the actual price-to-rent ratio and the equilibrium price-to-rent ratio, where the latter is the reciprocal of the per dollar user cost (equation A.3).[19] A positive deviation indicates that the market is overvalued and a negative deviation indicates that the market is undervalued. In order to calculate the per dollar user cost, as shown in equation A.2, we need the estimates of the interest rate (r_t), the running and transaction costs (ω_t), the depreciation rate (δ_t), the risk premium (γ_t), and the expected capital gain (g_t). The estimates for these parameters are obtained as follows.

[19] The actual price-to-rent ratios are adjusted for the quality difference between sold and rented houses. We use the adjustment factor estimated by Hill and Syed (2016) for New South Wales (Australia), which found that sold houses are on average 18.4% better in quality than rented houses.

To calculate r, we take the simple average of mortgage interest rates of residential properties and the interest rates of the 10-year New Zealand Government bond. The mortgage rates of residential properties are calculated by taking the simple average of the interest rates of the 2-year fixed rate mortgage loan and the floating rate mortgage loan (source: Reserve Bank of New Zealand). Here, the mortgage interest rates represent the cost of debt to the owner, and the 10-year bond rate (risk-free interest rate) represents the opportunity cost of the equity of the owner (Fox & Tulip, 2014). Our calculated r fluctuated around 7% during 1996–2008, experienced a drop of around 2% during the GFC period in 2009 followed by a steady decline during 2010–2017, reaching around 3% in 2017.

We set the average running and transaction cost, ω, at 2.0% of the property price. We follow Fox and Tulip (2014) who estimate running costs of 1.2% (excluding repair costs) and a transaction cost of 0.7% of the property prices (see also Beracha and Johnson 2012). We fix the depreciation rate of properties, δ, at 2.5% of the property price. This is the gross depreciation rate estimated by Harding, Rosenthal, and Sirmans (2007) using American Housing Survey data over the period 1983–2001. The risk premium associated with owning versus renting a property is set at γ = 1.0% of the property price. Flavin and Yamashita (2002) find that the risk of owing a property in the US housing market is 2% of the property price. Sinai and Souleles (2005) report that the volatility of rents is about half that of house prices, and since γ is supposed to measure the differential between the risks of owning versus renting, we fix it at 1.0%. Given that these values are held constant for the whole sample period and across regional markets, our $\omega + \delta + \gamma$ is set at 5.5%. It should be noted that Girouard et al. (2006) fixed $\delta + \gamma$ at 4% for the 18 OECD countries (including New Zealand) they studied over the 1990–2004 period. Verbrugge (2008) fixed $\omega + \delta + \gamma$ at 7% for the US over the 1980–2004 period, and Hill and Syed (2016) fixed $\omega + \delta + \gamma$ at 5.5% for Australia over the 2001–2009 period.

The expected nominal capital gain g is calculated using the past performance of the housing market. More specifically, the expected capital gain in period t is assumed to be the moving average of actual nominal capital gain over the preceding z years. We consider three different values of z: 5, 10 and 15 years. The capital gains are obtained using the residential property price index (RPPI) of New Zealand published by the Reserve Bank of New Zealand. The index is available from December 1979, which is more than 17 years back from the first month of our sample data, allowing us to calculate the expected capital gain for $z = 15$. RPPI is available only at quarterly frequencies, which is converted to monthly indexes through the use of simple geometric mean interpolations of the quarterly indexes.

