TWENTY FIFTH ANNUAL PACIFIC-RIM REAL ESTATE SOCIETY CONFERENCE

MELBOURNE, AUSTRALIA, 14-16 JANUARY 2019

HOUSE PRICE DIFFUSION OF HOUSING SUBMARKETS IN GREATER SYDNEY

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ABSTRACT

Despite numerous studies have investigated house price diffusion between regional cities, few have considered the ripple effects of housing submarkets within a metropolitan city. This study, therefore, expands upon the limited literature to have examined house price diffusion of housing submarkets (namely, low-priced and high-priced submarkets) in Greater Sydney, one of the most diverse housing markets in Australia, using convergence tests, cointegration techniques, Granger causality and dynamic ordinary least square cointegration test. The results show a long run relationship in house prices exists between these two submarkets in Greater Sydney. Importantly, the empirical results show that a large degree of diffusion take place from the less prosperous submarket to the high-end submarket. This supports the equity transfer hypothesis in which house price in the low-priced submarket will be transmitted into the high-priced submarket. The study also finds that the low-priced submarket is the primary reactor to changes in economic fundamentals. These findings have some profound implications to policy makers and housing investors.

Keywords: Greater Sydney; housing submarkets; house price diffusion; cointegration; Granger causality, housing policy

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1.0 INTRODUCTION

Given the importance of housing to national and local economies, extensive studies have examined the interrelationships of regional housing markets. In general, these studies have largely focused on the extent to which regional housing markets are interrelated and what is known as a ripple effect. Although empirical evidence of the ripple effect has been demonstrated in regional housing markets, theoretical explanations for the phenomenon are still not entirely clear. This could be attributed to the complexity of housing market dynamics. To capture the complexity of housing market dynamics, there is a growing interest in the relationships of housing submarkets.

Importantly, an analysis of housing submarkets may unveil important information (e.g. residential asset wealth distribution) that is not available at the aggregate national or capital city level; thereby allowing useful tools for analysing housing market dynamics (Gibler and Tyvimaa, 2014; Teng et al., 2017; and Teye et al., 2018). This also allows policy makers, households, investors and lending institutions to make an informed decision. In addition, Meen (1996) and Adair at al. (2000) highlight the complex relationships that exist at a housing submarkets level within metropolitan areas, indicating that housing market dynamics are better analysed as a series of interconnected submarkets.

Nevertheless, limited consideration has been placed upon the ripple effect of housing submarkets. While there is some evidence on the distinct features of different housing submarkets (Doh-Khul et al., 2006; Leishman et al., 2013), few studies explicitly explain the interrelationships of housing submarkets (Ho et al., 2007; Wilson et al., 2011; Teye et al., 2018). Specifically, Teye et al. (2018) found that house price causally flows from the central to the peripheral submarkets in Amsterdam, implying the migration hypothesis in which businesses and households will relocate to a region where housing price is relative lower. However, the finding of Ho et al. (2007) supports the hypothesis of equity transfer in which households, particularly repeat buyers would like to move up the property ladder; thereby submarkets with lower prices (or quality tiers) will be transmitted to submarkets with higher quality tiers. Empirical evidence, therefore, is available to support both competing hypotheses in explaining the causes of interrelationships of housing submarkets; thereby there remains much to explain. In sum, the extant literature shows that there is a growing attention of housing submarkets within a metropolitan city but has not fully considered how and why there is a ripple effect among housing submarkets. This study therefore aims to contribute to the literature by complementing the existing work on house price diffusion through an analysis of housing submarkets perspective in the context of Greater Sydney, one of the most diverse housing markets in Australia.

Greater Sydney provides an interesting case study. Greater Sydney is the most populous city in Australia (ABS, 2016a). It is characterised with highly socially imbalanced (Baum, 2004) and economically polarised (Randolph and Tice, 2014; Randolph and Holloway, 2005). Bunker et al. (2005) discusses the polarised spectrum of housing opportunities in Sydney. They find that higher income households mainly live in waterfront and inner-city areas, while the most disadvantaged households live in the middle and outer city suburbs. These shades of socioeconomic differences have led to a more diverse household living arrangements, resulting in the existence of housing submarkets across Greater Sydney. The increasing socially and economically polarisation of Greater Sydney implies that the existence of ripple effect in housing submarkets in Greater Sydney through the equity transfer channel. The equity transfer hypothesis posits that households, particularly those living in relatively low-priced areas would likely move up the property ladders. As such, housing price will be transmitted from the relatively low-priced submarkets to the relatively high-end submarkets. However, the ripple effect, if any, can also be explained by the migration hypothesis. It asserts that households and businesses move to areas with relative low price by taking the advantages of price differentials. As a consequence, house prices will be transmitted from less prosperous areas to high-end submarkets. Coincidentally, the Australian governments have introduced a number of policies to spur economic development in areas that are relatively lower price such as Western Sydney. These include the launch of City Deal and the Western Sydney airport, relocating public servants to Western Sydney (NSW Department of Planning, 2010). In other words, an examination of Greater Sydney has provided a natural experiment to examine these two competing hypotheses.

The paper seeks to contribute to the limited submarket literature in the interrelationships of housing submarkets in the following ways. Firstly, this study contributes to the scant empirical literature on ripple effects of housing submarkets in general and housing submarkets in Greater Sydney in particular. Specifically, ripple effects could be greater in local housing markets than regional markets in light of the complexity of housing market dynamics, particularly for local housing markets (Jones and Leishman, 2006). As discussed earlier, an investigation of housing submarkets in Greater Sydney therefore may uncover important housing information that is not available at the aggregate level. By considering disparities among different housing submarkets of Greater Sydney, this study is able to differentiate among two main competing hypotheses of the ripple effect (i.e. the migration hypothesis and the equity transfer hypothesis) empirically. The findings will offer further insights into the theoretical explanations of the ripple effect; thereby an enhanced decision making can be made by policy makers and stakeholders.

Secondly, one of the unique features of this study, to the best of our knowledge, is that the existence of a ripple effect in housing submarkets is assessed using both Meen (1999)'s stationarity procedure and cointegration testing for the first time. Despite a limited number of studies have been devoted to the interactions of housing submarkets (Ho et al., 2007; Wilson et al., 2011; Taye et al., 2018), none of these studies formally assess the constancy of the ratio of house prices in a given submarket to the metropolitan house price in the long-run as proposed by Meen (1999). Importantly, Lean and Smyth (2013) highlight that studies that used cointegration and Granger causality tests tend to find much evidence of a ripple effect in regional housing markets, whilst mixed findings are found by studies that have utilised stationarity tests. In other words, the documented ripple effect by previous housing submarkets should be further investigated. Using both unit root tests of housing price ratios and cointegration tests to examine the ripple effect in housing prices of Greater Sydney offer robust empirical evidence of ripple effect existence in housing submarkets for the first time.

Thirdly, the study is one of the few studies to examine the existence and house price stability of the spatially defined submarkets within Greater Sydney. Unlike previous studies that only consider one indicator in housing submarkets definition, this study considers a range of indicators (i.e. administrative delineation, housing prices, social and economic background) in identifying different housing submarkets for the first time. This probably offers an enhanced understanding of housing submarkets identification. Moreover, this is the first study to examine whether sub-housing markets exist in Greater Sydney despite being characterised as a socially polarised city. The findings of the study provide greater insights into the housing literature and offer enhanced information to housing investors and policy makers for a more informed decision making.

The rest of the paper is structured as follows – Section two explores the predominantly used definitions of submarket including the challenges involved. Section three discusses the relevant literature review, highlighting the methods and findings from previous submarket studies. Section four describes the data and estimation methods used in the paper, while section five discusses the empirical findings. The final section sets out the concluding statements.

2.0 DEFINITION AND IDENTIFICATION OF HOUSING SUBMARKETS IN GREATER SYDNEY

There is no unanimity in the definition of housing submarkets (Leishman, 2009; Bourassa et al., 1999; Michaels and Smith, 1990) and the identification process is still fraught with numerous theoretical and methodological challenges (Bourassa et al., 1999). Watkins (2001), for example, encapsulates the challenges of developing housing submarket models due to a number of reasons such as a lack of a single and coherent definition of a housing submarket; variation in the urban area under investigation; variation in the timeframe and the effect of changes in market fundamentals; and differences in the statistical means of testing the existence of submarkets. Even though housing submarkets can be differentiated socially and spatially (Randolph and Tice, 2014; Straszheim 1974), Michaels and Smith (1990) argue that spatial factors are more important than structural factors in defining submarkets. Despite all these challenges, researchers have put forward several definitions of housing submarket that tend to incorporate spatial connotation, socioeconomic parameters, culture, households' taste and preferences.

