International Funding Cost and Mortgage Interest Rate Transmission in Australia

Author

Pham, Quynh

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Quynh Chau Pham

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Quynh Chau Pham
BSs, BC, MPhil (Vietnam)

Department of Accounting, Finance and Economics
Griffith Business School
Griffith University

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Abstract

This document is constructed from four interrelated empirical papers examining the mortgage interest-rate pass-through mechanism in the Australian banking market over the period 1997:1–2015:12 employing an anonymous sample of 20 banks anonymised. In particular, the transmission from both the bank international funding cost and the cash rate to the effective interest rate on the variable home loans for owner-occupiers, both asymmetries (downward and upward) and symmetries (homogeneity or heterogeneity), are investigated in parallel in the short run and in the long run. Furthermore, the effects of the recent Great Recession (GFC) on this transmission mechanism are carefully considered in different manners while controlling for nonlinearity, slope heterogeneity, complex cross-sectional dependencies arising from both observed and unobserved common factors in panel data. The economic imperative of this examination focuses on seven key reasons: (i) the paramount importance of the Australian mortgage market to monetary policy transmission, housing and financial soundness in Australia, and to the stability of global banking and financial markets, (ii) the salient characteristics of the mortgage products, (iii) the high oligopoly of the mortgage market and banking sector, (iv) the heavy reliance of Australian banks on wholesale funding to finance their mortgages, (v) the increased public concern about bank mortgage rate-setting behaviour and a proliferated attention of regulators (Australian Prudential Regulation Authority [APRA], Reserve Bank of Australia [RBA] and related bodies) towards the enhancement of banking competition and financial soundness, (vi) the small quantity of the literature on the policy rate–mortgage rate transmission using micro-data, considering the substantially dire effect of the GFC on this asymmetric transmission in Australia, and (vii) a lack of knowledge about the role of bank international funding cost on mortgage rate pass-through mechanisms in Australia.

The first empirical essay explores Australian mortgage interest-rate pass-through: does international funding cost matter? This study contributes significantly to the existing literature on the policy rate–mortgage rate association, with two key novelties. This is the first empirical analysis of the transmission from changes in international funding cost to mortgage interest rates at individual Australian banks and provides fresh convincing evidence for this cointegrating relationship. This essay is the first comprehensive analysis of the cash rate transmission to mortgage rates for Australia with regards to impact, short-term cumulative and long-term asymmetries. From a wider governing perspective, this bank-based interest-rate finding is supportive of the development of a comprehensive proxy for bank marginal funding cost, as opposed to the implementation of the cash rate. This study further contributes to the descriptive literature that argues 'international funding cost affects bank mortgage rate-setting behaviour' by providing new insights: that the significant positive asymmetries of mortgage rate adjustments to changes in the international funding cost and the cash rate exist in the long term for virtually all individual banks. The instant and short-term cumulative asymmetries have also occurred in several sampled banks, but they show wide discrepancies in size and sign. The long-term positive asymmetry and short-term heterogeneous asymmetry in the funding cost transmission provide empirical support to the market power of Australian banks in pricing. These findings of the first study suggest that, while the regulators revise and reform their banking governance regimes, they should seriously consider the key factor of bank market power, as well as bringing stronger customer protection procedures into effect. Finally, this essay explores three components, international funding cost, the cash rate, and mortgage rate pass-through, showing for the first time a strong interactive effect of foreign funding cost and the cash rate on mortgage rates at an individual level. The finding suggests that the prudential bodies, APRA and RBA, should carefully consider the international funding cost–mortgage rate

nexus if they are striving against potential housing finance and economic fragility. In this study, I conclude that mortgage rate adjustments are being significantly adjusted in response to international funding cost shocks for individual banks, while the cash rate drives mortgage rates in both short term and long term. The nature of these transmission mechanisms is asymmetric in three dimensions: immediate, in the short run and in the long run.

The second empirical essay, building on the first study, provides a comprehensive analysis of the asymmetric association between bank funding costs and mortgage rates, considering account the effect of the crisis and the bank-specific and time effects on this transmission. This initial study examines such a relationship in a small open economy but its mortgage market is one of the eight world-leading mortgage markets, based on the EMF (2016) statistics. The Australian ratio of total outstanding residential loans (home loans) to GDP is the fourth highest (60%), just behind the Netherlands (95%), the UK (68%), and the US (63%), but well above the four others, Spain (52%), France (44%), Germany (42%) and Japan (41%). However, based on their ratios of total mortgages (home loans and housing loans for investors) to GDP in the IMF (2017) database, Australia (105%) stands closely behind only the Netherlands (110%), but far above most of the others, the US (80%), the UK (90%), and the rest (around 50–60%). Therefore, it is of paramount importance to identify whether the crisis has any impact on the transmission of funding costs to mortgage rates in Australia, given the collapse of the US sub-mortgage market and the 2007–11 systemic banking crises in the US, Greece, Spain, Belgium, Iceland, Ireland, which are associated with a housing credit boom similar to Australia's current position (Laeven & Valencia, 2013). Moreover, it is crucial to assess whether international funding cost attributes to the recent 'out-of-cycle' mortgage price-setting conduct of Australian banks after the GFC. This essay contributes further econometrically to the literature by investigating the effect of both bank-specific and time dimension on the interest-rate

transmission mechanisms that have been disregarded in the prior literature. This empirical essay finds that, although the cash rate transmission in Australia has been weakened since the GFC, banks have still continued setting their mortgage rates in an upward asymmetric manner, increasing faster than falling. Importantly, this study ascertains that the post-crisis effects of foreign funding costs on mortgage rates are stronger than the pre-crisis and GFC influences. The findings indicate that the cash rate has been unable to reduce the bank markups charged over funding costs after the crisis. This study concludes that, since the GFC, Australian banks' pricing behaviour has remained positively asymmetric in the long term, but it has significantly transformed from a cash-rate-based model to a foreign-funds-rate-based model. Therefore, this study proposes several important policy implications—for significant reforms of the RBA, and with stronger competition and customer protection schemes for the APRA and Australian Competition and Consumer Commission [ACCC].

The third empirical essay further explores heterogeneity in mortgage interest-rate pass-through at an Australian bank level by answering three research questions: (i) Do unobservables affect the interest-rate transmission, both symmetric and asymmetric, when considering both bank-specific effect and time dimensions? (ii) Is the nature of the long-term interest-rate transmission, both symmetry and asymmetry, accurately homogeneous? (iii) Does the international funding cost still affect the mortgage rate when controlling for cross-sectional dependence? This is the first study in the literature on monetary policy rate transmission to empirically investigate the effect of unobserved factors on the transmission while carefully testing the cross-sectional dependence properties of the macro panel data. As finance and banking environments are highly integrated, locally and internationally, it is important to examine the role of unobservables in bank price-setting behaviour, considering cross-sectional dependence inherent in panel data. Thus, this study provides convincing evidence to understand far more deeply and accurately

the bank funding cost–mortgage rate nexus. A richer line of research has hitherto investigated heterogeneity in the interest-rate transmission mechanism outside and in Australia; however, these studies have mostly disregarded the presence of complex cross-sectional dependencies, both observed and unobserved common factors which arise from national and global economic shocks. As far as could be ascertained, none of the prior studies nationally and globally investigate the effect of the unobservables and cross-sectional dependences on these monetary policy transmission mechanisms, both symmetric and asymmetric. Intuitively, the literature assumes that interest rate properties are cross-sectionally invariant. However, this study argues that the omission of unobservables and cross-sectional dependence in the existing literature can produce seriously biased estimated results, with their subsequently misleading inference. The empirical results of this essay show that the transmission mechanisms, both symmetric and asymmetric, have been significantly affected by unobservables which are attributed to the strong presence of complex cross-sectional dependencies in panels. Contrary to intuition, and as hypothesised, this essay finds that, at the bank level, the nature of these long-term transmission mechanisms is heterogeneous. The estimated results of the international funding cost effect on mortgage rate pass-through have been significantly robust. From a practical viewpoint, these findings raise questions about the standard design of monitoring focused homogeneous transmission recommendations. Thus, this study calls for an innovative configuration in modelling interest-rate pass-through. Consistent with the second essay, this study documents the strong impairment of the long-term cash-rate transmission since the crisis, while bank mortgage price-setting behaviour has become closer to their foreign funding cost developments.

The fourth essay is motivated by the findings of the cash-rate transmission breakdown in these two previous essays. The researcher conducts an empirical examination of the effects of

macroeconomic conditions and credit risk premium on the mortgage rate-setting behaviour of Australian banks prior to, during and after the GFC to provide deep insight into the third literature strand of this transmission mechanism. This leading work finds significant evidence of the influential roles of the unemployment, changeability in the Australian dollar value, volatility in the bank foreign-funding markets, and business and consumer confidence in affecting the asymmetric pass-through of the mortgage rates since the crisis. The findings of this paper therefore shed light on the implementation of forthcoming monetary policy reforms. These outcomes are beneficial for depository institutions and prudential supervisors as well. It is fundamental for commercial banks to deeply understand these determinants when they design and pursue their pricing strategies because these determinants of the mortgage rates could affect the asymmetric adjustments of other bank rates differently (Perera & Wickramanayake, 2016). The findings are useful for the APRA and ACCC in maintaining and enhancing market competition, banking soundness and financial stability. The findings confirm a strong integration between financial instability and monetary transmission that would benefit prudential legislators in designing and configuring more appropriate schemes of maintaining financial stability.

This thesis also extends the prior literature by employing a bank-based interest-rate dataset at high weekly-frequency in a single-country study. The use of micro-data in the study of asymmetry and heterogeneity in interest-rate pass-through is actually important for making the findings relatively advantageous to those of the macro-data analyses. This research therefore provides cooperative insights to complement monetary policy that in aggregated-data work are possible to miss or mask (ECB, 2017a). This thesis based on the findings of these interrelated studies concludes that: (i) international funding cost is a statistically driving factor of bank mortgage rates in Australia for individuals or bank-specific groups given the presence of cross-

sectional dependence, (ii) the nature of the transmission from international funding cost to mortgage rates is upwardly asymmetric in the long term, (iii) wide discrepancies in mortgage price-setting occur in the short run, (iv) since the crisis, banks have partially repriced their mortgage rates only in the monetary easing episodes; however, their mortgage rates have, for the most part, fully responded to an international funding cost shift, decreasing at a greater rate than they increase, (v) these long-term transmission mechanisms, both symmetric and asymmetric, are significantly heterogeneous, (vi) when controlling for macroeconomic conditions, bank mortgage rates have responded asymmetrically and sizably to instant shocks in the cash rate, but they insignificantly respond to cash rate shocks in the long run. The mortgage rates however have considerably repriced towards the deteriorating labour market, the appreciation and depreciation in the Australian dollar value, the volatility of banks' foreign-funding markets, as well as changes in business and consumer confidence. This research provides empirical support to the transmission of the cash rate, considering (i) the nexus of international funding cost and mortgage rates and (ii) the nexus of macroeconomic environment and mortgage rates; therefore, proposes important policy implications.

Statement of Originality

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

[redacted]

(Signed)_____
Quynh Chau Pham

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<u>The all papers included are co-authored</u>

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Section 9.1 of the Griffith University Code for the Responsible Conduct of Research ("Criteria for Authorship"), in accordance with Section 5 of the Australian Code for the Responsible Conduct of Research, states:

> To be named as an author, a researcher must have made a substantial scholarly contribution to the creative or scholarly work that constitutes the research output, and be able to take public responsibility for at least that part of the work they contributed. Attribution of authorship depends to some extent on the discipline and publisher policies, but in all cases, authorship must be based on substantial contributions in a combination of one or more of:
>
> - Conception and design of the research project
> - Analysis and interpretation of research data
> - Drafting or making significant parts of the creative or scholarly work or critically revising it so as to contribute significantly to the final output.

Section 9.3 of the Griffith University Code ("Responsibilities of Researchers"), in accordance with Section 5 of the Australian Code, states:

> Researchers are expected to:
>
> - Offer authorship to all people, including research trainees, who meet the criteria for authorship listed above, but only those people.
> - Accept or decline offers of authorship promptly in writing.
> - Include in the list of authors only those who have accepted authorship
> - Appoint one author to be the executive author to record authorship and manage correspondence about the work with the publisher and other interested parties.
> - Acknowledge all those who have contributed to the research, facilities or materials but who do not qualify as authors, such as research assistants, technical staff, and advisors on cultural or community knowledge. Obtain written consent to name individuals.

Included in this thesis are papers in *Chapters 3, 4 and 5* which are co-authored with other researchers. My contribution to each co-authored paper is outlined at the front of the relevant chapter. The bibliographic details for these papers including all authors are:

(Where a paper(s) has been published, or accepted for publication, you must also include a statement regarding the copyright status of the paper(s).

Chapter 3: Pham, Q.C., Liu, B., Roca, E. (2018). Australian mortgage interest-rate pass-through: Does international funding cost matter? In: *The 2018 Joint Asia-Pacific Network for Housing Research (APNHR) Conference and the Australasian Housing Researchers Conference (AHRC)* held by Griffith University in Gold Coast on 6-8 June. Available on

https://www.griffith.edu.au/__data/assets/pdf_file/0015/561210/APNHR-2018_Proceedings.pdf.

The copy right of this paper has been transferred to the 2018 APNHR and AHRC Conference Organising Committee.

Chapter 4A: Holland, Q.C.P., Liu, B., Roca, E., Salisu, A.A. (2018). Mortgage asymmetric pricing, cash rate and international funding cost: Australian evidence. Conditionally accepted: *International Review of Economics and Finance* (ABDC A-ranked journal).

Chapter 4B: Holland, Q.C.P., Liu, B., Roca, E. (2018). International funding cost and heterogeneous mortgage interest-rate pass-through: A bank-level analysis. Published in *Empirical Economics* (ABDC A-ranked journal), 1-35. doi:10.1007/s00181-018-1488-6.

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Chapter 5: Holland, Q.C.P., Liu, B., Roca, E. (2018). Asymmetric determinants of mortgage interest-rate pass-through: A panel nonlinear common-factor analysis**.** Targeting to *Journal of Monetary Economics* (ABCD A*-ranked journal).

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_____ 01 December 2018

Name of Student Quynh Chau Pham

(Countersigned) ___[redacted]_____ 06 December 2018

Supervisor: Benjamin Liu

(Countersigned) [redacted] 06 December 2018

Supervisor: Eduardo Roca

Thesis research outputs to date

Published paper

1. Holland, Q.C.P., Liu, B., Roca, E. (2018). International funding cost and heterogeneous mortgage interest-rate pass-through: A bank-level analysis. *Empirical Economics* (ABDC A-ranked journal), 1-35. doi:10.1007/s00181-018-1488-6

Under review paper

1. Holland, Q.C.P., Liu, B., Roca, E., Salisu, A.A. (2018). Mortgage Asymmetric Pricing, Cash Rate and International Funding Cost: Australian Evidence. Conditionally accepted: *International Review of Economics and Finance* (ABDC A-ranked journal).
2. Holland, Q.C.P., Liu, B., Roca, E. (2018). Asymmetric determinants of mortgage interest-rate pass-through: A panel nonlinear common-factor analysis. Submitting to *Journal of Monetary Economics* (ABDC A*-ranked journal).

Conference proceeding

1. Pham, Q.C., Liu, B., Roca, E. (2018). Australian mortgage interest-rate pass-through: Does international funding cost matter? Accepted on 29 May 2018: In: Smart and Sustainable Housing Futures: Towards an Efficient and Equitable Housing Delivery System. *The 2018 Joint Asia-Pacific Network for Housing Research (APNHR) Conference and the Australasian Housing Researchers Conference (AHRC)* held at Griffith University, Gold Coast, Australia in 6–8 June 2018. Available on https://www.griffith.edu.au/__data/assets/pdf_file/0015/561210/APNHR-2018_Proceedings.pdf

Refereed Australian and international conference presentations

1. Holland, Q.C.P., Liu, B., Roca, E. (2018). Asymmetric determinants of mortgage interest-rate pass-through: A panel nonlinear common-factor analysis. Accepted to present at the 26th Conference on the Theories and Practices of Securities and Financial Markets (SFM), at National Sun Yat-sen University, Taiwan, 6-7 December, 2018.
2. Holland, Q.C.P., Liu, B., Roca, E. (2018). Asymmetric determinants of mortgage interest-rate pass-through: A panel nonlinear common-factor analysis. Accepted to present at the World Finance and Banking Symposium, Taiwan, 13-14 December, 2018.
3. Pham, Q.C., Liu, B., Roca, E. (2018). Australian mortgage interest-rate pass-through: Does international funding cost matter? Presented at the 2018 Joint Asia-Pacific Network for Housing Research (APNHR) Conference and the Australasian Housing Researchers Conference (AHRC) held at Griffith University, Gold Coast, Australia in 6–8 June 2018.
4. Holland, Q.C.P. (2018). PhD outputs. Participated in the Campus for Finance - WHU New

Year's Conference 2018, Koblenz, Germany, 17-18 January, 2018.

5. Pham, Q.C., Liu, B., Roca, E. 2017. Australian bank mortgage price-setting behaviour pre- and post-GFC: does international funding cost matter? Accepted for presentation at the 30th Australasian Finance and Banking Conference, Sydney, 13-15 December, 2017.
6. Pham, Q.C., Liu, B., Roca, E. 2017. International funding costs and heterogeneous pass-through in Australian bank mortgage interest rates: A disaggregated data analysis. Accepted for presentation at the 1st International Conference on Energy, Finance and the Macroeconomy (ICEFM) organised by Montpellier Business School, Montpellier, France, 22-24 November, 2017.
7. Pham, Q.C., Liu, B., Roca, E. 2017. Australian bank mortgage price-setting behaviour pre- and post-GFC: Does international funding cost matter? Accepted for presentation at the 25rd Conference on the Theories and Practices of Securities and Financial Markets (SFM), Taiwan, 15-16 December, 2017.
8. Pham, Q.C., Liu, B., Roca, E. 2016. Mortgage asymmetric pricing and international funding cost: evidence in Australia. Presented at 2016 Asia-Pacific Network for Housing Research Conference, Guangzhou, 16-19th December, 2016.
9. Pham, Q.C., Liu, B., Roca, E. 2016. Bank mortgage interest rate asymmetrical adjustments to international funding cost in Australia. Accepted for presentation at the World Finance and Banking Symposium, Dubai, 14-15 December, 2016.
10. Pham, Q.C., Liu, B., Roca, E. 2015. The mortgage interest rates and cash rate cycle relationship and international funding cost: Evidence in the context of Australia. Presented at the Australasian Housing Researchers Conference 2015, University of Tasmania, Hobart, 21-22 February, 2015.
11. Pham, Q.C., Liu, B., Roca, E. 2015. International funding cost, mortgage interest rate and cash rate cycle relationship: evidence in the context of Australia. Accepted for presentation at the Cambridge Business & Economics Conference, Cambridge, UK, 1-2 July, 2015.

Internal and external symposium presentations

1. Presented “Australian bank mortgage price-setting behaviour in the boom and post global financial crisis periods: Does international funding cost matter?” at the 2017 Social and Affordable Housing Symposium, Griffith University, Brisbane (25 September 2017).
2. Presented “International funding costs and Australian bank mortgage pricing: A disaggregated analysis” at the Lunchbox seminar–PhD edition held by Griffith Environmental Futures Research Institute, Griffith University (15 Sep 2017).
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4. Presented “Asymmetric mortgage pricing in Australian banking sector” at the PhD Student symposium, Griffith University (25 Feb 2016).
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7. Presented "The mortgage interest rates and cash rate cycle relationship and international funding cost: evidence in the context of Australia" at the 3th Annual Personal Finance and Investment Symposium, Flinders University, Adelaide (13 November 2014).

Discussant Experience

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Data and Computer Code Availability

The data that support the findings of this research are available from CANNEX but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Instructions for how other researchers can obtain the data and all the information needed to proceed from the raw data to the results of the paper (including codes) are, however, available from the corresponding author upon reasonable request and with permission of CANNEX.

Abbreviations

AAPR	The annual adjustable percentage rate of mortgages
ABS	Australian Bureau of Statistics
ACCA	Australian Competition and Consumer Commission
ADIs	Authorised depository institutions
AFMA	Australian Financial Markets Association
AMG	Augmented Mean Group
ANZ	Australia and New Zealand Banking Group Limited
APRA	Australian Prudential Regulation Authority
ARDL	Autoregressive distributed lag
AUD	Australian Dollar
BBSW	The 3-month A$ bank bill swap rate
CBA	Commonwealth Bank of Australia
CCE	Common Correlated Effect Mean Group
CD	Cross-sectional dependence
CDS	Credit default swap
CFA	Cost of funds approach
CIPS	Cross-section augmented Im–Pesaran–Shin test
CR5	The five-largest bank concentration ratio
DCCE	Dynamic Common Correlated Effect Mean Group
DSGE	Dynamic Stochastic General Equilibrium
DSUR	Dynamic Seemingly Unrelated Regression
EC-EGARCH-M	Error Correction-Exponential Generalised Autoregressive Conditional Heteroskedastic-in-Mean
ECB	European Central Bank
ECT	Error correction term
EMF	European Mortgage Federation
EMU	European Monetary Union
EONIA	Euro Overnight Index Average
EU	European Union
GDP	Gross Domestic Products/annual economic output
GFC	Global financial crisis/recent Great Recession/2008 crisis
HHI	Herfindahl-Hirschman index
HIA	Housing Industry Association
HNC	Homogeneous non-causality
IMF	International Monetary Fund
IP-VAR	Interactive Panel Vector Autoregressive
IPI	Industrial production index
IRPT	Interest-rate pass-through

LIBOR	London Interbank Offer Rate
LM	Lagrange multiplier test
LTV	Loan-to-value-ratio
M-TAR	Momentum Threshold Autoregressive Regression
MFAA	Mortgage & Financial Association of Australia
MG/MGE	Mean Group Estimator
MPA	Monetary policy approach
NAB	National Australia Bank Limited
NAMG	Nonlinear Augmented Mean Group
NARDL	Nonlinear Autoregressive Distributed lag (NARDL)
NPLs	Non-performing loans
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Square
PANCOVA	Panel Analysis of Covariance
PANIC	Panel Analysis of Nonstationarity in Idiosyncratic and Common components
PMG/PMGE	Pool Mean Group Estimator
PURT	Panel unit root tests
RBA	Reserve Bank of Australia
RMBS	Residential mortgage backed securities
RMSE	Root mean square errors
ROA	Returns on total assets
ROE	Returns on equity
SIBOR	Singapore Interbank Offer Rate
SUR	Seemingly Unrelated Regression
TAR	Threshold Autoregressive Regression
The Wallis Inquiry	The Financial System Inquiry
UK	The United Kingdom
US	The United States of America
VAR	Vector Autoregressive Regression
EC/VECM	Error Correction/Vector Error Correction model
WACL	The weighted average cost of liabilities
WBC	Westpac Banking Corporation
WLS	Weighted Least Square

Chapter 1: Introduction

1.1 Introduction

This chapter is structured in 7 sections. In particular, Section 1.2 provides the background and motivations for undertaking this research by highlighting the paramount prominence of the relationship of bank funding cost to mortgage rate adjustments for both the market participants and the economy. Section 1.3 presents concisely the research questions related to each empirical essay. The research methodology, including the sample, data, and the theoretical framework and empirical models employed to answer these research questions, are presented in Section 1.4. The key findings and implications of the research are summarised in Section 1.5. Section 1.6 discusses how this thesis augments the existing literature, while an outline of the thesis is given in Section 1.7.

1.2 Background and research motivation

This thesis constructed from four interrelated empirical essays explores the effect of bank marginal funding costs, both the cash rate and the international funding cost, on mortgage interest rate adjustments for Australian banks. Figure 1.1 visualises the overview of this thesis. The first examination answers the questions regarding whether international funding cost affects mortgage rate adjustments of individual banks immediately, in the short run and in the long run, and whether this relationship is symmetric or asymmetric, as well as whether the long-run asymmetry exists in the cash rate transmission. The second paper investigates whether such a relationship still holds when synchronously taking into account the bank-specific and time effects, whether the policy rate transmission to mortgage rates has been impaired due to the GFC, and if so whether the international funding cost is attributable to the transmission breakdown between the cash rate and mortgage rate. The third study explores the heterogeneity in mortgage rate pass-through, both symmetric and

asymmetric, while controlling for potential unobservables and cross-section dependence inherent in the macro panel data. The fourth essay examines the asymmetric determinants of the mortgage interest-rate pass-through for Australian banks.

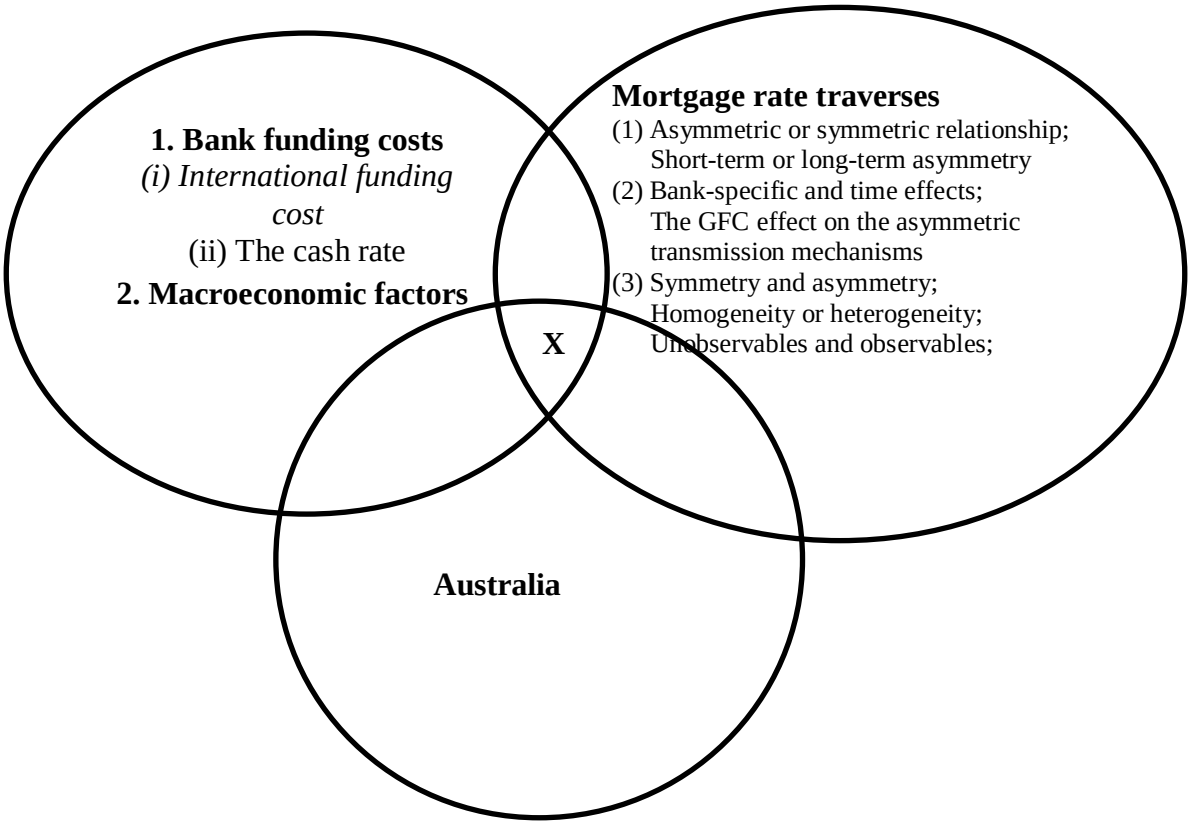

Figure 1.1. Overview of the thesis

The mortgage interest rate channel is integral to the monetary policy transmission process not only for Australia, which implements an inflation-targeting regime, but also for the top world-leading residential mortgage markets of Australia, Germany, France, Japan, Spain, the US, the UK, the Netherlands, based on the EMF (2016) statistics. The term 'interest-rate pass-through' (IRPT) mechanism is used to refer to the transmission of policy rates or market reference rates to retail interest rates. The IRPT study determines how fast (speed) and how much (amount) a unit change in policy/market reference rates is transmitted to bank retail interest rates. In modelling, the pass-through process of a retail rate is shaped by changes in either a policy rate or a compatible maturity market rate that is a common proxy for the marginal cost of bank funding in the existing literature. The superior effectiveness of monetary policy, with regard to the real economy, is theoretically associated with a faster and fuller traverse of these changes to bank interest rates. The study of the mortgage IRPT at a bank level is therefore a matter of concern to the banking supervisory and regulatory bodies, the APRA, RBA and ACCC, in Australia because of two key issues, heterogeneity and asymmetry, which have established two mainstream strands of the literature on monetary transmission worldwide. The examination of heterogeneity is desirable from a macro-policy perspective because far more substantial discrepancies in the mortgage IRPT mechanism would challenge the conduct of monetary policy and the accomplishment of a targeted inflation rate to stabilise and enhance finance and banking sectors as well as the economy. The heterogeneity is specifically a matter of the greatest concern to the ECB as documented in the extensive literature, see the Andries and Billon (2016) survey. Moreover, monetary policy rate changes have a significant impact on house prices via the housing interest rate channel (Robstad, 2018), and on industrial growth rates and economic output via business lending rates (Naraidoo & Raputsoane, 2015). Therefore, the majority of IRPT heterogeneity studies have been extensively and systematically conducted, especially for the European Economic and Monetary Union (EMU) economies.

In contrast, the issue of asymmetries in mortgage rate-setting has been closely perceived from a household perspective. In Australia in particular, bank mortgage price-setting has made ongoing headlines on media since the crisis. This matter has also attracted a great deal of academic and administrative interest because of the wealth effects on consumption and financial and social stability (Jansen, 2013). Depository institutions (hereafter banks) are theoretically expected to symmetrically pass on policy and/or market rate changes to their retail rates. In reality, banks that have a certain market power because of an imperfect competitive environment can exert their power in price-setting. Asymmetric interest rate adjustments occur when banks asymmetrically adjust their retail rates to policy/market rate rises or rate cuts, resulting in a larger magnitude and/or speed of their rate adjustments, and a different distribution of welfare. More precisely, an increase in bank marginal funding cost typically shaped by a policy/market reference rate is slower and less completely transmitted to deposit rates than to an equivalent decrease, the so-called upward rigidity of deposit rate adjustments. However, an increase in the funding cost is faster and more completely transferred to lending rates than to an equivalent decrease, the so-called downward rigidity of lending rate adjustments. These are considered as an upward or positive asymmetry. In both scenarios, neither depositors nor borrowers gain any benefit from a policy/market rate cut or a rate rise that they would get under a symmetric market condition (Meyer & Cramon-Taubadel, 2004). Such a pricing practice over time will seriously induce significant net-welfare losses for households in Australia, where over 60% of total outstanding mortgages, the equivalent of nearly 60% of GDP, are composed of home loans for owner-occupiers.

Bank funding costs constitute an essential part of monetary transmission; they are also a greatest matter of concern to financial stability (see Beau, Hill, Hussain, & Nixon, 2014). The GFC has considerably initiated serious constraints on bank funding markets, negatively affecting banking operations, monetary policy, and the structure of financial markets, as well as economic activities,

inducing a higher cost of bank funding globally (Cifarelli & Paladino, 2016; Gerlach, Mora, & Uysal, 2018; IMF. Monetary and Capital Markets Department, 2008). A number of studies have documented empirical evidence of the policy rate transmission breakdowns, both locally (Lim, Tsiaplias, & Chua, 2013; Liu, Margaritis, & Qiao, 2016) and internationally (Aristei & Gallo, 2014; Hristov, Hülsewig, & Wollmershäuser, 2014). The conventional framework based on the initial assumption that policy/market rates are the straightest driving factors of retail lending rates is suspected of being ill-equipped to identify two important phenomena since the GFC—increased spreads of lending rates over the policy/market rates, both locally and internationally, and the wider heterogeneity in bank lending rates in the Euro area (ECB, 2013, 2017a). Using the more appropriate indicator of bank marginal funding cost, instead of policy/market rates such as the weighted average cost of liabilities (WACL) proposed by Kapuściński and Stanisławska (2018), and Von Borstel, Eickmeier and Krippner (2016), is therefore of paramount importance to the current empirical setting of mortgage and lending interest rates.

Banks' mortgage and other retail loans cannot be priced separately from their funding costs owing to the nature of banking. Banks funds themselves from two main different sources, retail funding, which is borrowed form mostly households and other economic agents on domestic deposit markets, and wholesale funding, sourced mostly from banks, financial institutions and corporations in private markets (IMF, 2012). The Australian mortgage funding model is specifically wholesale-based funding and this share of mortgage funding is mostly sourced from foreign suppliers (hereafter, foreign funds). This composite of Australian mortgage funding has increased from nearly 20% to 30% of total bank liabilities, during the whole sample period (RBA Statistics, Table B2). The share of foreign funds in total mortgage funding in Australia is around 35%, which is far greater than those in the Euro area countries at an average of 10% (European Mortgage Federation (EMF), 2016; Turner & Nugent, 2015). Given the national and global prominence of the mortgage market, the imperative

portion of international funding in mortgage funding composition of Australian banks and the important role it has in the IRPT mechanisms that ultimately impact on the economy, this thesis focuses interest on examining the relationship between international funding cost and mortgage interest rates for Australian banks. Meanwhile, this research discovers far deeper asymmetry and heterogeneity in the mortgage IRPT mechanisms with the cash rate considering the roles of the international funding cost and macroeconomic conditions in the transmission prior to, during and after the GFC.

Key motivational grounds for conducting this empirical research into the influence of international funding cost on mortgage rate adjustments in Australia can be divided into three categories: (i) the particular features and the essential and critical role of the housing credit market, (ii) increased public and political concerns towards bank mortgage price-setting behaviour, the proliferated local and global attention on stabilising housing and mortgage markets, and the development of a sound banking competitive environment, and (iii) the shortages and limitations of the existing literature on the mortgage IRPT in Australian and world banking markets. These motivations have been logically discussed in each empirical essay. To honour the limited space of the introduction, the motivation of the thesis has been visually captured in Figure 1.2.

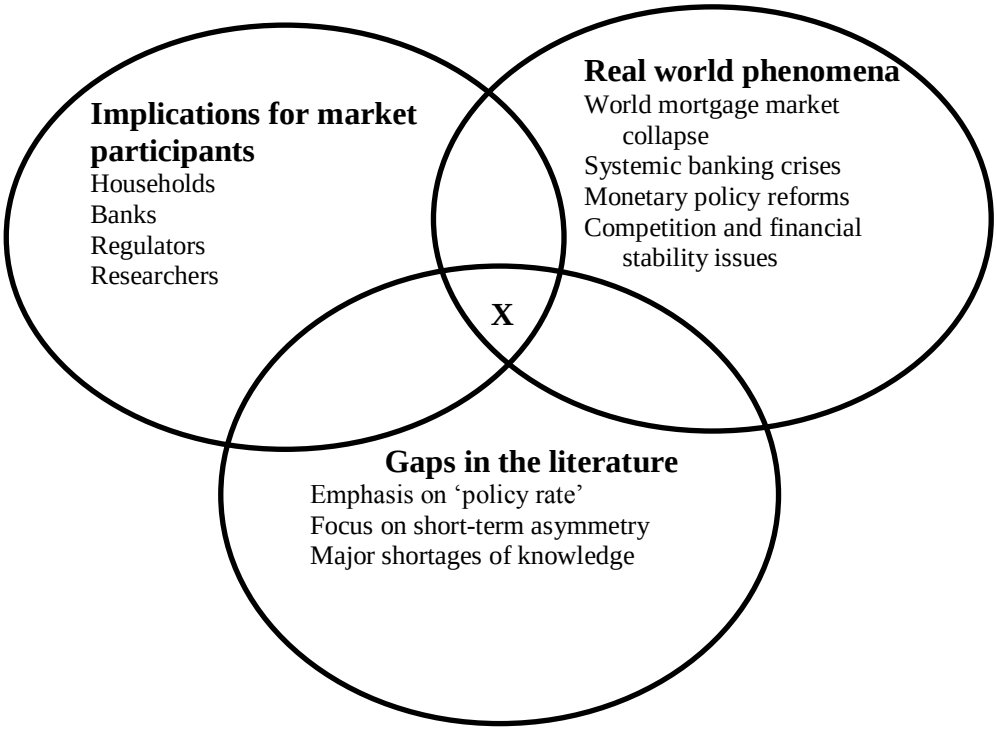

Figure 1.2. Thesis motivations

My research on the existing literature on the IRPT shows that none of the prior studies empirically explores the association between international funding cost and mortgage rate pass-through in Australia. None of the prior Australian studies comprehensively investigates the long-term asymmetries of mortgage rate adjustments to cash rate changes; the international studies have also ignored this importance issue. More importantly, none of the existing studies have examined the effect of the crisis on the mortgage IRPT, considering both bank-specific and time effects. Most importantly, the influence of unobservables and cross-sectional dependence potentialities has largely been disregarded. No empirical analysis has been found examining the role of macroeconomic environment in the cash rate transmission considering the asymmetric effects. These literature gaps are discussed in detail in Section 1.3.

1.3 Literature gaps and research questions

1.3.1 Essay 1: International funding cost and mortgage rate pass-through

The nexus between bank international funding cost and mortgage rate pass-through in Australia is empirically narrated in the first essay of this thesis. This essay also conducts a parallel examination of the cash rate transmission to bank mortgage rates. Empirical studies have extensively investigated retail interest rate adjustments to changes in policy rates and/or market rates, locally (see Lim et al., 2013; Valadkhani & Anwar, 2012) and internationally (see Becker, Osborn, & Yildirim, 2012; Bernhofer & Van Treeck, 2013; De Bondt, 2005; Von Borstel et al., 2016). The marginal cost pricing model by De Bondt (2005), under the assumption of market power, is commonly and theoretically used to quantify the adjustment speed and amount of retail interest rates to policy/market rate shocks. However, my review of the mortgage IRPT literature shows that the empirical studies have focused on examining the transmission of policy/market rates only. These studies are mostly EU-based and advanced markets, employing policy rates or short-term money market rates in the strands of both heterogeneity and asymmetry. Several current contributions (Kapuściński & Stanisławska, 2018; Von Borstel et al., 2016) employ a new indicator of the marginal funding cost, the WACL in modelling the IRPT after the GFC. The studies reviewed that use aggregated data at country or cross-country levels are particularly prevalent. Although a number of these studies have established the importance of the cash rate, the bank marginal funding cost, to the IRPT mechanisms, surprisingly no empirical efforts have been made to empirically explore the role of international funding cost in mortgage rate pass-through for Australian banks. This present study is a timely contribution to the extant literature by filling this research gap with the empirical investigation of the international funding cost–mortgage rate pass-through nexus in Australia.

Recently, numerous researchers (Apergis & Cooray, 2015; Valadkhani, 2013; Valadkhani & Anwar, 2012; Valadkhani & Worthington, 2014) employing bank-level interest-rate data have investigated asymmetry in the mortgage IRPT mechanism for Australian banks, while a few studies using aggregated data examine heterogeneity in this mechanism (Lim et al., 2013; Sathye, 2013). However, the existing studies have been mostly constrained by examining symmetric pass-through or asymmetry in short-run dynamics only. In particular, these studies are limited to considering the asymmetry in adjustment speed or/and immediate responses of bank interest rates. This extensive disregard for examining long-run asymmetries can produce the biased incomplete pass-through results in the literature (Kwapil & Scharler, 2010; Verheyen, 2013). The traditional methodology built on the error/vector error correction model (EC/VECM) framework is one of the most significant drawbacks of the existing work. As another novelty, this major limitation on ignoring long-run asymmetry in the literature is solved in this essay by employing the nonlinear autoregressive distributed lag (NARDL) model advanced by Shin, Yu, and Greenwood-Nimmo (2014). Therefore, this study sheds new light on these shortages of knowledge by answering three major questions:

1. Does the international funding cost play a significant role in the mortgage rate transmission at an individual level in the presence of the cash rate?
2. What is the nature of this relationship: symmetry or asymmetry?
3. Does any asymmetry exist in the long-term pass-through of mortgage rates in response to changes in both the cash rate and the international funding cost?

1.3.2 Essay 2: Asymmetric mortgage pricing and the GFC impact

The second empirical essay provides a robustly comprehensive analysis of how the mortgage IRPT mechanisms with regards to both the international funding cost and the cash rate in Australia have been affected due to the crisis. In theory, the magnitude of mortgage rate adjustments is associated

with that of cash rate shocks, based on the assumption that the cash rate, the policy rate in Australia, is the key funding indicator for mainstream bank funding. In fact, mortgage and other lending rate adjustments have recently and increasingly diverged from the cash rate cycle since the GFC, arousing considerable controversy from both the public and legislators about the 'out-of-cycle' mortgage pricing behaviour of banks. There has also been increased attention from regulators to banking competition, housing and financial stability, as well as to customer protection issues.[1] However, relatively few contributions have been made to investigate the crisis effect on the mortgage rate pass-through, given these topical issues in Australia. Three studies have recently considered potential asymmetries in mortgage rate pass-through arising from market structure changes due to the crisis for Australia (Liu et al., 2016; Valadkhani, 2013) and the UK (Ahmad, Aziz, & Shahina, 2013). Only Apergis and Cooray (2015) study asymmetries in both short- and long-run IRPT for major banks in Australia, the UK and the US, considering the effect of the crisis on the mechanisms by splitting the sample into two sub-spans, before and after the GFC. These authors find that, after the GFC, only the major Australian banks asymmetrically reprice their mortgage rates upwards corresponding to cash rate changes.

Prior empirical studies have several major limitations. First, in the Australian studies, a dummy variable is used simply to measure the GFC effect; therefore, their findings narrow to the higher post-crisis markups than the prior-crisis ones. Second, these studies show inconclusive findings. Valadkhani (2013) documents positive asymmetry in the short-term pass-through of mortgage rates

[1] Government Inquiry – Competition within the Australian banking sector, at http://www.treasury.gov.au/banking/content/_downloads/competitive_and_sustainable_banking.pdf
Australia Government - Financial System Inquiry (2014), Financial System Inquiry Final Report, released 7 December 2014 at http://fsi.gov.au/publications/interim-report/02-competition/banking-sector/
Australia Government - Improving Australia's Financial System Release (2015) ISBN: 978-1-925220-67-4 at http://www.treasury.gov.au/~/media/Treasury/Publications%20and%20Media/Publications/2015/Government%20response%20to%20the%20Financial%20System%20Inquiry/Downloads/PDF/Government_response_to_FSI_2015.ashx
1 http://fsi.gov.au/files/2014/08/APRA_2.pdf

at a bank level, which supports the concentration hypothesis and benefits mortgage lenders. On the contrary, the two studies by Ahmad et al. (2013), and by Liu et al. (2016), find an upward rigidity/negative asymmetry in the adjustment speed of mortgage rates in the UK and Australia. Apergis and Cooray's (2015) finding is consistent with Valadkhani (2013) for Australia, but inconsistent with Ahmad et al. (2013) for the UK, who find both lending and housing rate are faster to reduce than to increase when the policy rate changes. However, Apergis and Cooray's (2015) results could be masked by using a weighted average rate on consumer loans, housing loans and corporate loans, which can explain their inconsistent finding with the conclusion of Ahmad et al. (2013) for the UK market. Third, another drawback of the prior studies is that they omit the bank-specific effect in modelling. Finally, very few of the extant studies use a comprehensive bank-level dataset of mortgage rates for a relatively long period and a large number of banks (Fuertes & Heffernan, 2009; Fuertes et al., 2010; Valadkhani, 2013). Several other contributors, for example Valadkhani and Worthington (2014) for Australia, Allen and McVanel (2009) for Canada, De Haan and Sterken (2011) for Netherlands and Hofmann and Mizen (2004) for the UK, use only a small number of their major banks. The model shortcomings and the inaccessibility of mortgage rate datasets due to regulatory confidentiality can explain these drawbacks. This study strives to fill these gaps in the literature by answering three research questions.

1. Are there both short-term and long-term asymmetries in the pass-through of the cash rate and the international funding cost into the mortgage rate in Australia, considering the effect of both bank-specific and time-dimension?