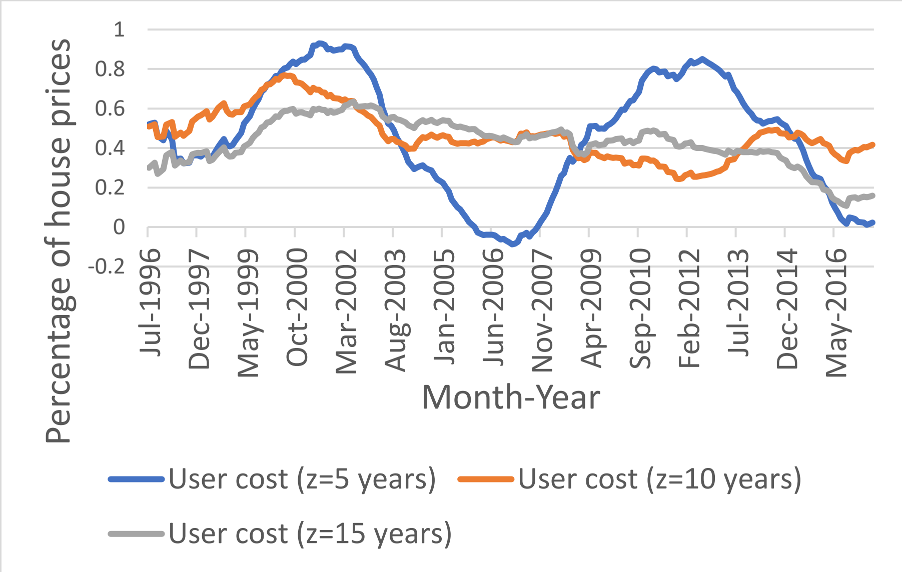

Figure A.2. 1 User costs with expected capital gain extrapolated using different past time horizons (z=5, 10, and 15 years), 1996-2017

Inserting these values for r, ω, δ, γ and g in equation A.2, we find the user costs, shown in figure A.2.1. The figure shows that the value of z plays a pivotal role in determining the values of user costs. When z = 5, the expected capital gain becomes highly volatile, resulting in negative or near 0 user cost in some periods, which is implausible and makes the user cost unusable (1/v i.e. the equilibrium price-to-rent ratio becomes a very large number or undefined). Therefore, the user cost estimate at z = 5 is not considered further in our analysis. The finding of extreme volatility of per dollar user cost when the expected capital gain is extrapolated from past performance of short horizons has been noted previously by many, including Diewert (2009); Girouard et al. (2006); Hill and Syed (2016); Verbrugge (2008). Diewert (2009) argues that a longer time horizon of 10 to 20 years is more plausible in terms of how market participants form their expectations. Girouard et al. (2006) estimate that housing cycles in a sample of English-speaking countries (including New Zealand) last on average about 18 years and argue that extrapolation over 20 years may provide a good approximation of the long-run underlying trend. In the case of New South Wales in Australia, Hill and Syed (2016) used a 20-year horizon in order to prevent user cost being too volatile for its effective use. In our case, we conduct our wavelet analysis using user costs calculated at $z = 10$ and $z = 15$, and we do not find any meaningful difference in the results obtained from these two sets of wavelet analysis.

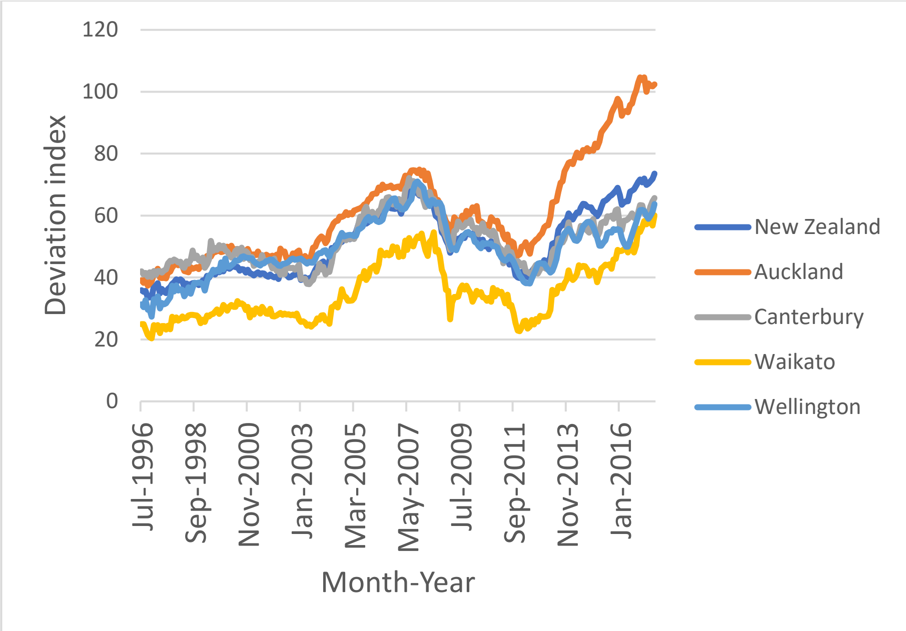

Figure A.2. 2 Deviation of the housing market from its equilibrium

Figure A.2.2 shows the deviations obtained for New Zealand as a whole and the four regional markets. The figure shows that the deviations were positive, i.e. the markets were overvalued, for the whole sample period, although there were substantial changes in the extent of the deviation during the sample period.[20] During 1996–2003, the deviation remained relatively stable, but then increased steadily during 2003–2008. The GFC caused a large drop in the deviation in 2009, which resulted in a subsequent correction during 2010–2012, followed by a steady increase. While this is the general pattern, there are noticeable differences across the markets. The deviation in Auckland has always been larger than in other markets, and this has increased further during the sample period. Waikato, on the other hand, had the smallest positive deviation and remained in this position through the whole sample period. The deviations of Wellington and Canterbury were close to Auckland in the beginning of the sample but by the end of the sample period were lower than the New Zealand average.