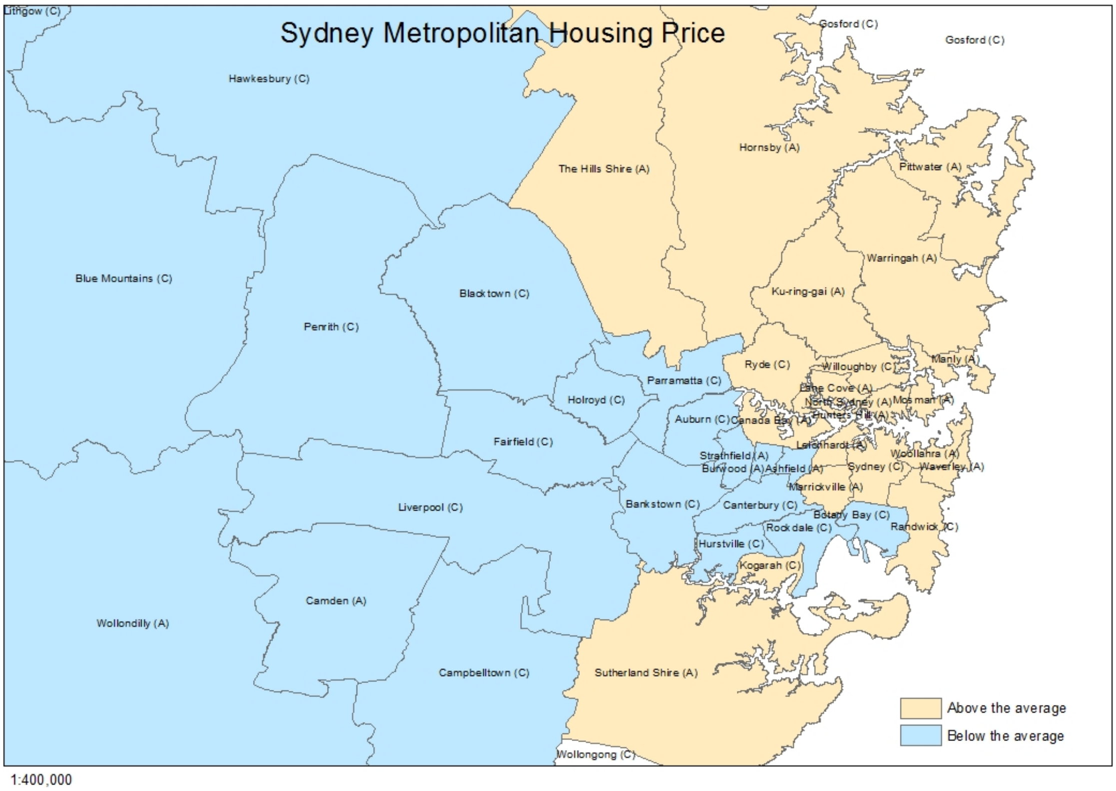
Housing submarkets are generally defined as clusters of dwellings, which are practically and reasonably close substitutes of one another, but unsuitable substitutes for dwellings in other groups at the same time (Kauko et al., 2002; Bourassa et al. 1999). The formation of housing submarkets are the result of income and preferences of the residents combined with their administrative setups. Kauko et al. (2002) explain that the segmentation is often based on the following factors: tenure or lease agreements, house types, source of financing, age of the building stock, and the location. Leishman et al. (2013) add further insight into submarket delineation, asserting that the existence of housing submarket is the result of the simultaneous existence of significant differences of preferences in relation to house types, sizes and locations. Consequently, the identification process of submarkets may take several forms subsumed into pricing clusters, non-pricing clusters or a combination of the two.

To consider both pricing and non-pricing clusters, the delineation of submarkets in this study is based on these three key factors: the degree of house price substitutability (Gibler and Tyvimaa, 2014; Kauko et al., 2002); socioeconomic characteristics (Chen et al., 2009; Ling and Hui, 2013); and spatial delimitation (Jones and Leishman, 2006; Ling and Hiu, 2013). Economists often define housing substitutability through similar house prices based on certain attributes that include the sociocultural choices made by households (Gibler and Tyvimaa, 2014). Jones and Leishman (2006) and Michaels and Smith (1990), argued that location is an integral part in defining submarkets. These three elements are, therefore, fundamental in defining submarkets within Greater Sydney.

Recognising the importance of these elements in housing submarkets definitions, the submarket identification process in this study is a combination of pricing and non-pricing approaches dubbed 'socioeconomic localisation'. It follows an identification process that examines location as defined by governance institutions such as Western Sydney Regional Organisation of Councils (WSROC), Northern Sydney Regional Organisation of Councils (NSROC) and Southern Sydney Regional Organisation of Councils (SSROC). We group LGAs to form five major regions of Greater Sydney - western region, eastern region, northern region, southern region, and inner-west region. These regions are reported in Appendix 1. However, these regions are further grouped into a relative high-priced submarket and a relative low-priced submarket. The difference in terms of median house prices between the high-priced and low-priced submarkets is depicted in Figure 1. The relative high-priced submarket consists of LGAs with house price that is above the median house price of Greater Sydney. They are LGAs in the eastern and northern regions. In addition, these LGAs have similar socioeconomic characteristics (see Table 1), highlighting a high degree of house price substitutability within the submarket.

On the other hand, the relative low-priced submarket is the area of Greater Sydney that clusters LGAs whose house price is below the median house price of Greater Sydney. The low-priced submarket consists of LGAs in the western, inner-west and southern regions of the city. Even though house price in the Sutherland LGA is above the average price in Greater Sydney, it has greater socioeconomic similarities with LGAs in the low-priced submarket; thereby it was classified as the low-priced submarket. Overall, there is a high degree of house price substitutability in this submarket.

Figure 1: Comparative Median House Prices of Greater Sydney



This identification of housing submarket in Greater Sydney is further guided by the index of relative socio-economic disadvantage (SEIFA)[1] computed by the ABS. As highlighted by Chen et al. (2009) and Ling and Hui (2013), clustering LGAs with similar socio-economic features is an effective way to identify housing submarkets since wealthy suburbs tend to have more resources for the effective delivery of infrastructure, public services, green space and shading. Furthermore, relatively wealthy LGAs can influence decisions around planning process including the location of high density communities; thereby widening socioeconomic inequality in cities (Taylor et al., 2016).

A clear socioeconomic disparity between the two submarkets has been identified from Table 1, comparing the socioeconomic characterisation in these LGAs. As can be seen from Table 1, the average SEIFA index of the low price submarket (1005) is below the average score of Greater Sydney (1039). In addition, some LGAs in this submarket depict a very low score such as Fairfield (856), Auburn (929), Holroyd (929), Liverpool (952). Conversely, the average SEIFA index for the high-end submarket is above the average score of Greater Sydney. Importantly, all LGAs in this wealthy submarket show a SEIFA index that is above the average score of Greater Sydney. The only exception is Sydney LGA. Importantly, some LGAs in this affluent submarket reveal a very high SEIFA index, including Ku-ring-gai (1121), Woollahra (1115) and Mosman (1115). This further highlights the socioeconomic disparities between the low-priced and prosperous submarkets in Greater Sydney. These confirm the appropriateness of using socioeconomic characteristics as part of the model use to delineate submarkets in this study. In summary, the glaring disparities in terms of house

[1] This index is computed by incorporating household income, participation in the work force, education, family dynamics and housing arrangement. A score below 1000 indicates relative socioeconomic disadvantage.

prices, socioeconomic characteristics, and location of these submarkets validate the delineation of Greater Sydney into relatively low-priced and high-priced submarkets.