2. Does the cash rate still drive the mortgage rate in the presence of the international funding cost after the GFC?

3. Has Australian bank mortgage pricing behaviour changed since the crisis?

1.3.3 Essay 3: Mortgage IRPT: Homogeneity or heterogeneity

The third empirical essay of this thesis endeavours to identify the nature of the long-term IRPT mechanisms, both symmetric and asymmetric, while controlling for cross-sectional dependence and unobserved common factors. This research on the extant empirical studies of heterogeneity in the IRPT clearly ascertains that the mortgage-rate pass-through mechanism constitutes an integral part of monetary transmission, nationally and globally. Differing from other sectors, the banking environment is highly interactive through economic, regulatory, political, and other channels domestically and internationally. Bank operations are subjected to considerable phenomena ranging from national policy changes to global economic shocks, such as the recent financial and sovereign debt crises. Given the importance of the Australian mortgage market and the increased heterogeneity in lending rates recorded across banks within a given country or different economies due to the GFC, the urgent need highlights deeper understanding of what is the intrinsic property of the long-term pass-through from funding cost shocks to mortgage rates, heterogeneity or homogeneity as intuitively hypothesised and accepted in literature. This study sheds light on this imperative issue by assessing the effect of unobserved common factors on the mortgage rate–funding cost nexus for Australian banks.

My review of the literature on heterogeneity in IRPT studies discloses three important knowledge shortages and limitation. First, no empirical studies of the transmission from the policy rate/money market rate/funding cost to retail interest rates consider the effect of unobserved common factors on this transmission neither Australia nor other countries. In contemporary econometrics, finance, and macroeconomics, this matter is of paramount consideration because ignoring this issue in modelling highly produces sizable distortions of estimated results, and thus leads to serious misleading inferences (Omay, Çorakcı, & Emirmahmutoglu, 2017; Pesaran, 2006). Second, a disregard for cross-

sectional dependence (CD) in modelling is the major shortcoming in the literature, which is highly attributed to the contradictory findings and the questionable nature of the long-term pass-through (homogeneity or heterogeneity). Cross-sectional correlation arising from both observed (modelled) and unobserved (non-modelled) common factors, national and global, is theoretically inherent in interest rate panels. A solid foundation for the CD properties of macro panel data has been established in the contemporary literature on growth and econometrics (Bai & Ng, 2004; Castagnetti, Rossi, & Trapani, 2017; Eberhardt & Teal, 2013). However, the literature on interest rate transmission has persistently overlooked this important issue by repeatedly using standard panel-cointegration models, such as the MG and PMG estimators (Horvath, Kotlebova, & Siranova, 2018; Horváth & Podpiera, 2012; Illes, Lombardi, & Mizen, 2015; Kapuściński & Stanisławska, 2018). Ignoring the CD in these conventional techniques, which are based on the assumption of cross-sectional independence, most likely provided unreliable estimates with severe size distortions (Omay et al., 2017; Pesaran, 2006). Given this serious matter, the applicability and generalisability of the results to other market are serious concerns. Finally, preceding Australian studies mainly focused on the strand of asymmetry (Apergis & Cooray, 2015; Lim, 2001; Valadkhani & Anwar, 2012). Several researchers have recently assessed heterogeneity in this transmission (Lim et al., 2013; Sathye, 2013), but they employed the datasets of different aggregated interest rates on mortgages, deposits, and other retail products. Also, the international literature, using comprehensive micro-data of retail lending and/or mortgage interest rates, is hitherto scant with the presence of several studies for the Czech Republic (Horvath et al., 2018; Horváth & Podpiera, 2012), Belgium (De Graeve et al., 2007), and Poland (Kapuściński & Stanisławska, 2018), the United States (Gerlach et al., 2018), and Chile (Pedersen, 2018). These reviewed studies used data at monthly frequency. However, the Chilean and US analyses investigated the transmission of corporate lending and deposit rates only. This study contributes to the extension

of the literature using micro-level data of bank mortgage rates at weekly frequency. This study strives to be first with three key research questions of interest.

1. Do unobservables affect the interest rate transmission, both symmetry and asymmetry, when considering both bank-specific and time effect?
2. Is the nature of the long-term interest rate transmission, both symmetry and asymmetry, accurately homogeneous?
3. Does the international funding cost still affect the mortgage rate when controlling for cross-sectional dependence?

1.3.4 Essay 4: Asymmetric determinants of mortgage interest-rate pass-through

This essay examines the role of different macroeconomic factors in the cash rate transmission considering the impact of the GFC. The effectiveness of the policy transmission mechanism is of vital interest to policy makers and depository regulators. Investigating the potential factors attributed to this transmission breakdown since the crisis is immensely useful. Contrary to the two richer lines of research on heterogeneity and asymmetry in interest-rate pass-through, a newer line of the literature on IRPT determinants has been rapidly established since the aftermath of the GFC. A review of the preceding studies synthesises two key research gaps. First, a paucity of the literature on asymmetric determinants of the IRPT has been available up to date. Several studies (Gregor & Melecký, 2018; Perera & Wickramanayake, 2016) investigate nonlinearity in the interest-rate response function, but not asymmetry. Two publications for the Dominican Republic (Grigoli & Mota, 2017) and Chile (Pedersen, 2018) have considered asymmetry in speed of the adjustments, but not the size asymmetry of the pass-through degrees. Only the Australian researchers (Holland, Liu, & Roca, 2018) using the innovative estimation method to control for heterogeneity and complex cross-section dependencies have documented size asymmetry in the pass-through of the Australian bank mortgage rates.

However, they focus individually on the role of bank international funding costs. Second, the existing literature on pass-through determinants are extensively confined to standard panel cointegration, panel-VAR methods that largely disregard the slope heterogeneity and cross-section dependence issues. Few researchers (Bogoev, 2010; Gambacorta & Mistrulli, 2014), using the seemingly unrelated regression (SUR) method control for these two important issues in their panels, but this model restricts its residual distribution to be normal and the regressors to be exogenous. This assumption is highly invalid for macro-panel data with large *T*. Also, the SUR model is unable to quantify size asymmetry of the interest rate adjustments. This empirical essay is the first to undertake the responsibility of answering two key research questions.

1. Do macroeconomic conditions play any significant role in affecting the asymmetric interest-rate transmission, when considering both observables and unobservables?
2. Are these factors attributed to the impairment of the long-term cash rate transmission since the GFC?

1.4 Data, key variables and methodology

1.4.1 Sample period and data

For all empirical essays, this research employs the Cannex survey of Australian lenders (purchased by Griffith University) to construct a sample of 20 Australian banks anonymised over the period 1997:1–2012:8. The dataset of the episode 2012:9–2015:12 was manually collected from Info Choice Pty Ltd via http://www.infochoice.com.au. The sample-span selection is important for three reasons: it spans the full booming mortgage period; it includes the crucial banking reforms formally implemented and validated since 1997, such as the establishments of the APRA, Wallis Inquiry, and inflation targeting framework; it covers the period of extreme financial distress, such as the 2007-

collapse of the UK and US mortgage lenders, the ensuing GFC, systemic banking crises, and the sovereign debt crisis.

Initially, this research considers the weekly bank-specific observations of a full 18-year period available in the mortgage rate database. The final sample of this thesis varies across the four empirical essays, due to the missing data or technical requirements. Specifically, the first empirical essay comprises a maximum of 993 weekly observations of mortgage rates on each of 20 individuals; the second and the third include 14,120 weekly observations on a 20 bank-panel for a 13-year period; the fourth comprises a panel of 19 banks and 162 months with 3,078 observations. The second and the third also obtain a full balanced panel-sample of 20 banks and 706 weeks, after screening. The dataset used in the last three essays is partitioned into four subsets, sector, major, foreign, and region owing to the particular features of the sampled banks. To examine the crisis effect, the full sample in the second and third essays is also divided into three sub-periods, 216-week pre-crisis episode 2002:7–2007:6, 131-week crisis 2007:7–2009:12, and 131-week post-crisis period 2010:1–2015:12. Similarly, the monthly sample in the last study is split into: 60-month pre-crisis, 30-month crisis, and 72-month post-crisis periods. The funding cost data for the cash rate and the international funding cost, data on macroeconomic conditions and risk premium are obtained from the Bloomberg terminal at Griffith University.

1.4.2 Key dependent variable: Effective mortgage rate

The effective variable mortgage rate on standard home loans is employed to investigate whether bank funding costs, both the international funding cost and the cash rate, affect the mortgage IRPT mechanisms in this research. Generally, the reviewed literature uses the nominal interest rate of mortgages. However, owned-occupiers in Australia are charged a significant number of mortgage fees. The use of the effective mortgage rate is therefore more appropriate because it reflects the full

costs of mortgages, including all kinds of fees (Liu & Roca, 2015). The mortgage rate variable is constructed from the annual adjustable percentage rate of mortgages (AAPR) of the individual sampled banks. Only standard adjusted rate mortgages, that occupy a maturity of 25–30 years with an A$250,000 loan size, are selected to create the comparable data among the sample.

1.4.3 Key independent variables: the cost of funds rates

International funding cost is the first key independent variable in the first three empirical essays. To measure the effect of this funding cost, the 3-month A$ bank bill swap rate (BBSW) is employed as the proxy for the foreign-funds rate variable. The BBSW as the AFMA definition, which represents the midpoint of the nationally observed best bid and best offer for AFMA Prime Bank Eligible Securities, including bank accepted bills and negotiable certificates of deposit, is used to provide reference interest rates for the pricing and revaluation of Australian dollar derivatives and debt securities. This indicator is typically referenced when Australian banks issue their foreign funds, both onshore and offshore; however, the LIBOR is the benchmark rate for offshore issues only (Guttmann & Rodgers 2015; RBA 2006). The official cash rate is the second exogenous variable used in this research. This variable acts as the risk-free rate of bank funding costs or the proxy for domestic funding cost because it is a direct measure of monetary policy stances and a key mainstream funding indicator (Beau et al., 2014; Fabbro & Hack, 2011; Wilkins et al., 2016).

1.4.4 Explanatory variables

Three sets of macroeconomic environment and bank risk perception are used to capture their potential influence on the policy rate transmission mechanism in the last essay. The first category captures any influential effects of the macroeconomic conditions, including six variables to be proxies for changes in unemployment, appreciation and depreciation in the Australian value, and business and consumer

confidence. The second group combines four variables to measure the impact of macro-financial environment on the cash rate transmission, specifically the HIA new home sale indicator, the stock market price index and the volatility of banks' foreign-funding markets. The last set including four variables represent the domestic, global credit risk and bond-market risk premium perceived by banks.

1.4.5 Methodology: NARDL, Panel-NARDL, and AMG models

To investigate the nonlinear relationship between funding costs and mortgage rates, this research adopts the nonlinear autoregressive distributed lag (NARDL) approach and innovatively extends this into different panel forms. Specifically, the original NARDL model is fully adopted in the first essay to simultaneously estimate instant, cumulative short-run and long-run asymmetries in the mortgage IRPT mechanism for individual banks. The distinctive innovations of the asymmetric cointegration single-equation approach from the conventional cointegrating methods, such as the EC/VECM, the TAR, and the smooth transition ECM, are (i) jointly modelling cointegration and asymmetry dynamics in a single equation and (ii) releasing the nonstationary assumption. Moreover, in the second essay, the Shin et al. (2014) NARDL model is productively implanted in a panel ARDL to yield a nonlinear panel ARDL model, or the Panel-NARDL (p,q) for the mortgage rate adjustment by bank i at time t. The Panel-NARDL therefore enables researchers to capture not only simultaneous short- and long-term asymmetries, but also bank-specific and time effects of panel data.

The superlative performances of these innovative models, the NARDL and Panel-NARDL, are primarily fourfold. First, these approaches overcome the drawbacks of the conventional techniques by simultaneously capturing both short-term and long-term asymmetries in the IRPT. Second, the NARDL approach eliminates the omission of hidden cointegration that is a significant shortcoming

of linear models.[2] Decomposing the exogenous variables into positive and negative partial sums is the novelty of this framework. This procedure enables the detection of hidden cointegrating relations between variables by differentiating between nonlinear cointegration, linear cointegration, and the absence of cointegration. The NARDL model is therefore far more efficient in the study of pass-through asymmetries. Third, the NARDL method is able to produce a graphical presentation of cumulative dynamic multiplier effects that enable the direct observation of the sign asymmetry and/or the duration of disequilibrium without modelling the asymmetric error correction parameter. Finally, the sharper estimates and stronger inference can be achieved by using the Panel-NARDL model that by design allows for exploring both the time-dimension and cross-section variations in panel data rather than using time-series techniques.

The third and fourth essays of this thesis employ the heterogeneous linear and nonlinear augmented mean group (AMG) models for panel data to investigate the heterogeneity in the long-term pass-through, both symmetric and asymmetric. The linear AMG model (Bond & Eberhardt 2013; Castagnetti et al. 2017; Eberhardt & Bond 2009) enables the detection of cross-sectional dependence, which arises from observed and unobserved common factors, as well as heterogeneity in symmetry pass-through. The nonlinear common-factor panel-data model, called the nonlinear AMG (NAMG) estimator, creatively builds on the AMG and the NARDL methods. This approach facilitates the incorporation of the observables and unobservables, heterogeneity, and asymmetry in its model-setting.

[2] Hidden cointegration exists if two time series are not cointegrated in the conventional sense but their positive and negative components are cointegrated (Granger & Yoon, 2002)

1.5 Major findings

The key focus of this thesis is examining the relationships of bank funding costs, both the international funding cost and the cash rate, with mortgage rate adjustments in Australia in different contexts. This section outlines the key findings for each empirical essay.

The empirical results of the first study confirm the established long-term relationship between international funding cost and mortgage rate pass-through with significant rejection of the null no cointegration hypothesis for most banks individually. This study documents significant evidence for the existence of positive long-term asymmetries in the mortgage IRPT mechanisms with both the cash rate and the international funding cost. These findings specify that banks increase their mortgage rates faster and stronger than they decrease them in response to their funding cost changes, indicating banks' exertion of their market power in pricing in the long run. Furthermore, this essay finds that mortgage rates are instantly and intermediately transmitted when the bank funding costs revise. However, this study also shows a wide variation in the short-term pass-through and evidence of short-term size asymmetries in some banks. These findings advise that both the cash rate and the international funding cost have instantaneous and intermediate asymmetric effects on the mortgage rate pass-through mechanisms.

The second essay investigates the asymmetric responsiveness of mortgage rates to changes in the cash rate and the international funding cost, considering the bank-specific and time effects as well as the effect of the GFC on these pass-through mechanisms in Australia. The study clearly shows that among the four sampled groups the foreign banks yield the highest positive asymmetry degrees in the long-run transmission of both funding rates. The major group in contrast is the most unhurried to instantly reprice their mortgage rates, while the regional group is the price-follower in the short and long run. The empirical results indicate that major Australian banks with more market power appear

to have a greater positive asymmetry in the long run and they are quieter to respond to immediate funding shocks. After the GFC, the regional bank's mortgage rate asymmetric degrees are at the lowest level for both cash rate and foreign-funds rate equations, much lower than those of the foreign and major groups. Notably, the economic significance of the results suggests that the post-crisis effects of foreign-funding costs on mortgage rates are stronger than the pre-crisis and GFC influences. Finally, this study provides empirical evidence to confirm the impairment of the long-term cash-rate transmission after the crisis.

The third essay of this thesis, which explores the precise nature of symmetric and asymmetric pass-through for Australian banks, notably finds that the accurate long-term relationships of mortgage rates with the funding costs, both the international funding cost and the cash rate are strongly heterogeneous. The finding is imperatively important for policy implications because the traditional literature has provided the analogous ongoing conclusion of homogeneity in long-term symmetric pass-through, which is highly biased information due to the disregard of cross-sectional dependence potentialities. Importantly, this essay statistically documents the substantial effect of unobservables on the mortgage rate pass-through mechanisms, which has not previously been identified in the literature on monetary transmission. The significant results of the international funding cost–mortgage rate nexus still hold and have been significantly robust when controlling for unobservables and cross-sectional dependence. These findings call for urgent policy reforms: I propose an innovative modelling procedure in the setting of mortgage and retail interest rates.

The fourth essay, motivated by the outcome of the two aforementioned studies that is the impairment of the cash rate transmission due to the GFC, investigates the role of different macroeconomic conditions in affecting this transmission. This essay first validates the significant influence of macroeconomic development and deterioration on the pass-through mechanism, while controlling for

nonlinearity, nonstationarity, slope heterogeneity and complex cross-section dependencies. More importantly, this analysis documents statistically and significantly, the increasing influence of these macroeconomic conditions on the pass-through mechanism, taking the prime role of the cash rate since the crisis. This essay provides new insight into the literature on the interaction between the monetary transmission and financial stability.

1.6 Contributions

Key contributions to the contemporary literature have thus been made from the research findings and their implications.

1.6.1 Essay 1: Major contributions

The first empirical essay examined both the nexus between the international funding cost and mortgage rate pass-through and that between the cash rate and mortgage rate traverse. The novelty of this essay is drawn in Figure 1.3, through the intersection of the three circles, as suggested by (Faff, 2015). This study has made two significant contributions to the literature on the IRPT. As far as could be ascertained, this is the first study to show that international funding cost is of statistically significant importance to the mortgage rate pass-through mechanism at individual banks in Australia. The presence of asymmetries exists in immediate responses, cumulative short-term and long-term traverses. This study is also the first comprehensive, sophisticated analysis of asymmetries in the transmission of the cash rate to mortgage rates for three dimensions: impact, short term and long term. Prior studies consider the asymmetries in the policy transmission for short-term dynamics only (De Haan & Sterken, 2011; Fuertes et al., 2010; Liu, Margaritis, & Tourani-Rad, 2011; Valadkhani & Anwar, 2012; Valadkhani & Worthington, 2014). This present study investigates the long-run asymmetries of this transmission mechanism and proposes that researchers use this framework to

supplement the sufficiency of the IRPT studies and to enhance their results. Ignoring long-term asymmetries in the literature highly has probably made the estimation procedure less sufficient, but has resulted in biased estimated results producing misleading inference (Kwapil & Scharler, 2010). Moreover, this study contributes to the descriptive IRPT literature with the hypothetical presumption that 'international funding cost acts as a determinant of mortgage rates' by providing a new insight, that the cointegrating relationship between international funding cost and mortgage rate pass-through in Australia has been empirically established. The nature of this relationship is also confirmed to be positively asymmetric in the long run. This study brings together two streams of bank funding costs—the international funding cost and the cash rate—and for the first time shows how they interact in parallel with the mortgage rate traverse in Australia.

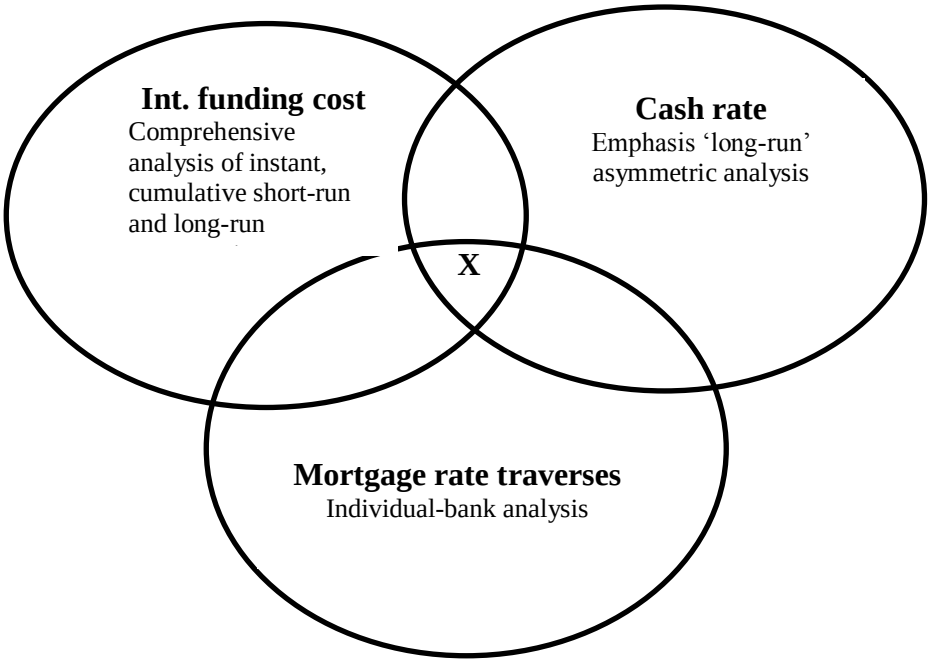

Figure 1.3. Diagram characterising the novelty of the first empirical essay

1.6.2 Essay 2: Major contributions

Figure 1.4 visualises the novel aspects of the second empirical essay. This study extends the existing literature on asymmetric IRPT mechanisms. In particular, this pioneer research in the field of monetary transmission finds that in the long run bank mortgage rates in Australia asymmetrically respond to changes in the foreign funding cost and the cash rate, decreasing faster and stronger than increasing when controlling for both cross-section and time-variance effects. This first panel analysis of the mortgage IRPT shows new insights into bank mortgage price-setting behaviour that have not been found in the literature using time-series data. Importantly, this study contributes to the literature by empirically and explicitly investigating crisis effect on the mortgage IRPT mechanisms in Australia. Thus, this study provides convincing empirical evidence for the ongoing debate and the growing public concern about the 'out-of-cycle mortgage rate price-setting behaviour' of Australian banks in the aftermath of the GFC.

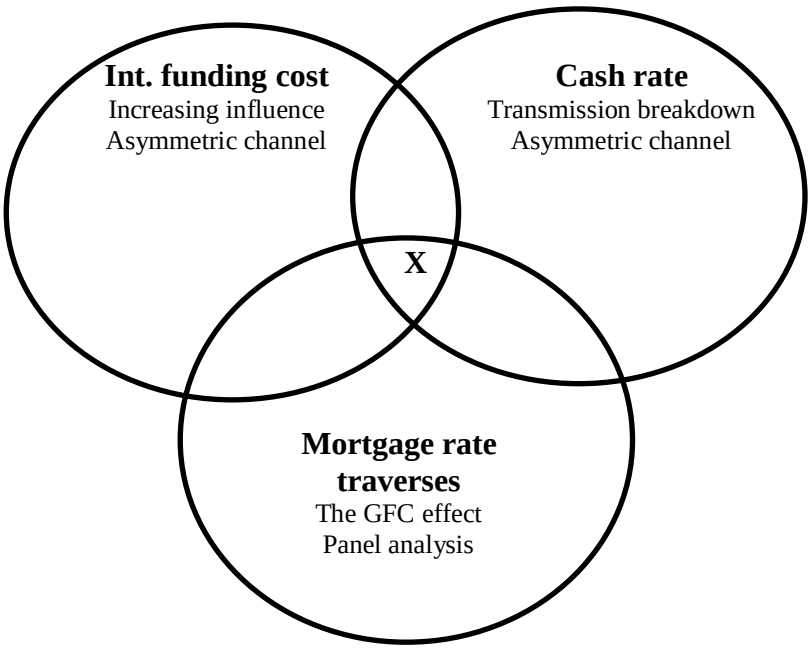

Figure 1.4. Diagram characterising the novelty of the second empirical essay

1.6.3 Essay 3: Major contributions

The valuable contributions of the third empirical essay to the literature on monetary transmission are exhibited in Figure 1.5. This study methodologically contributes to the literature by handling the heterogeneity in the long-term relationships between bank funding costs—the foreign funding cost and the cash rate— and mortgage rate traverses, both symmetric and asymmetric. Given that the long-run symmetry pass-through of retail interest rates is commonly documented as the homogenous relationship, it is critical to investigate the real nature of this relationship. Cross-sectional dependence potentials are theoretically inherent in interest rates as well as other macroeconomic series in panel form. However, the major shortcoming of the most reviewed literature arises from using standard econometric techniques that intuitively assume that cross-sectional correlation properties of panel data are invariant. This study therefore sheds new light and proposes an innovative estimation procedure in the setting of retail interest rates. Furthermore, this study contributes a pioneer design for the IRPT literature by explicitly examining the effect of unobservables on the transmission mechanisms, both symmetric and asymmetric. This study successfully confirms that overlooking cross-section dependence in the study of heterogeneity in the symmetry IRPT and totally disregarding unobservables lead to insufficient estimates and serious biased results. Most importantly, this study gives the first empirical contribution to the extant literature on monetary policy transmission by documenting heterogeneity in the long-term traverses of mortgage rates, not only in the symmetry but also in the asymmetry.

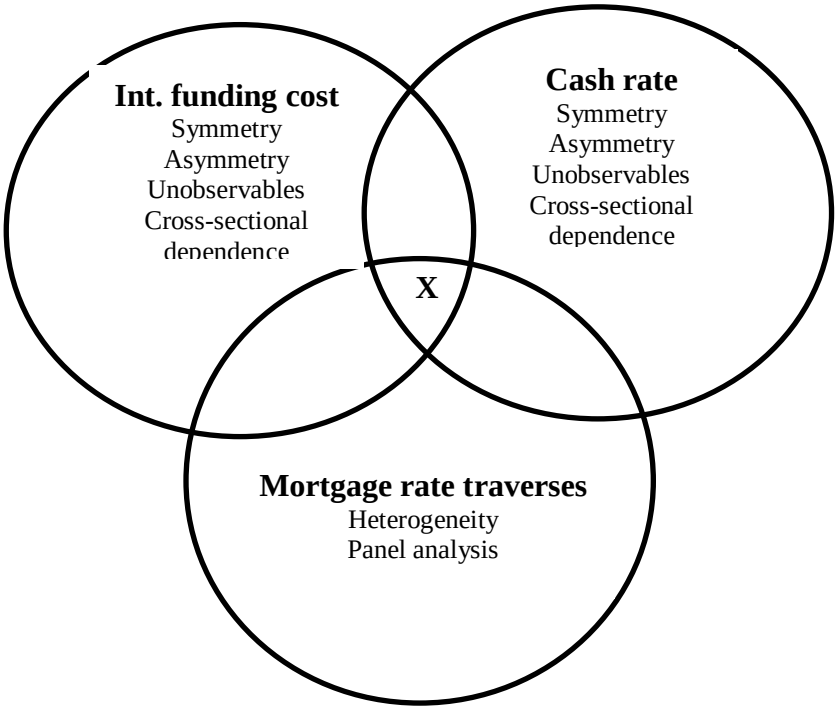

Figure 1.5. Diagram characterising the novelty of the third empirical essay

1.6.4 Essay 4: Major contributions

Figure 1.6 exhibits the key contributions of the last study in this thesis. This is the first empirical analysis exploring asymmetric determinants of the bank mortgage IRPT considering the role of macroeconomic conditions. The novelty of this essay, therefore, contributes to the literature on the integration between monetary transmission and financial stability. It is paramount importance for policy makers in banking and financial governance and supervision given the fragile global market in the aftermath of the GFC. The findings of the significant role of macroeconomic environment in affecting the policy rate transmission also benefit banks in designing and managing their competitive strategies. This study is notably useful in academy because investigating asymmetric determinants of the retail interest-rate pass-through can solve the source of low incompleteness documented in the literature on heterogeneity (Kwapil & Scharler, 2010). Finally, this essay contributes to the development of the rudimental strand of research on determinants of the retail interest-rate pass-

through by the sophisticated econometric procedure which simultaneously control for nonlinearity, nonstationarity, heterogeneity and complex cross-sectional dependencies.

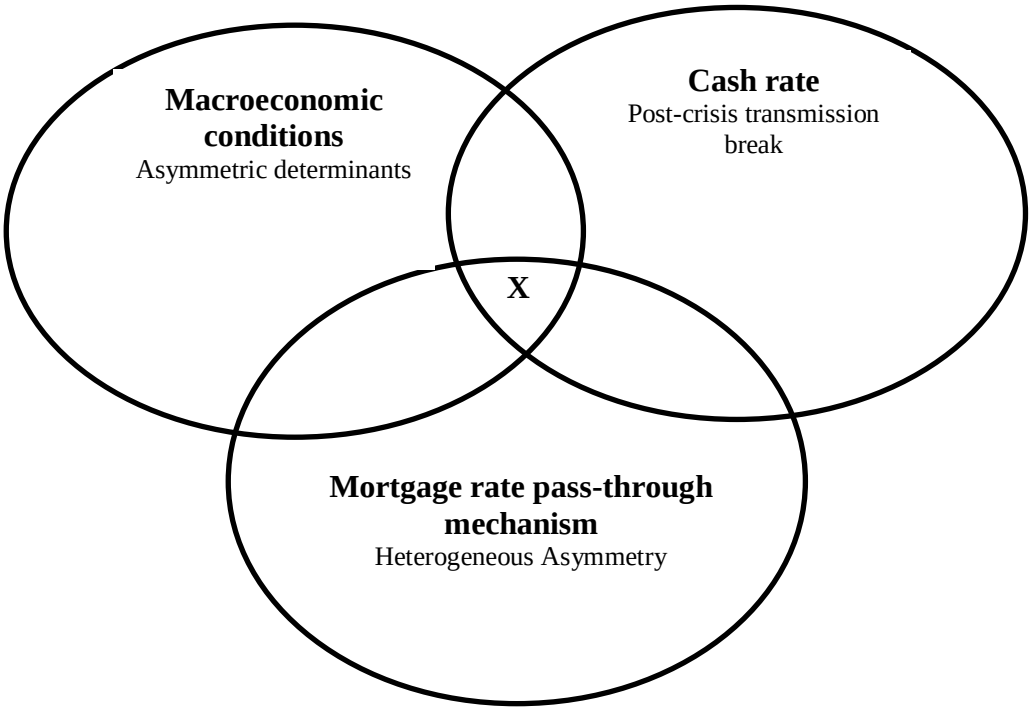

Figure 1.6. Diagram characterising the novelty of the fourth empirical essay

1.6.5 Other contributions

This research employs a relatively comprehensive sample of variable mortgage rates from 20 Australian banks anonymised over the period 1997:1–2015:12. Examining the bank funding cost–mortgage rate association in Australia in this period is essential because of three major events: the first, the primary regulatory reforms in 1997, for example the establishments of the APRA, Wallis Inquiry, and the implementation of the inflation-targeting regime; the second, the 2008–09 GFC, enabling an examination of crisis effects in three separately periods, pre-, GFC and post-GFC; the third, a full booming mortgage period with a ratio of mortgage debt to GDP from nearly 30% to 105% (author's calculation).

This study further contributes to the literature by using weekly effective mortgage rates at a bank-based level that offer several key advantages for scrutinising bank mortgage rate setting behaviour. The use of the effective rates covers the full costs of mortgages (Liu & Roca, 2015). Most previous studies e.g., Toolsema & Jacobs (2007) for the Netherlands; Liu et al. (2011) for New Zealand; Valadkhani & Anwar (2012) for Australia use macro-data of the advertised mortgage rates at a monthly interval. This research employs micro-data at a weekly high frequency. The longer the data interval is, the higher the probability of missing shocks within this interval; therefore, using weekly data helps to mitigate missing potential observations to increase the accuracy of the analysis. Most importantly, using bank-level data in the IRPT study augments aggregated-data studies and thus provides banking supervisors and regulators with insightful understandings in two key aspects. First, micro-data allow the more reliable analysis of substantial heterogeneity in the IRPT, overcoming the aggregation bias of the studies using macro-data (De Graeve et al., 2007). Sizable heterogeneity within an economy or cross-countries which arises from market structure changes due to the GFC may be missed or masked in the macro-data analyses due to the aggregation of data, resulting in misleading inferences (ECB, 2017a). Second, bank-level data enable shedding light on the noticeable heterogeneity in lending rates across banks within a given country since the crisis, because of the heterogeneity in their funding costs.

1.7 Thesis structure

The remainder of this thesis is designed as follows. Chapter 2 reviews the related literature and analyses the key features of the Australian mortgage market. Chapter 3 scrutinises the effect of international funding cost on mortgage rate pass-through at an individual bank, and the nature of this transmission mechanism. Chapter 4 combines two chapters. Chapter 4A examines the influence of the GFC on the asymmetric transmission of bank funding costs to mortgage interest rates,

simultaneously considering bank-specific and time effects, which is placed in the appendix to honour space limitation. Chapter 4B explores the long-term heterogeneity in both symmetric and asymmetric transmission mechanisms while controlling for observed and unobserved common factors which generate complex cross-sectional dependencies. Chapter 5 investigates asymmetric determinants of this pass-through mechanism which are attributed to the deterioration in the cash rate transmission since the GFC. Chapter 6 concludes the thesis and outlines the implications of the findings and directions for subsequent work.

Chapter 2: Literature review and market background

2.1 Introduction

Chapter 2 reviews the theoretical and empirical literature on monetary policy rate transmission and discusses the institutional background of the Australian housing finance market. First, Section 2.2 reviews the literature related to each empirical essay of this thesis to identify the gaps in the body of knowledge. Subsequently, key research questions are developed that fill the identified gaps and make significant contributions. In particular, the existing literature on the selection of bank marginal cost-of-funds rates in the IRPT study is reviewed in Subsection 2.2.1. Two mainstream strands of the literature on asymmetry and heterogeneity in the mortgage IRPT are appraised in Subsection 2.2.2 and Subsection 2.2.3. A new line of research on determinants of the IRPT mechanism is reviewed in Subsection 2.2.4. Second, this chapter briefly analyses the institutional background in Section 2.3, including the key features of the residential mortgage market in Subsection 2.3.1, and mortgage suppliers in Subsection 2.3.2. Section 2.4 summarises Chapter 2.

2.2 Literature review

The aim of this section is to understand the current state of research in the domain of mortgage and lending interest rate adjustments to changes in bank funding costs, including the selection of exogenous marginal cost variables in modelling retail IRPT, asymmetry, and heterogeneity in, and determinants of, this transmission.

2.2.1 Bank funding cost in lending interest-rate pass-through study

This section reviews the employment of the marginal funding costs in the existing literature on IRPT with the main focus on bank lending rates. The empirical literature is commonly and theoretically

directed by the marginal cost pricing model, with its underlying assumption of market power. Under imperfect market competition banks set their lending interest rates over a profit markup (Freixas & Rochet, 2008). A long-term association between policy/money market rates and retail interest rates is modelled in a straightforward bivariate form by De Bondt (2005). This theoretical model builds on the nature of banks and postures that their business activities and loan portfolios are predominantly financed by external economic agents on the money and deposit markets. A retail bank rate is the dependent variable of this model; the exogenous cost-of-funds rate variable either is a monetary policy rate, the so-called monetary policy approach (MPA), or a compatible mature money market rate, the so-called cost-of-funds approach (CFA).

2.2.1.1 Policy rate and compatible mature money market rate

Conventionally, policy rates and compatible mature money market rates are the two types of marginal cost-of-funds rates. First, depending on the selection of the exogenous variables, empirical IRPT studies detailed in Andries and Billon (2016) adopted either the MPA (e.g., Sander & Kleimeier, 2004) or the CFA (e.g., De Bondt, 2005). The former focuses solely on capturing the effect of monetary policy rate changes on retail interest rates. Only administered policy rates or short-term interbank rates thus act as proxies for the cost-of-funds rates in the estimated models. For example, Liu, Margaritis, and Tourani-Rad (2008) and Sander and Kleimeier (2004) proposed simultaneous effects of changes in the referencing money market rate on both short- and long-term bank deposit and lending rates through changes in the yields of short- and long-term financial instruments. Second, the CFA focusing on banks' price-setting decision takes market rates of compatible maturities to retail bank rates as proxies for the cost-of-funds rates to examine how depository institutions set their interest rates. The ground for this method is that market rates represent banks' funding costs when raising funds from various sources in money markets and opportunity costs in capital markets (De

Bondt, 2005). In practice, other factors that can affect bank price-setting are demand side (inflation, GDP growth), market power, risk premia, and bank characteristics such as size, capitalisation, and liquidity (Freixas & Rochet, 2008). However, a retail bank lending rate is mostly approximated over the marginal cost of funds rate because funding cost is the driving factor owing the nature of banking operations (Fabbro & Hack, 2011; Rousseas, 1985). Therefore, the two mainstream strands of the empirical literature on heterogeneity and asymmetry in the IRPT typically use a bivariate equation.

2.2.1.2 Weighted average cost of liabilities (WACL)

The MPA assumption is that these policy or money market rates are seen as the key opportunity cost of funding outside the scope of bank lending decisions; this assumption, however, holds only if the profit margin is constantly taken over the business cycle (Rousseas, 1985). The traditional monetary transmission mechanisms were impaired in many countries by the severe impact of the GFC (see Aristei & Gallo, 2014; Sathye, 2013). Subsequently, a new wave of the literature proposes an alternative measurement of the marginal cost-of-funds rate, namely the weighted average cost of liabilities (Illes et al., 2015; Kapuściński & Stanisławska, 2018; Von Borstel et al., 2016). This innovative proxy of the marginal funding cost has been documented to perform much better than the conventional indicator in modelling IRPT. Another cross-country study (Cifarelli & Paladino, 2016) modelled changes in bank funding cost to eight European countries, by using the German Government bond yield spreads.

Summary

A review of the bank funding cost and lending rate pass-through literature shows that these studies are EU-based and employ the policy rates or short-term money market rates in the mainstream MPA strand. The second main strand of the literature uses market rates at the compatible maturity with

lending rates, categorised in the CFA. The new strand currently adopts the WACL to measure the effectiveness of the monetary transmission in the aftermath of the GFC. A majority of the reviewed studies are single country or cross-country examinations using aggregated data. Overall, the reviewed studies ascertain that banks' funding costs are integral to the monetary transmission mechanism.

2.2.1.3 Gaps in the literature

My research on the extant literature proposes two important research gaps. First, although the recent development in constructing the WACL indicator (Kapuściński & Stanisławska, 2018; Von Borstel et al., 2016) quantifies the marginal funding cost more precisely in the study of the IRPT, I am unaware of any prior study of heterogeneous IRPT that has considered the effect of foreign-funding costs for Australian banks. Second, a scarcity of empirical evidence for the presence of the long-term asymmetry in the policy rate transmission to mortgage rates is another major research gap. My review of the available studies shows that only Apergis and Cooray (2015), who used the NARDL model, provided a more comprehensive analysis of asymmetric adjustments, both short- and long-term, of the averaged lending and deposit rates to changes in policy rates (the 90-day futures rates for the United Kingdom and United State, and the 90-day bank bill rate for Australia). This study focuses on the top, major banks, four (4) in Australia, 10 in the United Kingdom, and 10 in the United States. Static developments in econometric modelling most probably attribute to this major drawback in the existing literature. The nonlinear EC/VECM/Threshold ECM models and their recent extensions (see Valadkhani & Anwar, 2012; Valadkhani & Bollen, 2013) have been prevalently employed in the literature since the pioneering research of, Allen, Rutherford, and Wiley (1999) and Scholnick (1996), and current studies, such as Gerlach, Mora, and Uysal (2018). This procedure enables researchers to quantify only short-term asymmetric speed or instant amount asymmetry because of its inherent

weakness in model setting. This thesis seeks to solve these major challenges by answering three research questions.

1. Does the international funding cost play a significant role in the mortgage rate transmission at an individual level in the presence of the cash rate?
2. What is the nature of this relationship: symmetry or asymmetry?
3. Does any asymmetry exist in the long-term pass-through of mortgage rates in response to changes in both cash rate and international funding cost?

2.2.2 Asymmetry in mortgage interest-rate pass-through

A fundamental principle of a perfectly competitive market is that prices symmetrically respond to changes in marginal costs. In financial markets, an efficient monetary transmission mechanism is characterised by a complete long-term pass-through from changes in policy interest rates to market and consumer interest rates. It is ascertained that rigidity in this transmission signifies an asymmetric adjustment, indicating the ineffective transmission mechanism, resulting in net welfare losses. Examining the amount and speed of asymmetric adjustments of consumer interest rates, therefore, provides convincing evidence for the efficacy of a monetary policy, the enhancement of financial soundness, market competition, and financial stability. Numerous efforts have been made, locally and globally, to examine asymmetry in the policy transmission to retail interest rates, making this strand of the literature on monetary transmission mainstream. However, the study of mortgage IRPT has remained largely unexplored and mostly confined to advanced countries. This section reviews both the theoretical and empirical literature on asymmetry in monetary policy rate transmission.

2.2.2.1 Theoretical evidence

Numerous theories clarify asymmetric pricing. This section mainly reviews the following prominent theories explaining asymmetry in retail interest rate adjustments, with the key focus on bank lending rates. The market concentration, imperfect competition, adjustment costs, and switching costs theories explain asymmetry in both short-term and long-term pass-through of interest rates. Conversely, the credit rationing or information asymmetry hypothesis (Stiglitz & Weiss, 1981) clarifies short-term asymmetry.

Concentration or market power theory (Hannan & Berger, 1991) is most widely used to justify asymmetry in interest rate adjustments with the assumption of menu costs and monopolistic competition. This scheme theorises that banks' retail rates respond to market rate shocks more slowly in more concentrated markets. Hannan and Berger (1991) corroborated this hypothesis by providing the evidence of higher upward rigidity than downward rigidity in deposit rates in the United States. This theory is implicit in the ensuing extensive literature on monetary policy transmission (e.g., De Bondt, 2005; De Graeve, De Jonghe, & Vennet, 2007; Hofmann & Mizen, 2004; Neumark & Sharpe, 1992). Moreover, highly concentrated markets created by strict entry barriers or geography are associated with weak competition pressure (Bikker & Haaf, 2002; Khan, Kutan, Ahmad, & Gee, 2017) in which banks can collude in pricing, resulting in a positive asymmetry in interest rate adjustments. In particular, upward rigidity in deposit rates and downward rigidity in lending rates are anticipated. Toolsema and Jacobs (2007) thoroughly examined this collusive pricing hypothesis by analysing the Dutch mortgage market. The authors postulate that tacit collusion with symmetric information of the oligopolistic market middlemen is a key factor of downward asymmetry in bank lending and mortgage rate adjustments. A high concentrated market enables banks to conspire together to favour themselves even though this conspiracy is illegal. If the assumption of symmetric

information about input prices and banks' collusion exists, as a consequence banks adjust their lending interest rate upwards faster than downwards even though an increase in input price is common knowledge because changes in market rates are transparent, signalling a tacit collusive agreement. Banks can make abnormal incomes as long as no one reduces its price to market rate cuts. Evidence of price coordination exists in the Dutch mortgage market, which is globally concentrated. The five largest banks in the Netherlands, holding over 85% of total sector assets, (ECB, 2017b: Chart 2.10) predominate over this mortgage market. De Haan and Sterken (2011) documented that those three others of the 'Big-5' followed a price leader in pricing their mortgage rates, indicating the dominant role of this leader in the market and its tacit collusion with these main players. Toolsema and Jacobs (2007) found short-term upward asymmetry in the Dutch mortgage rate adjustments to increases in 5- and 10-year government bond rates, confirming the collusive pricing hypothesis. Wang and Lee (2009) documented supporting evidence for this collusive pricing theory with the finding of short-term downward rigidity in the lending rates in Hong Kong, Taiwan, and the Philippines.

Second, the imperfect competition theory (Kopecky & Van Hoose, 2012) ascertains that the greater pass-through is associated with the greater competition in banking loan and deposit markets. Along the same lines, Sander and Kleimeier (2004) constructed an internal competition index by weighting the number of foreign-owned banks and their share of loans and deposits to measure the effect of competition on IRPT. They find significant evidence of upward rigidity in deposit rate adjustments due to weak competition stance. In the Euro area, banks are slower to increase their deposit rates in response to a market rate rise, while faster to reduce these rates to a market rate cut. Van Leuvensteijn, Kok Sørensen, Bikker, and Van Rixtel (2013) document convincing evidence for bank loan markets in Euro area countries that are the more competitive markets, the lower lending rates, and the greater transmission of market rate shocks into retail interest rates. Furthermore, if banks fiercely contest in a market segment, they are likely to encounter the potential risk of customer losses after responding

to market rate shifts. Highly competitive markets induce banks to reluctantly increase their lending rates while speedily reduce the rates in response to market rate hikes or cuts, resulting in a negative asymmetry, which favours borrowers (Hannan & Berger, 1991; Neumark & Sharpe, 1992).