[20] This finding that the housing market in New Zealand was consistently overvalued during our sample period is in line with OECD data that has consistently ranked New Zealand's housing market as one of the top 10 overvalued housing markets among OECD countries.

Additional data description and results

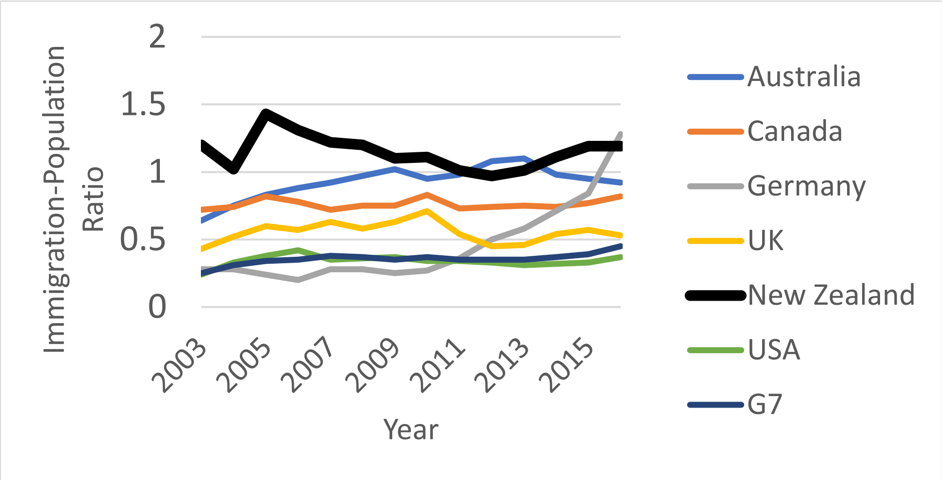

Figure A.2. 3 Permanent (net) immigration-to-population ratio in some top migrant destination countries, 2003–2016

Note: OECD data source

Table A.2. 1 Unit root tests on immigration and housing market variables

Key variables	Regions	ADF			PP		
		Intercept	Intercept and Trend	Unit root	Intercept	Intercept and Trend	Unit root
Price	New Zealand	0.0001	0.0005	No	0.0000	0.0000	No
	Auckland	0.0000	0.0000	No	0.0000	0.0000	No
	Canterbury	0.0563	0.1925	Yes	0.0000	0.0000	No
	Waikato	0.0000	0.0000	No	0.0000	0.0000	No
	Wellington	0.0088	0.0423	No	0.0000	0.0000	No
Rent	New Zealand	0.3378	0.6334	Yes	0.0000	0.0000	No
	Auckland	0.0000	0.0000	No	0.0000	0.0000	No
	Canterbury	0.3875	0.7283	Yes	0.0000	0.0000	No
	Waikato	0.6550	0.8559	Yes	0.0000	0.0000	No
	Wellington	0.0000	0.0000	No	0.0001	0.0000	No
Price-to-rent ratio	New Zealand	0.0000	0.0000	No	0.0000	0.0000	No
	Auckland	0.0000	0.0000	No	0.0000	0.0000	No
	Canterbury	0.0000	0.0000	No	0.0000	0.0000	No
	Waikato	0.0000	0.0000	No	0.0000	0.0000	No
	Wellington	0.0326	0.1300	Yes	0.0000	0.0000	No
Immigration	New Zealand	0.0307	0.1195	Yes	0.0000	0.0000	No
	Auckland	0.0067	0.0311	No	0.0000	0.0000	No
	Canterbury	0.0065	0.0339	No	0.0000	0.0000	No
	Waikato	0.0147	0.0559	Yes	0.0001	0.0001	No
	Wellington	0.0001	0.0010	No	0.0000	0.0000	No

Note: The p values are obtained from the unit root tests—Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests. The tests are conducted on the first difference of these variables.