Table 1: ABS 2016 Index of Relative Socio-Economic Disadvantage of the Submarkets

LOW-PRICED SUBMARKET	SCORE	HIGH-PRICED SUBMARKET	SCORE
AUBURN	929	RANDWICK	1052
BANKSTOWN	935	SYDNEY	1027
BLACKTOWN	986	WAVERLY	1091
BLUE MOUNTAINS	1045	WOOLLAHRA	1115
CAMDEN	1056	RANDWICK	1052
CAMPBELLTOWN	950	HORNSBY	1091
FAIRFIELD	856	HUNTER HILLS	1098
HAWKESBURY	1028	KU-RING-GAI	1121
HOLROYD	929	LANE COVE	1111
LIVERPOOL	952	MANLY	1092
PARRAMATTA	1039	MOSMAN	1115
PENRITH	999	NORTH SYDNEY	1108
WOLLONDILLY	1043	PITTWATER	1092
BOTANY BAY	1001	RYDE	1058
HURSTVILLE	1020	THE HILLS SHIRE	1107
KOGARAH	1020	WARRINGAH	1092
ROCKDALE	1002	WILLOUGHBY	1083
SUTHERLAND	1080	**AVERAGE SCORE**	**1088**
ASHFIELD	1053		
BURWOOD	999		
CANADA BAY	1068		
LEICHHARDT	1053		
MARRICKVILLE	1053		
STRATHFIELD	1026		
AVERAGE SCORE	**1005**		

The 2016 ABS index of relative socio-economic disadvantage of the LGAs of the low-priced and high-priced submarkets. A score below 1000 denotes relative disadvantaged and above 1000 denotes relative advantaged. All LGAs in the high-priced submarket had a score above 1000, whilst those in the low-priced submarket had mixed results. The average score of the high-priced submarket is significantly higher than the low-priced submarket, demonstrating the difference in the socioeconomic characterisation of the two submarkets.

3.0 LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

An increasing attention has been placed on housing submarkets in the housing literature. A housing submarket is principally a result of the differences in terms of key socioeconomic, demographic, cultural and spatial factors. Thus, a housing market, particularly in a metropolitan area, should be analysed as a segmented and interconnected collection of housing submarkets, where each submarket characterises a set of exchange possibilities that include structural and locational attributes such as building, infrastructure, neighbourhood condition and status, environment, and public services. Both housing buyers and sellers reasonably view these housing characteristics as close substitutes (Galster, 1996). This is further reported by Bramley et al. (2008), who viewed submarkets as properties and locations that are likely considered as relatively close substitutes to housing demand. Hence location is an inherent attribute for both rental and sale dwelling properties (Galster, 1996). Besides, Bramley et al. (2008) report that an understanding of the demographic, social and economic characteristics of a neighbourhood is vital for both national and local housing policy makers.

Previous submarket studies have demonstrated the enhanced predictability power of submarket models and how property prices are determined by different functional relationships (Chen et al., 2009). One implication of housing submarkets is that the actual price of a given housing package may be different from that predicted primarily in terms of its attributes. Therefore, both attributes and submarket conditions are crucial factors in predicting housing prices (Galster, 1997). Bunker et al. (2005) demonstrate that there are series of typical submarkets resulting from the urban consolidation policy in Sydney, which are overlapping and have unique locational and spatial characteristics. Chen et al. (2009) compared the forecasting precisions of a single market hedonic model with seven spatially segmented markets that include two statistical clustering methods, three predefined geographical delineations, a method that combines statistical clustering and predefined areas, and a random segmentation method. They conclude that models with spatially disaggregated submarkets perform better in forecasting housing prices than a model without submarkets. A similar study was conducted by Leishman et al. (2013), using data on housing transactions from Perth, Western Australia, comparing three competing submarket modelling strategies - city-wide 'benchmark'; series of submarket-specific hedonic estimates; and multilevel model. In all three scenarios, they find that a separate estimation of the models for potential submarkets has a superior predictive power to the benchmark city-wide OLS hedonic model. Wilson et al. (2010) employ a cointegration analysis to investigate interaction among submarkets in the long run across the urban area of Aberdeen in the UK and how the different housing submarkets respond to different economic circumstances. By classifying house prices into low-priced, medium-priced and high-priced markets, Wilson et al. (2010) find that, price movement is varyingly binding over the long run in all three housing markets, implying that price behaviour in a 'micro' market does influence price behaviour in the same submarket over the long run. However, except for the short run, interest rate does not seemingly appear to influence the behaviour of any of these submarkets over the long run.

Furthermore, there is voluminous body of housing studies that focuses on the co-movement of housing prices at city, national and international levels. The work of Meen (1996) asserts that house price in one region is driven by house prices in other regions, indicating that housing markets can be viewed as a series of interrelated submarkets. This also known as a ripple effect. In the UK, for instance, Meen (1999) and MacDonald and Taylor (1993) show spillover effects or ripple effects across cities. Specifically, changes in house prices in London will be transmitted to other cities of the country. Similarly, Stevenson (2004) finds that house prices spread from Dublin to the regional centres and then to the peripheral areas. The ripple effect is also documented by Akimov et al. (2015) in Australia. These studies, however, mainly focus on housing price diffusion among different cities. Gupta et al. (2015), who examine co-movement of housing prices in Euro area using a fractional cointegration approach. Gupta et al. (2015) report that the Euro area is cointegrated with Belgium, Germany and France, and cointegration does exist between some European countries. In Australia, Luo et al. (2007) examine the ripple effects of house prices across Australia eight capital cities using a cointegration test and an error correction model. Their study shows a diffusion pattern across these cities with Sydney having the most equilibrium relationships with other cities followed by Melbourne. In the US, Doh-Khul et al. (2006) did a housing submarket study using a cointegration approach and found that existing properties are more responsive to expansionary monetary policies than new properties. McCord et al. (2014) explore the dynamic linkages and causal relationships between six key property types in Northern Ireland. Their findings show causal relationships between house price at particular pricing structures, but limited causalities at different ends of the price spectrum. Lean and Smyth (2013) also found a ripple effect is transmitted from the most developed states to the less developed states of Malaysia.

Importantly, this phenomenon is potentially more relevant to housing submarkets within a metropolitan city. As discussed earlier, there has been a growing amount of literature that has been devoted to the importance of housing submarkets as housing submarkets offer critical information that is not available at the aggregate level (Bourassa et al., 1999; Chen et al., 2009; Leishman et al., 2013). In addition, Meen (1996) and Adair et al. (2000) posit that housing market dynamics are better analysed as a series of interconnected submarkets in response to its complexity. Coupled with the complexity of housing market dynamics and the existence of housing submarkets, Jones and Leishman (2006) suggest that ripple effects could be greater in local housing markets compared with regional housing markets. However, little study has been devoted to examine the linkages between different housing submarkets within a metropolitan city. We explore the existence of a ripple effect of housing submarkets through the following hypothesis:

Hypothesis 1: There is empirical evidence to support the notion of ripple effect within a metropolitan city.

A variety of theoretical models have been proposed to explain the ripple effect, but the underlying theoretical explanations for the ripple effects are still not entirely clear. For instance, Ho et al. (2007) find strong evidence of ripple effect from housing submarkets with low quality (e.g. rental market) to housing submarkets with high quality, reflecting the equity transfer hypothesis in which households would like to trade up for a better house. The equity transfer hypothesis asserts that the possibility that movements in house prices are first observed in the relatively low-priced submarket before moving to the relatively high-priced submarket. Specifically, the spillover occurs when households trade up to the relatively high-priced submarket due to a gain in equity resulting from market valuation. This diffusion pattern is well noted by Galster (1996), who reports that a gain in equity can induce homeowners to move from one submarket to the other. This has also been discussed by a seminal study of Sweeney (1974). Sweeney (1974) proposed a filtering model in which a housing market is categorised into different quality levels. Households would relocate to houses of different qualities according to their willingness to pay and affordability or income levels. Stein (1995) expends the filtering model by considering households' equity. He asserts that if house prices are rising, current owners' home equity rises, increasing their wealth and allowing them move up their property ladder by trading up for the next higher quality homes. Similarly, households' ability to buy another house will fall sharply if house prices fall. As discussed earlier, the relative high-priced submarket in Greater Sydney is largely characterised by higher income and higher socioeconomic status (Randolph and Holloway, 2005). This combination of factors can potentially attract people to trade up to these areas when their equity increases. Based on this discussion, we formulate the following hypothesis:

Hypothesis 2a: House prices will be transmitted from the relative low-priced submarket to the relative high-priced submarket.