Third, Hofmann and Mizen (2004) explained price rigidity in loans and deposits by advancing the adjustment and menu costs theory. This theory originally assumes that if the changes in market interest rates are negligible or naturally transitory, financial institutions are unwilling to adjust their rates due to the existence of searching costs, menu costs (direct price adjustment costs), and supply (indirect/quantity) adjustment costs due to changes in customer quantities. Theoretical results specify that increases in loan demand that are direct adjustment costs will be associated with an increase in price adjustment speed and higher bank market power, resulting in a greater rigidity in lending rate pass-through. In contrast, if adjustment costs of bank interest rates are indirect, such as supply costs, the transmission speed can be less or more rigid. In an extension of this theory, Hofmann and Mizen (2004) proposed a menu cost function to analyse asymmetric adjustments of mortgage rates corresponding to policy rate shocks at a UK bank level. An association between adjustment costs and interest rate adjustments is required, to have instantaneously complete pass-through. Prior to responding to policy rate shocks, banks are assumed to forecast the trend of a set of small changes to policy rates amassing them in a retail rate adjustment and to predict turning points. The turning points may mitigate their costs of reversals by catching downward or upward policy rate shifts. In a comparison with their adjustment costs, for example the costs of establishing a borrower-lender long-term relationship, banks are highly reluctant to adjust their lending rates if their profit function is flat. Hofmann and Mizen (2004) theorised that banks feasibly reprice in an asymmetric manner if these accumulated policy rate changes are estimated to have a similar path and if their menu costs are less than the loss of unchanged lending rates. Banks' two options when responding to policy rate shocks are lowering margins and lowering the expected spreads by increasing retail rates. The former

decision results in a rigid traverse, while the latter produces a complete pass through. The authors propose that transitory pass-through can prevail in the transmission process due to anticipation of the prospective policy stance. Fuertes, Heffernan, and Kalotychou (2010) provided supporting empirical evidence for this model. Results of their study showed that these housing rates are asymmetrically transmitted more rapidly to policy rate rises than to rate cuts when they are overcharged, but transmitted more rapidly to policy rate cuts if they are underpaid. However, the relationship between banks' market power and adjustment costs is so complicated; therefore, explaining asymmetry in interest rate adjustments remains an interesting challenge for researchers.

Fourth, the switching costs hypothesis (Heffernan, 1997; Lowe & Rohling, 1992) explains asymmetric adjustments of interest rates based on the market power assumption. This hypothesis postulates that unsophisticated clients are likely reluctant to swap their financial products or their suppliers even when they recognise the presence of a high switching costs. The price stickiness can activate and stimulate the financial institutions' manipulation in their pricing. In this situation, deposit interest rates are anticipated to be upward rigidity, while lending rates are projected to be downward rigidity.

Finally, the asymmetric information framework (Stiglitz & Weiss, 1981) supposes that adverse selection and moral hazard are two major problems for financial institutions when their lending interest rates are increased in response to market rate rises. In the short term, banks tend to replace their significant increases in lending rates with their credit rationing in response to an upward pressure on their lending rates, resulting an upward rigidity in lending rates.

2.2.2.2 Empirical evidence

Empirical studies of the asymmetric transmission of the money policy and capital market rates to mortgage rates have been extensively explored, in particular in the US and advanced markets that can

be divided into two categories: lender preference and borrower preference. The former, almost all studies of asymmetric pricing of home loans, confirms that housing interest rates tend to be asymmetrically stickier to decreases in bank funding costs than to increases. A single-country analysis (Allen, Rutherford, & Wiley, 1999) tested the responsiveness of mortgage rates to changes in the US Treasury and Aaa and Baa corporate bond rates during the period 1971 to 1994. The findings showed a stronger pass-through speed from market rate rises into mortgage rates than that from rate cuts. Allen and McVanel (2009) concluded no evidence of asymmetry in the Canadian mortgage market in long-term pass-through of the 3- and 5-year fixed home-loan rates in response to changes in the 3- and 5-year Government bond rates, but significant evidence for an upward asymmetry in the short-term. The authors proposed both the asymmetric speed (sign asymmetry) and adjustment amount (size asymmetry) in short-term pass-through of Canadian fixed mortgage rates. Positive asymmetric adjustments of mortgage rates to changes in bond rates or money policy rates have also been identified in both single-country or cross-country analyses for numerous housing credit markets, in countries such as Singapore and Malaysia (Scholnick, 1996), Canada and the United States (Scholnick, 1999), and the United Kingdom (Fuertes & Heffernan, 2009; Fuertes et al., 2010). Evidence of downward rigidity that supports the concentration theory is found in most of these markets, while the UK findings reaffirm the adjustment and menu costs hypotheses. However, Scholnick (1999) failed to identify the existence of asymmetries in the US long-term mortgage rate adjustments. Recent Australian studies using aggregate data (Liu, Margaritis, & Qiao, 2016; Valadkhani & Anwar, 2012) or bank-level data (Apergis & Cooray, 2015; Valadkhani, 2013; Valadkhani & Worthington, 2014) have documented convincing evidence for the occurrence of a positive asymmetry in the short-term pass-through of mortgage rates corresponding to cash rate surprises. These studies attained a similar conclusion. They found the prevalent presence of a positive asymmetry in housing rate adjustments

in the short run arising from bank market power, using both concentration and switching costs theories.

Conversely, the evidence of upward rigidity in home-loan rate adjustments that benefits mortgage holders has been confirmed in several markets. In Singapore, Chong, Liu, and Shrestha (2006) found that the consumer interest rates on 15-year housing loans, 3-year hire-purchase loans, prime lending loans, and all sampled deposits are adjusted more quickly to the SIBOR when the retail rates are above their equilibrium than below their equilibrium. The asymmetric speed and instant pass-through of mortgage rates, both fixed and floating, in response to the cost of funds approximated by the 6-month deposit rate are found in New Zealand (Liu et al., 2008; 2011). In particular, these authors affirmed that New Zealand lenders responded more quickly to funding cost cuts than they did to cost rises. Similar findings of a short-run negative asymmetry in mortgage rate adjustments, which favours borrowers, were affirmed for the four largest Dutch banks in the Netherlands (De Haan & Sterken, 2011), Malaysia (Zulkhibri, 2012), the United Kingdom (Ahmad et al., 2013) and the United States (Payne, 2007; Payne & Waters, 2008), at a country level. Studies of the Dutch and New Zealand mortgage markets supported the competition hypothesis, while the analyses for Malaysia, the United Kingdom and the United States confirmed the customer reaction and adverse selection hypotheses.

2.2.2.3 Gaps in the literature

Five important research gaps exist in this strand of the literature. The first key research gap is associated with the asymmetric transmission of international funding cost to mortgage rates at bank or country levels, both locally and internationally. To the best of my knowledge, none of the empirical research I reviewed directly relates the asymmetric transmission of foreign-funding cost to mortgage rates, in Australian or overseas mortgage markets. The recent strand of the literature focuses on the asymmetric association between the cash rate and nominal mortgage rates for Australian banks. Liu

et al. (2016), Valadkhani and Anwar (2012), Valadkhani and Bollen (2013), and Valadkhani and Worthington (2014) have consistently documented empirical evidence of the positive asymmetries, both the sign and the short-term size, at bank or country levels. Among the conspicuous international studies, just three (Allen & McVanel, 2009; De Haan & Sterken, 2011; Liu et al., 2011) have modelled both the sign and size asymmetries in short-run pass-through of mortgage rates to policy or market rates. The majority of existing studies solely quantified the speed asymmetry (Ahmad et al., 2013; Chong, Liu, & Shrestha, 2006; Fuertes et al., 2010; Liu et al., 2008). The second research gap is a paucity of literature on investigating the asymmetric effect of the GFC on the policy rate transmission to mortgage rates. Three single-country studies have recently considered potential changes in the policy rate transmission to mortgage rates due to the GFC for Australia (Liu et al., 2016; Valadkhani, 2013) and the United Kingdom (Ahmad et al., 2013). The Australian researchers simply used a dummy variable to be a proxy for the GFC effect and their findings were connected to the higher markups in the post-crisis period compared with conditions prior to the GFC. However, the study findings were ambiguous; therefore, this is the third research gap. Valadkhani (2013), using bank-level data, found the short-term positive asymmetric adjustments of mortgage rates to policy rate shocks, favoured Australian lenders and completely differed from the other two. Conversely, both Ahmad et al. (2013) and Liu et al. (2016) using aggregated data documented an upward rigidity/negative asymmetry in speed of the transmission for the United Kingdom (the former) and Australia (the latter). Only the cross-country study (Apergis & Cooray, 2015) explicitly examined the presence of short- and long-run pass-through asymmetries before and after the crisis by dividing the full sample into two sub-spans. By doing so, they measured the effect of the crisis on the policy transmission and found significant evidence of post-GFC upward asymmetries for Australian banks only. Their finding is consistent with that of Valadkhani (2013) who found that Australian banks adjust their lending and mortgage rates corresponding to a policy rate rise faster than a rate cut.

However, this study could conceal the nature of each loan product by using a weighted average rate on consumer loans, housing loans, and corporate loans. This may explain why their finding is inconsistent with the Ahmad et al. (2013) outcome who found an upward rigidity in both lending and housing rate pass-throughs for the United Kingdom. Moreover, the reviewed studies are subject to another significant limitation because they mainly focus on the time-series dimension. None of them quantifies the asymmetry in panel form to consider both bank-specific and time effects, which is the fourth key research gap. Finally, very few of the extant studies identified asymmetric IRPT at the transaction mortgage rate level. My research on this strand of the existing literature shows that just four papers (Apergis & Cooray, 2015; Fuertes & Heffernan, 2009; Fuertes et al., 2010; Valadkhani, 2013) employed a comprehensive bank-level dataset of mortgage rates, except a weighted lending rate for the first study. Several other contributions, Valadkhani and Worthington (2014) for Australia, Allen and McVanel (2009) for Canada, De Haan and Sterken (2011) for the Netherlands, and Hofmann and Mizen (2004) for the United Kingdom are narrow in the number of major banks they included. The unavailability of bank interest rates, especially mortgage rates, in the form of datasets due to the strictly confidential regulations in banking, can also explain the shortcoming. This study endeavours to fill these gaps in the literature with the following research questions.

1. Are there both short-term and long-term asymmetries in the pass-through of the cash rate and the international funding cost into the mortgage rate in Australia, considering both bank-specific and time-dimension effects?

2. Does the cash rate still drive the mortgage rate in the presence of the international funding cost after the GFC?

3. Has Australian bank mortgage pricing behaviour changed since the crisis?

2.3.1 Heterogeneity in mortgage interest-rate pass-through

The efficiency of monetary policy transmission is measured through the flexibility and completeness in the pass-through from policy or money market rate shifts to retail lending and deposit rates. Subsequently, this transmission governs the relationship between monetary supply and economic output. From this perspective, the lending and mortgage interest rate channels play an integral part in the monetary transmission with ultimate influence on investment and consumption, as well as the real economy. Given the utmost importance of the interest rate channel, the study of heterogeneity in this transmission mechanism has become the other mainstream of the literature. A review of this strand focusing on the pass-through of mortgage rates is rationally provided.

2.3.1.1 Aggregated evidence

Empirical IRPT studies in mortgage markets using nonlinear techniques are mostly confined to core advanced economies. Conversely, the literature on retail bank interest-rate pass-through is extensive and diverse regarding data, time spans, country selections, various techniques, procedures, and findings. This critique focuses on reviewing the work conducted for the pass-through of bank mortgage interest rates. These available studies are classified into two groups based on datatypes: aggregated and disaggregated. A majority of both single- and cross-country studies employ macro datasets at mostly monthly frequency for both fixed and variable rates of mortgages. These analyses are all motivated by market innovations resulting from the introduction of the EU zone in 1999, deregulation, market and policy reforms in the OECD, and transition economies or ensuing market structure changes originated by the US mortgage defaults, the subsequent GFC, and the sovereign debt crisis. Numerous single-country analyses have assessed the degrees of integration between housing interest rates and policy rates in well-developed mortgage markets: Australia (Liu et al. 2016; Lowe, 1995; Sathye, 2013), Sweden (Harbo Hansen and Welz 2011), and the United Kingdom

(Becker et al. 2012). Most cross-country studies (Bernhofer and Van Treeck 2013; De Bondt 2005; Illes et al. 2015; Sorensen and Werner 2006) examined heterogeneity in bank price-setting behaviour for the Euro-zone area using the compatible maturity market rates as proxies for the cost of funds rates. Recent country-level studies have investigated the effect of the GFC on heterogeneous pass-through of monetary policy/market rates to bank interest rates on deposits, mortgages, and business, as well as consumption loans across the EU members (Aristei & Gallo, 2014; Belke et al., 2013; Hristov et al., 2014; Von Borstel et al., 2016). These researchers used different techniques with the dominance of the ECM and its extensions and provided vague findings.

For the Euro zone and most single advanced markets, the patterning of the main findings is as follows: The immediate and long-term pass-through for mortgage interest rates and other retail rates on corporate, consumer loans and deposits are mostly incomplete, except mixed results found in New Zealand. Short-term lending rates are more responsive to policy rates than the longer maturity rates. Lending interest rates respond faster and to a greater extent than deposit rates. Heterogeneity exists in both short- and long-term pass-through. However, ambiguous findings were found in several mortgage markets. The Swedish results found the complete long-term pass-through for floating rates on mortgages. Also, Liu et al. (2008) found mixed results for New Zealand: the transmission of the policy rate to both fixed and floating rates on mortgages is incomplete, consistent with the US and Singaporean results (Chong et al., 2006; Payne, 2006a, b), but complete long-term pass-through is found for the 2- and 5-year fixed rates on mortgages and bond yields with compatible maturities in line with the results of De Bondt (2005) and Sorensen and Werner (2006). These studies largely confirmed the positive effect of market innovations and policy reforms on pass-through with a fuller size and faster speed in the EU zone and New Zealand (De Bondt, 2005; Liu et al., 2008), except by Bernhofer and Van Treeck (2013), who made contrary findings. Moreover, regarding the GFC impact on the interest rate channel, the findings are vague. Most studies found transmission breaks in the

sizes of the immediate and long-term pass-through for Australian, EU, Swedish, and the US mortgage markets (Aristei & Gallo, 2014; Harbo, Hansen, & Welz, 2011; Hristov et al., 2014; Lim et al., 2013; Liu et al., 2016; Sathye, 2013). On the contrary, Von Borstel et al. (2016) concluded there was no impairment and Illes et al. (2015) posited an incomplete long-term pass-through and the existence of the stable bank price-setting behaviour in the Euro zone after the GFC.

In Australia, since the pioneers, Lowe (1995) and Lowe and Rohling (1992), several researchers (Lim et al., 2013; Liu et al., 2016; Sathye, 2013) have examined the integration between the cash rate and mortgage interest rates using aggregated data. Sathye (2013) considered the GFC effect on the transmission of the cash rate into the home lending standard variable rate and concluded the existence of a break in this relationship due to the crisis. However, Sathye's (2013) results may be constrained by using data over the period 1999:9–2009:8, which may not allow more sophisticated tests to be performed, except the unknown structural break Quandt–Andrews test. Lim et al. (2013), using macro data over the period 1982:3–2012:3, proposed a new approach to measure the interactions between the cash rate and bank interest rates on fixed mortgages (United States), variable home loans (Australia), and 3-month deposits before, during, and after the GFC. Their findings showed that until mid-2007, both Australian and US banks partially transmitted policy rate changes into their mortgage rates, but the former were more likely to pass on these changes than the latter. This finding is consistent with not only the prior Australian work, but also the aggregated European studies, which confirmed the fact that a home-loan variable rate is more reactive to policy rate changes than a fixed mortgage rate at a long (30-year) maturity. Since the GFC, an overshooting long-term pass-through has been found for each sampled interest rate and these magnitudes found in the United States are higher than those in Australia, reflecting US banks' stronger reaction to the greater volatility in this market. A dramatic plunge in the mortgage rate pass-through in Australia from 1.5 in late 2009 to nearly unity in early 2010 could have resulted from changes in monetary policy stances from easing

to tightening and the funding cost rise. Overall, Lim et al. (2013), Lowe (1995), and Sathye (2013) documented incomplete pass-through results for variable mortgage rates and other lending rates in line with a majority of aggregated studies.

2.3.1.2 Disaggregated evidence

Contrasting with the mainstream literature using aggregated data, a few studies employing disaggregated data explored the link between mortgage interest rates and the cost of funds rates. The lack of a long series of individual bank rates is seen as a key ground for the scarce evidence on the effects of monetary shocks on retail rates and bank price-setting. In particular, De Graeve et al. (2007), adopting the CFA, took compatible maturity market rates as proxies for the cost of funds rates for 31 Belgian banks. These authors investigated the price-setting conduct of this bank-specific sample for 13 types of interest rates, including fixed-rate mortgages from 1993:1–2002:12. Similarly, Horváth, and Podpiera (2012) used different money market rates, 1-month to 1-year, to examine how bank interest rates on Czech mortgages, non-corporate, consumption loans, and deposits reacted to market shocks. Their bank-specific sample ranged from 13 (for mortgages) to 20 banks (for business loans and deposits) for the period January 2004 to December 2008. The latest study in Poland (Kapuściński & Stanisławska, 2018) examined the driving factors of lending rates on house-purchase and business loans for 19 Polish banks over the period Jan 2005 to July 2016. The authors used high–frequency data at monthly intervals, and the standard panel cointegration models, typically the MG and PMG estimators. Using a comprehensive bank-level dataset with a relatively long period and various products offers more efficient estimated results, overcomes aggregation bias problems (detailed in Imbs et al., 2005), and enables researchers to analyse other factors determining the IRPT rigidity.

Overall, these bank-level studies provided result patterning as follows: First, a fuller size and faster speed of pass-through were found for all individual interest rates compared with the results of the

aggregated-data analyses. Second, the incompleteness of immediate and short-term pass-through exists for all individual interest rates, but shows wide variations in size and speed across different products and banks in line with the cross-country analyses using aggregated data. For example, the size and adjustment speed of the Belgian 5-year deposit rate were very slow at 0.022 and 0.115, but those of the 5-year mortgage rate were much faster at 0.035 and 0.22, respectively. Third, these studies, consistent with the EU research using aggregated data, confirmed that the size of long-term pass-through is homogeneously closer to unity for the longer maturity rates.

However, the results of these studies are still vague to a certain extent. First, mixed long-term findings were found in the Belgian, and Czech banks. A full responsiveness exists for interest rates on some types of deposits and personal loans, but incomplete pass-through for the mortgage and other retail rates. Second, Czech and Belgian bank deposits have much fuller instantaneous pass-through than mortgages (De Graeve et al., 2007; Horváth & Podpiera, 2012), but the UK results by Fuertes and Heffernan (2009), and Fuertes et al. (2010) were completely opposite. Third, Polish banks transmitted nearly complete changes in both money market rate and marginal funding cost to their mortgage and other lending rates in the long run, but the Belgium banks passed on a half to their mortgage rates.

The existence of heterogeneity in short-term pass-through and these inconclusive findings in the literature have been theoretically and empirically explained. The theoretical grounds are disparities in market structure, credit risk (De Bondt, 2005; Hannan & Berger, 1991; Neumark & Sharpe, 1992), adjustment and menu costs (Hofmann & Mizen, 2004), competition (Kopecky & Van Hoose, 2012), and capital buffer (Baglioni, 2007), of which market power is the most important factor. Empirical contributions have also documented other factors of heterogeneity in the pass-through: diversifications and market developments (Cottarelli & Kourelis, 1994), and bank-specific characteristics (De Graeve et al., 2007; Fuertes et al., 2010; Horváth & Podpiera, 2012).

2.3.1.3 Gaps in the literature

From the extant empirical studies, it is clear that the mortgage rate transmission mechanism is integral to monetary policy mechanisms, nationally and globally. My review of this strand reveals three important knowledge shortages. First, no empirical studies of the transmission from the policy rate/money market rate/funding cost to retail bank interest rates have considered the effect of unobserved common factors on this transmission, neither in Australia nor in other countries. In contemporary econometrics, finance, and macroeconomics, this matter is of paramount consideration. Differing from other sectors, the banking environment is highly interactive through economic, regulatory, political, and other channels domestically and internationally. Bank operations are subjected to considerable phenomena ranging from national policy changes to global economic shocks, such as the recent financial and sovereign debt crises. Given the importance of the Australian mortgage market and significant structural developments since the GFC, the urgent need highlights deeper understanding of to what extent the unobservables influence bank price-setting behaviour. This study sheds light on assessing the effect of unobserved common factors on the mortgage rate–funding cost nexus for Australian banks. Second, not taking cross-sectional dependence into consideration is the major shortcoming in the literature on monetary policy transmission, which is highly attributed to the contradictory findings and the questionable nature of the long-term pass-through (homogeneity or heterogeneity). Cross-sectional correlation arising from both observed (modelled) and unobserved (non-modelled) common factors, national and global, is theoretically inherent in interest rate panels. A solid foundation for the CD properties of macro panel data has been established in the contemporary literature on growth and econometrics (Bai & Ng, 2004; Castagnetti, Rossi, & Trapani, 2017; Eberhardt & Teal, 2013). However, the literature on interest rate transmission has persistently overlooked this important issue by repeatedly using standard panel-cointegration models, such as the MG and PMG (Horvath et al., 2018; Horváth & Podpiera, 2012; Illes et al., 2015;

Kapuściński & Stanisławska, 2018). Ignoring the CD in these conventional techniques, which are based on the assumption of cross-sectional independence, most likely provided unreliable estimates with severe size distortions (Omay et al., 2017; Pesaran, 2006). Given this serious matter, the applicability and generalisability of the results to other market are serious concerns. Finally, preceding Australian studies mainly focused on the strand of asymmetry (Apergis & Cooray, 2015; Lim, 2001; Valadkhani & Anwar, 2012). Several researchers have recently assessed heterogeneity in this transmission (Lim et al., 2013; Sathye, 2013), but they employed the datasets of different aggregated interest rates on mortgages, deposits, and other retail products. Also, the international literature, using comprehensive micro-data of retail interest rates, is hitherto scant with the presence of several studies for the Czech Republic (Horvath et al., 2018; Horváth & Podpiera, 2012), Belgium (De Graeve et al., 2007), and Poland (Kapuściński & Stanisławska, 2018), the United States (Gerlach et al., 2018), and Chile (Pedersen, 2018). These reviewed studies used data at monthly frequency. However, the Chilean and US analyses investigated the transmission of corporate lending and deposit rates only. This study contributes to the extension of the literature using micro-level data of bank mortgage rates at weekly frequency. This study strives to be first with three key research questions of interest.

1. Do unobservables affect the interest rate transmission, both symmetry and asymmetry, when considering both bank-specific effect and time dimensions?
2. Is the nature of the long-term interest rate transmission, both symmetry and asymmetry, accurately homogeneous?
3. Does the international funding cost still affect the mortgage rate when controlling for cross-sectional dependence?

2.4.1 Determinants of retail interest-rate pass-through

The effectiveness of the retail interest-rate pass-through mechanism constitutes an essential part of the efficacy of monetary transmission. This is of vital interest to the RBA in conducting their monetary policies to achieve the targets of economic output, inflation, and employments. The worsening long-term transmission of the policy rate arising from the GFC therefore has been the central attention of policy makers and created a new line of research on the IRPT determinants. Several studies, for example, have recently attempted to examine how credit and liquidity risk affect the policy transmission (Beirne, 2012; Kapuściński & Stanisławska, 2018; Pedersen, 2018)

2.4.1.1 Preceding GFC evidence

The third strand examining determinants of retail interest-rate pass-through is still rudimentary knowledge in comparison with the two major strands of the literature on heterogeneity and asymmetry in the IRPT mechanism. The pioneers Cottarelli and Kourelis (1994) extended the markup framework of Rousseas (1985) to identify disparities in the pass-through of the prime and nonprime lending rates corresponding to the 3- and 6-month market rate changes. The researchers employed a two-stage approach to analyse the monthly dataset of 31 developed and developing countries for the period 1983–1993. The ARDL model is first used to estimate the pass-through parameters then the WLS and OLS models are employed to measure the cross-country variations in these pass-through coefficients. Key variables of the economic and financial structures, including inflation, financial development, market risk, negotiable short-term financial instruments, bank ownership, market concentration, or competition are used to explain for the pass-through stickiness and cross-country variations of the pass-through. Cottarelli and Kourelis (1994) found the significant relationship between most of these explaining factors and the pass-through process, except the market concentration or banking competition, negotiable short-term financial instruments issued by firms,

and financial development proxied by GDP per capita. This work is the key theoretical and empirical basis in examining determinants of the pass-through process.

Since the precursors (Cottarelli & Kourelis, 1994; Mojon, 2000) to the GFC, this strand focuses mainly on the prime role of banking competition/concentration in the IRPT in both country- and bank-level studies. From a cross-country perspective, Corvoisier and Gropp (2002) constructed the Herfindahl indices (HHI) measuring bank concentration levels for each Euro member. They used a number of bank products to identify the effect of increasing concentration by deregulation on bank pricing in the Euro area. This index is still employed in recent emerging-country investigations (Gopalan & Rajan, 2017; Ozdemir & Altinoz, 2012). Previous studies found that increasing competition improves the IRPT in deposit markets, but has an insignificant effect on loan markets (Sander and Kleimeier, 2004). Van Leuvensteijn et al. (2013) adopting the Boone indicator, a new competition measure, investigated the influence of market contestability on loan interest rates over the period 1994–2004. Their findings show that: (1) the stronger competition among banks that exists, the lower loan interest rates are set, and (2) the greater pass-through degree of market rate adjustments into bank rates will be. Several single-country studies employ bank-level data with the application of different concentration and competition indices (De Graeve et al., 2007; Fuertes et al., 2010). Also, a recent study of an emerging market (Chileshe & Akanbi, 2016) using the HHI, and Lerner indices examines the impact of banking competition on the IRPT in Zambia from 1998:Q1–2015:Q2. Their findings confirm that stronger competition improves the pass-through process which are consistent with the previous findings in the Euro area. Concentration and competition factors are concluded to be the driving factors of the retail interest-rate pass-through.

2.4.1.2 Post-crisis evidence

Since the GFC, identifying influential factors of the IRPT has attracted more attention (Beirne, 2012; Gambacorta & Mistrulli, 2014; Gregor & Melecký, 2018; Havranek, Irsova, & Lesanovska, 2016; Perera & Wickramanayake, 2016). This newer and richer line of research on determinants of the interest-rate pass-through is confined to a certain number of macroeconomic, financial structure, and bank-specific factors. Following Cottarelli and Kourelis (1994), most cross-country studies have examined key macroeconomic-financial factors influencing the IRPT; most bank-level analyses focus on identifying bank characteristics. In particular, inflation, economic growth, financial development, market volatility, sector competition, foreign bank participation, sector stability and profitability are confirmed to be significant determinants of the transmission (Leroy & Lucotte, 2016; Perera & Wickramanayake, 2016). Several single-country analyses have taken selected macroeconomic-financial determinants such as, GDP, business condition, market volatility, and inflation (Bogoev, 2010; Gambacorta, 2008; Kitamura, Muto, & Takei, 2016). Bank-specific characteristics including: liquidity, capital adequacy, efficiency, size, and credit risk are mainly captured in bank-level data analyses before (Bogoev, 2010; De Graeve et al., 2007; Fuertes et al., 2010; Gambacorta, 2008), and after the GFC (Havranek et al., 2016; Horváth & Podpiera, 2012; Kitamura et al., 2016). The Italian (Gambacorta & Mistrulli, 2014) and Japanese (Kitamura et al., 2016) bank-level studies have also investigated the effect of demand side, measured by firms' market funding, debt to equity and interest coverage ratios, on the corporate lending-rate pass-through. Several main institutional characteristics such as, organised quality, governance, and accountability have been considered to explain bank rate-setting variations (Perera & Wickramanayake, 2016).

Summary

Most country-level studies focus on assessing heterogeneity in the pass-through in the Euro area owing to the importance of the common currency that makes the monetary transmission among the Euro members crucial. Several studies examine the pass-through determinants in emerging markets (Grigoli & Mota, 2017; Pedersen, 2018), and enlarge to investigate simultaneously low income, emerging, and industrial economies (Gigineishvili, 2011; Perera & Wickramanayake, 2016). Single-country analyses using bank-level data, especially the mortgage markets, remain scarce in several countries, such as the Czech (Havranek et al., 2016; Horváth & Podpiera, 2012), the Polish (Kapuściński & Stanisławska, 2018), and Japanese (Kitamura et al., 2016) banking sectors.

Findings of the reviewed literature on the IRPT determinants are heterogeneous. Most macroeconomic and financial structure factors, except GDP growth, are confirmed to be significant determinants in most cross-country studies (Cottarelli & Kourelis, 1994; Leroy & Lucotte, 2016; Perera & Wickramanayake, 2016), and single-country analyses (Bogoev, 2010; Gambacorta, 2008). In particular, per capita GDP insignificantly affects the short-term transmission in the sample of 31 industrial and developing countries over the sampled period, 1983–1993, by Cottarelli and Kourelis (1994). However, this variable is confirmed to have the significant and positive influence on the transmission in the 10 euro-zone markets (Sander & Kleimeier, 2004), or in 70 countries from all development stages (Gigineishvili, 2011). Market volatility is typically affirmed to have reverse effect on the pass-through. However, Leroy and Lucotte (2016) have found a positive impact on house-purchase lending rates. Regarding bank-specific characteristics, liquidity, capitalisation, and lending relationship, are found to negatively influence the adjustment speed and short-term pass-through parameters of Italian bank rates on both loans and deposits, while bank size positively affects these pass-through coefficients (Gambacorta, 2008; Kitamura et al., 2016). However, the opposite findings are found in the Belgian (De Graeve et al., 2007) and Czech (Horváth & Podpiera, 2012) markets. The Macedonian findings of Bogoev (2010) are mixed. This researcher documents either

positive or negative impacts of the bank-specific factors, market volatility, inflation, and economic growth on the immediate multipliers of the lending rate transmission varying among individual banks.

2.4.1.3 Gaps in the literature

Ambiguous findings of the reviewed literature on pass-through determinants possibly arise from the sample selections, datasets, variable measures, and estimated models. Selected samples can generate variations in findings owing to differences in market structure and time spans. The first major constraint of the extant literature, both aggregated data and disaggregated data analyses, could stem from the variable measurement and estimated procedures. The two-stage approach analyses (De Graeve et al., 2007; Fuertes et al., 2010; Horváth & Podpiera, 2012) first employ the ECM to estimate pass-through parameters, and then separately regressed them on the key determinants related to bank-level characteristics and/or economic structure. Other studies (Gambacorta, 2008; Perera and Wickramanayake, 2016; Kitamura et al., 2016) adopt the direct approach which directly regresses determinants in the pass-through regressions. The results estimated by the ECM for time series (Sander and Kleimeier, 2004; Fuertes et al., 2010) would be inefficient because of disregarding the effect of cross-section units. Using conventional panel cointegration techniques (Horvath et al., 2018; Horváth & Podpiera, 2012; Kapuściński & Stanisławska, 2018; Leroy & Lucotte, 2016), or recent approaches such as the quadratic method (Dubecq, Monfort, Renne, & Roussellet, 2016), would produce substantially distorted results, because these methods disregard nonlinearity, slope homogeneity and cross-sectional correlation issues in their model setting. A few studies (Bogoev, 2010; Gambacorta & Mistrulli, 2014) apply the SUR model (Zellner, 1962) to tackle this issue. However, these researchers only examine the symmetric determinants and/or short-term pass-through and document the signs of the determinants. This study aims to fill this gap in the literature by adopting the nonlinear augmented mean group (NAMG) method in panel form proposed by Holland

et al. (2018). This model, built on the decomposition procedure of the NARDL approach (Shin et al., 2014) and the panel common-factor AMG method (Bond & Eberhardt, 2013; Castagnetti, Rossi, & Trapani, 2017; Eberhardt & Bond, 2009), enables researchers to estimate simultaneously and directly asymmetric pass-through parameters of mortgage rates associated with increases and decreases in each determinant while controlling for slope homogeneity and complex cross-sectional dependencies.

Second, empirical analyses on the IRPT determinants are uncultivated with a few analyses using disaggregated data of mortgage interest rates (De Graeve et al., 2007; Fuertes et al., 2010; Holland et al., 2018; Horváth & Podpiera, 2012). Most existing studies have mainly explored pass-through determinants of prime rates, which are limited to firm lending rates or the weighted lending and deposit rates. Empirical research on pass-through determinants of mortgage rates remain scarce. Fuertes et al. (2010) separately investigate the key pass-through determinants of mortgage rates at the UK bank-level for the period 1993:1–2005:6. Leroy and Lucotte (2016) examine the determinants of the borrowing costs on house-purchase loans, but these researchers use a country-level dataset or the data is out of date. Lacking long-time interest rate series on mortgage credit is the key explanation for this paucity of the literature. This essay contributes to this literature strand of the pass-through determinants by constructing a novel dataset of occupied-housing loan rates at the bank level.

Most importantly, the reviewed literature customarily focuses on identifying symmetric determinants of the interest rate pass-through, whereas few studies (Fuertes et al., 2010; Grigoli & Mota, 2017; Kitamura et al., 2016) have tackled the asymmetric determinants of the IRPT. Fuertes et al. (2010) have separately explored the effects of bank-specific balance sheet characteristics on size asymmetry, curvature, and adjustment speed of mortgage rates for the UK banks over the period 1993:1–2005:6. However, the UK researchers investigate the impacts on short-term pass-through only. Kitamura et al. (2016) have considered this impact on short- and long-term corporate lending rates for 115

Japanese banks in the period 2003:3–2014:9. They find no clear evidence of the asymmetric adjustments between rising and falling periods, and also no obvious asymmetric influence on the pass-through. These findings might be insufficient because the researchers only use dummy variables to control for the periods of interest rate increasing and decreasing. The Dominican study using the asymmetric momentum threshold autoregressive (M-TAR) ECM provides significant evidence of asymmetry in speed adjustments of the various bank rates, but not for the long-term transmission. Given a paucity of the literature on the asymmetric determinants of the retail interest rate transmission, and its crucial policy implications, this examination attempts to close this gap by exploring the asymmetric influence of potential drivers on the mortgage rate pass-through at the Australian bank level. My study includes macroeconomic-financial conditions and banks' perceived credit-risk factors to identify influential determinants of the asymmetric pass-through of mortgage interest rates in Australia with regard two research questions.

1. Do macroeconomic conditions play any significant role in affecting the asymmetric interest rate transmission, when considering both observables and unobservables?
2. Are these factors attributed to the impairment of the long-term cash rate transmission since the GFC?

2.3 Australian market background

This section discusses the institutional setting of the Australian residential mortgage market in order to highlight the importance of exploring the relationship of international funding cost with mortgage interest rate adjustments in Australia.

2.3.1 The market

The Australian mortgage market, one of the top five global markets that are greater than 100% of GDP, is well developed (see Figure 2.1). Its value, $1,860.45 billion in December 2016 which was more than the value of the listed equity market, represented/represents approximately one-third of total outstanding market credit. In this area, owner-occupied housing loans constitute two-thirds of the total, equivalent to over 60% of GDP (author's calculation based on data from APRA 2017; ABS 2017a, b, hereafter 'author's calculation'). Australia and Canada are among the OECD countries that emerged relatively unscathed from the recent global financial distress. Their mortgage markets have remained stable—increasingly so in the last decade—whereas numerous others such as Iceland, Denmark, Portugal, Spain, the US and Netherlands, observed a significant decline in their market sizes. The UK market size in particular crashed to an all-time low, from over 200 to 92% of GDP in 2012, and stands at a hitherto low rate at 90 percent (IMF 2017).

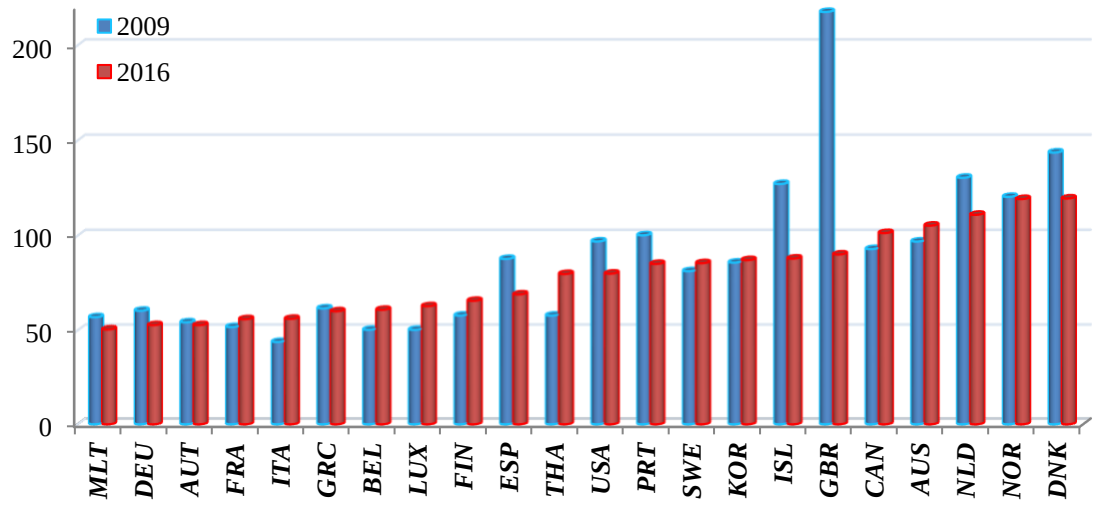

Figure 2.1 Mortgage market sizes of OECD countries, percent of GDP. Source: IMF 2017, Financial Soundness Indicators Database. Data is as of December 2016 or latest available

All types of housing finance have soared over the analysed period (see Figure 2.2). Mortgage debt outstanding as a percentage of GDP has trebled from nearly 30% at the beginning of the sampled

period to 93% in 2006, and has increased with a mortgage boom up to 105% during the last decade (IMF 2017). The prolonged flow of mortgages to homeowners and investors has built up massive household indebtedness. Compared with annualised household disposable income, by December 2016 total housing debt had increased 2.5 times, to 134%, and residential mortgage debt or owner-occupied housing loans had doubled, reaching 100.2% (RBA 2017 "Household Finance -E2").

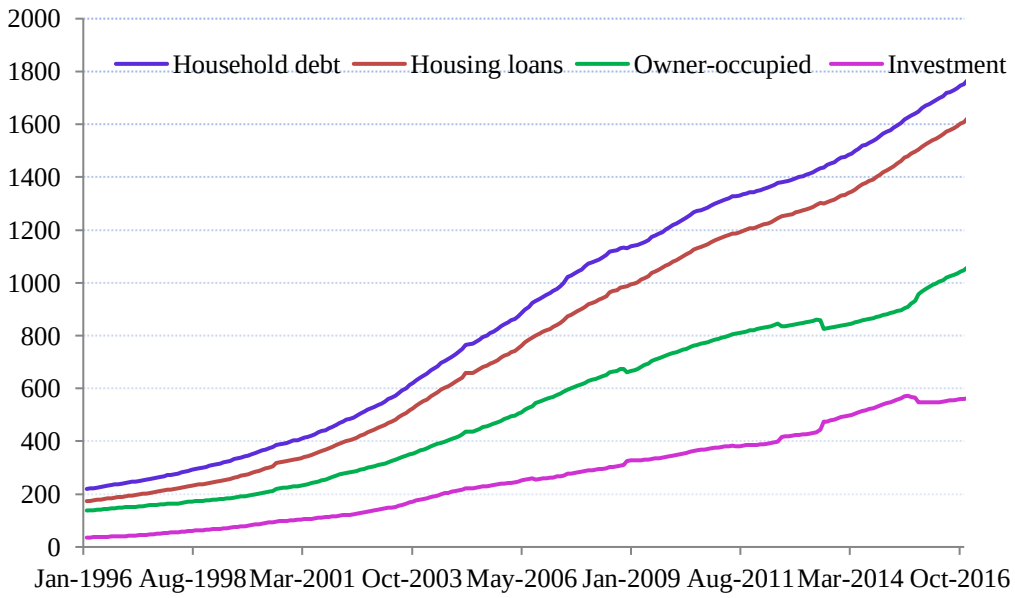

Figure 2.2 Housing debt developments in Australia, AU$ billion, year ending December. Source: RBA 2017 Statistics, Table D02

Mortgages, the largest proportion of household liabilities and bank balance sheets, comprise about 80–90%; personal loans have reduced from 20 to 10% of the total during the analysed time-span (see Figure 2.3). In particular, owner-occupied loans, which have largely controlled housing finance, fluctuated slightly around 60% of the total mortgage debt during the sampled period, excluding two trivial dips following the 1997 Asian financial crises and the 2012 financial distress in Europe. Australia differs from most OECD economies, which crashed immediately after the GFC of 2008–2009. Australia's mortgage market decreased slightly in owner-occupied loans in 2007, recovered rapidly in the following year, with an incredible upturn until mid-2012, as the outcome of policy

initiatives undertaken in both pre- and post-GFC, before plummeting to the pre-Asian crisis level in 2013–2014 and barely recovering since November 2015. Conversely, investment housing loans, which account for roughly one-third of housing lending, exhibit an upward trend over the whole period. This segment grew noticeably in the first half of the sampled period, resulting from changes in tax regimes in 1999 that enabled property investors to deduct their operating costs. These costs, including interest costs against income, can be deducted from paying tax on either real capital gains or on nominal gains at 50% discount[3]. From September 2006 to September 2008, loans to housing investors marginally declined due to the influence of the 2007 Northern Rock downfall. After 2008, this market segment recovered to the pre-crisis level, continued to expand to a peak of 35% of the total market share in August 2015, before reducing until the end of 2016.

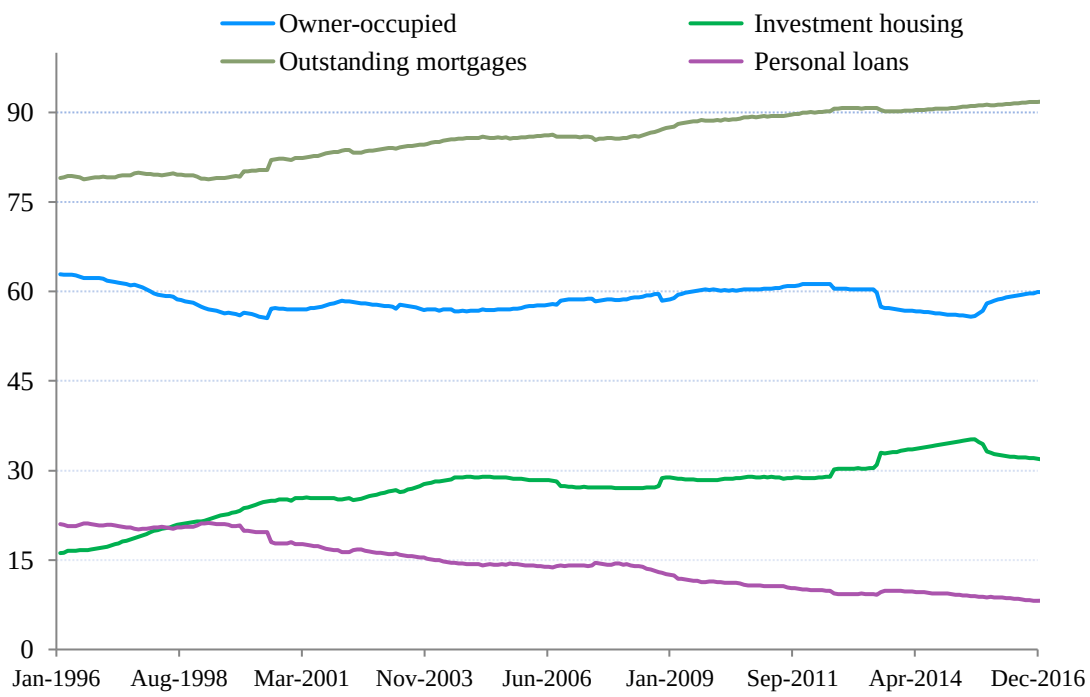

Figure 2.3 Housing debt composition. Source RBA 2017 Statistics, TableD02

[3] Details of the Australian tax system are in Treasury (2008, 2009)

Variable interest rate mortgages are most prevalent in Australia, the UK, and the Euro area, differing from the US where fixed-rate mortgages dominate with three quarters of the total (Fuster and Vickery 2015). The percentage of variable home loans has increased to 85 for Australia. Only a small minority of new housing loans are provided at fixed rates of one to three years, accounting for around 15% of total dwellings financed (ABS 2017b "Table 9a-1"), but these loans automatically revert to the interest rates on standard variable mortgages after these fixed periods have expired. However, mortgages in Australia include a significant number of fees beyond these interest charges (Liu and Roca 2015; Lowe 1995). The prevalence of standard variable rate mortgages highlights the importance of the Australian market in the monetary transmission mechanism, because variable interest rates are highly responsive to developments in monetary policy stances and/or money market rates.