Table A.2. 2 Number of lags selected by AIC, SC, and HQ criteria for Granger causality tests between immigration and the housing market variables

Housing market variables	Regions	AIC	SC	HQ
	New Zealand	14	12	12
	Auckland	14	12	12
Price	Canterbury	16	1	13
	Waikato	14	12	12
	Wellington	12	12	12
	New Zealand	15	12	12
	Auckland	15	12	12
Rent	Canterbury	13	13	13
	Waikato	19	14	15
	Wellington	24	12	12
	New Zealand	18	12	12
	Auckland	14	12	12
Price-to-rent ratio	Canterbury	13	1	13
	Waikato	14	12	14
	Wellington	14	13	13

Note: The lags are selected using Akaike information criterion (AIC), Schwarz information criterion (SC) and Hannah-Quinn information criterion (HQ) models.

Table A.2. 3 VAR Granger causality Wald tests between immigration and the housing market variables using the number of lags selected by the SIC and HQ criteria

Regions	Housing market variables	SIC		HQ	
		H_o: M does *not* Granger cause H	H_o: H does *not* Granger cause M	H_o: M does *not* Granger cause H	H_o: H does *not* Granger cause M
New Zealand	Price	33.09***	25.51**	33.09***	25.51**
	Rent	55.90***	24.69**	55.90***	24.69**
	Price-to-rent ratio	42.19***	37.85***	42.19***	37.85***
Auckland	Price	29.75***	31.95***	29.75***	31.95***
	Rent	49.50***	18.65	49.50***	18.65
	Price-to-rent ratio	28.51***	27.28***	28.51***	27.28***
Canterbury	Price	2.34	2.12	24.65**	4.51
	Rent	35.39***	23.05**	35.39***	23.05**
	Price-to-rent ratio	0.02	0.34	31.15***	12.00
Waikato	Price	6.40	8.00	6.40	8.00
	Rent	41.03***	34.31***	32.17***	39.23***
	Price-to-rent ratio	37.61***	25.09**	42.19***	23.87**
Wellington	Price	33.01***	12.39	33.01***	12.39
	Rent	29.69***	20.83	29.69***	20.83
	Price-to-rent ratio	34.85***	17.23	34.85***	17.23

Note: F statistics are given by Granger causality Wald tests between immigration and the housing market variables. *M* and *H* refer to the change in the immigration-to-population ratio and the change in the housing market variables, respectively. The symbols *** and ** denote the significance at the 1% and 5% level, respectively. The lag lengths in the equations are selected by Schwarz information criterion (SIC) and Hannah-Quinn information criterion (HQ).

Essay Three

Table A.4. 1 List of countries' regions/ states/ provinces under study

Country	Region/State/Province
Australia	Australian Capital Territory, New South Wales, Northern Territory, Queensland, South Australia, Tasmania, Victoria, and Western Australia
Canada	Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Ontario, Prince Edward Island, Quebec, and Saskatchewan
New Zealand	Auckland, Canterbury, Waikato, and Wellington

Table A.4. 2 Data source

	Variables	Data source
Australia	Consumption	Australian Bureau of Statistics Household final consumption expenditure Period: 1990-2018
	Gross state product	Australian Bureau of Statistics Real gross state income, chain volume measures Period: 1992 - 2018
	House price	Australian Bureau of Statistics Residential Property Price Indexes: Eight Capital Cities Period: 2003-2018 Quarterly data is transferred to annually data by selecting the index in the second quarter.
	Population	Australian Bureau of Statistics Period: 1981-2018
Canada	Consumption	Statistics Canada Detailed household final consumption expenditure Table: 36-10-0225-01 Period: 1981-2017
	Gross provincial product	Statistics Canada Gross domestic product Data for GDP is taken from two tables as follows. • Table: 36-10-0402-01 Period: 1997-2018 • Table: 36-10-0396-01 Period: 1984-2008
	House price	Statistics Canada New housing price indexes (1997=100) Table: 18-10-0205-01 Period: 1986-2019
	Provincial population	Statistics Canada Table: 17-10-0005-01 Period: 1971-2018 1997=100
	Provincial consumer price index	Statistics Canada Table: 18-10-0005-01 (formerly CANSIM 326-0021) Period: 1984-2018 2002=100
New Zealand	Consumption	Statistics New Zealand Retail trade Table reference: RTT007AA

	Period: 2003Q4-2017Q2 Data availability for 4 main regions, including Auckland, Canterbury, Waikato, and Wellington
Gross domestic product	Infometrics Period: 1999Q2 – 2018Q4 Constant (2010)
House price	REINZ House price index Period: 1990-2018Q1 We convert monthly house price index to quarterly series by selecting the last month of the quarter
Regional population	Statistics New Zealand Table: DPE051AA Period: 1996-2018
Regional consumer price index	Statistics New Zealand June 2017 quarter (=1000) Period: 2006Q2-2019Q2