On the other hand, Teye et al. (2018) focus on subdistrict house price movements in Amsterdam and find that house price casual flow occurs fairly from the central to the peripheral subdistricts, supporting the migration hypothesis. Comparable evidence is found by Okikarinen (2006) in Finland. Ling and Hui (2013) also demonstrated that the long-term relationships among housing submarkets in Hangzhou, an emerging market, can be explained by development behaviour and family relocation pattern to some degree. Importantly, they found the flow from city centre to the periphery areas (or high-priced areas to low-end areas). The migration hypothesis posits that house prices will be transmitted from the relative high-priced submarkets to the relative low-priced submarkets through migration. This diffusion pattern, as described by Jones et al. (2003) and Meen (1999), occurs when households move to areas with relative low price. The crux of this hypothesis is also discussed by Gray (2017). Their study argues that households to take advantage of price differentials often put an upward pressure in the relative low-priced submarket. Households relocate to the relative low-priced submarkets in response to changes in the spatial distribution in house prices. Such household movements are well documented in regional markets by Gupta et al. (2015). This discussion leads to the second hypothesis:

> *Hypothesis 2b: House prices will be transmitted from the relative high-priced submarket to the relative low-priced submarket.*

To sum up, housing submarkets have strong analytical significance (Leishman et al., 2013). An investigation of housing submarkets provides greater perspectives into housing market dynamics and housing policy analysis (Galster, 1996), and restricting examination to a single metropolitan housing market can therefore yield incorrect inferences about housing price dynamics. Although there is an increasing contention regarding whether a ripple effect exist amongst housing submarkets within a metropolitan city, the theoretical explanation for the phenomena has not been fully understood. Additionally, a housing submarket analysis is somewhat limited in Australia despite Greater Sydney is an economically and socially diverse city.

4.0 DATA AND METHODOLOGY

4.1 Data

Quarterly data at local government area (LGA) level over 1991-2016 was collected for the two submarkets of Greater Sydney - the relative low-priced and the relative high-priced submarkets[2]. House price data was collected from Housing NSW and they use sales statistics that are derived from the information provided on the transfer of land that is lodged with Land and Property information NSW (Housing NSW, 2016). For market fundamentals, data and information were collected from diverse sources. Data on state final demand, which is a major proxy of the economic performance of the state of NSW was obtained from ABS and it includes economic activities relating to household and government final consumption expenditure, private and public capital investment (ABS, 2018a). Building starts data was gathered from ABS and they refer to the commencement of the first physical building activity on site that includes the materials fixed in place and/or the hiring of labour (ABS, 2018b). Estimated population of NSW was also collected from ABS (ABS, 2017c), while the Australia S&P 300, which gives insightful knowledge of the performance of the Australia stock market was obtained from Thomson Reuters Eikon. These variables often drive house prices (Brady, 2014; Hui and Yue, 2006). As the data was collected from various sources, the variables were all set at 1.00 from the first quarter of 1991 to remove any scaling effects on the data. Further diagnostic tests such as unit root test and LM test for serial correlation were conducted to correct any disturbances in the data. Table 2 gives a summary of the data of the variables used in the study[3]. Further, the median house prices of two submarkets are graphically displayed in Figure 2.

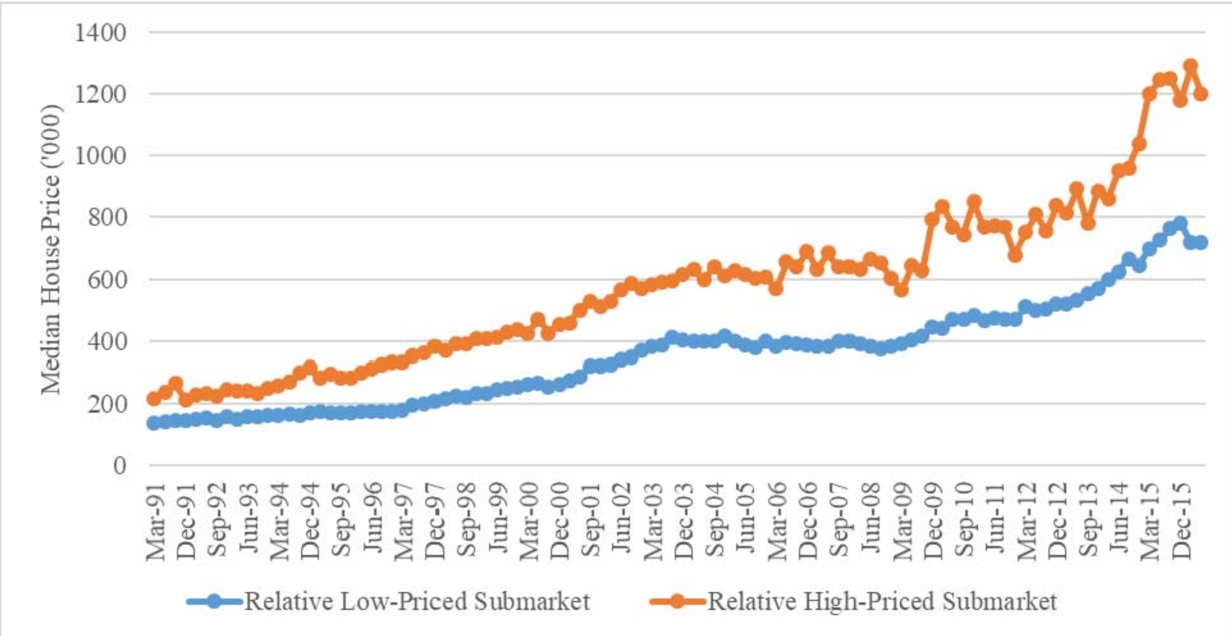
[2] The study period did not go beyond 2016 since the amalgamation of local councils within NSW commences this year, which essentially affects LGA data beyond 2016. However, the amalgamation of LGAs does not overlap across regions. Four of the study regions of Greater Sydney were affected by this amalgamation. In the west region, the City of Canterbury and Bankstown is a merger of the previous Bankstown and Canterbury councils; and the Cumberland Council combined the previous Holroyd and Auburn councils. In the inner-west region, the Inner-West Council was formed by the merger of the former Ashfield, Leichhardt and Marrickville councils. In the north region, Northern Beaches Council replaced the former Manly, Pittwater and Warringah councils. In the south region, the Georges River Council merged the former Kogarah and Hurstville councils. There is no merger in the east region.

[3] Applying these rescaled data in the regression analysis will not affect the t-values and the R^2, rather it makes the interpretation of the results a lot easier. A similar approach was done by Hoesli et al. (2007).

Table 2: Summary Statistics of the Variables

Statistic	Low Priced	High Priced	State Final Demand	ASX S&P 300	Building Starts	Population
Mean	354,000	574,000	76,099	22,528	10,680	6,688,290
Median	381,000	587,000	71,490	17,069	10,871	6,631,024
Max.	780,000	1,290,000	138,017	51,239	18,660	7,739,274
Min.	136,000	215,000	36,291	5,137	5,416	5,883,248
Std. Dev.	164,000	261,000	28,879	13,714	2,657	525,55

Figure 2: Median House Price Movement in the Submarkets of Greater Sydney



The house price movements in both submarkets show a generally upward trend in both submarkets. However, the disparity of housing prices between both submarkets has been widening over time, implying the existence of submarkets in Greater Sydney. Specifically, house prices are generally relatively lower in the low-priced submarket compared to the relatively high-priced areas throughout the study period. The house price differential among two housing submarkets is also consistent with the documented disparities in income levels, wealth, educational levels and employment opportunities between these two submarkets.

*4.2 **Methodology***

The analysis undertaken for this study involved three stages. Firstly, we examine the existence of ripple effect among housing submarkets with the Meen (1999)'s procedure. Secondly, the long-run linkage between different housing submarkets was assessed. Lastly, the long-run linkages between housing prices and market fundamentals are investigated.

*4.2.1 **The Meen (1999)'s Stationary Procedure***

Following Meen (1999), the existence of ripple effect in Greater Sydney was examined using Meen (1999)'s ratio of house prices procedure. As highlighted by Meen (1999), failure to detect stationarity in the regional-national house price ratios suggests regional and national house prices are segregated. This is an indication of segmentation or long-run divergence. On the other hand, if the ratio of house prices in a given region to the national house price is stationary, it can be asserted that house price should be constant in the long run; thereby there is a ripple effect.

To examine the existence of a ripple effect for two submarkets in Greater Sydney, both the Augmented Dickey Fuller and Phillips-Perron unit root tests were applied to test to the ratio of the median house price of each submarket of Greater Sydney to the median house price of Greater Sydney. The null hypothesis implies that housing prices are segregated between regions. However, the alternative hypothesis suggests that long-run constancy in the ratios, confirming the existence of a ripple effect among housing submarkets of Greater Sydney.