In Australia, banks play a predominant role, among the authorised deposit-taking institutions (ADIs), in mortgage financing, accounting for 80–90% of the total market share, while the combined share of credit unions and building societies is negligible at less than 5%, equivalent to the share of wholesale lenders (see Figure 2.4). This market is much more oligopolistic than the Canadian market, where small lenders hold a larger market share—up to one quarter of the total market (MFAA 2014). Moreover, the Australian mortgage market is oligopolistic because of the dominance of the four largest domestic banks: Australia and New Zealand Banking Group Limited (ANZ), Commonwealth Bank of Australia (CBA), National Australia Bank Limited (NAB), and Westpac Banking Corporation (hereafter the Big-4), whose combined market share increased from 63% at the start of our sample to 85% by December 2016. This increase results mainly from these banks' acquisitions and from the withdrawal of wholesale lenders after the Northern Rock breakdown in 2007–08. As a result, market concentration, which has increased significantly since then, has aroused considerable interest, as well as media coverage, on banks' interest rate setting and price dispersion.

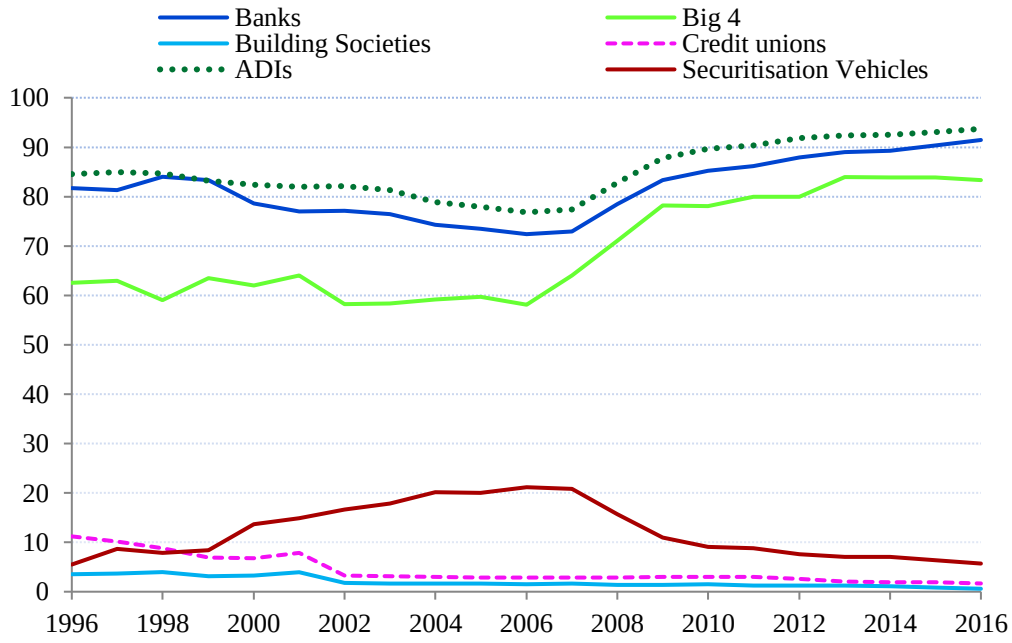

Figure 2.4 Mortgages outstanding by lenders in percent. Author's calculation from Sources: APRA 2017 Statistics "Quarterly ADI Performance"; ABS 2017b, Table 12

2.3.2 The mortgage suppliers

Mortgages in Australia are mainly issued by 152 depository institutions, which currently encompass 82 banks, 4 building societies, 58 credit unions, and 8 other ADIs (APRA 2017). The researcher thus focuses only on the key characteristics of the banking system because its market share is dominant, as analysed earlier (Figure 2.4). First, this sector is highly dominated by the Big-4 in financing mortgages. These banks hold around 75% of the total sector assets and have issued 80–85% of the total outstanding mortgages post-GFC. The Big-4 operate internationally but focus mainly on domestic markets, both the wholesale and the retail banking services. The remainder of the banking sector comprises 26 smaller Australian owners with no international focus, 7 subsidiaries, and 45 branches of foreign banks.

Second, the core lending operations of Australian banks concentrate heavily on mortgages (see Figure 2.3). They finance their largest exposure to households as housing loans, which increased overall by 1.5 times during the sampled span. After a decline in 2007–08, outstanding mortgages rapidly

regained their pre-2007 level from 2009, and have currently surged to over 60% of the total bank domestic loan value (Author's calculation based on RBA 2017 data "Banks Assets - D2"). Importantly, Australian banks have hitherto possessed the highest ratio internationally of residential real estate loans to total bank loans, much higher than those of the rest (see Figure 1, Chapter 4A). This proportion has grown steadily to 64% since the GFC, while those rates in Norway, Finland, and the Netherlands have remained stable, and those in the US have dropped significantly. Given the recent extreme global economic recessions associated with the cascade of the UK and US mortgage defaults, a well-functioning banking sector in Australia is of great interest locally and internationally.

Heavy reliance on foreign borrowings to fund domestic bank lending is another notable feature of the Australian mortgage finance system. Its dependence has been comparatively high, globally, since the GFC (Ralston et al. 2011). For example, international liabilities of banks as a percentage of GDP were 52 in 2012 (Bailey et al. 2012). Overall, banks raise funds from world financial markets with approximately one quarter of total liabilities, equivalent to over 35% of total mortgage funding (Ralston et al., 2011; MFAA 2014; Turner and Nugent 2015). Given the recent default of the UK mortgage lender, relying greatly on overseas borrowings can generate financial instability associated with housing booms (Cerutti et al. 2017).

Finally, Australia experienced major reform in its regulatory financial system during the sample span. The APRA, established in 1997 along with the Financial System Inquiry (the Wallis Inquiry), is responsible for supervising all financial institutions, which were only self-controlled under their corporate governance practices before these reforms. The APRA plays a key role in enhancing competition, financial soundness and market efficiency. Meanwhile, the RBA has continued to advance and maintain high standards of monetary instruments in order to exercise effective monetary policy. Thus, these regulatory reforms have significant impacts on the financial market and

institutions' operations, and on the effectiveness of monetary transmission, especially bank price-setting conduct.

The Australian mortgage finance system has experienced significant developments and structural changes during our sample period. These developments pose an important question: To what extent do they affect bank mortgage rate-setting conduct? This major question is addressed in this research.

2.4 Summary

Chapter 2 provides a critical review of the relevant empirical literature and a discussion about the institutional background of the Australian mortgage market. This chapter subsequently outlines the major gaps in the literature on bank lending and mortgage interest rate adjustments. The existing literature is classified corresponding to the four empirical essays. First, the relevant literature on bank funding cost and lending interest rate adjustments was reviewed: 1) the monetary policy rate approach, 2) the cost-of-funds approach, and 3) the weighted average cost of liabilities. Most of the studies showed that monetary policy rates or market rates played an important role in bank repricing conduct. Relatively few efforts have been made to construct a new funding indicator for banks. The key research gap of the first essay is that none of the empirical studies explored the relationship between international funding cost and mortgage rate adjustments, either in Australia or in world markets.

Second, this chapter reviewed the relevant literature on asymmetry in the housing interest rate transmission, internationally and domestically, corresponding to the second empirical essay. The extant literature suffers from the limited dimensions of the conventional econometric models, and limited long-term time-series data of retail bank interest rates. Although preceding Australian and international studies provided evidence on short-term or speed asymmetry in lending interest rate

adjustments in response to policy rates. Only one study examines both long-term and short-term asymmetry in the policy rate transmission to weighted lending rates in a cross-country analysis for the major Australian, UK and US banks. None of the prior studies paralleled instantaneous, short-term cumulative and long-term asymmetries in the nexus of the pure monetary policy–mortgage rate and those asymmetries in the foreign-funding cost–mortgage rate nexus in panel form. Moreover, to the best of my knowledge, none of the studies examined explicitly the asymmetric effect of the GFC on the mortgage interest rate pass-through, either in Australia or in other countries.

Third, the review of the literature on bank lending and mortgage interest-rate pass-through covered two aspects: country heterogeneity and bank heterogeneity. The major gap for the third empirical essay is identified from this literature review. None of the existing studies investigated the effect of unobserved common factors on the interest rate transmission, domestically and internationally, neither the study of asymmetry nor the study of symmetry.

Fourth, the review of research on determinants of the retail interest-rate pass-through synthesising the existing literature prior to, and post crisis. The foremost research gap attained in this review is that none of the extant literature examined asymmetric determinants of this transmission, locally and globally.

Finally, this chapter analysed the noticeable particularities of the Australian mortgage market. The purpose of this section is to highlight the motivations of the thesis by discussing the distinctive institutional background of the Australian housing credit market. The mortgage boom period, a predominance of variable-rate home loans, the oligopoly of the market and banking system in financing mortgages, and an idiosyncratic wholesale funding model of mortgages provide important motivations for the sample selection to explore the relationship of international funding cost with mortgage interest rates for Australian banks and the nature of the transmission mechanism. The

divergence of the cash rate and mortgage rate cycle known as the ‘out-of-cycle’ price-setting behaviour of banks since the GFC and the importance of the Australian residential mortgage market to national and global financial stability motivates me to examine the crisis effect on the mortgage interest rate transmission in Australia.

Chapter 3: Australian mortgage interest-rate pass-through: Does international funding cost matter?[4]

This chapter includes a co-authored paper. The bibliographic details of the co-authored paper, including all authors, are:

Pham, Q.C., Liu, B., Roca, E. (2018). Australian mortgage interest-rate pass-through: Does international funding cost matter? In: Smart and Sustainable Housing Futures: Towards an Efficient and Equitable Housing Delivery System. *The 2018 Joint Asia-Pacific Network for Housing Research (APNHR) Conference and the Australasian Housing Researchers Conference (AHRC)* held at Griffith University, Gold Coast, Australia in 6–8 June. Available on https://www.griffith.edu.au/__data/assets/pdf_file/0015/561210/APNHR-2018_Proceedings.pdf.

My contributions to the paper involved:

"Generation of the research idea through extensive literature review; development of the theoretical framework and hypotheses; identification of the research models and relevant data; manual collection an additional set of the mortgage rate data in response to Applied Economics reviewer's requests in the second submission in my second year and organization into a usable format; STATA programming and analysis of the results; interpretation and discussion of the results; and the write up of the complete paper"

[redacted]

01 June 2018

Name of student: Quynh Chau Pham

[redacted]

01 June 2018

Corresponding author of paper: Quynh Chau Pham

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(Countersigned) __[redacted]__ 07 December 2018
Supervisor: Benjamin Liu

(Countersigned) 07 December 2018
Supervisor: Eduardo Roca

Abstract

This study examines heterogeneous interest-rate pass-through for Australian banks, relating the cost-of-funds rates to owner-occupied housing rates on weekly bank-level data from 1st January 1997 to 31st December 2015. The cash rate and the bank bill swap rate act as the proxies for bank funding costs, domestically and internationally. The nonlinear autoregressive distributed lag approach (Shin, Yu, & Greenwood-Nimmo 2014) is employed to investigate heterogeneous asymmetry in the pass-through. The results highlight the substantial asymmetry in the transmission of both bank funding rates. In the long run, banks are more responsive to passing on increases in the funding costs into their mortgage rates than to passing on the cost cuts. This study also finds evidence of the short-term asymmetries for several banks. The findings confirm that bank mortgage rate setting, apart from the cash rate, is significantly affected by international funding costs. This study provides several important policy implications.

3.1 Introduction

The interest-rate channel plays a vital role in monetary policy transmission for those economies implementing the inflation targeting regime, especially Australia. Changes in policy rates substantially influence not only retail and housing interest rates, but also house prices (Robstad 2018), with ultimate impacts on consumption, investment, and the real economy. The Australian mortgage market, one of the top five global markets, has the mortgage credit ratio to GDP greater than 100%, reached $1,614.27 billion of the household credit in February 2018, larger than the value of the listed equity market. In this area owner-occupied housing loans constitute two-third of the total, equivalent to 60% of GDP (author's calculation). The 2008 GFC has vitalised publicity surrounding bank mortgage-pricing behaviour. The great extent of media coverage and political interest related to mortgage interest rate movement provides a clear indication of this issue’s importance in Australia.

Reassessing the effectiveness of the housing interest rate transmission at an individual bank level is therefore of paramount important to banking regulators, policy makers, and the public.

The GFC has caused the cost of borrowing in world financial markets to have an unfavourable effect on Australian lenders. A controversy has surrounded banks' heavy reliance on foreign liabilities and its impact on their lending setting practices and financial stability (Bailey, Uffelen, & Wood 2012; Berkelmans & Duong 2014; Stewart, Robertson, & Alexandra 2013; Turner & Nugent 2015). These prior papers highlight the existence of the connection between the cost of international funds and the actual mortgage interest rates. However, these papers are all in the forms of descriptive studies; no systematic empirical studies have yet investigated this link. This study sheds new light on the literature supporting asymmetric pricing of housing interest rates by answering two questions: (1) whether the international funding cost affects the mortgage rate transmission, and (2) what the nature of that relationship is, symmetry or asymmetry?

The focus of this empirical essay is basically to examine the funding cost transmission to bank mortgage interest rates because banks' funding costs are essential for conducting monetary policy, enhancing the effectiveness of this transmission, and maintaining financial stability (Beau et al., 2014). The role of bank funding costs in this transmission mechanism is especially crucial for Australia where the inflation-targeting regime is fully implemented and the economy relies on bank-based funding. The study of interest-rate pass-through examines how fast (speed/sign) and how much (degree/size) banks adjust their retail interest rates in response to a unit change in a policy rate or a market rate. Housing interest rates, based on the marginal cost pricing model by De Bondt (2005), are priced as a markup over the bank marginal funding cost. The IRPT literature typically adopts either a monetary policy approach (MPA) or a cost-of-funds approach (CFA) (Sander & Kleimeier 2004). The former analyses the transmission of the policy rate to retail interest rates (e.g., Apergis &

Cooray 2015; Lim, Tsiaplias, & Chua 2013; Sathye 2013); the latter uses a market rate at a compatible maturity to the average maturity of loans to be a proxy for bank marginal funding costs (De Bondt 2005; De Graeve, De Jonghe, & Vennet 2007). Commonly, the marginal cost-of-funds rate in the existing literature is exemplified by a policy rate, a short-term (overnight) interbank market rate or a money market rate. Prior to the GFC, bank interest rates were confirmed to stably align with policy rates and/or money market rates. The alignment of policy, market and loan rates has been impaired since the GFC in Australia (Lim et al. 2013; Sathye 2013), or in the euro area (Aristei & Gallo 2014; Hristov, Hülsewig, & Wollmershäuser 2014). The efficacy of the IRPT and monetary transmission mechanism in an increasingly risky environment have been questioned due to the transmission breakdown (Cifarelli & Paladino 2016; ECB, 2013; Lim et al. 2013). Academia, moreover, encounters a real challenge in modelling lending rates when using the conventional methodologies (Kapuściński & Stanisławska, 2018).

This study provides a scientific investigation of the relationships between mortgage interest rates and both domestic and international funding costs for Australia. The nonlinear autoregressive distributed lag (NARDL) approach (Shin et al. 2014) is employed to analyse a bank-level dataset, obtained commercially from 20 anonymous Australian lenders, which providing approximately 90% of the total outstanding mortgages. The testable hypothesis about mortgage funding cost is theoretically developed from the De Bondt (2005) marginal cost pricing model. Bank funding costs are portioned into three key components, a risk-free rate, a risk premium and other costs in Beau, Hill, Hussain, & Nixon (2014). The cash rate is the direct measure of the risk-free rate; the other two are determined by bank-specific characteristics, debt instruments and macroeconomic factors. Banks raise funds from a wide variety of sources, retail deposits, wholesale funding and the bank's capital base. Australian banks' non-resident funding is the second largest component of the banking system's total liabilities, accounting an average for around 25% during the whole sample period (author's calculation

from RBA data, Table B2). Australian banks hold a globally prolonged position of using foreign funds at around 35% of total liabilities to fund their mortgages, compared to that of approximately 10% in Estonian, Greek and other European banks (ECB, 2017b; Turner & Nugent, 2015). In line with this decomposition, the foreign-funds rate is a possible measure of marginal wholesale funding costs for Australian banks.

The novelty of this paper is threefold. First, this study provides the source of the divergence between the cash rate and mortgage rates; this should be valid for mortgage markets with significant shares of international funds in the bank funding. Second, this paper extends the literature by using a novel weekly bank-specific dataset to examine the asymmetric transmission for Australian banks. Third, for each lender the empirical results of this study provide solid evidence for the simultaneous presence of their 'size asymmetry' in three dimensions, impact, short-run, and long-run. Previous studies (e.g., De Haan & Sterken 2011; Valadkhani 2013) mainly identified positive and negative deviations from the equilibrium path in their short-run dynamic models without modelling the size of the long-term asymmetry. This study discloses the full extent of asymmetric mortgage rate adjustments in response to changes in bank funding costs, both cash rate and foreign-fund rate.

The remainder of this paper is organised as follows. Research motivations are discussed in Section 2. Section 3 outlines the method, while Section 4 describes the data. Results are discussed in Section 5 and Section 6 draws key conclusions.

3.2 Why Australia?

Australia is a distinctive case with which to investigate the empirical relationship between banks' international funding costs and mortgage interest rates. This prominent mortgage market plays a crucial role in conducting monetary policies, enhancing the effectiveness of monetary transmission,

and maintaining financial stability nationally and globally, owing to its idiosyncratic features. This section focuses on three key appeals, residential mortgage products, the oligopoly of the market and banking system, and the mortgage funding model.

Residential mortgage products have four unusual market features. The first of these is the prevalence of adjustable-rate mortgages at roughly 85% of the total outstanding mortgages over the sample period (Australian Bureau of Statistics [ABS], 2017b). In particular, approximately 70% of the total housing loans are composed of the variable-rate home loan, which is typically on a 25–30 years contract with a 95% loan-to-value-ratio (LTV). In contrast, long-term fixed-rate mortgages are more prevalent in other markets, such as Belgium (75%), Germany (84%), the Netherlands (75%), the UK (54%) and the US (90%), see Badarinza, Campbell, and Ramadorai (2018). Second is that Australian banks use their discretion in pricing most of their variable-rate home loans. Conversely, banks' variable interest rates on house-purchase loans in numerous European markets are connected with an independent benchmark rate; in Canada, New Zealand, and the UK, these mortgages are only provided with a maximum interest rate cap (EMF, 2016). Third, interest payments of housing loans for owner-occupiers in Australia are not tax-deductible, while those for investors are deducted from their taxable income. On the contrary, home-loan borrowers in Poland, South Korea, the US and Norway benefit from full or nearly full capital-gain tax deductibility (IMF, 2011). The partial deductibility is imposed in most of other advanced economies, such as Belgium, Denmark, Italy, Japan, the Netherlands, Finland, Norway, and Sweden (see Cerutti et al., 2017, Table 2). Fourth, mortgage refinancing operations that discharge a current loan and create a new loan make Australia different from the US and numerous others (European Mortgage Federation (EMF), 2016). Australian mortgage borrowers are directly billed for all actuarial costs of refinancing. In addition, mortgages in Australia include a significant amount of fees, making the total cost of debt for owner-occupiers higher (Liu & Roca, 2015). These salient peculiarities of the variable-rate mortgages are integral to

the study of the mortgage interest-rate pass-through for Australia from a household perspective. The potential asymmetry in this transmission that is unfavourable for borrowers can occur due to high switching costs, as pointed out by Lowe (1995) and Lowe and Rohling (1992). In this study, the variable-rate mortgages of the banks sampled are selected in this study owing to their special properties. Hereafter the terminologies, mortgage and mortgage rate, are the variable-rate home loan and the effective interest rate on the variable-rate home loan.

The high oligopoly of the mortgage market and banking sector is the second noticeable market structure for Australia. More than 60% of owner-occupied loan approvals are provided by four major Australian-owned banks; ANZ, CBA, NAB, and WBC, see ABS Cat. no. 5609.0 Table 13. The Big-4 banks have provided more than 80% of total outstanding mortgages since the GFC (Figure 2.4, Chapter 2, Subsection 2.3.1) and account for 75% of the total sector's assets (author's calculation). This concentration ratio is much higher than those of the European banking system (an average of 50%): Germany (31%), France (nearly 50%), Spain (60%), three of five largest mortgage markets in Europe (ECB, 2017b). Compared to a ratio of the four largest banks' deposits to total residential deposits of 45% for the US, Bank of America, JP Morgan Chase, Wells Fargo and Citigroup, 75% for the four major UK banks, the Australian Big-4 ratio is much higher at 81% (Apergis & Cooray, 2015; VanHoose, 2013). Australia is still more concentrated than Belgium, Finland, and Portugal, whose concentration ratios are below 70% (ECB, 2017b). This highly concentrated market theoretically and empirically enables their banks to have more market power in price-setting. Practically, this distinct housing credit market has aroused considerable controversy, with ongoing debates over bank mortgage pricing conduct. Recently, media commentators as well as Australian Government ministers have censured banks for their inefficient mortgage pricing policies, the primary reason for the increasing divergence of mortgage rates and the cash rate since the GFC. Given such a

unique environment, this study expects a large variation in the asymmetric pass-through of variable mortgage rates at an individual bank-level.

The mortgage funding model in Australia, which significantly relies on short- and long-term wholesale debt, both onshore and offshore issues, is the most institutional consideration in this study context. Conversely, the US and Colombian lenders rely on securitisation; banks in most of other developed and emerging markets fund themselves from domestic deposits (Cerutti et al., 2017). This salient feature differentiates Australia's housing credit market from numerous other economies. Based on the APRA and RBA statistics, it is clear that Australian bank funding can be categorised into three key components, wholesale, deposit and securitisation. In particular, Australian banks source substantial mortgage funds from wholesale funding markets, mainly from foreign suppliers; hence, wholesale funds in Australia are typically considered to be international or foreign funds. During the sample period, the share of bank foreign funds has increased from below 20% to over 30%, whereas domestic deposits still play an important role in bank funding, accounting for 55–60% of the banking sector's total liabilities (RBA Statistics, Assets and Liabilities, Bank B2; Turner & Nugent, 2015; Winki, 2017). In particular, prior to the crisis this foreign-funding share of four major banks' funding composite was relatively close to their share of deposits at 45%, including 30% short-term and 15% long-term debt, see Deans & Stewart (2012: Graph 1). The main funding composition of regional banks and credit union has remained residential deposits, ranging from below 50% to over 80%, see Yanotti (2014: Table 2). Also, these small lenders have actively used the securitisation vehicle to finance their loan portfolios since 2000, but this composition has been negligible compared with their deposit-based funding. Therefore, it is expected that to a certain extent wholesale or foreign funding cost shifts affect bank mortgage-price setting at a bank level. Post-GFC shows a significant increase in domestic deposits and less dependence on overseas funds because of funding liquidity constraints in world financial markets. However, the wholesale funding composition was still large,

accounting for around 38% of mortgage funding in 2011 and nearly 35% in 2014. An average 25% of all bank liabilities is composed of foreign funding, indicating an ongoing high level in the use of international debt. The ratio of Australian bank wholesale funding to total sector's assets is much higher than that of numerous advanced mortgage markets in, for example, Canada (12.8% in 2014), Germany and Spain (nearly 16% in 2016), France (11%), Finland (nearly 15%), Greece, Italy and Austria (16%), or an average euro area at 15% (ECB, 2017b; MFAA, 2014). Australia has witnessed an increasing trend in the use of wholesale funding during the sample period from just below 20% to nearly 30%; the US banks have suffered a dramatic drop in their wholesale funding composition, both commercial paper (short-term) and repurchase agreement, from 18% in 2002 to 10% in 2010, with a recovery at 21% in 2013, but their share is still lower than in Australia (Buehler, Noteboom, & Williams, 2013). The share of securitisation in funding composition has never peaked at 8% of the ADIs' total liabilities. Securitisation has become a negligible amount since the onset of the GFC due to the withdrawal of the RMBS in 2007, constituting just 1% in the funding composite of the four major banks. In comparison, the share of securitisation funding for the US banks is at over 30% of total sector liabilities (Buehler et al., 2013).

Three key reasons may explain the heavy reliance of Australian banks on wholesale funding sources, both onshore and offshore issues. Since 2000, Australian lenders have tapped overseas wholesale markets that provided relatively cheaper funding sources under highly competitive market conditions. Household deposits are unable to fuel the fast growth rate of demand for housing credit due to a very high rate of homeownership at around 70% for nearly three decades (see ABS Cat no. 4130.0). The absence of government-back mortgage intuitions fails to provide a competitive funding vehicle for mortgage originators. In brief, bank mortgage rate adjustments can be significantly affected by the costs of international borrowing due to the large volume of this debt. A sterling scenario to empirically

investigate the role of international funding cost in the variable housing rate transmission for Australian banks is developed from these particulars of the Australian mortgage market.

The Australian mortgage market plays an important role in stabilising housing and housing financial markets, nationally and internationally. This world-leading market has constituted an integral part of the policy transmission mechanism. However, its house-price and housing-credit booms have currently aroused serious concerns, public, political, and regulatory—made media headlines—about market fragility and its dire consequences to households and the economy, for details of these definitions, see Cerutti et al. (2017). Seriously, empirical evidence confirms the stronger impact of interest rate shocks on house prices in the booming period (Goodhart & Hofmann, 2008; Kuttner, 2012). The Australian housing credit boom, which is associated with house-price bubbles in the central cities during the whole sample period, had plagued the economy, see 'Australia's budget' 15 May 2008 in *The Economist*. Globally, booming mortgage markets are to blame for financial distress through fast credit-growth that fuels real-estate booms (Kim & Min, 2011; Miles, 2014). In fact, Korea's booming real-estate and housing finance bursts initiated the 1997 Asian financial crisis. Out of the five economies (Spain, France, the US, the UK, and Australia) that held the highest rate of house price appreciation in the period 2001–2005, three have suffered a severe housing and mortgage market crash since 2007. Consequently, these bubbles bursting in the UK, the US and Spain have activated the GFC and Euro area tensions, ensuing ongoing systemic banking crises worldwide. Cerutti et al. (2017), and Laeven and Valencia (2013) have documented that credit booms are the major villains of banking crises. Given the substantial importance of the Australian mortgage market for maintaining the domestic and global financial stability, it is imperative to empirically investigate bank foreign funding cost as a critical driver of the variable mortgage rate pass-through.

Contradictory findings of the cash rate–mortgage rate pass-through literature and a lack of empirical evidence for the international funding cost–mortgage rate nexus make Australia an attractive case. In Australia, increasing attention to unusual mortgage rate movements in relation to the cash rate shocks has recently attracted researchers. However, the existing studies provide inconclusive findings. The incompleteness and short-run downward rigidity in passes-through of the cash rate to mortgage rates have been documented by Lowe and Rohling (1992). Their explanation is that Australian lenders are slower to reduce their housing rates in response to rate cuts than they are to rate rises, due to the existence of high switching costs. Currently, Australian households are still being charged substantial mortgage fees (Liu & Roca, 2015). In line with these pioneers' findings, more recent studies (Apergis & Cooray, 2015; Valadkhani & Anwar, 2012; Valadkhani & Worthington, 2014) have provided strong evidence of downward rigid adjustments of mortgage interest rates in the short run. These researchers conclude that nominal interest rates of mortgages, in response to the cash rate changes, are instantly increased faster and greater rather than decreased, due to bank market power. However, the Liu et al. (2016) finding dissents from the prior results. Researchers find that in the short run, mortgage rate adjustments are more sluggish in response to cash rate rise, but faster to cash rate cuts. The inconsistent findings in the literature can arise from variations in datasets, sample spans or models. For example, the mortgage rate datasets used by Lowe and Rohling (1992), and by Liu et al. (2016) are aggregated, while the others employ a bank-level dataset. To the best of my knowledge, moreover, no empirical study considers the role of international funding cost in the mortgage rate transmission for Australian banks. I have not yet found any empirical study that assess the important issue of foreign funding cost and its effect on bank mortgage interest rate adjustments in Australia. Indeed, in recent years, this country has observed instead numerous media debates between politicians, the public and Australian lenders on this topic. Bailey *et al*. (2012), Deans and Stewart (2012), Stewart *et al*. (2013), and Berkelman and Duong (2014) present facts and figures that show

the increasing trend of offshore funding costs for a qualitative analysis of some key elements that influence lender pricing. However, all these studies are in the form of descriptive analyses. This study has been encouraged by the lack of empirical evidence on this issue.

This study attempts to fill the gaps of the literature on interest-rate pass-through by identifying the role of international funding cost in affecting banks' mortgage rate-setting. This study also contributes to the development of the field by simultaneously investigating the asymmetry in this relationship for individual banks in three dimensions: immediate, cumulative short-run and long-run asymmetries.

3.3 Related literature and hypotheses development

This section develops key hypotheses related to the two research questions: (1) Whether the international funding cost affects the mortgage rate pass-through; and (2) What the nature of that relationship, symmetry or asymmetry, is. The hypotheses are established based on both the theoretical framework and the related literature reviewed in Section 2.1, Chapter 2.

3.3.1 International funding cost and mortgage interest-rate adjustments

The marginal cost pricing model by De Bondt (2005) and Rousseas (1985) is the key framework in investigating how interest rates are transmitted under imperfect market competition. A bank interest rate is approximated as a constant markup over the marginal cost-of-funds as follows:

$$br = \beta mr + \mu \tag{1}$$

where br and mr are the bank interest rate and the cost-of-funds rate. A constant markup (μ) and the size of the long-term pass-through coefficient (β) reflect the effectiveness of the transmission and have positive signs. β tends to be incomplete but close to unity when adjusting to the equilibrium. Although banks' lending interest rates are set on different factors—funding cost, credit and liquidity

risk premia and other elements—bank funding cost is always the most important driver (Button, Pezzini, & Rossiter, 2010; Fabbro & Hack, 2011). The focus of this study is simply to investigate the transmission of bank funding cost to mortgage rates for Australian banks. Modelling interest rate structure or identifying the determinants of net interest rate margins (e.g., Entrop, Memmel, Ruprecht, & Wilkens, 2015; Hainz, Horváth, & Hlaváček, 2014) is out of this study's focus.

The marginal funding cost for banks, apart from risk premia, is mainly determined from the variations in funding costs because banks fund themselves from diverse sources (Beau et al., 2014; De Bondt, 2005; Fabbro & Hack, 2011). Australian banks' mortgage funding composite comprises mainly retail deposits and wholesale funds discussed in the previous section. The cash rate is still the benchmark for mortgage pricing (Lim et al., 2013) because it affects bank domestic funding costs obtained from savers' deposits and other domestic borrowings. The cash rate, which is the monetary policy rate in Australia, also acts as a risk-free rate of bank funding costs as defined by Beau et al. (2014). Empirically, numerous recent studies (Apergis & Cooray, 2015; Liu et al., 2016) consistently confirm that changes in the cash rate strongly affect Australian financial market rates and affirm that the cash rate is a strong exogenous variable to mortgage rates. Although the cash rate has vigorously experienced downward cuts since the crisis to stimulate the economy, it is on hold at 1.5%, still higher than the policy rates in numerous OECD countries. It is expected that the cash rate still drives bank mortgage repricing. As well as financed by local deposits, Australian lenders' large use of the mortgage wholesale funds financing from international sources supports the hypothetical presumption by some researchers (Bailey et al., 2012; Deans & Stewart, 2012; Fabbro & Hack, 2011) that international funding cost acts as a determinant of mortgage rates. This presumption is in line with Davis (2011), Stewart et al. (2013), Berkelman and Duong (2014), who conclude that international wholesale funding has played a significant role in bank financing. Following from these considerations, my first two hypotheses are created at the individual bank level:

***H1a*:** A causality relationship, both short-term and long-term, running from international funding cost to variable mortgage interest rates is anticipated to exist in Australia

***H1b*:** Cash rate shocks affect mortgage rate adjustments not only in the short run, but also in the long run.

3.3.2 Asymmetric transmission hypotheses

Asymmetry in the IRPT theoretically and empirically occurs when financial institutions unequally adjust their retail interest rates in response to funding cost/market rate rises or rate cuts, resulting in a larger magnitude and/or speed of interest rate adjustments, and a different distribution of benefit. More precise, increases in bank funding cost are slower and less completely transmitted to deposit rates than equivalent decreases in funding cost. Meanwhile, increases in the funding cost are faster and more completely transmitted to lending rates than equivalent decreases in funding cost. They are considered as upward rigidity in deposit rate adjustments and downward rigidity in lending rate adjustments, or a positive asymmetry. Obviously, both scenarios are detrimental to banks clients whether depositors or borrowers. Banks will profit from the exertion of this positive asymmetry, an indication of net welfare losses, which suggests important policy implications. This study concentrates on the possibility of the positive asymmetry in mortgage rate adjustments to funding cost changes.

Three key theories predominate in explaining asymmetry in interest-rate pass-through, market concentration, switching and adjustment costs hypothesis, and imperfect competition. First, financial institutions operating in weakly competitive markets or in oligopolistic market segments are likely to have an incentive to pass on policy/market interest rate changes incompletely to their retail rates because banks are somewhat more powerful in price-setting, and vice versa (Hannan & Berger 1991). The market power enables banks to sluggishly adjust their mortgage interest rates downwards and

unhurriedly to increase their deposit rates upwards. This market power hypothesis has been largely confirmed, for example, in the UK banking market (Fuertes and Heffernan, 2010), in the UK, the US, and Australian markets (Apergis & Cooray, 2015). Second, the switching and adjustment costs hypothesis theorises, about asymmetry, that these high costs make borrowers stick with their existing financial products and/or lenders, resulting in a weaker competitive market (Hofmann & Mizen, 2004; Lowe, 1995). Subsequently, lenders can exert their pricing power to profit from their customers. Rocha (2012) posits that—the differences in switching costs, having inadequate access to information, lacking alternative sources of consumer financial products, and encountering higher search costs—lead to a lower personal loan price elasticity, and result in the rigidity of the personal lending rates in Portugal. Third, the imperfect competition theory officially modelled by Kopecky and Van Hoose (2012) explains that banks operating in highly competitive markets are under threats of losing their customers if they increase lending interest rates corresponding to market rate shocks. The highly competitive environment precludes asymmetric price-setting conduct in Chile (Pedersen, 2018), or induces New Zealand banks to speedily adjust their business lending rates downwards to prevent customer loss (Liu, Margaritis, & Tourani-Rad, 2011).

The question of interest is: do Australian banks asymmetrically adjust their mortgage interest rates corresponding to international funding cost shifts? In this field, no empirical evidence exists, either in Australia or in world financial markets, to the best of my knowledge. However, the positive asymmetry mainly stems from the oligopoly of the banking market, with its dominance of monopolistic middlemen, menu costs, asymmetric information (Toolsema and Jacobs, 2007). Empirically, strong evidence has been found of rigid downwards in the cash rate transmission to lending and mortgage interest rates at both country and bank levels in Australia (Apergis & Cooray, 2015; Lim, 2001; Valadkhani & Anwar, 2012; Valadkhani & Worthington, 2014). Moreover, the particularities of the variable rate mortgage and housing finance discussed in Section 2—the

prevalence of variable-rate mortgages, the discretion of banks, the oligopoly of the market—signify the potential presence of asymmetry in bank mortgage pricing conduct. Therefore, the following hypotheses are created at the individual level:

***H2a*:** It is expected that banks asymmetrically re-price their mortgage interest rates in response to international funding cost shocks in both the short run and the long run.

***H2b*:** In the long run, cash rate shocks are positively and asymmetrically transmitted to mortgage interest rates.

3.4 Data and econometric methods

3.4.1 Sample and data

An 18-year time span from 1st January 1997 to 31st December 2015 is selected owing to its economic importance. First, this period covers a full mortgage boom with a 70% surge in outstanding mortgage debt as a percentage of GDP (author's calculation). Second, the primary regulatory reforms—the establishments of the APRA, Wallis Inquiry, and inflation-targeting framework—were formally implemented and endorsed. Third, the sample spans extreme financial distress, the 2007-collapse of the UK and US mortgage lenders, the ensuing GFC, and the sovereign debt crisis, which allows for capturing potential structure changes in the banking market.

A novel bank-level dataset of weekly effective interest rates on variable home-loans is created from 20 anonymous commercial banks which issue approximately 90% of the total outstanding mortgages in the studied period (author’s calculation). The selected sample thus is relatively well represented. Of the total 37 sampling banks, the 20 remaining after screening comprise four major and 13 smaller Australian-owned banks, and three foreign-owned subsidiaries. The major banks create the oligopoly

of the banking system with the predominance of mortgage market share at 85% (author's calculation). It is thus expected to be heterogeneous mortgage price-setting practices.

This study uses the annual adjustable percentage rate (AAPR) of standard variable mortgages for owner-occupiers, synthesised into the notion 'effective mortgage rate' ER_t that covers all kinds of fees paid by borrowers, (including commissions, compulsory loan insurance premium), which is a significant amount (Liu & Roca, 2015). Data of the mortgage rates were commercially obtained from Cannex's survey of Australian lenders. Two weekly exogenous funding variables are retrieved from Bloomberg DataStream. The official cash rate, CR_t, that is the interest rate paid on overnight funds, is a driving force of the overall cost of banks' funding because its alteration signals changes in market interest rates, subsequently changes in the cost of domestic borrowings for banks (Wilkins et al. 2016). The cash rate after vigorous cuts since October 2008 in response to the GFC is now on hold at its historic low of 1.5%, but is still well above extremely low policy rates, which are close to zero (Canada, the UK, the US, and non-Eurozone countries) or negative (Denmark, Eurozone area, Japan, Sweden, and Switzerland). The 3-month A$ bank bill swap rate (BBSW) is employed to be the proxy for the foreign-funds rate variable, BB_t. The BBSW is usually consulted when Australian banks issue their foreign funds, both onshore and offshore; the US$ LIBOR is a benchmark rate for offshore issues only (Guttmann and Rodgers, 2015; RBA, 2006). Thus, the use of the BBSW as the proxy for international funding costs in this study is more appropriate.

3.4.2 Estimation method

The NARDL approach by Shin et al. (2014) is employed to identify asymmetry in the mortgage rate pass-through for the individual banks. The NARDL model has extensively applied in financial economic studies owing to its notable advantages. This method overcomes major drawbacks of the conventional cointegration techniques by modelling jointly asymmetries and cointegration dynamics

in a single equation, and releasing the nonstationary assumption. Both short-term and long-term asymmetries are simultaneously captured in the NARDL setting, while the conventional techniques, such as the ECM, the threshold ECM, the Markov-switching ECM and the Smooth Transition ECM, enable researchers to estimate asymmetries in the adjustment speed only. By decomposing the exogenous variables into positive and negative partial sums, the NARDL model is able to accurately differentiate between nonlinear cointegration, linear cointegration, the absence of cointegration. The NARDL model is therefore avoids omitting hidden cointegration.[5] Importantly, this model enables for observing asymmetric adjustment paths and/or duration of disequilibrium in a graphical presentation of cumulative dynamics multiplier effects without modelling the asymmetric error correction parameters. By accommodating heterogeneous asymmetries on impact, in the short term and in the long term, the NARDL model has instantly become the ideally practice workhorse for researchers in pass-through study of house prices and commodities (e.g., Atil, Lahiani, & Nguyen, 2014; Katrakilidis & Trachanas, 2012) and exchange rate pass-through (Brun-Aguerre, Fuertes, & Greenwood-Nimmo, 2017).

The linear ARDL model, under the unrestricted error correction specification of the marginal cost pricing model in Eq. 1, is

$$\Delta br_t = \mu + \rho br_{t-1} + \delta mr_{t-1} + \sum_{i=1}^{p-1} b_i \, \Delta br_{t-i} + \sum_{i=0}^{q-1} c_i \, \Delta mr_{t-i} + \varepsilon_t \qquad (2)$$

where the dependent variable br_t is the weekly effective mortgage interest rate, ER_t, in this study which is measured by the annual adjustable percentage rate (AAPR) of individual banks. The exogenous variable mr_t is either the weekly cash rate, CR_t, or the international funding cost, BB_t in

[5] Hidden cointegration exists if two time series are not cointegrated in the conventional sense, but their positive and negative components are cointegrated (Granger & Yoon 2002).

this analysis. The symbols p and q refer to the respective lag orders for the dependent variable and the exogenous variables in the distributed lag part, respectively, while ε_t is the white noise. The maximum number of 12 lags for both p and q is used to select the optimal number of lags (p, q) based on the lowest values of the information criteria. Δ is the first different operator and ρ is the error correction term.

The Shin et al. (2014) NARDL approach captures nonlinearities among time-series variables. This model requires the partial sum decomposition of the cost-of-funds rates. Therefore, the exogenous cost-of- funds rates are decomposed into their positive and negative partial sums of their increases and decreases as follows

$$mr_t^+ = \sum_{j=1}^{t} \Delta\, mr_j^+ = \sum_{j=1}^{t} \max(\Delta mr_j\,, 0), \quad mr_t^- = \sum_{j=1}^{t} \Delta mr_j^- = \sum_{j=1}^{t} \min(\Delta mr_j\,, 0) \qquad (3)$$

where $mr_t = mr_0 + mr_t^+ + mr_t^-$ and mr_t is either BB_t or CR_t. The partial sum process of funding cost rises is mr_t^+, and that of funding cost cuts is mr_t^-. The initial value mr_0 can be set to 0.

The nonlinear asymmetric cointegration regression in Eq. (1) is formalised as

$$br_t = \beta^+ mr_t^+ + \beta^- mr_t^- + u_t \qquad (4)$$

where asymmetric long-run parameters are β^+ and β^- and the stationary zero-mean error process u_t indicates the deviations of bank mortgage rate from its long-run equilibrium. The NARDL (p,q) model for the effective mortgage rate changes faced by bank i at time t is obtained by embedding Eqs. (3) and (4) within an ARDL (p,q) in Eq. (2), as follows

$$\Delta br_t = \mu + \rho br_{t-1} + \delta^+ mr_{t-1}^+ + \delta^- mr_{t-1}^- + \sum_{j=1}^{p-1} \lambda_j\, \Delta br_{t-j} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta mr_{t-j}^+ + \pi_j^- \Delta mr_{t-j}^-)$$

$$+ \varepsilon_t \qquad (5)$$

where all variables are as defined above. The long-run asymmetry parameters of the funding rates are given by $\beta_i^+ = -\delta_i^+/\rho_i$ and $\beta_i^- = -\delta_i^-/\rho$. The superscripts (+) and (–) in Eq. (5) denote the positive and negative partial sums defined in Eq. (3). The impacts and short-run responses to increases and decreases in BB_t and CR_t are the significant coefficients in the vector $(\pi_{i,0}^+, \dots, \pi_{i,q-1}^+, \pi_{i,0}^-, \dots, \pi_{i,q-1}^-)'$. The NARDL model produces unbiased long-term pass-through coefficients and their inferences even in the presence of weakly endogenous nonstationary explanatory variables. These coefficients are theoretically positive, while short-term parameters can be either positive or negative because many factors can simultaneously affect the transmission at the funding cost shocks.

The NARDL estimated procedure comprises three main stages. First, a stable long-term relationship in Eq. (5) is identified by employing the F_{PSS} test (Pesaran et al. 2001), or the t_{BDM} test (Banerjee et al. 1998). The F_{PSS} tests the null hypothesis of no cointegration H_0: $\rho = \delta^+ = \delta^- = 0$ against the alternative of cointegration H_A: $\rho \neq \delta^+ \neq \delta^- \neq 0$, while the t_{BDM} tests the single restriction H_0: $\rho=0$ against the alternative H_A: $\rho<0$. Second, the Wald test is used to identify the short-run and long-run symmetric hypotheses. The long-run null hypothesis is H_0: $\delta^+ = \delta^-$, while the short-run null hypothesis can be tested by (1) H_0: $\pi_{i,0}^+ = \pi_{i,0}^-$ for the instantaneous response, and (2) $\sum_{j=0}^{q-1}\pi_j^+ = \sum_{j=0}^{q-1}\pi_j^-$ for cumulative dynamic effects. The rejection of these symmetric hypotheses, either in the short term or the long term, confirms the asymmetric adjustments of the mortgage rates to funding costs, internationally and domestically. If both null hypotheses of the short-run and long-run symmetries cannot be rejected, the NARDL Eq. (5) should be considered as the traditional ECM-ARDL estimation in Eq. (2). If null hypothesis of either short-term or long-term symmetry is rejected, the NARDL model will be replaced with the short-run asymmetry Eq. (6) or long-run asymmetry Eq. (7), respectively.

$$\Delta br_t = \mu + \rho br_{t-1} + \delta mr_{t-1} + \sum_{i=1}^{p-1} \lambda_j \, \Delta br_{t-j} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta mr_{t-j}^+ + \pi_j^- \Delta mr_{t-j}^-) + \varepsilon_t \qquad (6)$$

$$\Delta br_t = \mu + \rho br_{t-1} + \delta^+ mr_{t-1}^+ + \delta^- mr_{t-1}^- + \sum_{i=1}^{p-1} \lambda_j \, \Delta br_{t-j} + \sum_{i=0}^{q-1} \pi_{i,j} \Delta mr_{t-j} + \varepsilon_t \qquad (7)$$

Third, Shin et al. (2014) bootstrap testing is implemented to plot the cumulative dynamic multiplier effect of a unit change in mr_t^+ and mr_t^- on br_t. These cumulative dynamic multipliers ascertain the evolution of the effective mortgage rates over the horizons $h = 0, 1, \ldots, H$ in response to a unit increase and decrease respectively of the cost-of-funds rates in period $h = 0$. The combination of these positive and negative cumulative dynamic multipliers therefore measures the IRPT asymmetry at horizon h and can be recursively obtained from Eq. (5):

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial br_{t+j}}{\partial mr_t^+}, \quad m_h^- = \sum_{j=0}^{h} \frac{\partial br_{t+j}}{\partial mr_t^-} \quad with\ h = 0, 1, 2, \ldots \qquad (8)$$

Note that as $h \to \infty$, then $m_h^+ \to \beta_i^+$, and $m_h^- \to \beta_i^-$ hence, the dynamic multipliers represent the traverse from the short run to the long run.

The hypotheses have rewritten based on Eqn. (5) as follows.

H1a: Cointegrating relationship H_0: $\rho = \delta^+ = \delta^- = 0$ vs H_A: $\rho \neq \delta^+ \neq \delta^- \neq 0$.

H1b: Negative speed of adjustments H_0^{1b}: $\rho < 0$ vs H_A^{1b}: $\rho > 0$.

H2a: Impact symmetry H_0^{2a}: $\pi_{i0}^+ = \pi_{i0}^-$ vs H_A^{2a}: $\pi_{i0}^+ \neq \pi_{i0}^-$

H2b: Cumulative short-run symmetry H_0^{2b}: $\sum_{j=0}^{q-1} \pi_j^+ = \sum_{j=0}^{q-1} \pi_j^-$ vs H_A^{2b}: $\sum_{j=0}^{q-1} \pi_j^+ \neq \sum_{j=0}^{q-1} \pi_j^-$

H3a: Complete long-run pass-through H_0^{3a+}: $\beta_i^+ = -\delta_i^+ / \rho_i \geq 1$ vs H_A^{3a+}: $\beta_i^+ < 1$ for funds rate rises; likewise, H_0^{3a-}: $\beta_i^- = -\delta_i^- / \rho_i \geq 1$ vs H_A^{3a-}: $\beta_i^- < 1$ for funds rate cuts.

H3b: Long-run symmetry H_0^{3b}: $\beta^+ = \beta^-$ vs H_A^{3b}: $\beta^+ \neq \beta^-$

3.5 Empirical results

3.5.1 Preliminary analysis

Figure 3.1 visually shows the movements of the variable mortgage rate (ER), cash rate (CR), and international funding costs (BBSW) for each bank coded by ID over the period 1997:1–2015:12. Overall, these time series seem synchronous over the sample period given a sharp plunge during the GFC. It appears, therefore, that mortgage rates seem to be driven by changes in both domestic and international funding costs. As shown in the figure these data series experienced three downward periods: 1997–99 (as the impact of the Asian financial crisis), 2001–02 (as Argentinian and Turkish economies' deep slumps) and 2008–09 (as the repercussion of the GFC). These recessions created the market restructuring and tightening credit conditions, resulting in these downward trends of the funding costs and mortgage rates. Therefore, the estimated model with a constant and a trend is appropriate for the series. The declining magnitudes of the mortgage rates and funding costs have been much wider since 2008, although these rates had reduced with similar speed over the two previous downward periods. It is suspected time break occurrence in the series in the last downward period.

Figure 3.1 The movements of the variable mortgage rate (ER_t) with cash rate (CR_t) and international funding cost BBSW (BB_t) 1st January 1997–31st December 2015

3.5.2 Unit root analysis

Understanding the distributional properties of a data series before employing the econometrics models is essential. This study uses the Clemente et al. (1998) unit root test with two structural breaks in a series, both instantaneous (AO2) and gradual (IO2) models. This test enables identifying two possible unknown breaks without any prior knowledge about timing. The details of the unit-root tests are not reproduced here to preserve space. Identifying the potential of structural breaks in the data is important because a structural break implies a multiple regression relationship between the dependent and independent variables with different intercepts and/or slopes.

Table 3.1 shows the stochastic properties for mortgage rate and funding cost variables. The results of Clemente unit root tests disclose that the majority of the variables are non-stationary on the level, but

all become stationary at the first difference, irrespective of the AO2 or IO2 models. The results show the existence of two time breaks in each series focusing on the GFC episode, which is consistent with the contemporary econometric and economic theories. This finding is consistent with that of Cross and Poon (2016) who similarly document the presence of the structural break in the 90-day Bank Accepted Bills/Negotiable Certificates of Deposit. Given the presence of structure breaks, none of the variables is found to be *I*(2), so that the compulsory condition for the application of the NARDL model is fulfilled. Furthermore, the existence of structure breaks in the time-series variables indicates the possibility of asymmetric relationships between variables.

Table 3.1: The Clemente et al. (1998) unit root test with two breaks in a series

	Additive outlier model (AO2)				Innovational outlier model (IO2)			
	t-statistics	TB_1	TB_2	*k*	*t*-statistics	TB_1	TB_2	*K*
Panel A: Variables at level (*I*(0))								
BB	-2.081	24/12/2007	1/12/2008	11	-5.833**	27/03/2006	15/09/2008	11
CR	-3.117	11/12/2006	5/01/2009	11	-6.484***	12/06/2006	17/11/2008	9
ERM1	-2.355	11/02/2008	13/10/2008	11	-4.835	17/04/2006	22/09/2008	9
ERM2	-2.296	21/01/2008	17/11/2008	11	-5.076	24/04/2006	6/10/2008	9
ERM3	-2.360	18/02/2008	20/10/2008	11	-4.777	24/04/2006	29/09/2008	12
ERM4	-1.644	25/02/2008	22/09/2008	10	-4.905	24/04/2006	29/09/2008	9
ERF1	-1.872	18/02/2008	20/10/2008	9	-4.893	1/05/2006	29/09/2008	10
ERF2	-2.315	25/02/2008	27/10/2008	9	-4.993	24/04/2006	6/10/2008	9
ERF3	-1.906	18/02/2008	27/10/2008	8	-4.287	1/05/2006	6/10/2008	12
ER8	-1.643	26/11/2007	27/10/2008	7	-3.748	1/05/2006	6/10/2008	9
ER9	-1.914	21/01/2008	27/10/2008	9	-4.678	24/04/2006	6/10/2008	9
ER10	-1.806	18/02/2008	22/09/2008	10	-5.004	24/04/2006	29/09/2008	10
ER11	-1.892	21/01/2008	17/11/2008	5	-4.976	24/04/2006	15/09/2008	10
ER12	-2.370	4/02/2008	27/10/2008	9	-5.231	1/05/2006	6/10/2008	12
ER13	-1.871	18/02/2008	29/09/2008	10	-5.166	8/05/2006	6/10/2008	9
ER14	-1.799	25/02/2008	29/09/2008	10	-4.851	24/04/2006	6/10/2008	10
ER15	-2.968	20/08/2007	22/12/2008	11	-5.977**	24/04/2006	29/09/2008	9
ER16	-2.048	25/02/2008	29/09/2008	11	-5.306	8/05/2006	6/10/2008	9
ER17	-1.332	3/03/2008	27/10/2008	11	-3.579	6/08/2007	1/09/2008	12
ER18	-4.479	30/10/2006	2/02/2009	12	-4.989	6/10/2008	5/10/2009	9
ER19	-2.263	18/02/2008	20/10/2008	10	-5.231	24/04/2006	15/09/2008	10
ER20	-1.758	18/02/2008	17/11/2008	11	-5.042	30/07/2007	6/10/2008	8
Panel B: Variables at the first difference (*I*(1))								
Δ*BB*	-7.282***	29/09/2008	2/02/2009	10	-8.902***	22/09/2008	17/11/2008	12
Δ*CR*	-7.029***	17/11/2008	16/03/2009	10	-7.561***	24/11/2008	23/03/2009	11

Δ*ERM1*	-7.230***	22/09/2008	19/01/2009	10	-7.969***	29/09/2008	26/01/2009	11
Δ*ERM2*	-6.232***	27/10/2008	26/01/2009	12	-12.265***	6/10/2008	2/02/2009	7
Δ*ERM3*	-6.834***	29/09/2008	26/01/2009	11	-7.822***	6/10/2008	2/02/2009	11
Δ*ERM4*	-5.804**	29/09/2008	26/01/2009	12	-9.597***	29/09/2008	2/02/2009	11
Δ*ERF1*	-7.400***	29/09/2008	2/02/2009	10	-9.482***	6/10/2008	9/02/2009	9
Δ*ERF2*	-6.815***	6/10/2008	2/02/2009	12	-9.170***	13/10/2008	9/02/2009	11
Δ*ERF3*	-5.730**	6/10/2008	1/12/2008	12	-9.744***	6/10/2008	8/12/2008	12
Δ*ER8*	-7.376***	19/02/2001	2/02/2009	10	-9.841***	26/02/2001	9/02/2009	8
Δ*ER9*	-6.232***	6/10/2008	2/02/2009	12	-8.705***	13/10/2008	9/02/2009	8
Δ*ER10*	-7.861***	29/09/2008	2/02/2009	10	-8.845***	6/10/2008	9/02/2009	8
Δ*ER11*	-7.092***	6/10/2008	9/02/2009	9	-9.266***	15/09/2008	16/02/2009	7
Δ*ER12*	-8.133***	6/10/2008	26/01/2009	10	-9.579***	13/10/2008	2/02/2009	8
Δ*ER13*	-7.390***	6/10/2008	2/02/2009	11	-8.745***	13/10/2008	9/02/2009	11
Δ*ER14*	-8.129***	6/10/2008	9/02/2009	10	-14.331***	13/10/2008	16/02/2009	3
Δ*ER15*	-6.566***	29/09/2008	2/02/2009	10	-7.518***	6/10/2008	9/02/2009	8
Δ*ER16*	-6.724***	6/10/2008	9/02/2009	12	-8.514***	13/10/2008	16/02/2009	8
Δ*ER17*	-8.222***	29/09/2008	1/12/2008	10	-9.218***	6/10/2008	29/12/2008	12
Δ*ER18*	-6.368***	6/10/2008	2/11/2009	12	-8.773***	13/10/2008	9/11/2009	12
Δ*ER19*	-7.309***	29/09/2008	2/02/2009	11	-8.302***	6/10/2008	9/02/2009	8
Δ*ER20*	-5.744**	1/03/2004	26/01/2009	11	-9.271***	1/09/2003	2/02/2009	7

This table presents the unit root test results (1) Selected bank mortgage rates are ERM_1–ERM_4, and ERF_1–ERF_3, for respectively, the major and foreign banks, while regional banks are from *ER8* to *ER20*. (2) The two unknown breakpoints (TB_1 and TB_2) are for both AO2 and IO2 models. The optimal lag order *k* is determined by a set of sequential *F*-test. Critical values collected from Clemente et al. (1998) based on 10,000 replications for a sample size of 1,000 observation are -6.07, -5.49, -5.24 for the AO2 and -6.17, -5.57, -5.30 for the IO2, for respectively, at the 1%, 5% and 10% significant levels. (3) The asterisks ***, ** and * signify the rejection of the null hypothesis of unit roots at the 1%, 5% and 10% levels, respectively

Also, the pairwise cointegration test results substantiate well-cointegrated relationships between (1) ER_t–BB_t and (2) ER_t–CR_t at 0.853 and 0.849, respectively. However, two exogenous funding cost variables, BB_t and CR_t are highly linearly related at 0.989 that is likely to be multicollinearity. Interest rate series are dominated by smooth, long term trends, so that these variables can behave individually as nonstationary random walks. All econometrics procedure hereafter is performed separately (1) ER_t–BB_t and (2) ER_t–CR_t to avoid spurious estimated results.

3.5.3 Asymmetric pass-through analysis

Table 3.2 presents the asymmetric results of the NARDL estimations, using the foreign-funds rate variable. Table 3.3 exhibits the estimated coefficients using the cash rate variable. In each table, Panel

A, B and C report, for respectively, the estimated mortgage rate coefficients for individual banks in major, foreign and region groups. The first four columns reveal long-term asymmetry, whereas the consecutive columns display short-term asymmetry and diagnostics. The bound test results, both t_{TDM} and F_{PSS}, validate the presence of cointegration between mortgage rates and the foreign-funds rate, but fail to confirm that relationship with the cash rate. Most estimates pass the serial correlation test, suggesting that the NARDL model is well specified.

This study first analyse the long-run asymmetry in the foreign-funds rate transmission. The adjustment speed is individually negative and highly significant for all estimates, validating a long-term cointegration between mortgage rates and the foreign funds rate for each bank. The positive and negative long-run coefficients associated with increases and decreases in the foreign funds rate are all highly significant at the 1% level and have correct signs, signifying a direct relationship. The long-run Wald results confirm the presence of the long-term asymmetry downwards for all banks, except one regional bank, coded ER_{20}; this signifies a positive asymmetry. This finding is consistent with Apergis and Cooray (2015). The long-run effect in absolute values of the funding cost rises is more pronounced than that of the cost cuts for all bank mortgage rates, which is preferable to banks. This finding underpins the market power hypothesis for Australia.

Table 3.2: Asymmetry results of the foreign-funds rate by NARLD Eqn. (5)

NARLD(p,q)	(a) Long-run asymmetry				(b) Short-run asymmetry						(c) Diagnostics		
	SoA (ρ)	Long-run IRPT		W_{LR} H_o:	Impact IRPT		W_{ISR} H_o:	Cumulative IRPT		$W_{CSR}H_o$:	t_{BDM}	F_{PSS}	χ^2_{SC}
		β^+	β^-	$\beta^+ = \beta^-$	π_0^+	π_0^-	$\pi_0^+ = \pi_0^-$	$\sum_{j=0}^{1}\pi_j^+$	$\sum_{j=0}^{1}\pi_j^-$	$\sum_{j=0}^{1}\pi_j^+ = \sum_{j=0}^{1}\pi_j^-$			
Panel A: Major banks													
ERM1(10,3)	-0.064***	0.850***	0.796***	81.81***	0.022	0.227***	–	0.218***	0.450***	10.268***	-6.188***	13.594***	1.786
	(0.010)	(0.040)	(0.037)	[0.000]	(0.046)	(0.035)				[0.000]	[0.000]	[0.000]	[0.087]
ERM2(10,3)	-0.078***	0.859***	0.806***	88.70***	0.188***	0.310***	3.375*	0.308***	0.541***	7.303***	-6.255***	14.375***	0.176
	(0.011)	(0.039)	(0.035)	[0.000]	(0.049)	(0.039)	[0.067]			[0.007]	[0.000]	[0.000]	[0.951]
ERM3(10,3)	-0.093***	0.908***	0.826***	180.83***	0.241***	0.353***	1.587	0.241***	0.456***	6.257**	-7.472***	19.162***	2.103
	(0.012)	(0.032)	(0.028)	[0.000]	(0.063)	(0.047)	[0.208]			[0.013]	[0.000]	[0.000]	[0.123]
ERM4(10,3)	-0.107***	0.882***	0.808***	184.26***	0.217***	0.228***	0.017	0.217***	0.388***	4.182**	-8.186***	23.203***	1.729
	(0.012)	(0.029)	(0.025)	[0.000]	(0.059)	(0.042)	[0.897]			[0.041]	[0.000]	[0.000]	[0.189]
Panel B: Foreign banks													
ERF1(11,7)	-0.037***	0.931***	0.864***	37.72***	0.196***	0.100***	0.700	0.779***	0.716***	0.264.	-5.622***	11.960***	1.482
	(0.009)	(0.054)	(0.049)	[0.000]	(0.051)	(0.042)	[0.403]			[0.608]	[0.000]	[0.000]	[0.218]
ERF2(10,3)	-0.044***	0.844***	0.785***	37.80***	0.287***	0.073	–	0.287***	0.316***	0.023	-5.809***	11.598***	1.012
	(0.008)	(0.057)	(0.052)	[0.000]	(0.054)	(0.045)				[0.879]	[0.000]	[0.000]	[0.410]
ERF3(10,3)	-0.035***	0.873***	0.792***	54.46***	0.127***	0.107***	0.239	0.303***	0.388***	0.787	-4.848***	9.092***	2.265
	(0.007)	(0.073)	(0.066)	[0.000]	(0.048)	(0.040)	[0.625]			[0.375]	[0.000]	[0.000]	[0.079]
Panel C: Regional banks													
ER8(10,7)	-0.044***	0.941***	0.914***	8.397***	0.290***	0.041	_	0.641***	0.699***	1.352	-4.409***	7.149***	1.369
	(0.010)	(0.009)	(0.009)	[0.004]	(0.055)	(0.045)				[0.245]	[0.000]	[0.000]	[0.190]
ER9(10,7)	-0.083***	0.991***	0.887***	226.30***	0.237***	0.027	_	0.486***	0.800***	0.288	-6.067***	13.926***	1.354
	(0.016)	(0.014)	(0.013)	[0.000]	(0.061)	(0.046)				[0.592]	[0.000]	[0.000]	[0.222]
ER10(11,7)	-0.036***	0.912***	0.845***	38.06***	0.132***	0.197***	0.098	0.616***	0.908***	0.056	-4.258***	7.363***	1.547
	(0.010)	(0.008)	(0.008)	[0.000]	(0.050)	(0.042)	[0.754]			[0.813]	[0.000]	[0.000]	[0.213]
ER11(11,7)	-0.077***	0.944***	0.866***	109.60***	0.181***	0.176***	0.045	0.555**	0.659***	4.596**	-7.021***	17.314***	1.559
	(0.015)	(0.013)	(0.012)	[0.000]	(0.061)	(0.047)	[0.832]			[0.032]	[0.000]	[0.000]	[0.124]

ER12(10,7)	-0.047***	0.832***	0.775***	35.81***	0.047	-0.043	_	0.520**	0.676**	0.293	-5.227***	9.671***	0.693
	(0.011)	(0.008)	(0.008)	[0.000]	(0.060)	(0.049)				[0.588]	[0.000]	[0.000]	[0.760]
ER13(10,7)	-0.043***	0.939***	0.864***	56.51***	0.121**	0.020	_	0.598**	0.777***	1.903	-5.135***	10.352***	1.324
	(0.010)	(0.008)	(0.008)	[0.000]	(0.052)	(0.044)				[0.168]	[0.000]	[0.000]	[0.228]
ER14(11,7)	-0.036***	0.907***	0.838***	41.42***	0.188***	0.039	_	0.700***	0.690***	0.384	-5.265***	10.682***	1.126
	(0.010)	(0.008)	(0.007)	[0.000]	(0.049)	(0.041)				[0.536]	[0.000]	[0.000]	[0.325]
ER15(10,7)	-0.082***	0.909***	0.888***	8.024***	0.130**	0.344***	6.565**	0.711**	0.845**	0.286	-5.837***	11.689***	0.609
	(0.018)	(0.015)	(0.015)	[0.005]	(0.059)	(0.049)	[0.011]			[0.593]	[0.000]	[0.000]	[0.610]
ER16(10,7)	-0.027***	0.913***	0.856***	16.78***	0.160***	0.024	_	0.670**	0.735***	0.443	-3.829**	5.465**	1.549
	(0.008)	(0.007)	(0.006)	[0.000]	(0.047)	(0.039)				[0.506]	[0.000]	[0.001]	[0.213]
ER17(10,7)	-0.033***	*1.065****	0.956***	27.15***	0.100	0.018	_	0.845**	0.883***	2.483	-3.103	3.777	1.511
	(0.011)	(0.011)	(0.010)	[0.000]	(0.065)	(0.050)				[0.116]	[0.002]	[0.011]	[0.210]
ER18(10,7)	-0.012**	0.639***	0.505**	9.544***	0.074	0.064	_	0.753***	0.716***	0.011	-2.564	2.908	1.612
	(0.006)	(0.004)	(0.004)	[0.002]	(0.058)	(0.048)				[0.916]	[0.011]	[0.034]	[0.098]
ER19(11,7)	-0.045***	0.881***	0.816***	54.08***	0.170***	0.187***	0.085	0.753**	0.677***	0.008	-4.482***	7.136***	1.692
	(0.011)	(0.009)	(0.008)	[0.000]	(0.053)	(0.044)	[0.770]			[0.930]	[0.000]	[0.000]	[0.167]
ER20(9,7)	-0.016**	0.793***	0.762***	0.599	0.114	0.200***	–	0.405**	0.626**	0.024	-3.189	4.215*	1.519
	(0.007)	(0.005)	(0.005)	[0.439]	(0.069)	(0.053)				[0.878]	[0.002]	[0.006]	[0.112]

Table 3.2 exhibits the results of the optimal NARDL estimates for the responsiveness of the mortgage rates to foreign funds rate changes for each bank of the three sampled groups in the corresponding panels. (2) The estimated long-run coefficients $\beta^{+}$and β^{-} are associated with increases and decreases in the cost-of-funds rate variable (in italics if equal to unity), defined by $\beta_i^{+} = -\delta_i^{+}/\rho_i$ and $\beta_i^{-} = -\delta_i^{-}/\rho$. (3) The parameters $\pi_0^{+}$and π_0^{-} measure the impact pass-through reflected in the same week as the cost-of-funds rate shock; and cumulative short-run dynamics are $\sum_{j=0}^{1}\pi_j^{+}$ *and* $\sum_{j=0}^{1}\pi_j^{-}$. (4) W_{LR} is the Wald statistics for the long-run asymmetry, W_{ISR} and W_{CSR} correspond to the Wald F-statistics for the contemporaneous and cumulative short-run asymmetry, respectively. (5) SoA is the average speed of the adjustment coefficient. (6) t_{BDM} and F_{PSS} are the *t*- and *F*-statistics of the Bound test for cointegration. The t_{BDM} (Banerjee et al. 1998) tests the single restriction H_0: $\rho_i = 0$ against the alternative H_{A}: $\rho_i < 0$. The F_{PSS} (Pesaran et al. 2001) tests the null hypothesis of no cointegration H_0: $\rho_i = \delta_i^{+} = \delta_i^{-} = 0$ against the alternative of cointegration H_{A}: $\rho_i \neq \delta_i^{+} \neq \delta_i^{-} \neq 0$.Critical values for the BDM *t*-test and the PSS *F*-test are, for respectively, – 4.1 (1%), – 3.53 (5%), – 3.21 (10%) and – 6.36 (1%), – 4.85 (5%), – 4.14 (10%). (7) Standard errors and *p*-values are given in brackets and parentheses; the asterisks ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3.3: Asymmetry results of the cash rate by NARLD Eqn. (5)

NARLD(p,q)	(a) Long-run asymmetry				(b) Short-run asymmetry						(c) Diagnostics		
	SoA	Long-run IRPT		W_{LR} H_o:	Impact IRPT		W_{ISR} H_o:	Cumulative IRPT		W_{CSR} H_o:	t_{BDM}	F_{PSS}	χ^2_{SC}
		β^+	β^-		π_0^+	π_0^-	$\pi_0^+ = \pi_0^-$	$\sum_{j=0}^{1}\pi_j^+$	$\sum_{j=0}^{1}\pi_j^-$				
	(ρ)			$\beta^+ = \beta^-$						$\sum_{j=0}^{1}\pi_j^+ = \sum_{j=0}^{1}\pi_j^-$			
Panel A: Major banks													
ERM1(10,6)	-0.008	*1.385****	*1.035****	4.660**	0.891***	0.675***	32.402***	1.845***	1.657***	5.975**	-1.094	1.714	1.141
	(0.007)	0.439	0.290	[0.031]	(0.034)	(0.021)	[0.000]			[0.015]	[0.274]	[0.163]	[0.332]
ERM2(10,6)	-0.020*	*1.079****	0.834***	20.429***	0.308***	0.133***	11.598***	1.701***	1.641***	0.283	-1.998	1.849	1.931
	(0.010)	(0.129)	(0.088)	[0.000]	(0.045)	(0.025)	[0.000]			[0.595]	[0.046]	[0.137]	[0.129]
ERM3(10,6)	-0.042***	*1.157****	0.834***	132.584***	0.216***	-0.024	–	1.788***	1.626***	5.393**	-3.523*	5.399**	0.816
	(0.012)	(0.057)	(0.035)	[0.000]	(0.046)	(0.025)				[0.020]	[0.000]	[0.001]	[0.634]
ERM4(10,6)	-0.036**	*1.190****	0.858***	53.455***	0.169***	0.003	–	2.206***	1.974***	3.199*	-2.472	4.969**	1.041
	(0.014)	(0.090)	(0.051)	[0.000]	(0.050)	(0.026)				[0.074]	[0.014]	[0.007]	[0.374]
Panel B: Foreign banks													
ERF1(11,6)	-0.012	*1.372****	*1.002****	5.357**	0.222***	0.085***	6.325**	2.314***	2.001***	5.241**	-1.286	2.044	2.647
	(0.009)	(0.396)	(0.249)	[0.021]	(0.051)	(0.032)	[0.012]			[0.013]	[0.199]	[0.106]	[0.104]
ERF2(10,6)	-0.008	*1.415***	0.980***	2.559	0.292***	0.080**	12.043***	1.988**	1.776**	1.597	-1.105	1.575	0.966
	(0.008)	(0.526)	(0.307)	[0.110]	(0.055)	(0.033)	[0.001]	1.439***	1.132***	[0.207]	[0.270]	[0.194]	[0.476]
ERF3(10,6)	-0.012*	*1.177****	0.809***	13.830***	0.062	0.031	–			8.640***	-1.919	2.108	11.372
	(0.007)	(0.214)	(0.141)	[0.000]	(0.047)	(0.028)				[0.003]	[0.055]	[0.098]	[0.001]
Panel C: Regional banks													
ER8(10,6)	-0.032***	*0.999****	0.900***	6.755***	0.322***	0.114***	9.054***	2.095***	1.522***	12.41***	-2.799	2.688	1.583
	(0.012)	(0.012)	(0.011)	[0.009]	(0.061)	(0.036)	[0.003]			[0.000]	[0.005]	[0.045]	[0.107]
ER9(10,6)	-0.058***	*1.227****	0.858***	173.30***	0.180***	-0.032	–	2.066***	1.741***	5.851**	-4.727***	8.687***	1.382
	(0.017)	(0.020)	(0.014)	[0.000]	(0.058)	(0.032)				[0.016]	[0.000]	[0.000]	[0.176]
ER10(11,6)	-0.009	*1.463***	*1.034****	2.751*	0.277***	0.099***	9.050***	2.365***	2.343***	0.741	-1.396	2.106	9.840
	(0.010)	(0.009)	(0.007)	[0.098]	(0.049)	(0.029)	[0.003]			[0.390]	[0.163]	[0.098]	[0.002]
ER11(11,6)	-0.066***	*1.124****	0.841***	138.60***	0.040	0.000	–	1.740***	1.747***	0.015	-4.054**	7.286***	1.692
	(0.017)	(0.018)	(0.014)	[0.000]	(0.059)	(0.031)				[0.902]	[0.000]	[0.001]	[0.134]
ER12(10,6)	-0.039***	0.971***	0.757***	37.79***	0.017	-0.037	–	1.030***	1.169***	0.212	-4.160***	5.956**	1.586
	(0.011)	(0.011)	(0.009)	[0.000]	(0.068)	(0.041)				[0.646]	[0.000]	[0.000]	[0.106]
ER13(10,6)	-0.032***	*1.129****	0.840***	49.68***	0.082	0.035	–	1.561***	1.601***	0.111	-3.947**	6.091**	1.567
	(0.011)	(0.011)	(0.008)	[0.000]	(0.053)	(0.033)				[0.739]	[0.000]	[0.000]	[0.111]
ER14(11,6)	-0.017*	*1.143****	0.849***	14.67***	0.068	0.059*	–	1.850***	1.728***	1.807	-1.359	1.386	3.247
	(0.010)	(0.010)	(0.008)	[0.000]	(0.051)	(0.030)				[0.179]	[0.174]	[0.246]	[0.039]
ER15(10,6)	-0.007	1.483	*1.037***	0.350	0.325***	0.092**	11.280***	2.452***	2.387**	0.679	-0.262	0.843	4.904

	(0.015)	(0.015)	(0.013)	[0.555]	(0.057)	(0.038)	[0.001]			[0.410]	[0.794]	[0.471]	[0.027]
ER16(10,6)	-0.016*	*1.108****	0.838***	9.241***	0.018	0.005	–	1.776***	1.706***	0.336	-1.918	2.350	11.592
	(0.008)	(0.008)	(0.006)	[0.002]	(0.051)	(0.031)				0.563	[0.055]	[0.071]	[0.001]
ER17(10,6)	-0.016*	*1.308****	0.930***	17.85***	0.032	-0.022	–	1.951***	1.488***	15.92***	-1.257	1.333	0.627
	(0.009)	(0.012)	(0.008)	[0.000]	(0.051)	(0.028)				[0.000]	[0.209]	[0.264]	[0.535]
ER18(10,6)	-0.011**	0.499*	0.132	8.763***	-0.063	0.001	–	1.296***	1.054***	1.774	-3.032	5.648**	0.676
	(0.005)	(0.005)	(0.003)	[0.003]	(0.064)	(0.038)				[0.183]	[0.003]	[0.001]	[0.776]
ER19(11,6)	-0.014	*1.185****	0.863***	9.315***	0.324***	0.090***	14.544***	2.241***	1.954***	5.968**	-1.207	1.411	1.806
	(0.010)	(0.010)	(0.008)	[0.002]	(0.053)	(0.032)	[0.000]			[0.015]	[0.228]	[0.238]	[0.165]
ER20(9,6)	-0.014**	0.777***	0.666***	0.742	0.188**	-0.012	–	1.041**	0.933***	1.546	-2.364	1.890	0.631
	(0.007)	(0.006)	(0.005)	[0.389]	(0.074)	(0.039)				[0.214]	[0.018]	[0.130]	[0.817]

This table reveals the results of the optimal NARDL estimations for the responsiveness of the mortgage rates to cash rate changes each bank of the three sampled groups in the corresponding panels. (2) The estimated long-run coefficients $\beta^{+}$and β^{-} are associated with increases and decreases in the cost-of-funds rate variable (in italics if equal to unity), defined by $\beta_i^{+} = -\delta_i^{+}/\rho_i$ and $\beta_i^{-} = -\delta_i^{-}/\rho$. (3) The parameters $\pi_0^{+}$and π_0^{-} measure the impact pass-through reflected in the same week as the cost-of-funds rate shock; and cumulative short-run dynamics are $\sum_{j=0}^{1}\pi_j^{+}$ *and* $\sum_{j=0}^{1}\pi_j^{-}$. (4) W_{LR} is the Wald statistics for the long-run asymmetry, W_{ISR} and W_{CSR} correspond to the Wald F-statistics for the contemporaneous and cumulative short-run asymmetry, respectively. (5) SoA is the average speed of the adjustment coefficient. (6) t_{BDM} and F_{PSS} are the *t*- and *F*-statistics of the Bound test for cointegration. The t_{BDM} (Banerjee et al. 1998) tests the single restriction H_0: $\rho_i = 0$ against the alternative H_{A}: $\rho_i < 0$. The F_{PSS} (Pesaran et al. 2001) tests the null hypothesis of no cointegration H_0: $\rho_i = \delta_i^{+} = \delta_i^{-} = 0$ against the alternative of cointegration H_{A}: $\rho_i \neq \delta_i^{+} \neq \delta_i^{-} \neq 0$.Critical values for the BDM *t*-test and the PSS *F*-test are, for respectively, – 4.1 (1%), – 3.53 (5%), – 3.21 (10%) and – 6.36 (1%), – 4.85 (5%), – 4.14 (10%). (7) Standard errors and *p*-values are given in brackets and parentheses; the asterisks ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

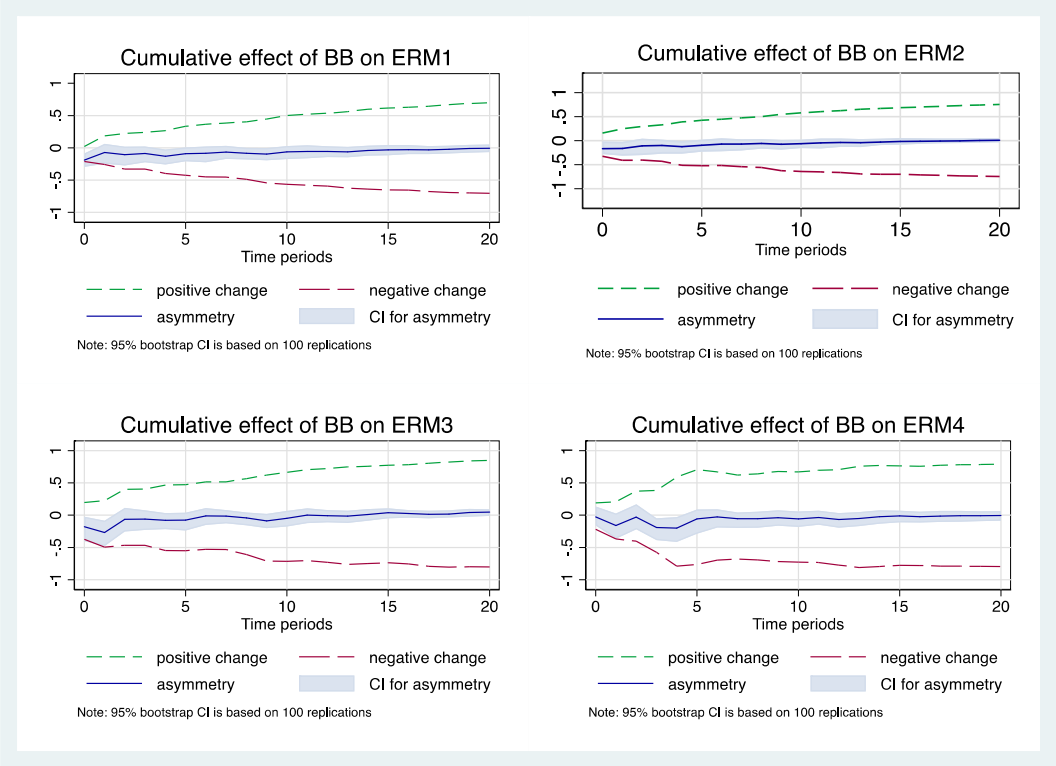
The cash rate results are reported in Table 3.3. All the Big-4 banks disclose asymmetric pricing conduct, while this behaviour presents in two out of three foreign subsidiaries, and ten out of 13 regional banks, validating that Australian banks asymmetrically adjust their mortgage rates corresponding to policy rate shifts. The asymmetric findings substantiate that, in the long run, the mortgage interest rates are influenced mainly by increases in the cost-of-funds rates. All the Big-4 among others reveal the lowest degrees of asymmetries, both positive and negative, indicating their strongest market power in mortgage pricing. These long-term magnitudes associated with funding cost rises and cuts are mostly close to unity for BB equations, and greater than one for CR estimations. This finding suggests that in the long run bank mortgage interest rates are comparatively responsive to funding cost changes, consistent with the existing literature. These asymmetric findings strongly validate the hypothesis of the oligopoly market.

The short-run asymmetry combines the instantaneous impact and cumulative asymmetry. These positive impacts associated with increases in funding costs are mostly highly significant at the 1% and 5% levels and have positive signs as expected, but those associated with decreases are mostly insignificant and have both positive and negative signs. These coefficients can be positive and negative because, at the time of the funding cost shock, bank price-setting can be affected by different factors. Positive impacts are much greater in size than negative impacts and wide variations in magnitudes exist in both positive and negative impact parameters. This result suggests that banks are more responsive to instant funding cost rises, but are slow to respond to cost cuts. The downward sluggish and heterogeneous findings are consistent with Fuertes et al. (2010) regarding the UK mortgage market: this study explains these negligible degrees of the negative impacts as menu costs and bank-specific characteristics. The symmetry tests for impact dynamics of the foreign funds rate are virtually insignificant. Only one regional bank, coded ER_{15}, reveals the asymmetric impact of the

foreign funds rate, whereas eight out of 20 banks immediately asymmetrically respond to cash rate shocks. This finding specifies a greater competition level in the wholesale funding market due to highly stringent market conditions, compared with the domestic market.

Figures 3.2 to 3.5 plot the cumulative dynamics of short-term asymmetry and heterogeneity in the mortgage rate pass-through for individual banks in corresponding panels in Tables 3.2 and 3.3. This research focuses on four key findings and their plausibility. First, the cumulative asymmetry in the transmission of the cash rate exists in nine out of 20 banks, including three major banks. Only four majors reveal the asymmetry in their foreign funds rate transmission, indicating their most dominant position in mortgage financing. Second, great variations in pass-through degrees exist among the tested banks. The cash rate estimations provide the superior cumulative asymmetry in size at much greater than one, while that of the foreign funds rate is considerably smaller than one. These estimated results show clearer heterogeneity and wider variations in the bank-specific pass-through from cash rate rather than from international funding cost.

a) Dynamic multipliers for the effective mortgage rate - foreign funds rate



b) Dynamic multipliers for the effective mortgage rate - cash rate

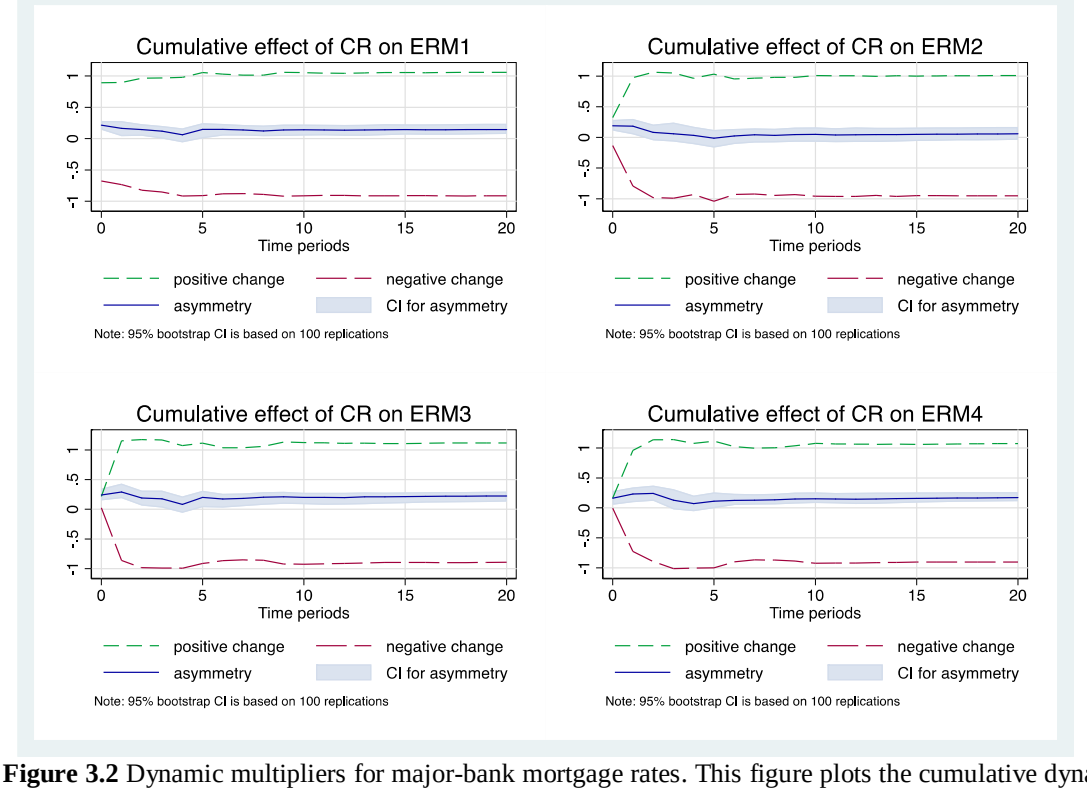
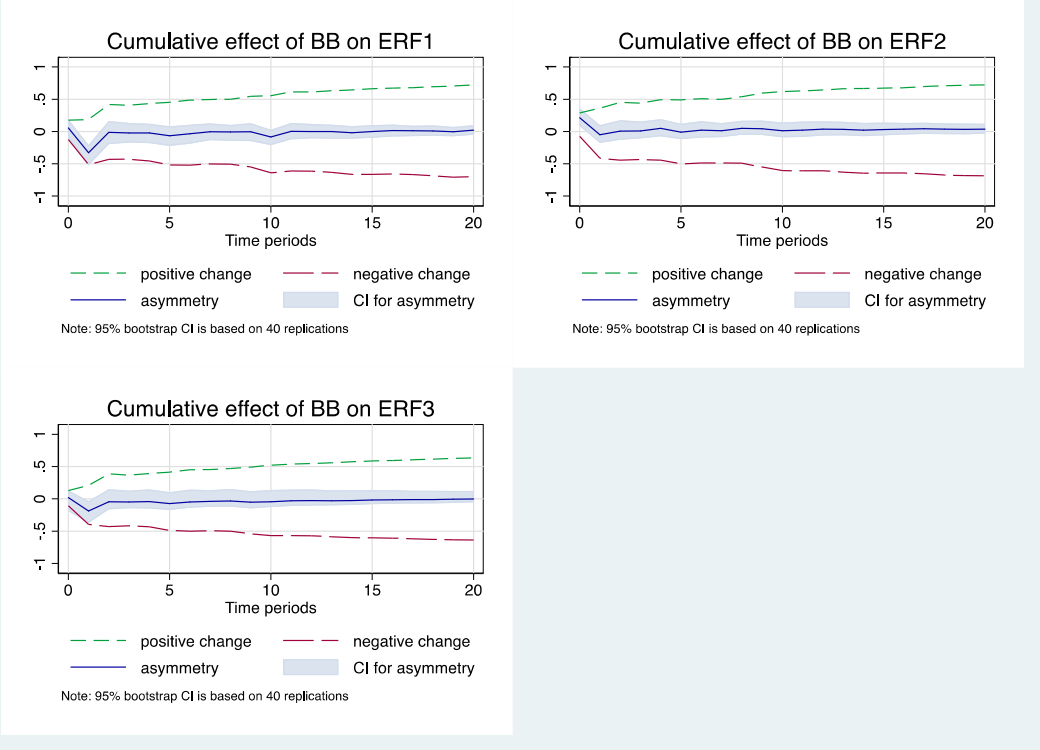


Figure 3.2 Dynamic multipliers for major-bank mortgage rates. This figure plots the cumulative dynamic multiplier effect of respectively a 1% increase or decrease of the cost-of-funds rates on the bank effective mortgage rates in percentage points on the vertical axis. Weekly intervals are on the horizontal axis.

a) Dynamic multipliers for the effective mortgage rate - foreign funds rate



b) Dynamic multipliers for the effective mortgage rate - cash rate

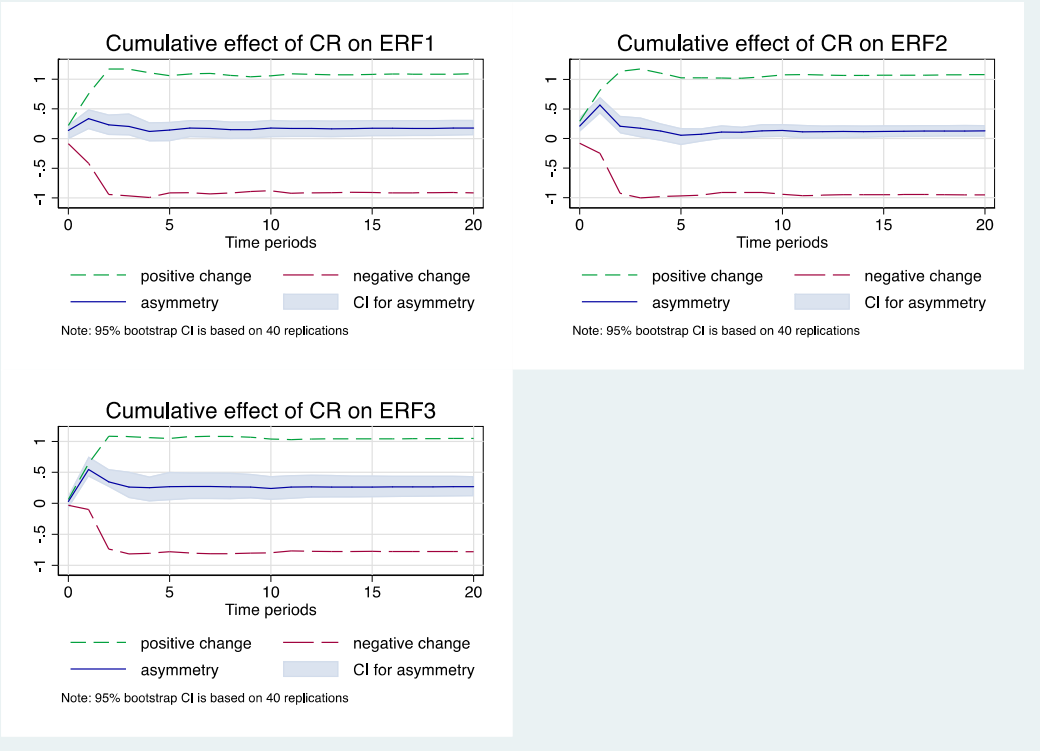


Figure 3.3 Dynamic multipliers for foreign-bank mortgage rates. The rest are similar to Figure 3.2.