4.2.2 Long-run Interrelationship of Housing Submarkets

The second stage of the analysis examines the long-run interrelationship of housing submarkets. A cointegration test was used to assess whether both submarkets are linked together over time. The price leader submarket is identified using the Granger causality test.

Unit Root Test

As a precursory step to the cointegration test, a unit root test was used to test for the stationarity of a variable and the order of integration (Gujarati and Potter, 2009). Three forms of the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit root models were employed. Tests with no intercept and trend, intercept but no trend, and intercept and a trend were conducted using ADF and PP. In other words, this may have a stochastic process with no drift, or it may have a drift, or it may have both deterministic and stochastic trends. These approaches are robust in dealing with heteroskedasticity and serial correlation (Wilson et al., 2010). In case of the KPSS, tests were done only for intercept but no trend, and intercept and a trend. To allow for these various scenarios, the tests are estimated in these three different forms.

Cointegration Test

Once the two variables are tested to be of the same order, we can proceed with the cointegration test for each pair of variables. Three cointegration tests were employed in the study. These tests including the Engle-Granger cointegration test, the Phillips-Ouliaris procedure and the Johansen cointegration test. As reported by Ong and Sing (2002), the Engle–Granger (1987) is one of the most popular approaches in testing for the long-run relationship between two variables. The Phillips-Ouliaris procedure is also widely used to estimate the cointegration between two variables. It does so by estimating both the variance ratio test and the multivariate trace statistic (Phillips-Ouliaris, 1990). The Johansen bivariate cointegration test was employed as a robustness check to the results of the these two cointegration tests.

A unique long-run relationship between two house price time series, high-priced (P_1) and low-priced submarket (P_2) is cointegrated if (i) both time series are I(1) (so the series are stationary on first-differencing) and (ii) there is some linear combination of P_1 and P_2, that is I(0). When conditions (i) and (ii) hold, we can conclude that the series P_1 and P_2 are cointegrated and we can conclude that any correlation over time between P_1 and P_2 is not spurious. Two types of cointegration tests are often applied – with trend and without a trend.

$$\mathbf{P_1 = \widehat{P_1} + e_t = \widehat{\alpha_0} + \widehat{\alpha_1} P_2 + \mu_t} \qquad \textbf{(1)}$$

$$\mathbf{P_1 = \widehat{P_1} + e_t = \widehat{\alpha_0} + \beta_t + \widehat{\alpha_1} P_2 + \mu_t} \qquad \textbf{(2)}$$

The product of β and t is a time trend. In applying cointegration technique, first we regress P_1 on P_2 as in (1) and (2), then we estimate μ_t as follows:

$$\hat{\mu} = \mathbf{P1} - \widehat{P_1} \qquad \mathbf{(3)}$$

We now test the OLS residual for stationarity using ADF regressions. Stationarity in the residuals would imply that the variables, house prices in the high-priced submarket are cointegrated with those in the low-priced submarket. This process is a two-staged cointegration test.

Granger Causality Test

Once a stable cointegration among the relatively high-priced and the relatively low-priced submarkets has been established, a Granger Causality test was utilised to examine which submarket leads and which one follows. Granger Causality test is based on the framework of a lag model to investigate the influence of house price on each other. Let the high-priced submarket be represented by X and the low-priced submarket by Y with house prices $\mathbf{P_x}$ and $\mathbf{P_y}$ respectively, the test is expressed as follows:

$$\mathbf{P_{xt} = \omega_0 + \omega_1 P_{xt-1} + \ldots\ldots\ldots + \omega_p P_{xt-p} + \delta_1 P_{yt-1} + \ldots\ldots\ldots\ldots + \delta_q P_{yt-q} + \varepsilon_t} \qquad \mathbf{(4)}$$

$$\mathbf{P_{yt} = \omega_0 + \omega_1 P_{yt-1} + \ldots\ldots\ldots + \omega_p P_{yt-p} + \delta_1 P_{xt-1} + \ldots\ldots\ldots\ldots + \delta_q P_{xt-q} + \varepsilon_t} \qquad \mathbf{(5)}$$

Granger causality test is undertaken with Vector Error Correction (VEC) model[4] that employs the Wald Chi-square test and F tests to test the joint hypotheses: $\mathbf{\delta_1 = \delta_2 = \ldots\ldots\ \delta_q = 0}$ for (4) and (5) and test the null hypothesis $\mathbf{P_y}$ does not Granger-cause $\mathbf{P_x}$ in (4) and $\mathbf{P_x}$ does not Granger-cause $\mathbf{P_y}$ in (5). Essentially, if $\mathbf{P_y}$ is Granger-caused by $\mathbf{P_x}$, it indicates that past house prices in the high-priced submarket contain useful information for predicting house price in the low-priced submarket.

4.2.3 Dynamic Ordinary Least Square Model

Lastly, the dynamic OLS procedure (DOLS) is utilised to examine whether the dominance role of a submarket can be attributed to its responsiveness to market fundamentals. To extend this analysis we test whether different housing submarkets respond to market fundamentals differently from the low-end housing market. The DOLS procedure is well designed to deal with potential simultaneity bias and small-sample bias among the explanatory variables by incorporating lagged and lead values of differences of these explanatory variables (Bentzen, 2004; Lee and Lee, 2014).

To determine the impact of market fundamentals on house prices of the two submarkets of Greater Sydney, the following DOLS model is set out in Equations (6) and (7). Let P_1 represents house price in the high-priced submarket and P_2 is the house price in the low-priced submarket:

$$\mathbf{P_1 = \beta_0 + \beta_1 SFD_t + \beta_2 BLDSTAT_t + \beta_3 POP_t + \beta_4 STKS_t} + \sum_{p=-m}^{m}\left(a_{2p}(\Delta SFD_{t+p}\right) + \sum_{p=-1}^{p}\left(a_{3p}(\Delta BLDSTAT_{t+p}\right) + \sum_{p=-1}^{p}\left(a_{4p}(\Delta POP_{t+p}\right) + \sum_{p=-1}^{p}\left(a_{5p}(\Delta STKS_{t+p}\right) + \varepsilon_t \qquad \mathbf{(6)}$$

[4] As discussed by Engle and Granger (1987), VEC models should be employed if the variables are cointegrated as the dynamic relation should be mis-specified if a traditional unrestricted Vector Autoregressive (VAR) was employed.

$$P_2 = \beta_0 + \beta_1 SFD_t + \beta_2 BLDSTAT_t + \beta_3 POP_t + \beta_4 STKS_t + \sum_{p=-m}^{m}\left(a_{2p}\left(\Delta SFD_{t+p}\right) + \sum_{p=-1}^{p}\left(a_{3p}\left(\Delta BLDSTAT_{t+p}\right) + \sum_{p=-1}^{p}\left(a_{4p}\left(\Delta POP_{t+p}\right) + \sum_{p=-1}^{p}\left(a_{5p}\left(\Delta STKS_{t+p}\right) + \varepsilon_t \qquad (7)$$

where the variables SFD is state final demand, a proxy of the economic performance of the state of NSW; BLDSTAT is building starts, representing the commencement of residential buildings; POP measures the population; and STKS is the S&P/ASX 300 index, representing the stock market. The estimated parameters, β_1 to β_4 are expected to be positive.

5.0 RESULTS AND DISCUSSION

The Meen (1999)'s Ratio Unit Root Tests

The existence of a ripple effect among housing submarkets in Greater Sydney was firstly examined using the Meen (1999)'s ratio of house prices procedure. Similarly, the Augmented Dickey Fuller and Phillips-Perron unit root tests are used to test the stationarity of the ratio of the median house price of each submarket of Greater Sydney to median house price of Greater Sydney. The results are reported on Table 3.

Table 3: Meen's Unit Root Ratio

	Ratio of Low-Price to Greater Sydney (t-stat)	**Ratio of High-Priced to Greater Sydney** (t-stat)
ADF	-3.63***	-3.86***
PP	-6.30***	-6.44***

The ADF and PP test the null hypothesis of a unit root in the ratio of the median house price of the low-priced submarket to the median house price of Greater Sydney, and the ratio of the median house price of the high-priced submarket to the median house price of Greater Sydney. Both the ADF and PP results reject the null hypothesis on level at P<0.00, indicating the existence of a ripple effect in the housing market of Greater Sydney. *** denotes a rejection of the tested hypothesis at the 1% level.