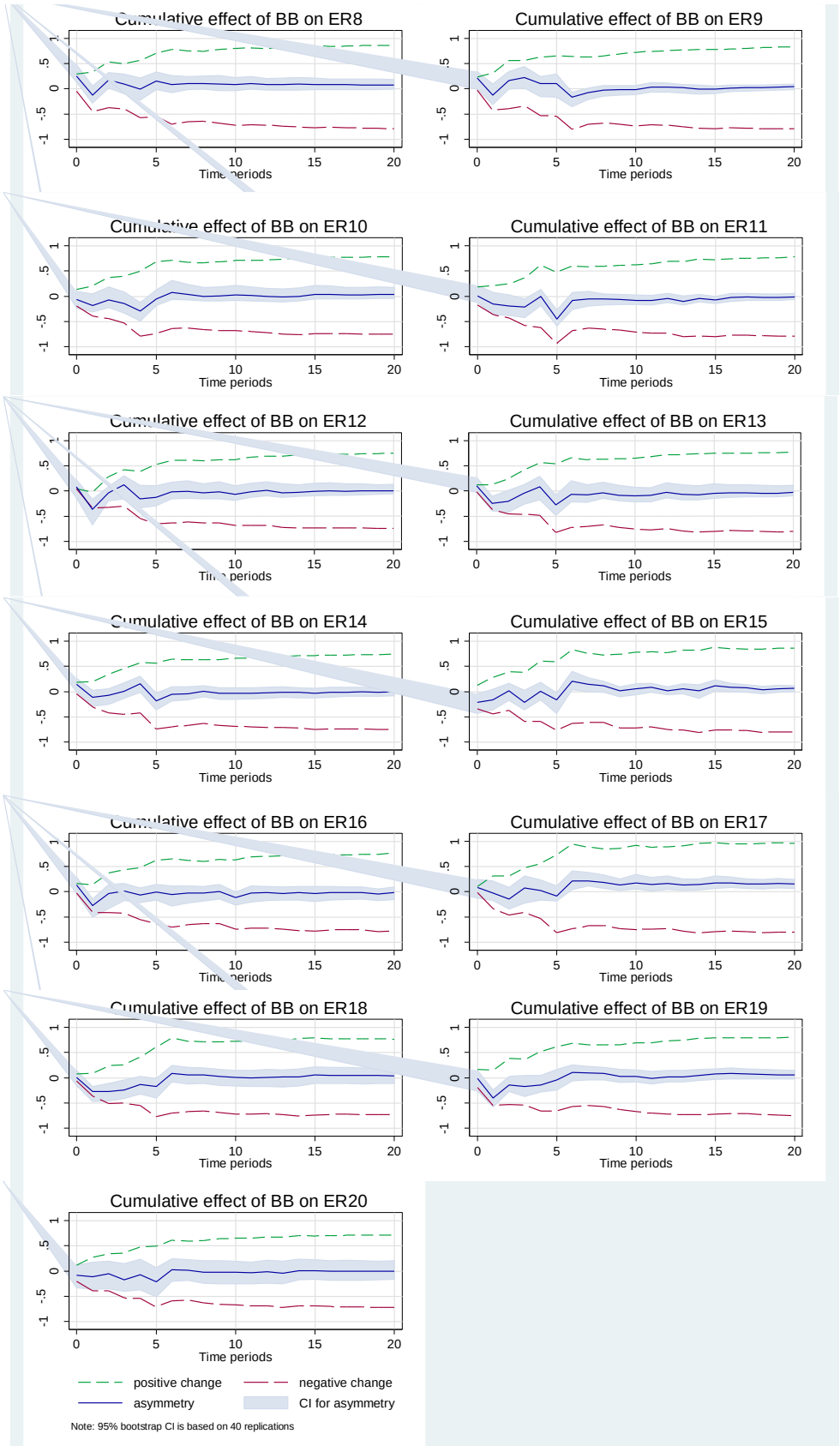


Figure 3.4 Dynamic multipliers for region-bank mortgage rates and the foreign funds rate.

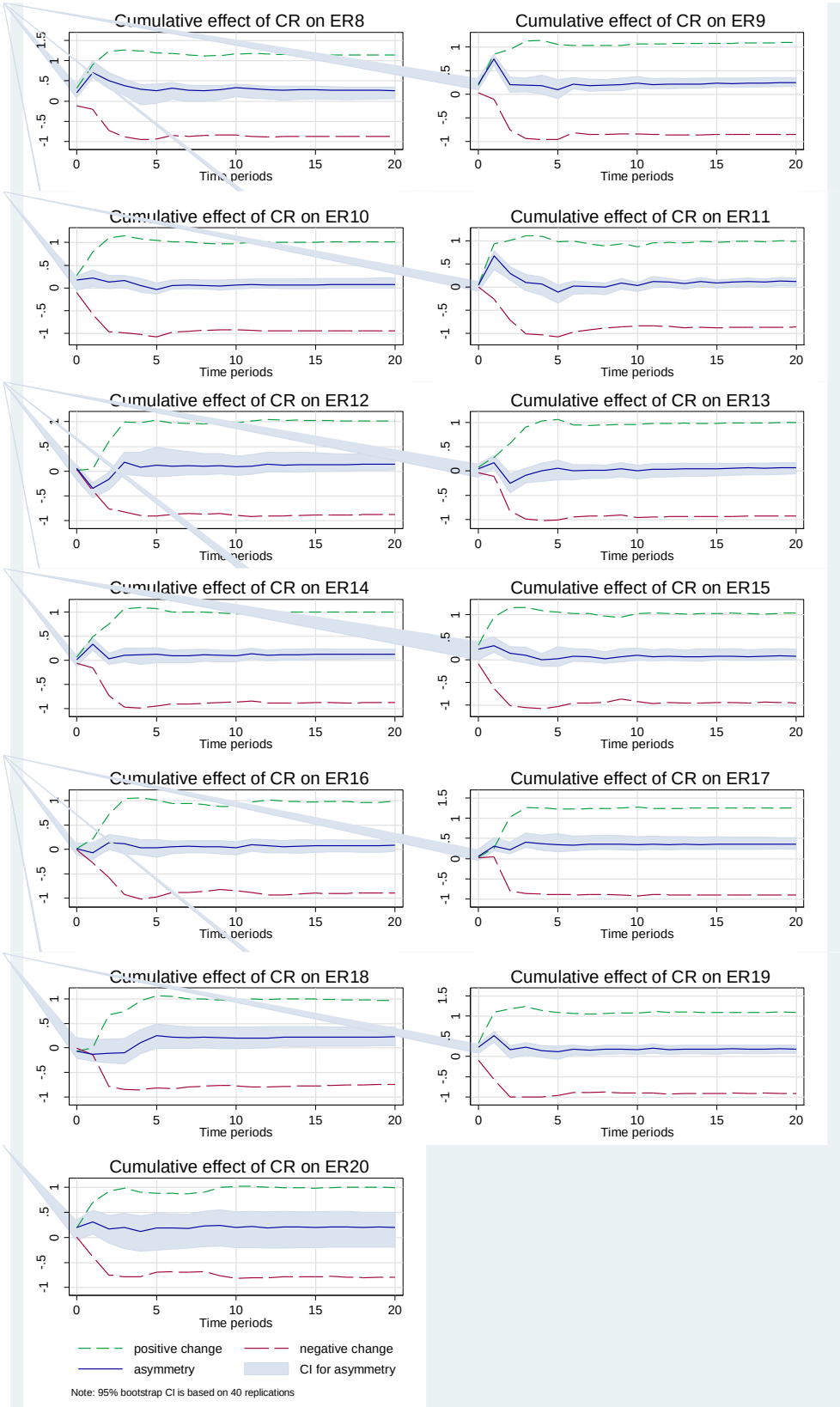


Figure 3.5 Dynamic multipliers for region-bank mortgage rates and the cash rate.

Third, banks differently react to cash rate and foreign funds rate changes. They are all greater and faster to transmit cash rate rises to their mortgage rates than to pass on the rate cuts, resulting in a positive asymmetry. This finding is consistent with prior studies (e.g., Apergis and Cooray 2015; Valadkhani 2013). Interestingly, most banks respond to the foreign funds rate in the opposite direction with a negative asymmetry that is similar to De Haan and Sterken (2011). The findings of this study indicate the higher competitive pressure for banks is in raising wholesale funds to finance their mortgages in the short term. Forth, all 13 smaller domestic-owned lenders among the sampled banks are the most responsive to increases and decreases in the cost-of-funds rates, both domestic and international. They have the highest magnitudes of the positive and negative multipliers and longer response intervals to the foreign funds rate, about 3–5 weeks, than to the cash rate, approximately 2 weeks. This finding validates their lowest market power and concludes that these banks are price-setting followers. In line with the expectation, the major and foreign banks are price makers, as shown in these figures; they are the most sluggish and unhurried to adjust their mortgage prices due to their market dominance, reconfirming the market concentration hypothesis.

This bank-specific study finds not only the long-run asymmetry in mortgage rate pass-through, but also the heterogeneous asymmetry and rigidity in the short run. These findings are highly consistent with the contemporary IRPT literature (Fuertes et al. 2010), indicating further work need to be done to determine which factors cause this heterogeneous asymmetry.

3.6 Conclusion

This study examined asymmetry in the transmission of the foreign funds rate and the cash rate to the mortgage rates for Australian banks over the 18-year period 1997:1–2015:12 using the NARDL model. The novel weekly bank-level dataset is constructed from the

effective interest rates on variable home-loans of 20 anonymous commercial banks. By doing so, parallel estimates of the pass-through from changes in the cash rate to mortgage rates, and the integration of the mortgage rate and foreign-funds rate have been conducted.

The results suggest that Australian banks asymmetrically set their mortgage rates in heterogeneous manner. Short-term heterogeneity and rigidity in the mortgage rate pass-through are found for all estimates, both cash rate and foreign-funds rate. The existence of the varied asymmetries across banks indicates significant disparities in mortgage rate setting. The long-term positive asymmetry is strongly confirmed for both cash rate and foreign-funds rate. The region group is the most competitive lenders with the highest pass-through magnitudes, while the Big-4 and foreign subsidiaries are market dominant. These findings reaffirm the oligopolistic market hypothesis for Australia. The asymmetry findings hence specify a stronger relationship between bank mortgage rates and international funding costs.

This work contributes to the IRPT literature with two important implications to monetary and financial stability perspectives. First, the findings provide convincing evidence of the strong influence of foreign-funding costs on mortgage rates. This empirical evidence is of practical use to the APRA and RBA because of the increased integration of Australian mortgage financing with world financial markets. The outlook for economic growth and inflation can be shaped by the volatility of bank funding costs. Therefore, foreign-funding costs that are integral to Australian banks' funding costs matters to the APRA and RBA for their micro-prudential and macro-prudential supervision. Second, the solid evidence of the positive asymmetry in the long term pass-through signals a series of consumer protection solutions that require the ACCC to implement. Banks have customarily passed on funding cost rises to their mortgage borrowers by setting higher rates on new lending,

thereby affecting consumer wellbeing directly and significantly because interest payments are nontax-deductible for home-loan borrowers. This pricing conduct over time could induce financial fragility because the higher costs of mortgage debt would increase the amount of unaffordable borrowing subsequent to the increased credit losses for banks.

This study motivates several key possible extensions, but is not limited to: (1) the in-depth examination of how the 2008 GFC affected funding cost transmission using panel data models, (2) the exploration of heterogeneity in the interest rate transmission mechanism considering the effect of observed and unobserved common factors that may cause seriously impact on the funding cost–mortgage rate relationship, (3) the discovery of asymmetric determinants of the monetary policy transmission mechanism for Australia, (4) the employment of the weighted average cost of liabilities in modelling retail interest rates for Australian banks, (5) the analysis of the cash rate–deposit rate nexus for Australian banks using the innovative methodology of this thesis, (6) the potential extension of this research to investigate asymmetry in commodity pricing at single-country or cross-country levels, and (7) the investigation of the funding cost–retail interest rate nexus, using the innovative methodology of the third essay, in other countries or in a cross-country study accounting for market structure differences.

Chapter 4: Australian mortgage asymmetric pricing: Heterogeneity, asymmetry and GFC impact

Chapter 4 of this thesis comprises two sections:

- Chapter 4A: Mortgage asymmetric pricing, cash rate and international funding cost: Australian evidence
- Chapter 4B: International funding cost and heterogeneous mortgage interest-rate pass-through: A bank-level analysis

Chapter 4A examines asymmetry in relationship between mortgage rates and bank funding costs over the sample period from 2nd July 2002 to 31st December 2015 using weekly panel data, considering both short- and long-term pass-through. Moreover, this chapter further examines the impact of the GFC on the pass-through mechanism and sheds light on the impairment of this asymmetric transmission of the cash rate in the long run.

Chapter 4B examines heterogeneity in the mortgage rate pass-through mechanisms, both symmetry and asymmetry. This essay empirically investigates the nature of the long-term relationship between mortgage rates and bank funding costs, both the cash rate and the cost-of-foreign-funds rate: homogeneity or heterogeneity. This chapter controls simultaneously nonstationarity, linearity and nonlinearity, slope heterogeneity and complex cross-sectional dependencies, which arise from both observed and unobserved common factors. This essay therefore sheds light on the IRPT literature where there is no examination for these important issues.

Compared to Chapter 4B, the scope of Chapter 4A is relatively limited in terms of research methods. Chapter 4B thus positions the main body of the thesis, whereas Chapter 4A is located in the Appendix 4A.

Chapter 4B: International funding cost and heterogeneous mortgage interest-rate pass-through: A bank-level analysis [6]

This chapter includes a co-authored paper. The bibliographic details (if published or accepted for publication)/status (if prepared or submitted for publication) of the co-authored paper, including all authors, are:

Holland, Q.C.P., Liu, B., Roca, E. (2018). International funding cost and heterogeneous mortgage interest-rate pass-through: A bank-level analysis. *Empirical Economics*, 1-35. doi:10.1007/s00181-018-1488-6

My contribution to the paper involved:

"Generation of the research idea through extensive literature review; development of the theoretical framework and hypotheses; identification of the research models and relevant data; the data organization into a usable format; STATA programming and analysis of the results; interpretation and discussion of the results; and the write up of the complete paper; the full revision of the paper"

_____ 01 June 2018
Name of student: Quynh Chau Pham

(Countersigned) _____ 01 June 2018
Corresponding author of paper: Quynh Chau Pham Holland

(Countersigned) __[redacted]___ 07 December 2018

Supervisor: Benjamin Liu

[6] I wish to acknowledge the constructive advice, useful comments and helpful suggestions given to us by Prof. Bertrand Candelon, the Editor, and the two anonymous reviewers of Empirical Economics, and by participants at the Lunchbox seminar–PhD edition held by Griffith Environmental Futures Research Institute on Sep 15 2017, at the Social and Affordable Housing Symposium held by Griffith University in Brisbane, Australia on September 25 2017, and at the Campus for Finance –WHU New Year's Conference 2018, Jan 17–18 in Koblenz, Germany. I am responsible for any error or omissions remained.

(Countersigned) 07 December 2018

Supervisor: Eduardo Roca

Abstract

This study examines the transmission of the cost-of-funds rates, domestically and internationally, to owner-occupied housing interest rates at the bank level for the period 2002(7)–2015(12) in Australia. Three main issues, cross-sectional dependence, parameter heterogeneity, and asymmetry, have been considered using the linear and nonlinear common-factor augmented mean group estimators. Significant unobservable coefficients in all estimates ascertain that unobserved common factors arising from both national and global shocks have a significant influence on mortgage rate transmission. The results of sizable heterogeneity and asymmetry, found in all estimates while controlling for cross-sectional correlations, highlight the substantial effect of the foreign-funds rate on long-run mortgage price-setting. This analysis finds a closer connection between mortgage interest rates and international funding cost; this study has also confirmed a declining transmission of the policy rate after the 2008 global financial crisis.

4.1 Introduction

The 2008 GFC had severe impact on banking stability with a large degree of country heterogeneity. The study of heterogeneity and asymmetry in interest-rate pass-through, therefore, has been renewed, with its main focus now on developed mortgage markets. Most recent papers, such as Bernhofer and Van Treeck (2013), Lim, Tsiaplias, and Chua (2013), and Sathye (2013), investigate heterogeneity in IRPT for advanced mortgage markets at cross-country or country levels. This set of the literature confirms the occurrence of short-term heterogeneity and long-term homogeneity in the pass-through. In relation to asymmetry, a few studies, which use bank-level data for Belgium (De Graeve et al. 2007), the Netherlands (De Haan & Sterken 2011), the UK (Fuertes et al. 2010), or the Czech Republic (Horváth &

Podpiera 2012), find extensive existence of short-term asymmetry in the IRPT. Apergis and Cooray (2015) document that the four major banks in Australia still yield asymmetry in pass-through from policy rates to their retail rates after the GFC, while this asymmetry does not exist for the UK and US.

Two imperative issues have been neglected in the IRPT literature. Disregarding cross-section dependence (CD) is the first major shortcoming. Cross-section correlation, which is typically encountered in the data of economic growth and credit spreads, is theoretically inherent in interest rate panels (Omay, Çorakcı, & Emirmahmutoglu 2017). Depository institutions nationally and globally operate in an interactive environment through economic, regulatory, political and other channels. Their price-setting policies are significantly subject to common phenomena ranging from national policy changes to global economic shocks such as the recent financial and sovereign debt crises. The contemporary literature on growth and econometrics has established solid foundations in the presence of CD properties in the macro panel data which arise from common factors, nationally and globally (Bai & Ng 2004; Castagnetti, Rossi, & Trapani 2017; Eberhardt & Teal 2013). However, this issue has remained untouched in the literature on interest rate transmission. Ignoring the CD in these standard heterogeneous panel methods has most likely produced unreliable estimates with severe size distortions (Omay et al. 2017; Pesaran 2006).

Second, the effects of policy rates on bank interest rates have weakened since the GFC.[7] This transmission breakdown is often interpreted as indicating changes in bank price-setting, but this view may be biased. Banks acquire funds from various sources, so their overall cost of funds reflects the whole range of diverse liabilities (Fabbro & Hack 2011). Recent global

[7] This transmission breakdown has emerged in Euro core advanced economies (Aristei and Gallo 2014; Hristov et al. 2014), and in Australia (Lim et al. 2013).

extreme shocks have induced a higher level of credit risk, liquidity risk, and competition, making the cost of market funding more expensive (ECB 2013). These significant changes in world financial markets violate the underlying assumption of an alignment between policy rates and retail interest rates (Naraidoo & Raputsoane 2015).

This study examines heterogeneity and asymmetry in the transmission of the cost-of-funds rates, domestically and internationally, to home-loan interest rates, controlling for cross-section dependence. The country selection has been made owing to the importance of Australian housing and housing finance markets from the perspectives of an effective monetary policy and wealth effects on consumption (Jansen 2013; Robstad 2018). Australia is one of the top five world largest mortgage markets, just standing behind Denmark, Norway, and Netherlands, whose ratios of total mortgage credit to GDP are greater than 100% (IMF 2017). Globally, Australia possesses the highest ratio of housing loans to total bank loans at 64%, a ratio that has continuously increased since the GFC (IMF 2017). Its mortgage market is highly oligopolistic: the dominance of four major banks constitutes over 85% of total market share (see Fig. 2.4, Chapter 2, subsection 2.3.1). Only Australia, of these five, raises considerable mortgage funds from wholesale sources; the others source their funds mainly from domestic deposits. A significant portion, around 35%, of Australia's mortgage funding is sourced from world financial markets (Ralston et al., 2011; Wilkins et al., 2016). This heavy reliance on foreign borrowings also poses a serious practical question for policy makers and banking regulators: housing finance markets with these characteristics are highly associated with house-price booms that potentially threaten financial stability, locally and internationally (Cerutti, Dagher, Ariccia, and Blanchard 2017).

The pronounced contribution of this essay to the literature is the implementation of novel econometrics techniques. Our heterogeneous panel-data models, which build on the augmented

mean group (AMG) method (Bond & Eberhardt 2013; Castagnetti et al. 2017; Eberhardt & Bond 2009) and on the NARDL framework (Shin et al. 2014), facilitate the incorporation of common factors, heterogeneity, and asymmetry in model-setting. This study applies the approach of Chudik and Pesaran (2015), which uses lags of the dependent variable as regressors in a dynamic setting. Both linear and nonlinear AMG models perform well in controlling for observed and unobserved common factors.[8] The researcher performs the models over the full-sample span for the banking sector and over three sub-groups: major, foreign, and region. The impact of the crisis on this transmission is scrutinised in the sub-sample analysis: before, during, and after the GFC. The researcher also estimates the degrees of mortgage rate adjustments to changes in the cash rate and the foreign-funds rate for all models. This essay carefully tests the CD properties of the dataset.

A new exogenous variable, the foreign-funds rate, is employed to supplement a new proxy for the cost-of-funds rates, along with the conventional use of the cash rate in the literature. The testable hypothesis, formed from the marginal cost-of-funds approach (De Bondt 2005), is that retail interest rates are set as a profit margin (markup) over the bank marginal funding cost. The overall cost-of-funds rate is mainly approximated from variations in funding costs because banks borrow from different sources. The existing literature typically uses policy rates or money market rates as the proxies for bank cost-of-funds rates. The rates that should be used for Australian banks, however, are the domestic and foreign-funds rates, due to their exceptional wholesale models of mortgage funds. Australia and South Africa (an emerging economy), the only countries amongst 53 sampled by Cerutti et al. (2017) that finance their mortgages from wholesale funding sources, accounting for only 0.038% of the Cerutti's et al. (2017) sample. The other 44 sampled developed and emerging countries, which account for

[8] The main advantages of the AMG model are discussed in Subsection 4.4.4 because of the space limitation of the introduction.

83.02%, source their funds mainly from retail deposits. At an individual level, banks' significant exposure to international debt is anticipated to affect their mortgage price-setting policies. This work empirically contributes hitherto unavailable evidence of the systematic nexus between international funds costs and mortgage interest rates.

This study also contributes to the development of the literature by employing a bank-level dataset of weekly variable home-loan interest rates. This high-frequency dataset, constructed from 20 anonymous Australian banks for the period 2002(7)–2015(12), enables researchers to eliminate the aggregation bias. Aggregating interest rate series can eliminate the possibility of heterogeneity in individual bank pricing behaviour, possibly resulting in biased results (De Graeve et al. 2007; Fuertes et al. 2010). Using a comprehensive disaggregated dataset offers more efficient estimated results; it also overcomes aggregation bias problems (detailed in Imbs et al. 2005).

This essay provides the first comprehensive bank-panel analysis of the mortgage IRPT, by considering cross-sectional dependencies in macro panel data, parameter heterogeneities and asymmetries. Our results affirm the presence of cross-sectional dependence in interest rate panels, heterogeneity, and asymmetry in the long-term pass-through. Most importantly, we find that the unobserved common factor is imposed on each bank. These findings have previously been unexplored in the literature on interest rate transmission, but our findings are consistent with the contemporary literature on growth and credit spreads (Castagnetti et al. 2017; Eberhardt & Teal 2013). Incomplete heterogeneity and positive asymmetry have been significantly verified, reaffirming the market power hypothesis, and indicating variations in bank mortgage rate setting conduct. Remarkably, the mortgage rates have perpetually been adjusted greater upwards than downwards in response to foreign-funds rate hikes or cuts since the crisis, but they significantly decrease corresponding to cash rate cuts only. These novel

findings validate our hypothesis that, since the GFC, bank price-setting has been closer to international funding cost movements than to the cash rate. These novel outcomes have important policy implications.

Section 2 reappraises the theoretical and empirical literature on heterogeneity and asymmetry in mortgage interest rate pass-through. Section 3 describes the sample and data, while Section 4 outlines the estimation strategy and models. Section 5 analyses the empirical results and Section 6 draws key conclusions and implications.

4.2 Literature review

The researcher briefly reviews two predominant theories, market concentration (Hannan & Berger 1991) and competition (Kopecky & Van Hoose 2012); I also scrutinise empirical support for rigidity in lending interest rate adjustments in the long term. Concentration theory posits that retail interest rates respond to market rate shocks more slowly in more concentrated markets due to collusion. Banks with greater market power can collude in pricing, resulting in upward rigidity in deposit rates and downward rigidity in lending rates, which favours lenders. Toolsema and Jacobs (2007) strongly propose that when banks adhere to a tacit collusive agreement, lending rates are asymmetrically stickier to decreases in policy and/or money market rates than to increases, resulting in positive asymmetry, even though an increase in input price is common knowledge because changes in market rates are transparent. Banks can make abnormal incomes as long as none reduces its price to a cost cut. Concentration theory is widely applied in the empirical literature on the transmission of changes in monetary conditions. Numerous studies in this strand confirm the existence of positive asymmetry in the pass-through of lending interest rates to policy rates or market rates for mortgage markets in the US (Allen, Rutherford, & Wiley 1999), Canada (Allen & McVanel 2009), Netherlands

(Toolsema & Jacobs 2007), the UK (Fuertes et al. 2010), and Australia (Apergis & Cooray 2015; Valadkhani & Anwar 2012).

The competition hypothesis postulates that highly competitive markets induce banks to reduce their mortgage rates quickly when policy and/or market rates decreases, but to increase the rates sluggishly when their funding cost rises. Banks encounter the fear of losing customers, so their reluctance to adjust their lending rates upwards results in negative asymmetry, which is preferable for mortgage borrowers. Several studies in Singapore (Chong, Liu, & Shrestha 2006), New Zealand (Liu, Margaritis, & Tourani-Rad 2011), Netherlands and the US (De Haan & Sterken 2011; Payne 2007) provide downward or negative asymmetry results supporting this customer-favourable hypothesis. Banks in these studies fiercely contest a product line in the same market segment, so are faster to reduce their housing rates downwards, but slower to increase these rates to preclude severe customer loss by accepting lower margins.

The second critique focuses on the study of heterogeneity in the IRPT that evaluates the responsiveness of housing interest rates to monetary policies. Single- and cross-country studies have assessed the degrees of integration between housing interest rates and policy rates: in Australia (Liu et al. 2016; Sathye 2013), in the Euro area Bernhofer & Van Treeck 2013; De Bondt 2005; Hristov et al. 2014), and in a comparison of Australia and the US (Lim et al. 2013). The few studies employing bank-level data are confined to several advanced mortgage markets. In particular, De Graeve et al. (2007) take compatible maturity market rates as proxies for the cost-of-funds rates to investigate heterogeneity in Belgian bank price-setting conduct. Other studies (Fuertes et al. 2010; Horváth & Podpiera 2012) focus on how mortgage and other retail rates closely react to policy rate changes in the UK and Czech Republic. Nonlinear ECM, VAR, panel cointegration, and ARDL-ECM techniques are commonly used. These studies mostly yield incompleteness for all retail interest rates, as well as large variations in size and speed of

short-term pass-through across different products and banks. The grounds for wide discrepancies in the short-term pass-through are significant differences in market concentration, credit risk, menu and switching costs, diversifications, market developments, and bank characteristics (De Bondt 2005; De Graeve et al. 2007; Fuertes et al. 2010; Horváth & Podpiera 2012).

The constraint of having so little empirical literature on monetary transmission at the bank level is the lack of long-time disaggregated series on mortgage interest rates in datasets, because of the requirements for strict confidentiality in banking. The most major shortcoming in the existing literature is that cross-section dependence has been largely disregarded when estimating conventional panel-data models. Panel cointegration approaches based on the ECM and/or VECM, and the panel ARDL models are commonly used (e.g., Bernhofer & Van Treeck 2013; De Graeve et al. 2007; Horváth & Podpiera 2012; Illes, Lombardi, & Mizen 2015). These methods, based on the assumption of cross-sectional invariants, disregard the presence of cross-sectional correlation in model setting so these studies document homogeneity in the mortgage rate pass-through in the long run. Sorensen and Werner (2006) pioneer controlling for cross-section dependence using the dynamic seemingly unrelated regression (DSUR) by Mark, Ogaki, and Sul (2005). However, this model requires a normal distribution of the residuals.

Internationally, the literature on interest rate pass-through using comprehensive bank-level mortgage rate datasets over a relatively long period remains scarce. The researchers are unaware of any preceding study that considers the effect of foreign funding costs, so our study begins to explore the literature area. The studies reviewed examine heterogeneity or asymmetry (speed and/or short-run only) separately, without considering the cross-section dependence issue. This paper therefore sheds light on this important area by controlling for cross-section

dependence while simultaneously investigating heterogeneity and asymmetry in the long-term mortgage price-setting that relate to both cash rate and foreign-funds rate at the bank level.

4.3 Sample and data description

4.3.1 Sample and data

The data span of 13 years, 1 July 2002 to 31 December 2015, is obtained from an initial 18-year bank-specific period because our econometrics techniques require a balanced panel sample. This period ranges over a number of recent financial crises (e.g., the GFC; the ensuing European debt crisis of 2010–11), allowing capture of potential market structural changes. The unanticipated macroeconomic shocks have been confirmed to induce structural breaks and nonlinearity in the real interest rates for 17 OECD economies, including Australia (Omay et al. 2017). Our 20 anonymous samples including four major banks, three foreign-owned subsidiaries, and 13 smaller Australian-owned banks provide approximately 90% of the total outstanding mortgages over the whole sample period (author's calculation). The representativeness of the selected banks is relatively well exemplified. A full balanced panel-sample of 20 banks and 706 weeks is obtained after screening. Because of the oligopoly of the banking system, the original sample is subdivided into four subsets: sector, major, foreign, and region. Heterogeneous mortgage price-setting practices are thus expected.

The panel dataset has a longer time span (T = 706 weeks) than other disaggregated studies (e.g., Apergis & Cooray 2015; De Haan & Sterken 2011), allowing for splitting the full sample into three sub-spans (before, during, and after the crisis) to assess the impact of the GFC on the transmission. The breakpoint, 1st July 2007, is selected for the pre-crisis episode 2002(7)–2007(6) of 216 weeks. The bankruptcy of the New Century Financial Corporation in April 2007 triggered the US subprime mortgage crisis of 2007–2010. The Northern Rock downfall

in September 2007 subsequently led to the British credit crisis, which strongly affected Australian bank price-setting conduct. Since the ensuing GFC, funding costs in global and Australian financial markets have significantly increased. This study analyses bank price-setting behaviour during the crisis 2007(7)–2009(12) of 131 weeks, and the post-crisis period 2010(1)–2015(12) of 314 weeks, separately due to crisis abnormality.

The weekly dataset employed uses the variable home-loan rates of 20 anonymous banks, the official cash rate (*CR*), the policy rate in Australia, and the 3-month A$ BBSW (*BB*). The effective home-loan rate variable, *ER*, is constructed from the annual adjustable percentage rate of mortgages covering all kinds of fees. To construct the comparable dataset, the researcher selects only standard adjusted rate mortgages with 25 to 30 years' maturity and the loan amount of A$250,000 for owner occupiers.[9] The weekly mortgage rates were commercially manually taken from Cannex's survey of Australian lenders (purchased by Griffith University). Two funding cost variables, *BB* and *CR*, are retrieved from the Bloomberg terminal at Griffith University. The 3-month A$ BBSW, a key unsecured short-term money market benchmark used globally,[10] acts as a better proxy for the foreign-funds rate variable than the US$ LIBOR. The BBSW is typically referenced when Australian banks source their foreign funds in both onshore and offshore financial markets; LIBOR is a benchmark rate for offshore issues only (Guttmann & Rodgers 2015; RBA 2006). Technically, using the A$ BBSW eliminates possible calculation errors from currency conversion. Although Australian banks' overseas debt is mostly denominated in US dollars, it is swapped into fixed or floating home currency contracts through foreign exchange swaps and/or currency swaps to hedge against the currency risk

[9] Owner-occupied loans indicate the value of housing loans to Australian households for the construction or purchase of dwellings for owner occupation; revolving credit or redraw facilities are originally approved for the purpose of predominantly owner-occupied housing (APRA 2017).

[10] The 3-month BBSW, which represents the midpoint of the nationally observed best bid and best offer for AFMA Prime Bank Eligible Securities, including bank accepted bills and negotiable certificates of deposit, is used to provide reference interest rates for the pricing and revaluation of Australian dollar derivatives and debt securities.

(Turner & Nugent 2015). The cash rate is widely used in the IRPT literature as the exogenous policy rate because it is a direct measure of monetary policy stances and a key mainstream funding indicator.

4.3.2 Data description

The pairwise cointegration test substantiates well-cointegrated relationships between nexuses ER_t–BB_t and ER_t–CR_t at 0.85. Two exogenous cost-of-funds rate variables, BB_t and CR_t, are likely to have perfect multicollinearity at 0.98. Two variables can behave individually, as nonstationary random walks, because interest rate series are dominated by smooth, long-term trends. Econometrics procedures hereafter have been conducted separately for each nexus, to eliminate spurious estimated results.

Standard procedures for macro panels commence with descriptive statistics (see Appendix 4II) disclosing relatively interesting information. The mean statistics indicate that both major and region banks ask relatively lower prices for home loans than the sector. The foreign group charges the most expensive average price for mortgages, while the regional banks offer the most competitive rate for their mortgage borrowers. However, the foreign group is the most stable in mortgage rate setting, while the region banks are the most volatile during the full-sample or sub-sample spans. The average price of foreign funds is relatively greater than the average price of domestic borrowings. The former is also more volatile than the latter. The Bartlett mean equality is performed to compare the means for pre-GFC, GFC, and post-GFC periods. The test results are reported in the last column of the table. Bartlett's test is prominently employed to test simultaneously for the equality of more than two means, while other tests compare two means at a time. The statistically significant chi-squares tests ascertain a statistical difference in the mean values of each of the variables across the three sub-periods, indicating the presence of structural breaks in the series, consistent with Omay et al. (2017).

Appendix 4I draws a visual inspection of any possible co-movement between mortgage rates and cost-of-funds rates. The evidence of this potential interaction appears clearly perceptible for both cash rate and foreign funding cost, given a sharp plunge during the GFC. Virtually all sampled banks revealed a strong positive cointegration between mortgage rates and the cost-of-funds rates. The figure also signifies the cross-section dependence properties of the panels. This paper has empirically tested this problem in Subsection 4.2 to preclude severe biased estimates and incorrect inference in the standard panel estimators, that is based on the assumption of cross-section independence (Pesaran 2006).

4.4 Estimation procedure

4.4.1 Theoretical marginal cost pricing model

De Bondt (2005) formally exposed the marginal cost pricing model[11] for determining retail interest-rate pass-through under imperfect market competition. A bank interest rate based on this approach is determined as a constant markup over the overall funding cost, as follows:

$$br = \beta mr + \mu \tag{1}$$

where *br* refers to the bank interest rate, and *mr* is the exogenous cost-of-funds rate. The size of the long-term pass-through coefficient, β, tends to be close to unity when adjusting to the equilibrium. The constant markup, μ, is appropriated by numerous elements affecting bank price-setting at the individual level, including demand side, competition, risk premia, and bank characteristics such as size, capitalisation, and liquidity (Freixas & Rochet 2008). Study of the influencing factors forms the determinant strand of the literature on monetary policy transmission, such as Fiszeder and Pietryka (2017) and Naraidoo and Raputsoane (2015).

[11] This model is based on the mark-up pricing contribution of Rousseas (1985)

The funding cost, which constitutes the most substantial determinant of bank price-setting, determines the pass-through magnitude. This marginal cost-of-funds rate attributes mainly to the availability of funding sources or close substitutes to banks, the availability of financial alternatives to borrowers, and the market power that affects the elasticity of demand for bank lending products (De Bondt 2005). The study of heterogeneity and asymmetry, in the transmission of the cost-of-funds rate to bank interest rates examining the responsiveness of retail interest rate adjustments to monetary policies, universally adopts this marginal cost pricing model. The empirical studies of heterogeneity and asymmetry in the pass-through have been mainstreamed in the literature on monetary transmission because bank lending rates constitute a core element of this mechanism. This paper is in line with these strands.

The selection in the literature of the exogenous cost-of-funds rate variable, *mr*, depends on individual study's focus. Studies adopting the MPA focus solely on capturing the effect of monetary policy on retail interest rates, so administered policy rates or short-term interbank rates act as proxies for the exogenous cost-of-funds rates. The CFA emphases banks' price-setting decisions, taking money market rates of compatible maturities to retail bank rates. This method theorises that the market rates represent banks' funding costs, when raising funds from various sources in money markets, and opportunity costs in capital markets. Both MPA and CFA approaches employ only an administered policy rate or a short-term interbank rate or a compatible market rate as the proxy for the exogenous cost-of-funds rate in the bivariate models, without including other explanatory variables. Several researchers adopt both approaches (e.g., Égert et al. 2007; Sander & Kleimeier 2004). This study follows the literature, incorporating the cash rate, and recruits the BBSW as the proxies for domestic and foreign funding costs.

4.4.2 Model selection tests

4.4.2.1 Cross-sectional dependence and homogeneity tests

Breusch and Pagan's (1980) LM test is not workable to detect cross-sectional dependence for panel data with large cross sections, $N > 10$ (Pesaran 2015). The Pesaran (2004) CD test replaces this LM test for large panels, where $T \rightarrow \infty$ first and then $N \rightarrow \infty$ under the null hypothesis of cross-section independence. This test has several pronounced features: it performs well for static and dynamic models, for balanced and unbalanced panels, and even for a miniature sample with five cross sections ($N = 5$). Pesaran's (2004) test enables not only the detection of global cross-sectional dependencies, but also the satisfactory examination of local cross correlations for macro panels with long time dimension ($T \rightarrow \infty$). The most advantageous feature of this test is its ability to conquer the cross-sectional dependence in the presence of structural breaks, both single and multiple, in data without size distortions. Our dataset, which encompasses a wide range of extreme global financial distress, is highly subjected to structural breaks, signifying the presence of nonlinearity. Our panel dataset has 20 banks ($N = 20$) and large time dimensions ($T = 706$): Pesaran's (2004) CD test is a practicably appropriate method for this study because sizable distortions may occur only when applying this test for panel-data models with large N and short T.

Conduct a slope homogeneity test is necessary to select a practicable cointegration test. Since our panel has large T and small N, we adopt the Swamy LM test because Pesaran and Yamagata's (2008) test is workable for panels only if the cross sections are relatively similar in size to the time dimensions. The null hypothesis of slope homogeneity is rejected, corresponding to a large chi-square statistic, indicating the existence of slope heterogeneity.

4.4.2.2 Panel unit root and cointegration tests

This study uses the cross-section augmented Im–Pesaran–Shin (CIPS) test of Pesaran (2007), extended by Pesaran, Vanessa Smith, and Yamagata (2013). Among the second-generation panel unit root tests, the CIPS and the panel analysis of nonstationarity in idiosyncratic and common components (PANIC) procedure of Bai and Ng (2004, 2010) have most prevalently outperformed their rivals in controlling for cross-section dependence (Pesaran et al. 2013). The former has quickly monopolised the contemporary literature owing to its simplicity of implementation, whereas the latter motivates more theoretical extensions because it is the more arguable approach. The PANIC approach, however, can produce distorted estimations when sample sizes are small ($N \leq 20$), while the CIPS test performs superlatively for small sample sizes (Reese & Westerlund 2016). Because our panel has 20 cross sections, we follow the empirical literature, adopting the CIPS to test for panel unit roots in the presence of the cross-section dependence properties of the data and diagnostics.

This essay employs the Westerlund (2007) panel cointegration test with robustness for cross-sectional dependence and slope heterogeneity. This technique capably accommodates not only unit-specific short-term dynamics, unit-specific trend, and slope parameters, but also cross-section dependence. This study accounts robustly for cross-section correlations and obtain mostly significant results.

4.4.3 Model selection decision

The results of the Pesaran (2004) CD test and the LM homogeneity statistics are reported in Panels A and B, Table 4B.5 Appendix 4B. The null hypothesis of cross-section independence is significantly rejected at the 1% level for each variable on level and at first difference, firmly confirming the existence of the cross-section dependence in the panels. The significant and

large LM statistics signify no slope homogeneity. The panels are strongly cross-sectionally correlated and slope heterogeneous based on these test results.

Table 4B.6 shows the CIPS test results for all groups. This essay uses a maximum number of 8 lags to determine the optimal lag length and serial correlation order. The CIPS results ascertain the stationarity of the mortgage rate variable on level for all groups. However, the results for two funding rates are mixed. The test signifies that the foreign-funds rate and cash rate are integrated at order one, suggesting that the cross-section correlations are heterogeneous based on these funds rates. The CIPS results show that the dependent variable *ER* is $I(0)$, while the exogenous variables all become stationary at $I(1)$, so the researcher can perform the cointegration test.

I estimate the robust p-value through 800 times of bootstrapping to control for possible bias due to the presence of the cross-section dependence. The cointegration test results in Table 4B.7 indicate most significant rejection of the no cointegration null hypothesis with the foreign-fund rate estimates. However, the group-mean cointegration could not prevail among all cash rate estimates, indicating that these banks have similar speed of adjustments to the long-run equilibrium. The results suggest that, to a certain extent, bank repricing is still subject to cash rate developments.

Overall, these preliminary tests strongly suggest the selection of a dynamic heterogeneous panel-data model based on a common-factor framework. This model can concurrently address the inherent cross-section dependence and nonstationarity of the macro panel data, as well as heterogeneity and asymmetry in the transmission for this analysis.

4.4.4 Empirical AMG models

The dynamic heterogeneous panel-data models for linearity (symmetry) and nonlinearity (asymmetry) build on a common-factor AMG method (Bond & Eberhardt 2013; Castagnetti et al. 2017; Eberhardt & Bond 2009). This approach allows the capture of bank-specific disparities in mortgage pricing in the presence of observable and unobservable common components in panel data. Theoretically, cross-sectional correlations can arise from both observed and unobserved common factors, nationally and globally. Unanticipated shocks, such as the GFC, national tax cuts, or the APRA's implementation of the Basel III capital reforms on 1 Jan 2013, unavoidably influence our sampled-bank operations and trigger wide discrepancies in mortgage price-setting, due to the sampled banks' heavy reliance on foreign funds and their international operations. Extreme global shocks also induce asymmetry in mortgage price-setting in the long run, as confirmed by Apergis and Cooray (2015).

Owing to the novel advantages of the AMG estimator, it is selected from the common correlated effect mean group (CCE) estimator (Pesaran 2006) and the dynamic CCE (DCCE) estimator (Chudik & Pesaran 2015), the innovative common-factor models for macro panel data. Both the AMG and DCCE models build on the CCE approach to accommodate variable nonstationarity, parameter heterogeneity, and cross-sectional dependence, but the DCCE is highly subject to small-sample bias in a dynamic specification (Chudik & Pesaran 2015). The AMG estimator contains the inherent strengths of the CCE model, which effectively performs (a) observables and unobservables, (b) potential linearity and nonlinearity, (c) in the presence of idiosyncratic and global business cycles, (d) for panel-data models with the small cross-section dimension, and (e) nonstationary, cointegrated, or non-integrated variables (Kapetanios, Pesaran, & Yamagata 2011). The AMG method differs from the CCE estimator: it incorporates an explicit estimate for unobservables providing meaningful economic

interpretation. If coefficients on the common dynamic process statistically and homogeneously equal unity, unobservables are imposed on each group. The AMG estimator, which capturing idiosyncratic time-varying unobservables by including a time-trend term in the model-setting, enables researchers to appropriately solve the information available in the dataset either the existence of nonlinearity, structural breaks, or cross-sectional dependence.