The results exhibit that the price ratio, in each case, is stationarity at the 1% significance level, indicating that there is long run constancy in these ratios and supporting the notion of the existence of ripple effects among the submarkets of Greater Sydney that will eventually restore the relationship into a long run equilibrium over time. Importantly, the presence of a ripple effect asserts a long run time invariant mean, that is, some long run price differential between submarkets where deviations are mean reverting. This suggests that the convergence of submarkets in Greater Sydney and house prices of a sub-housing markets in Greater Sydney to rise or fall first, and to gradually spread out to other sub-housing markets over time.

The documented results are consistent with the findings of Chien (2010), Cook (2012) and Lean and Smyth (2013) in the regional housing markets, highlighting that the existence of a ripple effect in housing markets seem to be a common result amongst the literature. Importantly, it asserts that the ripple effect does not only confine to regional housing markets, but also within a single housing market with strong heterogeneity or different submarkets. This also provides some empirical evidence to support the existence of a ripple effect in sub-housing markets. Further, this also offers some indirect support to the assertion of Jones and Leishman (2006) in which the ripple effect could be greater in local housing markets than regional markets.

Overall, the evidence of convergence or a ripple effect within a single housing market is presented by Meen's (1999) framework. Specifically, there is evidence of convergence or a ripple effect for both high-priced and low-priced submarkets in Greater Sydney. But the Meen's (1999) price ratio framework does not provide information about the housing price transmission mechanism among different sub-housing markets. To assess the long-run relationships between different sub-housing markets, a more in-depth analysis is required.

Unit Root Test

The results of the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit root models of the house prices of the two submarkets are reported in Table 4. In general, house prices of these two submarkets have unit root on levels but become stationary after first difference for both the ADF and the PP at the 1% significance levels. Both data series are integrated at the first difference level I(1). Rejecting the null hypothesis of the presence of a unit root indicates that house prices in these two spatially defined submarkets are not stable over time. The KPSS also rejects stationarity in level but it does not reject at first difference with a constant and a trend, confirming that the series are I(1).

Table 4: Unit Root Results of House Prices of both Submarkets

		Intercept without trend		**Intercept with trend**		**No intercept and trend**	
		Level (t-stat)	**1st Diff** (t-stat)	**Level** (t-stat)	**1st Diff** (t-stat)	**Level** (t-stat)	**1st Diff** (t-stat)
Low-Priced	ADF	1.42	-9.79***	1.02	10.07***	4.27	-4.27***
	PP	1.45	-9.85***	-1.12	-10.1***	4.16	9.06***
	KPSS	21.69***	0.01	9.08***	0.44		
High-Priced	ADF	1.25	14.18***	-1.10	-14.4***	3.21	-13.37***
	PP	0.61	-13.98***	-2.43	-14.3***	-1.92	-12.93***
	KPSS	22.16***	0.04	9.25***	0.87		

The ADF and the PP test the null hypothesis of a unit root in the house prices of both the low-priced and the high-priced submarket, whilst the KPSS tests the null hypothesis of no unit root. The results of the ADF and PP failed to reject the null hypothesis on level at P<0.05, but there is clear rejection after first difference at P<0.01 for all three scenarios: intercept without trend; intercept with trend; and no intercept and trend. The KPSS test supports these results, as it failed to reject stationarity on level but does not reject stationarity after first difference at P<0.01. *** denotes a rejection of the tested hypothesis at the 1% level, ** is rejection of the null hypothesis at 5% level, * is a rejection of the tested hypothesis at 10% level.

Overall, both housing submarkets have a unit root in levels, but both series are stationary after the first difference. This suggests that both series might be cointegrated over a long run; thereby a cointegration analysis was undertaken in light of both series being I(1).

Cointegration Test

To formally evaluate the long run relationship of both housing submarkets, a cointegration test was undertaken using the Engle-Granger and Phillip-Ouliaris cointegration tests, as well as the Johansen bivariate cointegration test. The results are reported in Tables 5 (a-b).

As can be seen from Table 5a, the null hypothesis of no cointegration for both submarkets can be rejected at the 1% significance level. Specifically, the tau-statistic and z-statistic are statistically significant at 1%, indicating there is a long run relationship between these submarkets of Greater Sydney. Comparable evidence is also found by the Johansen bivariate cointegration method which shows that there is at least one cointegrating equation in each pair of submarkets for both the trace (P<0.01) and max-eigen (P<0.01) statistics. The Johansen results in Table 5b are supportive of both the Engle-Granger and Phillip-Ouliaris cointegration tests of rejecting the null hypothesis of no cointegration at 1% significance level.

Table 5a: Engle-Granger and Phillip-Ouliaris Cointegration Tests (tau and z statistics)

	Dependent	Independent	tau-statistic	z-statistic
Engle-Granger	Low-priced	High-priced	-6.97***	-66.44***
	High-price	Low-priced	-7.06***	-67.92***
Phillip-Ouliaris	Low-priced	High-priced	-7.19***	-73.00***
	High-price	Low-priced	-7.26***	-73.97***

Both the Engle-Granger and the Phillip-Ouliaris cointegration tests reveal a contemporaneous long run relationship in house prices between the low-priced and high-priced submarkets. The null hypothesis of no cointegration is soundly rejected at P<0.01 by both tests. Each test used house price in one submarket as the dependent variable and the other as the independent and interchange the variables resulting into two set of results from both tests. All variables are I(1) as shown by the results of the ADF, PP and KPSS on Table 4.

Table 5b: Bivariate Johansen Cointegration Tests (Trace and Max-Eigen statistics)

	Trace-Statistic	Prob.	Max-Eigen-statistic	Prob.
None*	22.03***	0.00***	20.18***	0.00***
At least 1	1.84	0.17	1.84	0.17

The results of the bivariate Johansen cointegration test support both the Engle-Granger and the Phillip-Ouliaris results of a contemporaneous long run relationship in house prices between the low-priced and high-priced submarkets. The null hypothesis of no cointegration is soundly rejected at P<0.00. Similarly, all variables are first differenced stationary as shown by the results of the ADF, PP and KPSS on Table 4.

The cointegration tests, in general, provide findings supportive of long-run convergence in prices across housing submarkets in Greater Sydney. Specifically, there is a contemporaneous long run relationship between the relatively high-end and low-priced submarkets of Greater Sydney. This indicates that, over time, the changes in house price in a submarket (for example, the low-priced submarket), will certainly affect house prices in another submarket (for example, the high-priced submarket). The results are consistent with the finding of Wilson (2010) in which at least one cointegrating relationship within each of the broad classifications of housing markets in Aberdeen. Comparable evidence is also found by Jones et al. (2003) in which three cointegrating relationships out of the fifteen paired combinations of submarkets in Glasgow; and Oikarinen (2006), who confirmed the existence of cointegration between the suburbs and the city centre within Helsinki Metropolitan Area.

Overall, the combined long-run analysis of the co-integration and convergence test, indicate that there exists a common long-term relationship between housing submarkets in Greater Sydney. This implies that there is a ripple effect among housing submarkets in Greater Sydney.

Granger Causality Test

With the existence of cointegration between the high-end and low-priced submarkets, it raises the question of how house prices diffuse between these two submarkets. This section investigates the causality between both submarkets using a pairwise Granger causality test. The test allows us to identify the 'price leader' between both submarkets and determine the submarket that drives the other submarket. Further, the results also offer some empirical evidence to support the theoretical explanations of the ripple effect. Since house price series in both submarkets are first difference stationary, the results of the Granger causality are reported on Table 6.

Table 6: Pairwise Granger Causality Tests

Housing Type	Null Hypothesis	F-Stat	Prob.
All dwellings	ΔHigh-priced does not Granger cause Δlow-priced	1.09	0.34
All dwellings	ΔLow-priced does not Granger cause Δhigh-priced	12.16	0.00***

House prices for all dwelling are I(1) stationary. *** denotes a rejection of the tested hypothesis at the 1% level, ** is rejection of the null hypothesis at 5% level, * is a rejection of the tested hypothesis at 10% level.

The Granger-causality test reveals that the low-priced submarket is the dominant submarket in Greater Sydney. Specifically, the low-priced submarket Granger-causes the high-priced submarket at 1% significance level, suggesting that the low-priced submarket contains useful past information that can be used to explain the movement of house prices in the high-priced submarket. Fundamentally, housing prices in the low-priced submarket will be transmitted to the high-priced submarket. This suggests that when changes in market fundamentals occur, house prices first increase in the low-priced submarket and then it will be diffused to the high-priced submarket through current households' trade-ups resulting from the increase in equity of their current houses. The results can be interpreted as supporting the equity transfer hypothesis. Specifically, households, particularly repeat buyers are likely to purchase another, more expensive, home if house prices are rising. This can be explained by Stein's (1995) model in which rising house prices can increase current homebuyers' wealth and allow them to make a larger down payment for another home; thereby trading up is facilitated. Similarly, households' ability to purchase another home is decreased significantly if house prices fall.

Nevertheless, there is little evidence to suggest house prices in high-priced submarkets Granger-causes low-priced submarkets, indicating that house prices in high-end submarket cannot be transmitted into low-priced submarket. In other words, there is a unidirectional relationship between both submarkets. In addition, it also suggests that no evidence to support the migration hypothesis in Greater Sydney. Although results here are a clear departure from the finding of Teye et al. (2018) in Amsterdam, the results are somewhat consistent with the finding of Oikarinen (2006). He found little empirical evidence to support the notion of households will relocate in response to changes in the spatial distribution in house prices.

To sum up, the Granger-causality tests confirm that the relatively low-priced submarket is the dominant submarket in Greater Sydney in which house prices in the low-priced submarket will be transmitted to the high-end submarket, supporting the equity transfer hypothesis.

Long-run Linkages between Housing Prices and Market Fundamentals

The previous section provided some indication that shocks in the low-end submarket will be transmitted to the high-end submarket; thereby the low-priced submarket is a dominant market in housing price transmission. The next concern is whether the dominance role of the low-end submarket can be attributed to its responsiveness to market fundamentals. To extend this analysis we test whether different housing submarkets respond to the economic stimuli differently. More specifically, it assesses whether house prices in the low-end submarket are more responsive to economic fundamentals compared with the high-end submarket. To address this issue, the determinants of housing prices in both submarkets are scrutinized using a long run equilibria estimator, the dynamic ordinary least square (DOLS). State final demand, building starts, the S&P/ASX 300 Index, and population are used as proxies of market fundamentals. The results of the multivariate cointegration and DOLS are reported on Table 7[5].

Table 7: DOLS for Low-Priced and High-Priced Submarkets

$$P_1 = \beta_0 + \beta_1 SFD_t + \beta_2 BLDSTAT_t + \beta_3 POP_t + \beta_4 STKS_t + \sum_{j=-m}^{m}\left(a_{1j}\left(\Delta SFD_{t+j}\right)\right) + \sum_{j=-p}^{p}\left(a_{2j}\left(\Delta BLDSTAT_{t+j}\right)\right) + \sum_{j=-p}^{p}\left(a_{3j}\left(\Delta POP_{t+j}\right)\right) + \sum_{j=-p}^{p}\left(a_{4j}\left(\Delta STKS_{t+j}\right)\right) + \varepsilon_t$$

$$P_2 = \beta_0 + \beta_1 SFD_t + \beta_2 BLDSTAT_t + \beta_3 POP_t + \beta_4 STKS_t + \sum_{j=-m}^{m}\left(a_{1j}\left(\Delta SFD_{t+j}\right)\right) + \sum_{j=-p}^{p}\left(a_{2j}\left(\Delta BLDSTAT_{t+j}\right)\right) + \sum_{j=-p}^{p}\left(a_{4j}\left(\Delta POP_{t+j}\right)\right) + \sum_{j=-p}^{p}\left(a_{5j}\left(\Delta STKS_{t+j}\right)\right) + \varepsilon_t$$

Long Run Variable	**Low-priced Coefficient/t-statistic**	**High-priced Coefficient/t-statistic**
State final demand	(0.67)	(0.24)
	(1.97)*	(0.41)
Building starts	(1.39)	(0.57)
	(8.96)***	(1.73)*
Australia S&P 300	(0.48)	(0.15)
	(5.56)***	(1.40)
Population	(0.53)	(6.96)
	(0.22)	(1.51)
Constant	(-1.16)	(-6.97)
	(-0.57)	(-1.78)
Log likelihood	0.99	0.97

The dependent variable is the house price in each submarket and the explanatory variables, state final demand, building starts, Australia S&P 300 and population are proxies of economic fundamentals. *** rejects the tested hypothesis of no significance at the 1% level, ** rejects the null hypothesis of no significance at 5% level, * is a rejection of the tested hypothesis of no significance at 10% level. Coefficients are estimated with robust standard errors and the t-statistics are in parenthesis. The variables are scaled to 1.00 to address any scaling effects on the data.

The results from the DOLS models, shown in Table 7, exhibit that irrespective of submarkets, house starts do not only have a discernible impact on housing prices but are so to a statistically significant extent. The results are consistent with the finding of Miles (2009) and Lee (2011) in which housing starts are a form of "irreversible" investment. Importantly, housing starts are leading indicators of the business cycle (Green, 1997); thereby housing starts emerge as a key measure of the prosperity of an economy. In a similar vein, an expansion or contraction of an economy does have a significant impact on housing prices. As a result, it is reasonable to document a long-run positive link between housing starts and housing prices in both submarkets. Furthermore, housing starts have a stronger impact on the low price submarket than the high price submarket. This indicates the dominant role of the low-priced submarket.

As hypothesised, the coefficient of state final demand is positive and statistically significant at 10% for the low-end housing submarket. Comparable evidence is also found in the high-end housing submarket, but state final demand did not do so to a statistically significant extent. In short, it has a direct relationship with house price in both submarkets, indicating expansionary economic activities can possibly increase households' incomes and drive housing demand and prices. Similarly, a recession would significantly reduce the demand for

[5] Though not reported here, these variables are stationary after first difference I(1) and are cointegrated with house prices in both the low-priced and high-priced submarkets. Three different information criteria, Akaike (AIC), Schwartz Bayesian (SIC) and Hannan-Quinn (HIC) were used to determine the appropriate lag length. The information criteria suggest a minimum lag length of four for both the low-priced and high-priced submarkets. Using the LM test, the null hypothesis of no Serial correlation was also rejected at 5% significance level in both models. These suggest that the DOLS is appropriate.

housing particularly in the low-priced submarket. Comparable results were obtained at a national level by Worthington and Higgs (2013).

Results in Table 7 also reveal that the movement of the broader stock market would do have an impact on house prices in the low-priced submarket. However, the positive, but statistically insignificant, coefficient of the S&P/ASX 300 Index for the high-priced submarket suggests that whilst house prices in the high-priced submarket responded positively to the stock market in the long-run, it did not do so to a statistically significant extent. The long-run interrelationship between stocks and housing prices have also been widely discussed in the housing literature. This finding can be interpreted as supporting the earlier findings of Dvornak and Kohler (2007) and Lee et al. (2017) in which they found a direct link between stock market wealth and housing wealth in Australia. Another interesting observation is that population does have a positive effect on house prices. The results are intuitively appealing as population growth reflects higher housing demand. However, it is statistically insignificant in both submarkets. This could be, at least to certain extent, attributed to the deterioration of housing affordability, particularly among first home buyers in Australia over time (Lee and Reed, 2014). Nevertheless, the results are in line with the finding of Yates (2008) and the Productivity Commission (2004).

A comparison between the low-priced and high-priced submarkets does reflect some differences between both submarkets. Specifically, the low-priced submarket appears to be more responsive to market fundamentals, indicating that this submarket is more susceptible to changes in economic fundamentals. Specifically, state final demand, housing starts and stocks all have a significant impact on house prices in the low-priced submarket, whilst the high-priced submarket is only affected by housing starts in the long run. The results not only highlight that the low-priced submarket is more responsive to changes in market fundamentals compared with the high-priced submarket, but also further highlights the discrepancy between both submarkets. The finding can be interpreted as supporting the equity transfer hypothesis; whereby the low-priced submarket leads the high-priced submarket. Given households in the low-priced submarket are likely to respond to changes in market fundamentals at a faster pace, it is reasonable to document that house price shocks in this submarket will be transmitted to the high-priced submarket through a process of equity transfer. In summary, the dominance role of the low-end submarket can be attributed to its responsiveness to market fundamentals.