4.4.4.1 Linear dynamic AMG

This section produces the main models with a multifactor error structure to honour space limitation. First, given the importance of time-series properties in macro panel data, the dynamic heterogeneous panel-data model for Eq. (1) is formalised as

$$y_{it} = \alpha_{oi} y_{it-1} + \beta_{1i} cash_{it} + \beta_{2i} fund_{it} + u_{it} \tag{2}$$

where y denotes the mortgage rate, *ER*, cash and fund are the cash rate, *CR*, and foreign-funds rate, *BB*, in this analysis. Two exogenous funding costs variables comprise the observable parts of our model, with their parameters β_i allowed for bank-specific disparities. This heterogeneity is the major focus of this empirical analysis. Parameter α_{0i} is the structure estimator. If this parameter is set equal to zero, the dynamic model will be transformed into a static form. The subscripts *i* (*i* = 1,…,*N*) and *t* (*t* = 1,…,*T*) indicate banks and weeks, respectively. The unobservable error term is u_{it}.

The unobservables in Eq. (2) are simulated as $u_{it} = \alpha_{1i} + \lambda'_i \boldsymbol{f}_t + \varepsilon_{it}$. The linear equation for the symmetry analysis of the nexus between mortgage rates and funds rates, controlling for the unobservables, is specified as follows:

$$y_{it} = \alpha_{oi} y_{it-1} + \beta_{1i} cash_{it} + \beta_{2i} fund_{it} + \alpha_{1i} + \lambda'_i \boldsymbol{f}_t + \varepsilon_{it} \tag{3}$$

Eq. (3) incorporates bank-specific intercepts (α_{1i}), a multiple-structure of unobserved common factors $\boldsymbol{f}_t$ with group-specific factor loadings λ'_i to capture time-variant heterogeneity and cross-sectional dependence. The assumed white noise is ε_{it}. A time-trend term can also be included in the model, but in our case this variable is insignificant. The constant markup, α_{1i}, and long-term pass-through coefficients, β_i, are expected to have positive signs because, in the long term, market rate developments are fully transmitted into bank retail rates.

4.4.4.2 Nonlinear dynamic AMG

The NAMG model for the asymmetry analysis is obtained by incorporating the decomposing procedure of the NARDL approach (Shin et al. 2014) into the AMG framework. Eberhardt and Presbitero (2015) have identically adopted this method to form their asymmetric DCCE estimator. The NARDL modelling approach is ideal for the pass-through study because it inventively divides changes in exogenous variables into partial positive and negative sums of process. This setting, which enables researchers to capture size asymmetry, differs from the ECM, which allows measurement of asymmetry in adjustment speed only. This approach has quickly become common usage in the literature on the pass-through mechanism (e.g., Apergis & Cooray 2015; Brun-Aguerre, Fuertes, & Greenwood-Nimmo 2017).

Following Eberhardt and Presbitero (2015), our nonlinear AMG equation builds on the linear AMG and NARDL approaches, with the assumption of nonstationary observed and unobserved variables. The researcher first decomposes the exogenous variables into the partial sum decomposition of either the foreign-funds rate or the cash rate as $mr_{it} = mr_{i0} + mr_{it}^{+} + mr_{it}^{-}$. The initial value mr_{i0} can be set to 0. The latter two terms are positive and negative partial sums of processes, corresponding to increases and decreases in mortgage funding costs for each

bank. These partial sum processes of funding cost rises, mr_{it}^{+}, and funding cost cuts, mr_{it}^{-} are accumulated as

$$mr_{it}^{+} = \sum_{j=1}^{t} \Delta\, mr_{ij}^{+} = \sum_{j=1}^{t} \max(\Delta mr_{ij}\,, 0), \qquad mr_{it}^{-} = \sum_{j=1}^{t} \Delta mr_{ij}^{-} = \sum_{j=1}^{t} \min(\Delta mr_{ij}\,, 0) \quad (4)$$

The dynamic AMG version of our asymmetric model is specified as

$$y_{it} = \alpha_{oi} y_{it-1} + \beta_{1i}^{+} cash_{it}^{+} + \beta_{1i}^{-} cash_{it}^{-} + \beta_{2i}^{+} fund_{it}^{+} + \beta_{2i}^{-} fund_{it}^{-} + \alpha_{1i} + \lambda'_{i} \boldsymbol{f}_{t} + \varepsilon_{it} \quad (5)$$

where β_i^{+} and β_i^{-} are the asymmetric long-run parameters and these coefficients are theoretically positive.

4.5 Estimation analysis

4.5.1 Empirical results

Tables 4.1 and 4.2 present the linear AMG results of the full and sub-sample estimates for four sampled groups: sector, major domestic, foreign subsidiary, and region or smaller domestic in successive columns. The nonlinear AMG results are reported in Tables 4.3 (full sample) and 4.4 (sub-sample). Both static and dynamic AMG models are performed for all linear and nonlinear estimates. The full-sample results, both static [1] and dynamic [2], are shown in Tables 4.1 and 4.3. This section reports only the dynamic results of the sub-sample estimates in Table 4.2 (symmetry) and Table 4.4 (asymmetry) due to space limitation, but the static results are available upon request. In each table, Panel A reports the estimated results of the mortgage–foreign funds rate nexus and Panel B shows the mortgage–cash rate nexus.

Table 4.1: Symmetric results: full sample

Variable	Sector		Major		Foreign		Region	
	[1]	[2]	[1]	[2]	[1]	[2]	[1]	[2]
A. ER–BB								
$ER(-1)$		0.458***		0.506***		0.503***		0.426***
		(0.048)		(0.069)		(0.051)		(0.064)
L_{BB}	0.668***	0.362***	0.373***	0.800***	0.266***	0.707***	0.666***	0.375***
	(0.011)	(0.026)	(0.008)	(0.004)	(0.051)	(0.026)	(0.015)	(0.037)
UC	0.994***	0.966***	1.000***	1.000***	1.000***	1.000***	0.991***	0.944***
	(0.045)	(0.051)	(0.016)	(0.017)	(0.057)	(0.056)	(0.062)	(0.076)
Constant	3.218***	4.829***	4.759***	3.743***	5.326***	4.277***	3.208***	4.759***
	(0.072)	(0.123)	(0.049)	(0.048)	(0.281)	(0.224)	(0.099)	(0.167)
I(·) $\hat{e}_{it}$	-19.099 [a]	-17.045 [a]	-6.190 [a]	-5.505 [a]	-5.881 [a]	-2.884 [a]	-14.342 [a]	-11.722 [a]
RMSE	0.124	0.125	0.056	0.048	0.075	0.072	0.141	0.146
Obs.	13,815	13,795	2,824	2,820	2,118	2,115	8,873	8,860
Banks	20	20	4	4	3	3	13	13
B. ER–CR								
$ER(-1)$		0.462***		0.508***		0.498***		0.437***
		(0.041)		(0.065)		(0.024)		(0.053)
L_{CR}	0.654***	0.332***	0.372***	0.758***	0.265***	0.701***	0.651***	0.350***
	(0.013)	(0.033)	(0.009)	(0.004)	(0.055)	(0.030)	(0.017)	(0.048)
UC	0.994***	0.956***	1.000***	1.001***	1.000***	1.000***	0.991***	0.926***
	(0.043)	(0.056)	(0.017)	(0.018)	(0.057)	(0.057)	(0.059)	(0.084)
Constant	3.527***	5.081***	4.904***	4.133***	5.429***	4.558***	3.521***	4.849***
	(0.077)	(0.148)	(0.051)	(0.048)	(0.291)	(0.241)	(0.103)	(0.196)
I(·) $\hat{e}_{it}$	-18.352[a]	-17.196 [a]	-6.190 [a]	-5.434 [a]	-6.007 [a]	-2.088 [a]	-13.348 [a]	-11.724 [a]
RMSE	0.120	0.125	0.055	0.048	0.074	0.070	0.137	0.147
Obs.	13,815	13,795	2,824	2,820	2,118	2,115	8,873	8,860
Banks	20	20	4	4	3	3	13	13

(i) Table 4.1 reports the symmetric results for the full sample T = 706 weeks estimated by the linear AMG models with the effective mortgage rates as dependent variables *ER*. The mean coefficients across banks in the static and dynamic models are reported in [1] and [2] respectively for each bank group. Standard errors are in parentheses. Superscripts *, **, and *** indicate 10%, 5%, and 1% levels of the significance. (ii) Panel A reports the results of the mortgage rate and foreign-funds rate, while panel B exhibits those of the mortgage rate and cash rate nexus. (iii) *ER*(-1) refers to the lagged-one coefficient of *ER*. L_{BB} and L_{CR} are the long-term coefficients of the foreign-funds rate and cash rate, respectively. *UC* is the common process coefficient. (iv) Diagnostics tests on residuals include: a) I(·) $\hat{e}_{it}$ reports the Pesaran (2007) CIPS test with 2 lags, null of nonstationary, and asterisks [a] and [b] denote the rejection of the null hypothesis at the 1% level of significance on level and at 1st difference; b) Root mean square error (RMSE) indicates the residual size of each model.

Regarding the goodness of fit for two full-sample estimates (Tables 4.1 and 4.3), the major and foreign produce significantly smaller root mean square errors (RMSE) than the sector and region. The RMSE of the dynamic specifications are slightly fewer than those of the static RMSE, indicating that the dynamic estimates are more workable for the major and foreign. This implies that the two groups have more market power to exert price-setting disparities. The

static models, in contrast, work sufficiently for the region with the smaller RMSE, resulting in the analogous result for the sector, signifying the homogeneity in their price-setting. Of the sub-sample estimates, the dynamic AMG yields many fewer RMSE than the static specification (see Tables 4.2 and 4.4), validating the greater efficiency of the dynamic estimator in this study. Virtually all estimates significantly pass the nonstationary residual test. The CIPS diagnostic test results strongly statistically affirm the rejection of the nonstationary residual hypothesis, indicating that the selected estimators are sufficient to eliminate spurious regressions. The coefficients on the lagged dependent variables are positive and statistically significant in all estimations, signifying a high level of model persistence. The estimated coefficients and constants have correctly positive signs. Overall, the linear and nonlinear AMG estimators, both static and dynamic, perform well.

The coefficients of the common dynamic process are positive and statistically significant at the 1% level for all full-sample estimates, regardless of whether the static or dynamic, linear or nonlinear models. The magnitudes of this coefficient for linear and nonlinear specifications consistently equal unity, indicating that the unobservables are imposed on each individual and their sizable influence on the transmission. The results still hold for the sub-sample estimates, except for the pre-crisis cash-rate estimates of the foreign group. Prior to the GFC, foreign banks may operate relatively independently so local shocks have negligible impacts on their price policies, while the national shocks strongly affect domestic banks' re-pricing. Our results suggest that, since the crisis, bank mortgage pricing has been significantly affected by unobservable national and global shocks. These findings affirm that the unanticipated shocks, which produce cross-sectional correlations in macro panel data, have substantial impact on the IRPT. Our novel findings show that the study of the IRPT employing the conventional panel-data models can produce insufficient empirical results because the cross-section dependence

and nonstationary residuals are uncovered and insufficiently treated. These findings also motivate our further assessment of pass-through determinants.

4.5.2 Symmetric pass-through analysis

The results of both static and dynamic estimates in Table 4.1 confirm the substantial effects of the foreign-funds rate and of the cash rate on mortgage price-setting for Australian banks. All slopes of the foreign-funds rate estimates are statistically significant at the 1% level and are much greater than zero, substantiating the significant relationship between bank mortgage rates and international funding costs. The significant coefficients in the cash rate estimates reaffirm the alignment of the cash rate and mortgage rate, consistent with the literature (e.g., Lim et al. 2013; Sathye 2013). Our results ascertain the existence of heterogeneous long-term pass-through, which differs from the conclusion of long-term homogeneity in the literature (e.g. Bernhofer & Van Treeck 2013; De Graeve et al. 2007; Illes et al. 2015), which use the conventional panel-data models with the assumption of the cross-sectional independence. Our finding suggests that, at the individual level, banks yield strong discrepancies in mortgage price-setting. The magnitude results show that the mortgage rates have rapidly moved toward the long-term equilibrium of 0.65–0.80 accordingly funds rate changes, which is consistent with prior studies (Lim et al. 2013; Sathye 2013). These results specify that, for the long run, a 1% change in the cash rate or international funding cost would be incompletely transferred into the mortgage rates between 0.65% and 0.80%. The region and sector groups produce similar pass-through degrees, while the major and foreign banks show slightly greater coefficients for both foreign-funds rate and cash rate estimates. Our finding of incomplete long-term pass-through, which is in line with the conventional literature, is typically theoretically explained by variations in bank market power, competition, and menu costs.

This essay further estimates separately the three sub-periods, pre-GFC, GFC, and post-GFC, for each bank group to deeply assess the crisis effect on the funding cost transmission. The results of the linear dynamic AMG estimates in successive columns of Table 4.2 still significantly reaffirm the sizable influence of the unobservables on the transmission for each group.

Table 4.2: Dynamic symmetric results: sub-samples

	Sector			Major			Foreign			Region		
Variable	PreGFC (T=261)	GFC (T=131)	PostGFC (T=314)	PreGFC (T=261)	GFC (T=131)	PostGFC (T=314)	PreGFC (T=261)	GFC (T=131)	PostGFC (T=314)	PreGFC (T=261)	GFC (T=131)	PostGFC (T=314)
A: ER–BB												
$ER(-1)$	0.462***	0.492***	0.505***	0.515***	0.510***	0.507***	0.407**	0.500***	0.506***	0.453***	0.485***	0.504***
	(0.044)	(0.0325)	(0.020)	(0.073)	(0.075)	(0.033)	(0.198)	(0.012)	(0.033)	(0.057)	(0.040)	(0.025)
L_{BB}	1.064***	0.478***	0.164**	1.077***	0.652***	0.822***	1.025***	0.763***	0.714***	1.068***	0.479***	0.196*
	(0.026)	(0.0113)	(0.072)	(0.022)	(0.011)	(0.012)	(0.022)	(0.035)	(0.006)	(0.039)	(0.013)	(0.108)
UC	1.001***	1.001***	1.000***	1.002***	1.002***	1.001***	1.001***	1.000***	1.001***	1.000***	0.999***	1.000***
	(0.095)	(0.024)	(0.063)	(0.038)	(0.025)	(0.016)	(0.212)	(0.062)	(0.031)	(0.137)	(0.029)	(0.098)
Constant	1.278***	5.037***	5.952***	1.231***	3.969***	3.692***	1.514***	3.846***	4.261***	1.238***	4.672***	5.747***
	(0.165)	(0.0801)	(0.375)	(0.155)	(0.075)	(0.048)	(0.144)	(0.244)	(0.171)	(0.247)	(0.082)	(0.552)
I(·) $\hat{e}_{it}$	-3.145^{a}	-3.848^{a}	-4.443^{a}	-3.646^{a}	-4.439^{a}	-3.903^{a}	-0.173^{b}	-2.274^{b}	-3.040^{a}	-3.551^{a}	-3.749^{a}	-4.183^{a}
RMSE	0.077	0.090	0.079	0.015	0.057	0.041	0.069	0.078	0.035	0.084	0.090	0.088
Obs.	5,200	2,620	5,652	1,040	524	1,256	780	393	942	3,380	1,703	3,756
Banks	20	20	18	4	4	4	3	3	3	13	13	12
B: ER–CR												
$ER(-1)$	0.387***	0.484***	0.508***	0.391***	0.506***	0.506***	0.467*	0.495***	0.509***	0.382***	0.481***	0.509***
	(0.043)	(0.034)	(0.021)	(0.095)	(0.061)	(0.033)	(0.283)	(0.028)	(0.042)	(0.043)	(0.041)	(0.026)
L_{CR}	0.972***	0.371***	0.164	0.984***	0.898***	0.772***	0.934***	0.877***	0.701***	0.976***	0.373***	0.228
	(0.0406)	(0.0199)	(0.140)	(0.018)	(0.012)	(0.014)	(0.062)	(0.038)	(0.008)	(0.060)	(0.025)	(0.209)
UC	0.979***	0.999***	0.996***	0.900***	1.008***	1.001***	1.028	1.000***	1.001***	0.977***	0.993***	0.995***
	(0.236)	(0.035)	(0.063)	(0.241)	(0.025)	(0.040)	(0.659)	(0.068)	(0.050)	(0.342)	(0.043)	(0.095)
Constant	2.033***	5.790***	6.963***	1.998***	3.149***	4.104***	2.256***	3.372***	4.559***	1.998***	5.771***	5.530***
	(0.246)	(0.122)	(0.778)	(0.124)	(0.074)	(0.050)	(0.419)	(0.246)	(0.176)	(0.362)	(0.148)	(1.062)
I(·) $\hat{e}_{it}$	-2.851^{a}	-3.876^{a}	-4.324^{a}	-3.974^{a}	-3.618^{a}	-5.361^{a}	-5.388^{a}	-3.582^{a}	-3.516^{a}	-2.220^{a}	-3.859^{a}	-4.085^{a}
RMSE	0.083	0.089	0.079	0.013	0.059	0.041	0.047	0.078	0.039	0.090	0.089	0.088
Obs.	5,200	2,620	5,652	1,040	524	1,256	780	393	942	3,380	1,703	3,756
Banks	20	20	18	4	4	4	3	3	3	13	13	12

(i) Table 4.2 reports the dynamic symmetric AMG results of sub-samples for each bank group in successive columns. The mean coefficients across banks in the dynamic models are reported for each bank group. Standard errors are in parentheses. Superscripts *, **, and *** indicate 10%, 5%, and 1% levels of the significance. (ii) Panel A reports the

results of the mortgage rate and foreign-funds rate, while panel B exhibits those of the mortgage rate and cash rate nexus. (iii) *ER*(-1) refers to the lagged-one coefficient of *ER*. L_{BB} and L_{CR} are the long-term coefficients of the foreign-funds rate and cash rate, respectively. *UC* is the common process coefficient. (iv) Diagnostics tests on residuals include: a) $I(\cdot)$ $\hat{e}_{it}$ reports the Pesaran (2007) CIPS test with 2 lags, null of nonstationary, and asterisks [a] and [b] denote the rejection of the null hypothesis at the 1% level of significance on level and at 1st difference; b) Root mean square error (RMSE) indicates the residual size of each model.

Most slope coefficients are statistically significant at the 1% and 5% levels for both cash rate and foreign-funds rate estimations, reaffirming the established relationships. The sub-sample estimates reveal interesting results. Before the crisis, all groups completely transmitted foreign-funds rate changes to their mortgage rates. The pre-GFC slope parameters, are greatest in size, and are significantly larger than those of the full-sample, during, and post-crisis estimates. The cash rate transmission is nearly complete, consistent with existing studies using disaggregated data (Fuertes et al. 2010; Horváth and Podpiera 2012). These results indicate that the responsiveness of mortgage rates to cash rate changes is strongest before the crisis. Our finding validates the effectiveness of the monetary transmission in normal economic conditions because the underlying assumption of parallel movements between policy rates and retail interest rates holds only when central banks strongly exert control over money market rates. The magnitudes of the foreign-funds rate coefficient are relatively greater than those of the cash rate, indicating that banks are more responsive to their international funding cost. This finding is consistent with Lim et al (2013); these authors suggest that, prior to the crisis, the cash rate was set closer to macroeconomic purposes than to banks' funding indicator.

During and after the crisis, the slopes of both foreign-funds rate and cash rate significantly decrease for all estimates, while the markups dramatically increase. The results confirm the impairment of the cash rate transmission, implying that banks appear reluctant to follow the cash rate cycle after the crisis. The much greater markups specify that Australian banks have encountered higher risk when sourcing in the world financial markets because this markup measures competition, market risk premium, and regulatory factors (De Bondt 2005). The strongest decline in both cash rate and foreign-funds rate transmission has occurred in the region group since the GFC, especially the post-crisis estimated insignificance. Their lowest coefficients are attributable to the poor results of the sector. Both major and foreign banks have

produced a decline in their cash rate transmission, but their declining pace is slight and much lower than that of the region. The comparable decline in the foreign-funds rate transmission occurs in the foreign group, but this transmission of the major banks has significantly improved since the GFC. Since the crisis, the incomplete pass-through has been found for all sampled groups. These rigid findings are analogous to those of the full-sample estimates and the literature. Thus, our findings propose solid evidence for the substantial effect of the CFC on mortgage repricing behaviour in Australia.

The presence of heterogeneity and rigidity is commonly explained by the highly-concentrated market hypothesis. In this market, banks are able to exert their market power over mortgage borrowers to a certain extent, resulting in the incomplete pass-through. The Australian finance system is highly oligopolistic, similar to the British, Czech, and Dutch markets that reveal similar patterns of incomplete IRPT mechanism. Our results are in line with De Graeve et al. (2007) and Fuertes et al. (2010), who document that the sampled banks are reluctant to adjust their mortgage rates due to market structure, adjustment and switching costs. Our sub-sample analysis affirms the transmission breaks that are highly consistent with the recent studies, locally (Lim et al. 2013; Liu et al. 2016; Sathye 2013) and worldwide (Aristei and Gallo 2014; Hristov et al. 2014). One plausible reason for this breakdown is the decline in market competition since 2007 due to a noticeable increase in market concentration with the dominance of the Big-4 (see Fig. 2.4). The impairment and rigidity in pass-through also give an earlier indication of asymmetry in the transmission.

5.5.3 Asymmetric pass-through analysis

Table 4.3 presents in consecutive columns the asymmetric results of both static and dynamic AMG estimates for each group over the full-sample period. Wald test results in both static and dynamic nonlinear estimates are consistently significant at the 1% level, confirming the

existence of long-term asymmetry. Once again, the nonlinear results strongly reaffirm the significant impact of the unobservables on the transmission.

Table 4.3: Asymmetric results: full sample

Variable	Sector		Major		Foreign		Region	
	[1]	[2]	[1]	[2]	[1]	[2]	[1]	[2]
A. ER–BB								
$ER(-1)$		0.496***		0.508***		0.499***		0.488***
		(0.032)		(0.063)		(0.022)		(0.043)
L^{+}_{BB}	0.977***	0.737***	0.994***	1.007***	0.984***	0.954***	0.890***	0.775***
	(0.018)	(0.014)	(0.005)	(0.005)	(0.010)	(0.010)	(0.025)	(0.023)
L^{-}_{BB}	0.883***	0.681***	0.906***	0.921***	0.882***	0.859***	0.808***	0.712***
	(0.020)	(0.015)	(0.004)	(0.004)	(0.018)	(0.018)	(0.027)	(0.025)
UC	1.000***	1.001***	1.000***	1.001***	1.000***	1.000***	0.999***	0.999***
	(0.042)	(0.040)	(0.015)	(0.017)	(0.045)	(0.046)	(0.050)	(0.049)
Constant	6.567***	6.642***	6.599***	6.659***	6.619***	6.679***	6.550***	6.625***
	(0.041)	(0.041)	(0.038)	(0.039)	(0.066)	(0.069)	(0.061)	(0.062)
W-stat.	394.59	98.670	1742.60	1631.55	175.92	147.72	134.84	63.490
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
I(·) $\hat{e}_{it}$	-19.145[a]	-15.601[a]	-6.190[a]	-5.617[a]	-6.032[a]	-4.079[a]	-14.332[a]	-11.109[a]
RMSE	0.149	0.144	0.055	0.047	0.071	0.067	0.176	0.172
Obs.	13,815	13,795	2,824	2,820	2,118	2,115	8,873	8,860
Banks	20	20	4	4	3	3	13	13
B. ER–CR								
$ER(-1)$		0.480***		0.488***		0.493***		0.482***
		(0.036)		(0.0256)		(0.036)		(0.053)
L^{+}_{CR}	1.191***	1.194***	1.191***	1.191***	1.191***	1.191***	1.194***	1.185***
	(0.017)	(0.017)	(0.006)	(0.006)	(0.002)	(0.002)	(0.023)	(0.024)
L^{-}_{CR}	0.846***	0.850***	0.869***	0.869***	0.828***	0.828***	0.846***	0.843***
	(0.019)	(0.019)	(0.005)	(0.005)	(0.025)	(0.025)	(0.027)	(0.028)
UC	0.998***	1.001***	1.000***	0.999***	1.000***	0.999***	0.995***	0.999***
	(0.058)	(0.050)	(0.091)	(0.055)	(0.101)	(0.096)	(0.091)	(0.082)
Constant	6.605***	6.618***	6.639***	6.639***	6.659***	6.659***	6.582***	6.601***
	(0.044)	(0.044)	(0.043)	(0.041)	(0.080)	(0.079)	(0.065)	(0.066)
W-stat.	655.82	671.92	3267.96	2918.85	232.34	232.85	315.11	321.58
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
I(·) $\hat{e}_{it}$	-18.608[a]	-15.812[a]	-6.190[a]	-5.293[a]	-6.134[a]	-2.163[b]	-13.961[a]	-11.921[a]
RMSE	0.151	0.147	0.052	0.046	0.068	0.064	0.176	0.173
Obs.	13,815	13,795	2,824	2,820	2,118	2,115	8,873	8,860
Banks	20	20	4	4	3	3	13	13

(i) Table 4.3 reports the asymmetric results for the full sample. The mean coefficients across banks in the static and dynamic models are reported in [1] and [2] respectively for each bank group. (ii) *ER*(-1) is the lagged-one coefficient of *ER*. L^{+}_{Xit} and L^{-}_{Xit} refer to asymmetric coefficients of the cost-of-fund rates corresponding to increases and decreases in *BB* or *CR*, respectively. *UC* is the common process coefficient. (iii) Standard errors are in parentheses, while *p*-values are in square brackets. Superscripts *, **, and *** indicate 10%, 5%, and 1% levels of the significance. (iv) *W*-stat. is the results of the Wald test for the equality of long-term up and down effects.

(v) Diagnostics tests on residuals include: a) $I(\cdot)$ $\hat{e}_{it}$ reports the Pesaran (2007) CIPS test with 2 lags, null of nonstationary. Asterisks [a] and [b] denote the rejection of the null hypothesis at the 1% level of significance on level and at 1st difference; b) Root mean square error (RMSE) indicates the residual size of each model.

This part focuses on analysing the asymmetric results of the observables in the long run. The positive and negative long-run coefficients associated with increases and decreases in the foreign-funds rate are all highly significant at the 1% level and have correct signs, signifying a direct relationship. The positive coefficients are all greater in size than the negative ones in all estimates, confirming the presence of long-term downward asymmetry. This finding indicates that banks pass on more funding cost hikes, but transmit fewer the cost cuts into their mortgage rates, consistent with Apergis and Cooray (2015). Our finding of positive asymmetry validates the concentration hypothesis that banks in an oligopolistic market wield a certain extent of market power in price-setting. The long-run effect in absolute value of the funding cost rises on mortgage rates is more pronounced than that of the cost cuts for all groups. The asymmetric degrees of mortgage rates in response to cash rate are substantially larger than to the foreign-funds rate. The sector, for example, has a spread of positive and negative cash-rate coefficients at 0.345%, compared with 0.094% in the foreign-funds rate. This finding supports the topical publicity and political debate that banks profit themselves from the exertion of their mortgage borrowers corresponding to cash rate cuts. Banks' home-loan rate-setting based on cash rate movements is the most closely watched in Australia, where outstanding home loans equate with 60% of GDP. Asymmetric mortgage pricing downwards affects consumer wellbeing significantly (Jansen 2013); poses a real threat to households because mortgagors pay interest charges directly from their disposable income, as these costs are not tax-deductible.

Table 4.4: Dynamic asymmetric results: sub-samples

	Sector			Major			Foreign			Region		
Variable	PreGFC	GFC	PostGFC	PreGFC	GFC	PostGFC	PreGFC	GFC	PostGFC	PreGFC	GFC	PostGFC
A: ER–BB												
$ER(-1)$	0.464***	0.502***	0.506***	0.514***	0.510***	0.507***	0.451**	0.499***	0.501***	0.449***	0.501***	0.509***
	(0.040)	(0.028)	(0.019)	(0.072)	(0.075)	(0.029)	(0.193)	(0.024)	(0.015)	(0.048)	(0.035)	(0.025)
L^{+}_{BB}	0.334***	0.995***	1.005***	0.337***	1.011***	1.127***	0.321***	1.054***	1.119***	0.336***	1.021***	0.967***
	(0.070)	(0.013)	(0.060)	(0.009)	(0.010)	(0.007)	(0.071)	(0.044)	(0.036)	(0.098)	(0.018)	(0.088)
L^{-}_{BB}	0.0008	0.860***	0.901***	-0.0017	0.843***	1.008***	0.0004	0.915***	0.980***	0.00183	0.742***	0.877***
	(0.079)	(0.007)	(0.057)	(0.023)	(0.010)	(0.005)	(0.073)	(0.038)	(0.018)	(0.107)	(0.006)	(0.086)
UC	1.002***	1.003***	1.001***	1.003***	1.002***	1.001***	1.005***	1.000***	1.000***	1.000***	1.002***	1.001***
	(0.146)	(0.021)	(0.080)	(0.030)	(0.029)	(0.006)	(0.276)	(0.056)	(0.046)	(0.210)	(0.024)	(0.122)
Constant	6.621***	6.321***	6.467***	6.641***	6.233***	6.346***	6.664***	6.214***	6.271***	6.605***	5.831***	6.616***
	(0.072)	(0.062)	(0.100)	(0.052)	(0.028)	(0.142)	(0.142)	(0.087)	(0.120)	(0.108)	(0.100)	(0.139)
W-stat.	660.50	228.04	93.010	535.44	12583.5	166.60	686.08	77.350	25.840	766.65	329.29	55.760
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$I(\cdot)$ $\hat{e}_{it}$	-3.741^{a}	-3.817^{a}	-4.171^{a}	-3.678^{a}	-4.533^{a}	-4.160^{a}	-1.876^{b}	-2.829^{a}	-3.165^{a}	-3.906^{a}	-3.416^{a}	-3.997^{a}
RMSE	0.056	0.099	0.071	0.015	0.057	0.040	0.057	0.076	0.029	0.056	0.103	0.080
B: ER–CR												
$ER(-1)$	0.387***	0.484***	0.502***	0.388***	0.473***	0.504***	0.468*	0.497***	0.502***	0.382***	0.500***	0.506***
	(0.043)	(0.032)	(0.019)	(0.099)	(0.018)	(0.024)	(0.280)	(0.039)	(0.014)	(0.043)	(0.038)	(0.027)
L^{+}_{CR}	0.972***	1.526***	-0.0025	0.984***	1.508***	-0.002	0.934***	1.637***	-0.0007	0.976***	1.496***	-0.0024
	(0.041)	(0.028)	(0.079)	(0.018)	(0.008)	(0.0462)	(0.062)	(0.075)	(0.127)	(0.059)	(0.040)	(0.105)
L^{-}_{CR}	ND	0.896***	0.352***	ND	0.895***	0.386***	ND	0.962***	0.323***	ND	0.931***	0.352***
		(0.007)	(0.027)		(0.011)	(0.019)		(0.041)	(0.021)		(0.007)	(0.040)
UC	0.979***	1.005***	1.002***	0.895***	0.991***	1.001***	1.028	1.001***	1.001***	0.977***	1.010***	1.002***
	(0.240)	(0.038)	(0.089)	(0.249)	(0.085)	(0.026)	(0.664)	(0.061)	(0.055)	(0.347)	(0.031)	(0.134)
Constant	6.623***	5.777***	8.265***	6.644***	5.842***	8.355***	6.668***	5.594***	8.226***	6.608***	5.815***	8.251***
	(0.058)	(0.061)	(0.239)	(0.044)	(0.028)	(0.201)	(0.129)	(0.104)	(0.266)	(0.087)	(0.092)	(0.334)
W-stat.	-	484.34	101.01	-	13153.1	76.83	-	144.52	46.390	-	194.93	10.370
		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.001]

I(·) $\hat{e}_{it}$	-2.871 [a]	-3.678 [a]	-3.874 [a]	-3.990 [a]	-4.151 [a]	-3.360 [a]	-5.469 [a]	-3.033 [a]	-1.773 [b]	-2.236 [a]	-3.568 [a]	-3.390 [a]
RMSE	0.083	0.099	0.073	0.013	0.056	0.040	0.047	0.078	0.030	0.090	0.104	0.083
Obs.	5,200	2,620	5,652	1,040	524	1,256	780	393	942	3,380	1,703	3,756
Banks	20	20	18	4	4	4	3	3	3	13	13	12

(i) Table 4.4 reports the estimation results of the asymmetry AMG model for each sub-period: pre-GFC 1997:1–2007:6, GFC 2007:7–2009:12, and post-GFC 2010:1–2015:12 for each bank group in successive columns. The mean coefficients across banks in the dynamic models are reported respectively for each bank group. (ii) *ER*(-1) is the lagged-one coefficient of *ER*. L^{+}_{Xit} and L^{-}_{Xit} refer to asymmetric coefficients of the cost-of-fund rates corresponding to increases and decreases in *BB* or *CR*, respectively. *UC* is the common process coefficient. (iii) Standard errors are in parentheses, while *p*-values are in square brackets. Superscripts *, **, and *** indicate 10%, 5%, and 1% levels of the significance. (iv) *W*-stat. is the results of the Wald test for the equality of long-term up and down effects. (v) Diagnostics tests on residuals include: a) I(·) $\hat{e}_{it}$ reports the Pesaran (2007) CIPS test with 2 lags, null of nonstationary. Asterisks [a] and [b] denote the rejection of the null hypothesis at the 1% level of significance on level and at 1st difference; b) Root mean square error (RMSE) indicates the residual size of each model.

This essay conducts the nonlinear AMG model for each sub-period of each group to further examine the GFC effect on bank mortgage pricing. The results in Table 4.4 once again reaffirm the significant influence of the unobservables, except that the post-crisis cash-rate estimate for the foreign group is consistent with the sub-sample symmetry finding. The observable coefficients provide auspicious results for both funds rates. Prior to the crisis, banks significantly passed on funding cost increases only. The cash rate pass-through degrees are closer to unity and much larger than the foreign-fund rate transmission, supporting the symmetry findings. The researchers find the positive response of mortgage rates to the cash rate only, because in this period the policy rate constantly increases. Since the GFC, mortgage rates have been continuously associated with foreign-funds rate developments, consistent with Cifarelli and Paladino (2016). Banks have asymmetrically priced their mortgages upwards at high levels. These coefficients are equal or closer to unity in all GFC and post-GFC estimates. Positive impacts are much greater in size than negative impacts. Variations in magnitudes exist in both positive and negative parameters, signalling downward rigidity or positive asymmetry. The results of this essay substantiate that international funding costs have had stronger impact on mortgage rates since the crisis, indicating that bank mortgage price-setting has been closer to foreign-funds rate movements. The findings empirically support the view of Berkelmans and Duong (2014), and provide empirical evidence of the increasing reliance of Australian banks on foreign funds to finance their mortgages.

Conversely, the cash rate estimates show opposite results. The positive asymmetry in mortgage rate pass-through during the crisis has been found. These positive coefficients associated with cash rate rises are greater in size than the negative parameters. These positive slopes are all much larger than unity, indicating an overshooting response. This finding is in line with Lim et al. (2013) that banks set their higher mortgage rates to compensate for higher risk incurred.

Interestingly, this study find that all bank groups no longer responded to cash rate increases in the aftermath of the crisis. The post-crisis estimates yield insignificant and negligible positive coefficients. However, these banks significantly reduce their mortgage rates corresponding to cash rate cuts. This finding is inconsistent with the finding by Apergis and Cooray (2015), who document the existence of positive asymmetry in interest rate pass-through for Australia after the GFC. Our findings again support the theory of Eberhardt and Bond (2009), Omay et al. (2017), and Pesaran (2006) that the conventional methods used in the literature can produce highly biased and spurious results due to the lack of attention to cross-sectional dependence and nonstationary residuals untreated.

4.6 Conclusions

This study examines heterogeneity and asymmetry in the transmission of foreign funds and cash rates to mortgage rates for the period 2002(7)–2015(12), using a novel weekly dataset of 20 Australian banks. The innovative common-factor AMG and NARDL models are employed to examine heterogeneity and asymmetry in controlling for the cross-sectional dependence properties of the panel data. This essay also investigates the GFC effect on the transmission in a sub-sample analysis.

This work provides the first comprehensive bank-panel analysis of the mortgage IRPT that considers cross-sectional dependence, heterogeneity, and asymmetry. Controlling for the cross-sectional dependence properties of the panel data, this study find that the unobservables have significantly sizable influence on the transmission of both foreign-funds rate and cash rate. The results of the estimated observables suggest that Australian banks asymmetrically set their mortgage interest rates in a heterogeneous manner. Heterogeneity and asymmetry in the mortgage rate pass-through are found for all panel estimates. The existence of the varied heterogeneous responses across banks indicates significant differences in mortgage price-

setting. These findings affirm the market power hypothesis. The sub-period analysis found a declining influence of the cash rate on mortgage rate traverses after the GFC although the effect of the international funding cost has been increasing. The finding validates the argument that the divergence of bank mortgage price-setting from the cash rate shifts due to foreign funding cost.

This study provides three important policy implications. First, the findings provide empirical evidence of the strong integration between mortgage rates and foreign funding cost and of the decreasing reliance on the cash rate since the crisis. This evidence is of practical use to depository regulators, APRA and RBA, in implementing non-conventional monetary policy reforms. The regulators also need to pay close attention to the volatility of world finance markets when setting their policy rates. Second, it is critical for the RBA to construct a more properly comprehensive measure of the funding costs underlying mortgage interest rates. The focus of the *BB* measure in this analysis exemplifies only the foreign-funds rate. Further examination would require a more comprehensive measure of overall bank funding costs by constructing a weighted average cost of debt because bank liabilities are obtained from varied sources. Third, solid evidence that long-run positive asymmetry exists among the all sampled banks signals a series of consumer protection solutions that need to be put into effect.

Chapter 5: Asymmetric determinants of the mortgage interest-rate pass-through: A panel nonlinear common-factor analysis

This chapter includes a co-authored paper. The bibliographic details (if published or accepted for publication)/status (if prepared or submitted for publication) of the co-authored paper, including all authors, are:

Holland, Q.C.P., Liu, B., Roca, E. (2018). Asymmetric determinants of mortgage interest rate pass-through: A panel nonlinear common-factor analysis. Submitting to *Journal of Monetary Economics*.

My contribution to the paper involved:

"Generating the research ideas by reviewing and synthesising the existing empirical studies; identifying and developing the theoretical framework, research methods and relevant data; Collecting, calculating and organising the dataset into a usable format; STATA programming and analysis of the results; interpretation and discussion of the results; and the write up of the complete paper; the full revision of the paper"

_____ 30 November 2018

Name of student: Quynh Chau Pham

(Countersigned) _____ 30 November 2018

Corresponding author of paper: Quynh Chau Pham Holland

(Countersigned) ____ [redacted] _____07 December 2018

Supervisor: Benjamin Liu

(Countersigned) 07 December 2018

Supervisor: Eduardo Roca

Pages redacted

Chapter 6: Conclusion

6.1 Introduction

This chapter, which concludes this thesis on bank international funding cost and mortgage interest rate transmission for Australia, is organised as follows:

- Section 6.2 summarises the three empirical chapters of the thesis: the motivations, research questions and main findings.
- Section 6.3 highlights the research contributions and discusses the practical implications of the thesis findings; and
- Section 6.4 conveys several limitations of the thesis and signifies key suggestions for future work.

6.2 Summary of the empirical essays

The objective of this thesis is to investigate the relationship between international funding cost and mortgage interest rate transmission for Australia. In particular, this thesis encompasses three empirical chapters built on four empirical studies: 1) The international funding cost and bank mortgage rate linkage of individual banks and the nature of this relationship, 2) The asymmetric pass-through at the panel bank level and the effect of the GFC on this transmission, 3) Heterogeneity in the pass-through mechanisms considering complex cross-sectional dependencies and unobserved common factors, and 4) The asymmetric determinants of the mortgage IRPT. Essay 1 is placed in Chapter 3 of the thesis. The second and third studies are incorporated in Chapter 4 as 4A and 4B. The fourth study constitutes Chapter 5. From these interrelated studies, this thesis concludes that (i) international funding cost is a driving force of the mortgage rate transmission in Australia; (ii) macroeconomics conditions have played an increasing role in affecting this

pass-through mechanism, attributed to the long-term transmission breakdown from the GFC.

6.2.1 Essay 1: International funding cost and mortgage rate pass-through

The first empirical analysis of the relationship between the international funding cost and the variable home-loan rate is provided in Chapter 3. This chapter examines in parallel the long-term asymmetry in the mortgage IRPT relating to cash rate shocks. The investigation of these issues is of the utmost importance to Australia because of the predominance of home loans and the prevalence of variable-rate home loans for owner-occupiers, the heavy reliance of banks on foreign funds to finance housing loans, the oligopoly of the Australian banking and housing finance sectors, a paucity of the literature on long-term asymmetry in the policy rate transmission, and a few studies using bank-level data. Hence, this essay sheds light on the ongoing debate on whether international funding cost affects bank mortgage rate-setting behaviour in Australia. This essay further contributes to the existing literature that provides convincing evidence for the presence of the long-term asymmetry in the cash rate transmission to mortgage rates. The key findings of this study are summarised in Table 6.1.

Table 6.1 Summary of key findings in Essay 1

Key research questions	Main hypotheses	Key findings
Does the international funding cost play a significant role in the mortgage rate transmission at an individual level in the presence of the cash rate?	**H1a**: a cointegrating relationship exists, $\rho = \delta^{+} = \delta^{-} = 0$ **H1b**: There is negative speed of adjustments H_0^{1b}: $\rho < 0$ vs H_A^{1b} $\rho > 0$.	Yes. International funding cost and the mortgage rate are correlated in the long run, indicating that banks in Australia adjust their mortgage rates corresponding to their international funding cost changes.
What is the nature of this relationship: symmetry or asymmetry?	Based on **H2a**, **2b**, **3a**, and **3b.**	Asymmetry. In the long term, banks asymmetrically and greatly respond to changes in the foreign funds rate upwards, but reduce their rates at a lower rate.

	H2a: the presence of an instant symmetry, H_0^{2a}: $\pi_{i0}^{+} = \pi_{i0}^{-}$	Symmetry but incompleteness. Banks respond instantly to a rise in their foreign funding cost only. Significantly wide discrepancies in the short-term pass-through.
	H2b: the presence of cumulative short-run symmetry H_0^{2b}: $\sum_{j=0}^{q-1}\pi_j^{+} = \sum_{j=0}^{q-1}\pi_j^{-}$	Yes. Asymmetry upwards presents in the four major banks only, signifying that they have to encounter higher competitive in the wholesale funding than in the retail funding markets.
	H3a: Complete long-run pass-through H_0^{3a+}: $\beta_i^{+} = -\delta_i^{+}/\rho_i \geq 1$ vs H_A^{3a+}: $\beta_i^{+} < 1$ for funds rate rises;	Yes. Mortgage rates increase greater than unity in response to positive changes.
	Likewise, H_0^{3a-}: $\beta_i^{-} = -\delta_i^{-}/\rho_i \geq 1$ vs H_A^{3a-}: $\beta_i^{-} < 1$ for funds rate cuts.	No. Mortgage rates reduce less than unity in response to negative changes.
	H3b: Long-run symmetryH_0^{3b}: $\beta^{+} = \beta^{-}$ vs H_A^{3b}: $\beta^{+} \neq \beta^{-}$	Asymmetry downwards. The long-term transmission of the international funding cost is asymmetric, specifying that to mortgage rates in Australia asymmetrically react to changes in wholesale markets.
Does any asymmetry exist in the long-term pass-through of mortgage rates in response to changes in both the cash rate and the international funding cost?	Based on **H3a**, and **3b**.	Yes. Positive asymmetry occurs in the transmission of both the international funding cost and the cash rate. The presence of asymmetry downwards specifies that mortgage rates reduce at a greater rate than they increase, which is beneficial to banks.

6.2.2 Essay 2: Mortgage pricing conduct and GFC impact

6.2.2.1 Essay 2A: Asymmetry in mortgage price-setting

Chapter 4A investigated crisis effects on the Australian mortgage IRPT in a panel-data study, taking into account both the bank-specific and time effects. In particular, this study examines to a certain extent how the GFC affected the transmission of both the

international funding cost and the cash rate to mortgage rates. The key motivational narratives of this examination are: (i) the utmost importance of the housing credit market, locally and internationally, given the collapse of the world mortgage markets associated with a mortgage credit boom and the heavily reliance on wholesale funding, (ii) the increased divergence of mortgage rates from the cash rate cycle since the crisis, (iii) the recently unusual mortgage pricing conduct of banks, (iv) increased public and political concerns about banks' exertion over their mortgage borrowers and an ongoing debate towards banking and financial soundness and the development of sustainable housing and housing finance systems after the GFC, (v) few studies investigating crisis effects on the mortgage IRPT and their inconclusive findings, and a lack of panel-data studies. This essay sheds light on these important issues: whether the divergent of mortgage rates from the cash rate has increasingly occurred since the crisis due to the existence of international funding cost, and whether banks' mortgage price-setting behaviour has changed since the GFC. Table 6.2 summarises the main results of this study.