Robustness Checks

A number of robustness checks were undertaken in order to enhance the robustness of the baseline findings. First, there is still a critical remaining question of whether the abovementioned results can be generalised into different types of dwelling. To address this, we disaggregated all dwellings into strata and non-strata residential dwellings in the low-priced and high-priced submarkets in respect to the study of Morley and Thomas (2016) and Lee (2017), who have demonstrated that different types of housing have different risk-return profiles; thereby types of housing can be also defined as different housing submarkets. This is a key issue for policy makers and one that will enable more informed decision making. Strata titles, as defined by Housing NSW, include town houses, terraces/villas, flats/units, whereas non-strata title properties refer to detached houses. The empirical results are presented in Table 8.

Table 8: Pairwise Granger Causality Tests

Housing Type	Null Hypothesis	F-Stat	Prob.
Non-strata	∆High-priced does not Granger cause ∆low-priced	1.70	0.10
Non-strata	∆Low-priced does not Granger cause ∆high-priced	2.90	0.00***
Strata	∆High-priced does not Granger cause ∆low-priced	1.33	0.26
Strata	∆Low-priced does not Granger cause ∆high-priced	2.27	0.06*

House prices for all housing types are I(1) stationary. *** denotes a rejection of the tested hypothesis at the 1% level, ** is rejection of the null hypothesis at 5% level, * is a rejection of the tested hypothesis at 10% level.

Our cointegration tests[6] suggest that there is a long run relationship between strata units in the low-priced submarkets and the high-end submarkets. Comparable evidence is also documented in the non-strata houses at the 1% significance level. Results here confirm the preceding finding of low-priced and high-priced submarkets are cointegrated in a long run. This relationship is robust to different types of housing. Importantly, the results from Table 6 depict that non-strata house prices in the low-priced submarket Granger causes non-strata dwelling prices in the high-end submarket, suggesting that price changes in non-strata dwellings in the low-priced submarket would be transmitted to non-strata dwellings in the high-priced submarket. This finding also holds for strata dwellings in respect to a unidirectional link between low- and high-end submarkets. Overall, results here confirm that our baseline results are robust to different types of housing in general and there is a ripple effect through the household equity transfer mechanism in particular.

Second, one could make a case that a comparison of low-priced and high-priced submarkets in Greater Sydney could incorporate some biases in that inner-west and southern regions could be classified as a medium-priced submarket instead of a low-priced submarket. As such, the interrelationships of housing submarkets in Greater Sydney were re-estimated. Specifically, Greater Sydney is decomposed into three, namely low-priced, medium-priced, and high-priced submarkets. In a similar fashion to the 'price leadership' analysis, a pairwise Granger-causality analysis was undertaken and the empirical results are displayed in Table 9.

Table 9: Pairwise Granger Causality Tests

Housing Type	Null Hypothesis	F-Stat	Prob.
All dwellings	∆Low-priced does not Granger cause ∆medium-priced	4.41	0.00***
All dwellings	∆Medium-priced does not Granger cause ∆low-priced	1.89	0.12
All dwellings	∆Low-priced does not Granger cause ∆high-priced	4.87	0.00***
All dwellings	∆High-priced does not Granger cause ∆low-priced	1.49	0.21
All dwellings	∆Medium-priced does not Granger cause ∆high-priced	12.46	0.00***
All dwellings	∆High-priced does not Granger cause ∆medium-priced	1.41	0.24

House prices for all housing types are I(1) stationary. Inner-west and southern regions were excluded from the low-priced submarket in Table 6 to form the medium priced submarket. *** denotes a rejection of the tested hypothesis at the 1% level, ** is rejection of the null hypothesis at 5% level, * is a rejection of the tested hypothesis at 10% level.

The results exhibit that house prices in the low-priced submarket Granger causes house prices in the medium-priced and high-priced submarkets. This offers some further evidence to support that the ripple effect of housing submarkets is caused by the equity transfer channel

[6] The cointegration results are not reported for brevity. But the results are available from the authors.

in which households would relocate to houses of different qualities according to their affordability and willingness to pay. When there is a positive shock to the wealth of households, it leads to higher demand for the lower quality tier houses; the increase subsequently pushes up the demand and prices in higher priced markets due to the increased equity or wealth of current homeowners. Similarly, housing demand will drop in the low-priced submarkets first during a down turn market. As a result, it is reasonable to document that house price causal flow occurs fairly from the low-end submarket to the medium-price submarket. Importantly, the price leadership analysis further demonstrated that housing price in the medium-end submarket shocks ripple to the high-end submarket. However, no evidence of recursive ripples in which the shocks will be rippled or echoed, back to lower-price submarket. Overall, the results are consistent with the baseline results, indicating that the conclusion made earlier in respect to the equity transfer hypothesis still hold. Specifically, the low-priced submarket tends to feed information to the rest of other submarkets with higher prices.

6.0 CONCLUDING REMARKS

There is a growing interest in the interrelationships of housing submarkets but none has fully considered the causes of the interrelationships of these housing submarkets. This study contributes to the literature by complementing the existing work on house price diffusion through an analysis of housing submarket perspective in the context of Greater Sydney, one of the most diverse housing markets in Australia. We disaggregated submarkets into relative high-priced and relative low-priced submarkets. We deployed a pairwise cointegration test and a dynamic ordinary least square (DOLS) model to examine the ripple effect of both submarkets using the quarterly house price sales data published by Housing NSW over Q2:1991-Q2:2016.

The current study provides a number of important insights. Firstly, a contemporaneous long run relationship in house prices is established between the high-priced and the low-priced submarkets of Greater Sydney, indicating that these two submarkets are not segmented but converge to a single market over time. This suggests that there is a ripple effect within a single housing market. Secondly, house price changes diffuse from the less economically prosperous submarket (low-priced) to the high-end submarket. This supports the equity transfer hypothesis in which, as market fundamentals change, households would move to the high-priced submarket in respond to the increased equity. Thirdly, the equity transfer hypothesis is further confirmed by the dominance role of the low-priced submarket in respect to it primarily reacting to changes in market fundamentals. Specifically, house prices in this submarket are strongly associated with economic fundamentals (i.e. state final demand, Australia S&P 300, population and building starts), whilst no comparable evidence is found for house prices in the high-end submarket.

The findings have some profound implications. The evidence of equity transfer diffusion pattern shows that households in Greater Sydney tend to initially buy properties in less desirable areas but trade up to more desirable areas as their equity improves. This is particularly the case for residents from the low-end submarket, who tend to use their initial purchase as a springboard to subsequent purchases. Housing trade up towards the more prosperous submarket of the city has important implications for housing policymakers. This suggests that homeownership should be promoted and encouraged in light of it emerges as a critical strategy for most households to moving up the housing ladder. The existence of a contemporaneous long run relationship in house prices between the high-priced and low-priced submarkets of Greater Sydney means current and potential home owners are often affected in varying ways by ongoing changes in house prices in the city. As both submarkets are intertwining, residents from the submarket with low socioeconomic characteristics can potentially be affected more than those from the higher end of the spectrum. This is further exacerbated by the fact that the relative low-priced submarket is more affected by the market fundamentals than the relative high-priced submarket. This leads to a question that the appropriateness of uniform housing policies in addressing regional imbalances within the city. The study has therefore provided useful tools to policy regulators to addressing socioeconomic imbalances that are related to housing desirability within the city.

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8.0 APPENDIX

Appendix 1: Regions of Greater Sydney

WESTERN	SOUTHERN	INNER-WEST	EASTERN	NORTHERN
AUBURN	BOTANY BAY	ASHFIELD	RANDWICK	HORNSBY
BANKSTOWN	HURSTVILLE	BURWOOD	SYDNEY	HUNTER HILLS
BLACKTOWN	KOGARAH	CANADA BAY	WAVERLY	KU-RING-GAI
BLUE MOUNTAINS	ROCKDALE	LEICHHARDT	WOOLLAHRA	LANE COVE
CAMDEN	SUTHERLAND	MARRICKVILLE		MANLY
CAMPBELLTOWN	BOTANY BAY	STRATHFIELD		MOSMAN
FAIRFIELD				NORTH SYDNEY
HAWKESBURY				PITTWATER
HOLROYD				RYDE
LIVERPOOL				THE HILLS SHIRE
PARRAMATTA				WARRINGAH
PENRITH				WILLOUGHBY
WOLLONDILLY				

The classifications of the LGAs of Greater Sydney into regions five regions – west, south, inner-west, east and north. As discussed in Section 2, this taxonomy is based on the degree of house price substitutability, socioeconomic characteristics and spatial delimitation. These regions are further combined into low-priced (west, south and inner-west) and high-priced (east and north) submarkets.