Table 6.2 Summary of key findings in Essay 2A

Key research questions	Main hypotheses	Key findings
Are there both short-term and long-term asymmetries in the pass-through of the cash rate and the international funding cost into the mortgage rate in Australia, considering both bank-specific and time-dimension effects?	Australian banks reduce their mortgage rates more sluggishly in response to cash rate and foreign-funds rate reductions, while increasing their rates more speedily to these funds rates increases.	Yes. In the long term, both increases and decreases in the foreign-funds rate and the cash rate exercise significant and considerable impact on mortgage rates in all sampled groups. The magnitude is much greater for positive than for negative, resulting in positive asymmetry for all groups.
	Specifically:	
	H1a: There is a zero-asymmetric impact IRPT: $\pi_{i0}^{+} = 0$ for funds rate rises; likewise, $\pi_{i0}^{-} = 0$ for funds rate cuts.	Yes. All groups immediately respond to foreign-funds rate and to the cash rate changes, but wide discrepancy and incompleteness exist. Short-term asymmetry in the foreign-funds rate transmission exists for the major group only.

	H1b: There is complete asymmetric long-run IRPT $\beta_i^+ = -\delta_i^+/\rho_i \geq 1$ for funds rate rises; likewise, $\beta_i^- = -\delta_i^-/\rho_i \geq 1$ for funds rate cuts.	Yes. Positive asymmetry or asymmetry downwards present in the transmission of both the foreign-funds rate and the cash rate.
	H1c: There is negative speed of adjustments: ρ_i < 0 vs ρ_i > 0.	Yes. The adjustment speeds are all significant and negative, validating the long-run associations between mortgage rates and funding costs, both foreign and domestic.
Does the cash rate still drive the mortgage rate in the presence of the international funding cost after the GFC?	Pass-through speed and degrees after the GFC from foreign-funds rate to mortgage rates are expected to be greater than those before and during the GFC.	Yes. The cash rate still affects mortgage rates in the long run, but its effect has significantly weakened since the crisis based.
	H2a: Asymmetric impact IRPT for foreign-funds rate changes exists; $\pi_{itPost_{GFC}}^{\mp} > \pi_{itPre\ \&\ during_{GFC}}^{\mp}$ likewise,	Yes. Virtually all the short-term parameters of the mortgage rate–foreign-funds rate nexus are significantly asymmetric in the post-GFC period. Since the GFC, these mortgage lenders have been more responsive to immediate changes in the foreign-funds rate than to cash rate shocks
	Asymmetric impact PT for cash rate changes exists. $\pi_{itPost_{GFC}}^{\mp} < \pi_{itPre\ \&\ during_{GFC}}^{\mp}$	Yes. There is a significant drop in the size of the post-crisis instant response.
	H2b: Asymmetric long-run IRPT for foreign-funds rate changes: $\beta_{iPost_{GFC}}^{\mp} > \beta_{iPre\ \&\ during_{GFC}}^{\mp}$ likewise,	Yes. All sampled banks asymmetrically adjusted their home-loan rates downwards during and after the GFC
	Asymmetric long-run IRPT for cash rate changes: $\beta_{iPost_{GFC}}^{\mp} < \beta_{iPre\ \&\ during_{GFC}}^{\mp}$	Yes. The post-crisis magnitudes reduce.
	H2c: Comparing speed of adjustments for the foreign-funds rate: $\rho_{iPost_{GFC}} >$	Yes. Banks have been quicker in adjusting their mortgage rates to the foreign-funds rate shocks

	$\rho_{iPre\ and\ during_{GFC}}$; likewise,	than to cash rate changes since the crisis.
	Comparing speed of adjustments for the cash rate: $\rho_{iPost_{GFC}} > \rho_{iPre\ and\ during_{GFC}}$	No. The adjustment speed of the cash rate transmission has significantly dropped in the aftermath of the crisis.
Has Australian bank mortgage pricing behaviour changed since the crisis?	Based on **H2a**, **2b**, and **2c**.	No. Bank mortgage pricing behaviour in Australia has remained downward asymmetric, but it has switched from the cash-rate-based model to the foreign-funding-based model.

6.2.2.2 Essay 2B: Mortgage IRPT: Homogeneity or heterogeneity

Chapter 4B investigated the heterogeneity in the long-term pass-through of mortgage rates regarding both the international funding cost and the cash rate. Specifically, this study has systematically analysed both the symmetric and asymmetric transmission mechanisms controlling for unobservables and cross-sectional dependence theoretically inherent in the macro panel data. The findings of the existing literature on heterogeneity in the IRPT have hitherto documented the homogeneous long-term traverses. This issue arises from using conventional models with the assumption of cross-sectional independence. Ignoring the presence of cross-sectional dependence and totally disregarding unobservable effects in the setting of retail interest rates can seriously produce spurious estimated results because of sizable distortions, and thus, their inferences can highly misrepresent the results. Given the crucial role of the IRPT for monetary transmission, this study is of the greatest interest. This study sheds light on whether the mortgage IRPT mechanisms have been affected by unobserved common factors and cross-sectional dependence potentials. Table 6.3 presents the summary of the major findings for this essay.

Table 6.3 Summary of key findings in Essay 2B

Key research questions	Main hypotheses	Key findings
Do unobservables affect the interest rate transmission, both symmetry and asymmetry, when considering both bank-specific and time effect?	It is expected that unobservables affect the long-run traverses of mortgage rates, both symmetric and asymmetric.	Yes. Unobserved common factors significantly influence mortgage rate pass-through mechanisms, both symmetric and asymmetric in the long run.
Is the nature of the long-term interest rate transmission, both symmetry and asymmetry, accurately homogeneous?	The mortgage rate pass-through is anticipated to be homogeneous in the long run.	No. Heterogeneity in the long-run pass-through occurs in both symmetric and asymmetric mechanisms.
Does the international funding cost still affect the mortgage rate when controlling for cross-sectional dependence?	Banks adjust their mortgage rates towards changes in wholesale funding markets.	Yes. The significant results of the international funding cost–mortgage rate nexus still hold and have been significantly robust when controlling for unobservables and cross-sectional dependence, while mortgage rates only respond to the cash cuts after the GFC.

6.2.3 Essay 3: Asymmetric determinants of mortgage interest-rate pass-through

Chapter 5 studied potential roles of macroeconomic-financial and risk premium factors in influencing the monetary policy transmission to bank variable home-loan rates, considering the GFC impact. The key motivation of this essay is the impairment of the long-term transmission of the cash rate documented by the Australian literature (Holland et al., 2018; Liu et al., 2016; Sathye, 2013). The mortgage rate channel is always an integral part of the monetary transmission mechanism for Australia owing to its market dominance. The effectiveness of the transmission mechanism is of vital importance to the RBA and APRA as well in transferring the monetary policy decisions to the economy. Therefore, investigating what factors cause the long-term policy transmission breakdown is practically important. This essay contributes not only to the literature on determinants of the asymmetric IRPT, but also to a rudimentary line of research on the integration between monetary transmission and financial stability. The findings of this study are summarised in Table 6.4.

Table 6.4 Summary of key findings in Essay 3

Key research questions	Main hypotheses	Key findings
Do unobservables affect the asymmetric interest rate transmission, when considering both bank-specific and time effects?	It is expected that unobservables affect the long-run symmetric traverses of mortgage rates.	Yes. Unobserved common factors significantly influence long-term asymmetric pass-through of mortgage rates, both the full sample and sub-sample periods.
Do the macroeconomic conditions and risk premia play significant role in affecting the long-term pass-through of mortgage interest rates?	The mortgage rates are anticipated to significantly respond to changes in macroeconomic conditions and risk premia in the long run.	Yes. Asymmetric influences of the studied macroeconomic variables on the long-run pass-through mechanism have been established in the full sample period, except for the unemployment and risk premium factors.
Are these factors attributed to the worsening of the long-term cash rate	Bank mortgage rates are asymmetrically and significantly adjusted towards	Yes. The significant results of the increasingly instrumental roles of the studied macroeconomic variables in replacing the role of the cash rate in

transmission since the GFC?	changes in macroeconomic conditions rather than to cash rate shocks since the GFC.	the mortgage rate pass-through since the 2008-crisis.

6.3 Summary of the major contributions

The research contributes substantially to the contemporary literature from different perspectives. The first empirical essay provides two valuable contributions to the IRPT literature. First, this is the leading empirical analysis to show that the international funding cost is material to bank mortgage rate adjustments in Australia. This essay presents in particular that, in the long run, mortgage rates asymmetrically react to international funding cost shocks, increasing at a greater degree than decreasing, but their dispersion occurs in the short run. Second, this study for the first time offers convincing evidence for the asymmetries in the long-run pass-through of mortgage rates in response to cash rate changes. This essay brings into synchronicity the transmission of the international funding cost and the cash rate to mortgage rates.

The second empirical essay, combining two studies, advances the literature on heterogeneity and asymmetry in the IRPT mechanisms. Specifically, the first study of this essay offers two key points of interest. This is the first panel analysis of the asymmetric pass-through mechanisms of mortgage rates relating to both the international funding cost and the cash rate, considering the effect of both bank-specific and time-variances. This study demonstrates new insights into bank asymmetric mortgage pricing behaviour in Australia that have been omitted in the literature using time-series data. Importantly, this essay contributes to the literature by empirically and explicitly investigating crisis effects on these asymmetric mortgage traverses. The second study of this essay augments significantly two mainstream strands of the IRPT literature, both heterogeneity and

asymmetry in three distinctive aspects. First of all, the existing literature on heterogeneity in the IRPT has continuously overlooked one crucial fact of cross-sectional dependence properties of the panel data in the setting of retail rate adjustments. Given such a serious omission, this study addresses this arguable intuition by systematically testing and controlling for the presence of cross-section dependence, providing imperative insights for monetary policy. Second, this study for the first time explores the effect of unobservables on the IRPT, both symmetric and asymmetric. Third, this study is the first to show heterogeneity in the asymmetric transmission and thus contributes to the literature on asymmetry in the IRPT. The findings of this study therefore make valuable contributions to monetary transmission literature.

The last empirical essay enhances the third strand of the literature on determinants of the IRPT mechanism in two key aspects. First, this essay is the first empirical analysis investigating the determinants of asymmetric pass-through mechanism of mortgage rates which exposes the size asymmetry in each determinant. Second, this examination is the first of the determinant strand considering the two important issues in panel-data models.

6.4 Practical implications

The findings of this research have implications for institutions, such as legislators, borrowers, banks, and researchers. The robustly significant evidence of the cointegrating relationship between the foreign funding cost and the mortgage rate is of critical importance to banking regulatory and supervisory frameworks regarding monetary policy and financial stability. First and foremost, the outlook for economic growth and inflation can be shaped by the volatility of bank funding costs because of the increased integration of Australian mortgage financing with world financial markets. Given the protracted GFC and ensuing collapse of the Spanish and Greek mortgage markets, the housing credit

market in Australia with similarities to those markets, is in danger of house-price and mortgage bubble bursts; therefore, raises a major threat to the economy as well as the world financial markets. Such a relationship thus is a matter of significant concern to the RBA and the APRA in their policy decision-making. The research findings have strong relevance for not only regulators, but also banks, for their management schemes and strategies of hedging against wholesale-funding risk.

The convincing evidence of positive long-term asymmetry in the transmission of the international funding cost to mortgage rates, and increasingly influential roles of macroeconomic conditions in the mortgage rate pass-through armours policymakers with several key recommendations on financial soundness, market stability and customer protection. First, the ACCC should pursue implementation of a tougher series of consumer protection solutions. Therefore, this research is directly beneficial to home-loan borrowers. Second, for strengthening of the financial soundness and market stability, this research suggests a stringent supervisory and regulatory framework for bank price-setting that the APRA and RBA should be tasked with implementing. This practice not only matters to enhancing the soundness of banking and housing finance from a macro-policy perspective, but as a long-term measure will help to preclude banks from potential credit losses that would be associated with a rising funding cost environment and macroeconomic uncertainty (Beau et al., 2014). This research therefore empirically supports the Ellis and Littrell (2017) view of financial stability policies in a low interest-rate environment.

The solid evidence of the transformation in bank mortgage funding models, from the cash-rate-based to the foreign-funds-rate-based after the GFC mandates strong and urgent monetary policy reforms. First, more policy and academic attention should be put towards the policy transmission to deposit rates because the policy rate has had stronger impact

on deposits since the crisis in the US, as documented by Gerlach et al. (2018). This deposit rate channel now is a matter of paramount importance to monetary policy in transmitting effectively policy rate stances to the market rates and thus to the economy, instead of the transmission break in the mortgage rate channel. Second, this study suggests a comprehensive funding indicator that the RBA should be required to construct for a supplement to the cash rate. Third, this study thus directs researchers to explore this domain in other countries and Australia commodity markets.

The findings of heterogeneity in long-term pass-through of mortgage rates, both symmetric and asymmetric, are of paramount importance to both economic and academic considerations. This research provides valuable insights for monetary policy, given substantial dispersion in bank mortgage pricing behaviour arising from the GFC. From an academic perspective, this research offers several important implications. First, the empirical evidence of long-term asymmetry augments the incomplete long-term pass-through findings that have been broadly documented in the previous studies, which is consistent with the recommendation by Kwapil and Scharler (2010). Researchers should consider the possibilities for asymmetry in long-term pass-through in their model-setting. Second, the conventional econometric techniques used in the IRPT literature are significantly documented to be insufficient for the setting of retail interest rates. This research thus calls for an innovative configuration in modelling interest rate pass-through.

6.5 Limitations and suggestions for future research

Several limitations of this thesis may offer directions for future research. First of all, this research emphasises the role of the international funding cost in mortgage rate transmission by employing the BBSW as the proxy for bank foreign-funds costs. Second, this research focuses interest on exploring the long-run asymmetry in the policy rate transmission to mortgage rates by using the cash rate as the marginal cost of domestic

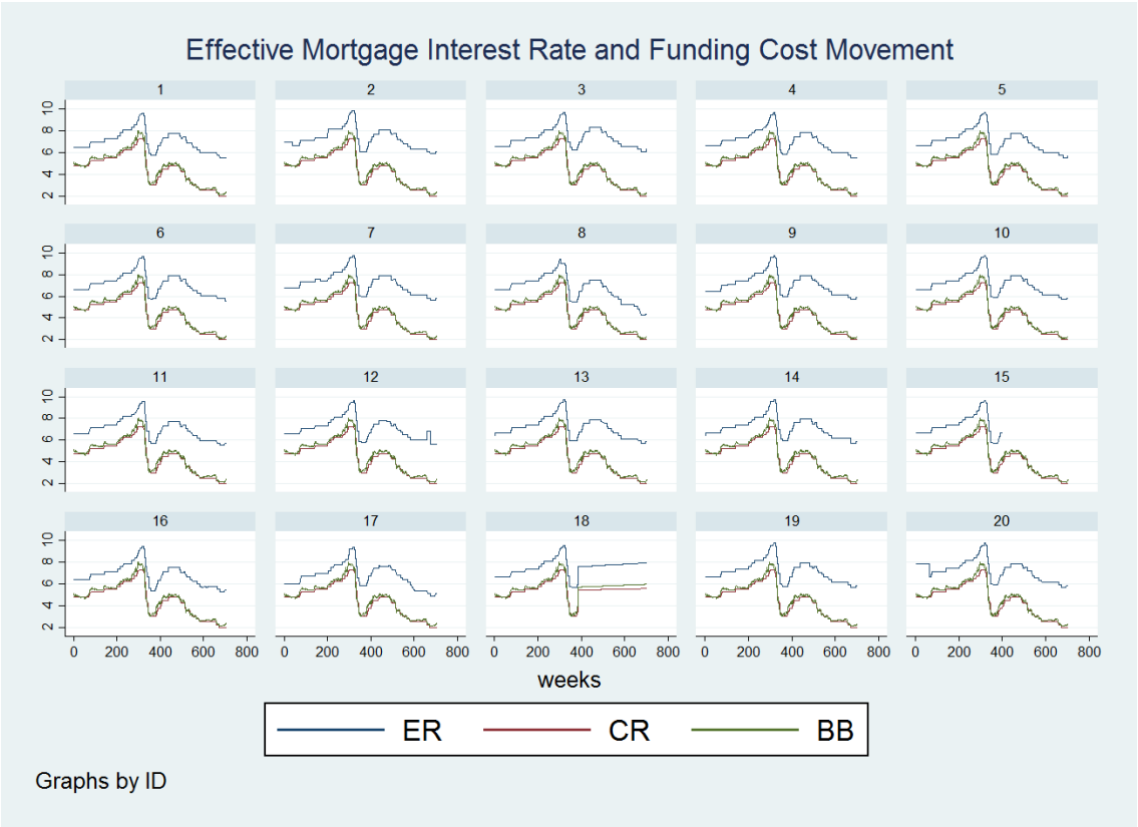
funds. Banks' mortgage funding is however sourced from a variety of liabilities. Therefore, it is necessary to construct a more comprehensive indicator of bank funding costs for approximating the marginal mortgage funding cost used in the IRPT study. Third, this research emphasises the roles of macroeconomic conditions and risk premium in affecting bank mortgage rate-setting. Nonetheless, this pricing conduct can be affected by other factors, such as market power, competition and bank efficiency that should be considered. Confidential bank dataset inaccessibility or unavailability in high-monthly frequency prevents researchers to examine this aspect.

Future directions related to the research limitations are proposed as follows. First, a potential project may involve constructing a comprehensive, accurate measurement of bank mortgage funding costs. This is a matter of current concerns to the RBA and banks as well. Second, an examination of the extent to which banks transfer the cash rate developments to their deposit interest rates is significantly important for the Australian context (see Gerlach et al., 2018). Such a study is very enlightening for monetary policy. Third, a study of heterogeneity in lending rates with borrower characteristics (e.g., Kitamura, Muto, & Takei, 2016), or bank efficiency (see Havranek et al., 2016) may provide new IRPT insights to the real economy.

This research also offers other useful suggestions. The innovative estimation procedure of the research can be applied to either a single- or cross-country analysis of heterogeneity in lending rates using panel data. Research on stock markets, housing price and commodity pricing also can apply this research framework for their panel-designs.

Appendix

Appendix to Chapter 4



Appendix 4I: Plot of the variables

Notes: ER denotes "the effective mortgage interest rate" for each bank. *CR* and *BB* are "the cash rate" and "the 3-month bank bill swap rate" as two funding cost proxies, domestically and internationally.

Appendix 4II: Summary Statistics for Panels/Groups

The mean statistic reveals that the region group is clearly the most competitive in setting effective mortgage rates within Sector, Major, and Foreign groups over time. Foreign has the most expensive charges, except in the pre-crisis period; their rates are higher than those of Sector, and Major. The major lenders set their mortgage rates slightly higher than Sector's. However, the region raises funds at the most expensive rates, both domestic and international. The Bartlett's test is predominantly used to test for equality of more than two means simultaneously, while other tests compare two means only. The aim is to ascertain whether there is a statistically significant difference in the mean values of each of the variables across the three mentioned sub-samples. The Bartlett test results, which are statistically significant at the 1% level, confirm the mean differences among variables within these sub-periods.

Variable	Mean				Std. Dev				Mean equality test (χ^2)
	Full	Pre-GFC	GFC	Post-GFC	Full	Pre-GFC	GFC	Post-GFC	
A: Sector									
BB	4.687	5.531	5.572	3.616	1.502	0.521	1.896	1.132	6.0e+03***
CR	4.450	5.362	5.289	3.454	1.432	0.489	1.750	1.079	5.8e+03***
ER	7.117	7.224	7.713	6.762	0.965	0.517	1.446	0.842	4.0e+03***
Obs.	14,120	5,220	2,620	6,280	14,120	5,220	2,620	6,280	
B: Foreign									
BB	4.634	5.531	5.567	3.499	1.510	0.521	1.899	1.037	914.771***
CR	4.451	5.362	5.285	3.346	1.442	0.489	1.754	0.998	885.369***
ER	7.210	7.217	7.828	6.947	0.914	0.505	1.391	0.796	587.245***
Obs.	2,118	783	393	942	2,118	783	393	942	
C: Major									
BB	4.634	5.531	5.567	3.499	1.510	0.521	1.899	1.037	1.2e+03***
CR	4.451	5.362	5.285	3.346	1.442	0.489	1.754	0.997	1.2e+03***
ER	7.109	7.273	7.732	6.713	0.955	0.486	1.458	0.792	925.377***
Obs.	2,824	1,044	524	1,256	2,824	1,044	524	1,256	
D: Region									
BB	4.715	5.531	5.574	3.679	1.497	0.521	1.895	1.175	3.9e+03***
CR	4.526	5.362	5.292	3.512	1.427	0.489	1.749	1.117	3.8e+03***
ER	7.098	7.211	7.681	6.733	0.978	0.529	1.454	0.864	2.5e+03***
Obs.	9,178	3,393	1,703	4,082	9,178	3,393	1,703	4,082	

Notes: BB and *CR* denote the cash rate and international funding cost. The effective mortgage rate variable is ER for each group. The mean equality, which is chi-square (χ^2) distributed, is employed to compare the means for pre-GFC, GFC and post-GFC periods.

Appendix to Chapter 4A

Chapter 4A: Mortgage asymmetric pricing, cash cate and international funding cost: Australian evidence [17]

This chapter includes a co-authored paper. The bibliographic details of the co-authored paper, including all authors, are:

Holland, Q.C.P., Liu, B., Roca, E., Salisu, A.A. (2018). Mortgage asymmetric pricing, cash rate and international funding cost: Australian evidence. Conditionally accepted: *International Review of Economics and Finance*.

My contribution to the paper involved:

"Generation of the research idea through extensive literature review; development of the theoretical framework and hypotheses; identification of the research models and relevant data; the data mining into a usable format; STATA programming and analysis of the results; interpretation and discussion of the results; and the write up of the completed original manuscript submitted to International Review of Finance and Economics (IRFE) in March 2017. For the first and second revised manuscripts resubmitted in Nov 2017 and April 2018, my tasks are: revising literature, hypotheses and methodology; the preliminary analysis and categorisation of the data into a usable format and providing direction on the scope and structure of the analysis to the co-author for coding and testing; analysis of the results; interpretation and discussion of the results; and the write up of the two revised manuscripts corresponding to reviewers' comments"

[17] I greatly appreciate the constructive feedback that Prof. Carl Chen, the journal editor, and the two anonymous referees of International Review of Economics and Finance have provided. It has enabled the authors to make significant improvements to this paper. I am also grateful for the helpful comments made by the participants at the Financial Planning and Investment Symposium, November 2014 at Flinders University; the Personal Finance and Investment Symposium (PFIS), November 2015 at Griffith University; the Australasian Housing Researchers Conference (AHRC), February 2015 at University of Tasmania; the Accounting and Finance Association for Australia and New Zealand Doctoral Symposium (AFAANZ), 29June–1July 2016, Gold Coast; the Asia-Pacific Network for Housing Research, December 2016 at Sun Yat-sen University, Guangzhou; and particularly the Griffith seminar participants at the PhD Brown Bag on Corporate Governance and Financial Markets on 2 December 2015; and the PhD Student Symposium on 25 February 2016. I thank Robert Faff and Henk Berkman, my reviewers of the 2016 AFAANZ for their valuable comments.

_____ 01 June 2018
Name of student: Quynh Chau Pham

(Countersigned) _____ 01 June 2018
Corresponding author of paper: Quynh Chau Pham Holland

(Countersigned) _ [redacted]_____07 December 2018
Supervisor: Benjamin Liu

(Countersigned) 07 December 2018
Supervisor: Eduardo Roca

Abstract

This study investigates asymmetry in the interest-rate pass-through at the bank level in Australia over the period 2002:7–2015:12 in a distinctive manner. First, we examine the transmission of the foreign-funds rate, in parallel with the cash rate, to bank mortgage rates. Second, we utilize the nonlinear autoregressive distributed lag (NARDL) framework of Shin et al. (2014) in panel form to capture both the time-variation and cross-section variation within bank groups. Third, we simultaneously explore heterogeneous asymmetry in the pass-through for funding cost increases and decreases on impact, in the short term and in the long term. Our results reaffirm the asymmetric relationship between the cash rate and mortgage rates. We validate that international funding costs do indeed asymmetrically drive mortgage rates. The heterogeneous asymmetry in interest-rate pass-through found in both full- and sub-sample analyses signifies that market pricing power exists in which the major banks are the most powerful in mortgage pricing, while the smaller lenders are price-takers. These findings provide important implications for policy makers, investors, and the public.

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charged over funding costs. Our finding suggests important reforms are needed in the RBA monetary policy.

Appendix to Chapter 4B

Appendix 4B: Model selection test results

Table 4B.5: Tests for cross-sectional dependence and heterogeneity of the data

Variable	Full (T = 706)	Pre-GFC (T = 261)	GFC (T = 131)	Post-GFC (T = 314)
A. CD statistics (Pesaran 2004) H_0: cross-section independence CD ~ N(0,1)				
Sector				
ER	333.56***	205.52***	156.30***	183.46***
BB	337.68***	222.69***	157.47***	184.75***
CR	338.98***	222.69***	157.34***	184.86***
ΔER	129.86***	75.50***	58.98***	74.32***
ΔBB	344.97***	222.26***	154.00***	194.06***
ΔCR	343.85***	222.26***	152.94***	193.68***
Major				
ER	64.77***	39.49***	27.92***	43.20***
BB	65.08***	39.57***	28.04***	43.41***
CR	65.08***	39.57***	28.04***	43.41***
ΔER	29.50***	23.08***	12.31***	19.15***
ΔBB	65.04***	39.50***	28.04***	43.41***
ΔCR	65.04***	39.50***	28.04***	43.41***
Foreign				
ER	45.01***	26.93***	19.68***	30.57***
BB	46.02***	27.98***	19.82***	30.69***
CR	46.02***	27.98***	19.82***	30.69***
ΔER	25.86***	11.13***	12.73***	15.81***
ΔBB	26.57***	27.93***	19.82***	30.69***
ΔCR	26.57***	27.93***	19.82***	30.69***
Region				
ER	204.80***	126.94***	100.11***	96.96***
BB	207.09***	142.68***	100.79***	97.78***
CR	208.32***	142.68***	100.66***	97.78***
ΔER	193.63***	45.96***	44.14***	48.91***
ΔBB	195.64***	142.41***	97.37***	119.05***
ΔCR	197.01***	142.41***	96.33***	118.64***
B. Homogeneity Breusch-Pagan LM test results				
b1. ER–BB				
Sector	6753.211***	2882.095***	3211.747***	6798.176***
Major	555.936***	615.779***	249.414***	318.195***
Foreign	592.717***	250.957***	111.066***	194.317***
Region	1407.434***	3388.397***	1572.373***	2923.141***
b2. ER–CR				
Sector	4294.014***	2150.732***	2312.629***	3728.225***
Major	373.413***	444.324***	204.633***	132.470***
Foreign	253.807***	343.830***	11.745***	83.079***

Region	773.349***	3291.722***	719.948***	1929.393***

(i) The LM test performs well with small *N*, large *T* panel data models. (ii) *** Significance at the 1% level. (iii) Δ is the first different operator.

Table 4B.6: Pesaran (2007) panel unit root test — CIPS

	Mortgage rate (ER_{it})				The cost-of-funds rates							
					Foreign-funds rate (BB_{it})				Cash rate (CR_{it})			
	Full	Pre-GFC	GFC	Post-GFC	Full	Pre-GFC	GFC	Post-GFC	Full	Pre-GFC	GFC	Post-GFC
Sector (N = 20)												
W/O Trend	-3.590^{***a}	-4.322 ^{***a}	-4.988^{***a}	-5.135^{***a}	-6.190^{***b}	-6.190^{***a}	-3.562^{***a}	-6.128^{***b}	-6.190^{***b}	-6.190^{***a}	-4.144^{***b}	-6.190^{***b}
W/Trend	-4.442^{***a}	-4.042^{***a}	-5.500^{***a}	-5.634^{***a}	-6.420^{***b}	-6.420^{***a}	-3.857^{***b}	-6.420^{***a}	-6.420^{***b}	-6.420^{***a}	-4.101^{***b}	-6.268^{***a}
Major (N = 4)												
W/O Trend	-4.183^{**a}	-4.934^{***a}	-6.190^{***a}	-6.108^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}
W/Trend	-4.464^{***a}	-5.511^{***a}	-6.385^{***a}	-6.391^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}
Foreign (N = 3)												
W/O Trend	-4.750^{***a}	-3.756^{**a}	-5.183^{***a}	-4.993^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}	2.610^{***a}
W/Trend	-6.036^{***a}	-3.374^{**a}	-5.413^{***a}	-5.542^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}	1.700^{***a}
Region (N = 13)												
W/O Trend	-3.547^{***a}	-3.058^{**a}	-5.114^{***a}	-4.644^{***a}	-6.190^{***b}	2.610^{***a}	-6.190^{***b}	-6.190^{***b}	-6.190^{***b}	2.610^{***a}	-6.190^{***b}	-6.190^{***b}
W/Trend	-4.366^{***a}	-3.798^{***a}	-5.538^{***a}	-5.371^{***a}	-6.420^{***b}	1.700^{***a}	-6.420^{***b}	-6.420^{***a}	-6.420^{***b}	1.700^{***a}	-6.420^{***b}	-6.420^{***a}
No. of Periods	706	261	131	314	706	261	131	314	706	261	131	314

(i) The null hypothesis of the Pesaran (2007) CIPS test with cross-sectional dependence is H_0: *(homogeneous non-stationary): bi = 0 for all i* for both constant and constant and trend models. Maximum number of 8 lags is used to determine the optimal lag length and the serial correlation order. Portmanteau (Q) test is set for white noise. (ii) Subscripts ^{a} and ^{b} denote results obtained at the 1% level of significance on level and at first difference. (iii) The asterisks *, **, and *** denote the rejection of the null hypothesis at the 10, 5, and 1% levels, respectively.

Table 4B.7: Westerlund (2007) Cointegration test

Statistics	A. ER–BB.				B. ER–CR			
	Full (T=706)	Pre-GFC (T=261)	GFC (T=131)	Post-GFC (T=314)	Full (T=706)	Pre-GFC (T=261)	GFC (T=131)	Post-GFC (T=314)
Sector								
G_t	-9.653[.000]	-23.183[.000]	-13.645[.000]	14.473[1.000]	-1.292[.148]	-20.409[.000]	-10.244[.000]	25.538[1.000]
G_a	-16.382[.000]	-38.116[.000]	-19.418[.000]	-6.656[.035]	-2.835[.133]	-63.893[.000]	-26.417[.000]	-3.089[.361]
P_t	-12.722[.000]	-24.581[.000]	-15.851[.000]	-12.867[.000]	-3.938[.009]	-13.622[.000]	-15.984[.000]	-7.110[.010]
P_a	-20.667[.000]	-38.564[.000]	-25.978[.000]	-11.719[.000]	-4.306[.077]	-27.911[.000]	-41.936[.000]	-10.956[.023]
Major								
G_t	-2.362[.020]	-7.225[.001]	-4.075[.008]	-5.272[.003]	-2.203[.010]	-13.130[.000]	-5.358[.003]	-2.532[.046]
G_a	-4.028[.005]	-10.153[.001]	-9.066[.001]	-3.900[.029]	-2.371[.043]	-63.089[.000]	-13.218[.003]	-3.976[.061]
P_t	-5.247[.000]	-8.631[.000]	-4.071[.034]	-5.686[.000]	-3.208[.000]	-9.227[.003]	-7.248[.001]	-3.337[.035]
P_a	-8.613[.000]	-16.275[.000]	-10.91[.004]	-5.842[.013]	-3.998[.004]	-40.808[.000]	-17.716[.001]	-5.866[.031]
Foreign								
G_t	-2.686[.013]	-1.844[.071]	-7.255[.000]	-3.120[.013]	-2.796[.004]	-8.247[.005]	-2.201[.091]	0.625[.828]
G_a	-3.167[.024]	-3.233[.039]	-7.416[.000]	-1.793[.129]	-3.007[.019]	-49.882[.003]	-4.736[.138]	0.539[.863]
P_t	-3.443[.004]	-2.123[.218]	-7.233[.000]	-4.712[.004]	-3.291[.001]	-0.806[.486]	-2.538[139]	0.163[.810]
P_a	-4.792[.009]	-3.404[.148]	-8.975[.000]	-3.888[.045]	-4.249[.004]	-2.568[.255]	-8.900[.036]	-0.248[.799]
Region								
G_t	-9.373[.000]	-14.611[.000]	-11.744[.000]	-17.843[.000]	-2.558[.009]	-36.496[.000]	-6.931[.008]	-9.459[.000]
G_a	-16.698[.000]	-20.817[.000]	-16.354[.000]	-33.684[.000]	-4.676[.006]	-84.419[.000]	-23.767[.000]	-28.511[.000]
P_t	-10.475[.000]	-6.274[.018]	-12.888[.000]	-13.032[.000]	-3.390[.018]	-1.430[.438]	-9.102[.005]	-6.134[.005]
P_a	-17.726[.000]	-7.233[.044]	-21.948[.000]	-12.139[.000]	-4.279[.056]	-2.514[.440]	-35.932[.001]	-9.420[.004]

(i) Table 4B.7 reports Z-values of the Westerlund (2007) panel cointegration test. Robust P-values are in square brackets. (ii) Panel A presents the results of the foreign-funds rate estimations for each bank group in successive columns, while Panel B reports the coefficients of the cash rate.

Appendix to Chapter 5

Appendix 5I: Descriptive statistics

	Variable	mean	sd	p50	min	max	N
Panel A: Macro-economic model							
On level	ER	7.08	0.97	7.1	4.28	9.87	3078
	CR	4.45	1.44	4.75	2	7.25	3078
	UR	5.31	0.61	5.29	3.98	6.38	3078
	CP	92.91	11.06	92.47	68.13	112.76	3078
	CI	0.08	5.2	0.2	-16.2	12.7	3078
	FF	0.12	5.85	0.7	-23.2	16.9	3078
	TB	0.2	7.24	-0.3	-20.3	28.2	3078
	BC	5.1	8.38	6.2	-30.3	19.3	3078
	HS	0.04	6.6	0.2	-16.9	39.4	3078
	AS	4617.05	902.62	4654.25	2797.4	6770.6	3078
	AP	1.45	0.16	1.45	1.11	2.03	3078
	DM	300.04	45.42	283.78	241.51	444.67	3078
At 1st diff							
	DER	-0.01	0.16	0	-1.19	0.62	3059
	DCR	-0.02	0.18	0	-1	0.25	3078
	DUR	0	0.14	-0.01	-0.31	0.41	3078
	DCP	0.12	2.07	0.33	-10.43	4.3	3078
	DCI	-0.01	7.99	-0.4	-22.4	28.7	3078
	DFF	-0.01	9.35	-0.6	-25.4	29.1	3078
	DTB	-0.01	11.13	-0.8	-26.3	35.5	3078
	DBC	-0.06	4.34	-0.45	-21.4	11.2	3078
	DHS	-0.01	10.05	-0.25	-40.2	51.7	3078
	DAS	0.38	3.81	1.21	-12.94	7.33	3078
	DAS	0.38	3.81	1.21	-12.94	7.33	3078
	DDM	0.34	2.73	0.19	-5.96	8.17	3078
Panel B: Credit Risk model							
On level	ER	6.41	0.74	6.17	4.28	8.31	4123
	CR	2.97	0.91	2.5	2	5.57	4123
	CD	43.97	19.01	40.23	19.41	97.68	4123
	AC	119.18	31.5	113.06	78	225.5	4123
	EC	96.91	37.53	81.91	48.91	208.38	4123
	UC	81.55	18.94	78.19	54.97	147.5	4123
	RP	7.59	0.95	7.34	5.76	11.11	4123
At 1st diff							
	DER	-0.01	0.18	0	-1.19	0.99	4104
	DCR	-0.01	0.24	0	-1.25	1.25	4104
	DCD	-0.24	7.41	-0.59	-29.25	29.76	4123
	DAC	-0.06	4.93	-0.25	-16.19	18.38	4123

DEC	-0.11	6.54	-0.47	-14.21	19.5	4123
DUC	0.05	5.74	-0.54	-15.01	22.54	4123
DRP	0	0	0	-0.01	0.01	4123

Appendix 5II: Correlation matrix

Panel A: Macro-economic model

On level		ER	CR	UE	CP	CI	FF	TB	BC	HS	AS	AP	DM
	ER	1											
	CR	**0.8758**	1										
	UR	**-0.8667**	**-0.7842**	1									
	CP	0.0268	-0.3317	-0.0967	1								
	CI	-0.1141	-0.0924	0.073	-0.0472	1							
	FF	-0.0402	-0.0321	0.0425	-0.0308	**0.6254**	1						
	TB	-0.0853	-0.0772	0.0428	-0.0496	**0.6216**	0.3213	1					
	BC	-0.2199	0.0052	0.2535	-0.0724	0.0657	0.0114	-0.0187	1				
	HS	-0.0917	-0.0806	0.0744	-0.0395	0.1251	0.1299	0.1155	-0.0027	1			
	AS	0.1789	-0.0036	-0.3669	0.4671	-0.0351	-0.011	-0.0744	0.0251	0.014	1		
	AP	**-0.5032**	-0.607	0.5114	-0.0514	0.0523	0.0409	0.1068	-0.403	0.0483	-0.4677	1	
	DM	**-0.5611**	-0.729	0.4442	0.2012	0.031	0.0451	0.0136	-0.2666	0.0534	0.3908	0.4378	1
At 1st diff		DER	DCR	DUE	DCP	DCI	DFF	DTB	DBC	DHS	DAS	DAP	DDM
	DER	1											
	DCR	**0.8101**	1										
	DUR	-0.2855	-0.2839	1									
	DCP	0.1840	0.3098	-0.0324	1								
	DCI	0.0804	0.0926	-0.0667	-0.1981	1							
	DFF	0.0374	0.0455	-0.0254	-0.1363	**0.6142**	1						
	DTB	0.1018	0.0389	-0.0534	-0.212	**0.6178**	0.3137	1					
	DBC	-0.1378	-0.0528	-0.0464	0.2549	-0.1146	-0.0836	-0.1625	1				
	DHS	0.0409	0.0481	0.0184	-0.0955	0.1898	0.1952	0.1322	0.0412	1			
	DAS	0.1541	0.2323	-0.0692	0.3388	-0.0179	-0.0498	0.0515	0.2805	0.1309	1		
	DAP	-0.1115	-0.1564	0.088	-0.6071	0.0967	-0.0167	0.1088	-0.307	0.029	-0.5296	1	
	DDM	0.0001	0.039	-0.0025	-0.4443	0.1061	-0.0135	0.0772	-0.1964	0.0289	-0.4121	0.7572	1

Panel B: Credit Risk model

On level		ER	CR	CD	AC	EC	UC	RP
	ER	1						
	CR	0.9836	1					
	CD	0.8969	0.9055	1				
	AC	0.8067	0.7996	0.8357	1			
	EC	0.8775	0.8656	0.8775	0.9471	1		
	UC	0.7865	0.7778	0.7693	0.9628	0.934	1	
	RP	0.8059	0.8314	0.7838	0.7725	0.7682	0.7318	1
At 1st diff		DER	DCR	DCD	DAC	DEC	DUC	DRP
	DER	1						
	DCR	0.8887	1					
	DCD	-0.0127	0.0157	1				
	DAC	-0.0731	-0.0711	0.2966	1			
	DEC	-0.1094	-0.1287	0.065	0.1456	1		
	DUC	-0.0843	-0.0672	0.2311	0.7417	0.1029	1	
	DRP	0.0205	0.0718	0.1688	0.2405	0.0245	0.222	1

Appendix 5III: Pass-through coefficients of the full sample obtained from the MG estimates

Variable	Long-term results					Short-term results			
ER	Sector	Major	Foreign	Region		Sector	Major	Foreign	Region
					ECT	**-0.0597*****	**-0.0659*****	**-0.0555*****	**-0.0587*****
						(-22.53)	(-48.64)	(-18.71)	(-14.69)
CR_p	2.032***	2.007***	1.530***	2.165***	ΔCR_p	-0.0500**	-0.0657***	-0.0235	-0.0513**
	(12.19)	(14.83)	(2.84)	(9.70)		(-2.44)	(-7.32)	(-0.20)	(-2.41)
CR_n	-1.813***	-1.685***	-1.737***	-1.876***	ΔCR_n	**-0.255*****	**-0.257*****	**-0.246*****	**-0.257*****
	(-17.40)	(-26.16)	(-5.50)	(-12.58)		(-34.09)	(-14.52)	(-88.87)	(-24.06)
UE_p	-0.763***	-1.026***	-0.808***	-0.665***	ΔUE_p	-0.0614***	-0.0160	-0.0179	-0.0875***
	(-5.37)	(-8.53)	(-3.14)	(-3.13)		(-2.99)	(-0.52)	(-0.37)	(-3.22)
UE_n	-4.448***	-3.914***	-4.496***	-4.614***	ΔUE_n	**0.324*****	**0.355*****	**0.263*****	**0.330*****
	(-16.21)	(-41.71)	(-11.47)	(-10.99)		(16.67)	(12.90)	(4.12)	(13.33)
CP_p	-0.0981***	-0.0720***	-0.103***	-0.106***	ΔCP_p	-0.0061***	-0.0131***	-0.00199	-0.0048**
	(-7.08)	(-14.27)	(-6.38)	(-4.94)		(-3.73)	(-12.38)	(-0.45)	(-2.43)
CP_n	-0.256***	-0.232***	-0.279***	-0.259***	ΔCP_n	**0.0358*****	**0.0447*****	**0.0355*****	**0.0329*****
	(-19.04)	(-102.29)	(-21.09)	(-12.46)		(20.87)	(18.22)	(19.61)	(16.90)
BC_p	0.108***	0.0843***	0.106***	0.116***	ΔBC_p	0.0001	0.0008*	0.0013***	-0.0005
	(16.26)	(24.81)	(7.93)	(12.83)		(0.10)	(1.65)	(4.77)	(-0.52)
BC_n	0.0477***	0.0394***	0.0437***	0.0516***	ΔBC_n	**-0.0165*****	**-0.0163*****	**-0.0155*****	**-0.0168*****
	(9.92)	(6.54)	(4.55)	(7.39)		(-34.41)	(-15.19)	(-10.27)	(-28.28)
TB_p	-0.0180***	-0.0205***	-0.0183***	-0.0171***	ΔTB_p	**0.0033*****	**0.0038*****	**0.0026*****	**0.0034*****
	(-6.43)	(-11.07)	(-8.49)	(-3.87)		(15.53)	(10.96)	(10.34)	(11.32)
TB_n	0.0022	0.0007***	-0.0008	0.0034	ΔTB_n	**0.0007*****	**0.0014*****	**0.0016*****	0.0003
	(0.84)	(3.61)	(-0.17)	(0.85)		(3.33)	(11.85)	(4.88)	(1.07)
AP_p	-0.213***	-0.204***	-0.209***	-0.217***	ΔAP_p	0.0013*	**0.0045*****	**0.0027*****	-0.0001
	(-18.86)	(-28.85)	(-6.91)	(-12.98)		(1.75)	(3.83)	(3.00)	(-0.16)
AP_n	0.0283***	0.0242**	0.0240*	0.0307***	ΔAP_n	**0.00776*****	**0.009*****	**0.0056*****	**0.0079*****
	(3.77)	(2.57)	(1.88)	(2.71)		(13.54)	(5.30)	(3.43)	(13.97)

DM_p	-0.0905***	-0.0537***	-0.125***	-0.0942***	ΔDM_p	-0.0003	-0.0001	-0.0009	-0.0002
	(-6.75)	(-10.73)	(-3.44)	(-5.15)		(-0.50)	(-0.05)	(-0.68)	(-0.28)
DM_n	-0.0368***	-0.0454***	-0.0621***	-0.0277	ΔDM_n	**-0.0124*****	**-0.0141*****	**-0.0082*****	**-0.0129*****
	(-2.69)	(-3.93)	(-2.77)	(-1.34)		(-12.00)	(-21.76)	(-5.95)	(-8.80)
Cons						0.361***	0.410***	0.335***	0.352***
						(19.89)	(31.19)	(9.93)	(13.37)
Obs.						3059	644	483	1932

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