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AUSTRALIAN BANK MORTGAGE INTEREST RATE PASS-THROUGH: DOES INTERNATIONAL FUNDING COST MATTER?

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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 January 1997 to 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. We also find evidence of the short-term asymmetries for several banks. Our findings confirm that bank mortgage rate setting is significantly affected by international funding costs, apart from the cash rate. This study provides several important policy implications.

Keywords: Asymmetry; interest-rate pass-through; bank mortgages; NARDL model

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INTRODUCTION

The interest rate channel plays a vital role in monetary policy transmission for the 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 impact on consumption, investment, and the real economy. The Australian mortgage market is one of the top five global markets that their mortgage credit ratios to GDP are greater than 100 percent. Its size 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 percent of GDP (author's calculation from APRA 2017; ABS 2017a, b). The effectiveness of the housing interest rate transmission therefore is of great interest to banking regulators, policy makers, and the public. The 2008 global financial crisis (GFC) has vitalized publicity surrounding bank mortgage pricing behaviour. The huge extent of media coverage and political interest related to mortgage interest rate movement provides a clear indication of this issue's importance.

The study of interest rate pass-through examines how fast and how large banks adjust their retail interest rates corresponding 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 bank marginal funding cost. The literature on interest rate pass-through (IRPT) 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), while the latter examines the pass-through from a market rate, either of a maturity similar to the average maturity of loans, or the most correlated with loan rates (De Bondt 2005; De Graeve, De Jonghe, & Vennet 2007). Commonly, a policy rate or a money market rate is used to be the proxy for bank marginal funding cost. Bank interest rates were confirmed to stably align with policy rates and/or money market rates prior to the GFC. 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 transmission breakdown has raised major concerns about the efficacy of the IRPT mechanism in an increased risky environment (Cifarelli & Paladino 2016; Lim et al. 2013).

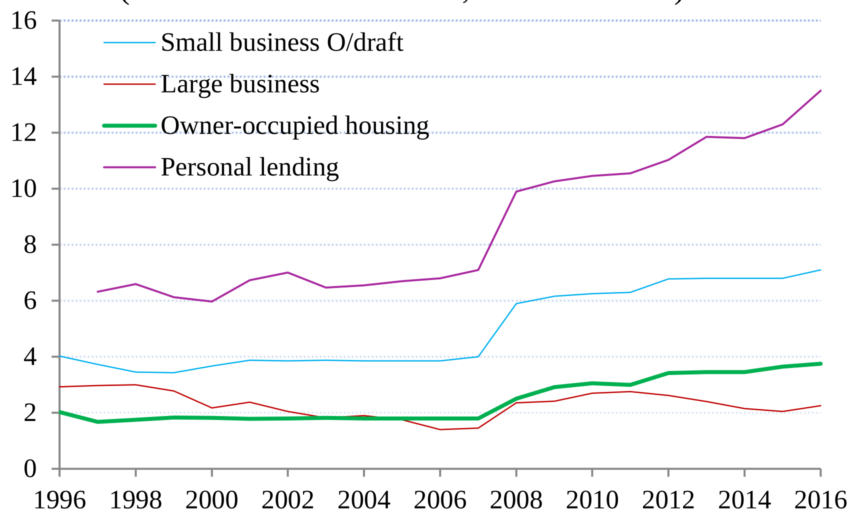


Figure 1. Spreads of the bank lending rates over the cash rate. Source: RBA (2017) "Statistics, Tables F1, 2, 5".

Australia has recently experienced upward trends in spreads of bank interest rates over the cash rate, while the synchronous declines in absolute terms of the rates have gradually occurred since 2008 (see Figure 1). Valadkhani (2013) documents the empirical evidence of a significant upward shift of mortgage rate spreads over cash rate for the 23 Australian lenders since the GFC. Increases in these spreads are typically interpreted to indicate changes in bank pricing behaviour, but this view may be biased. The GFC has given rise to the cost of borrowing in world financial markets, unfavourably affecting Australian lenders. A controversy has surrounded the heavy reliance of banks 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 mortgage interest rates. However, they are all in the forms of descriptive studies, no systematic empirical studies have yet investigated this link. This paper sheds new light on the literature supporting asymmetric pricing of housing interest rates by answering two questions, whether the international funding cost affects the mortgage rate transmission, and what is the nature of that relationship.

This study provides a scientific investigation of the relationships between mortgage interest rates and both domestic and international funding costs. 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 percent of the total outstanding mortgages. The testable hypothesis about mortgage funding cost is theoretically based on the marginal cost pricing model by De Bondt (2005) and Beau, Hill, Hussain, & Nixon (2014). Bank funding costs are portioned into three key components, a risk free rate, a risk premium and other costs. The cash rate is the direct measure of the risk free rate. The remainders 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’ offshore wholesale funding is the second largest component of total liabilities, accounting for around 20–30 percent, just below retail deposits at nearly 60 percent during the last decade (Wilkins, Gardner, and Chapman 2016). Australian banks also hold a globally prolonged position in using foreign funds, around 35 percent, to fund their mortgages (Turner and 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 which should be valid for mortgage markets with significant shares of international funds in the bank funding. Second, this paper contributes to the extension of 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 fully extent of asymmetric adjustments between mortgage rates and bank funding costs, both cash rate and foreign fund rate.

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

THEORETICAL AND EMPIRICAL MODELS

The marginal cost pricing model by De Bondt (2005) and Freixas and Rochet (2008) is the key framework in determining how interest rates are transmitted under imperfect market competition.[1] A bank interest rate is approximated as a constant markup over the marginal cost of funds as follows:

$$br = \beta mr + \mu \quad (1)$$

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.

Financial institutions operating in weakly competitive markets or in oligopolistic market segments are likely to have an incentive to incompletely pass on market interest rate changes to their retail rates because they are somewhat more powerful in price setting, vice and versa (Hannan & Berger 1991). This market power hypothesis has been largely confirmed, for example, in the UK market by Fuertes and Heffernan (2010), in the UK, US, and Australian mortgage markets by Apergis & Cooray (2015). 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. Subsequently, lenders can exert their pricing power to profit from their customers. Rocha (2012) posits that differences in switching costs, inadequate access to information, lacking alternative sources of consumer financial products, and encountering higher search costs lead to a lower personal loan price elasticity, resulting in the rigidity of the personal lending rates in Portugal.

We use the NARDL approach by Shin et al. (2014) 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 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.[2] 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 parameter. By accommodating heterogeneous asymmetries on impact, in the short term and in the long term, the NARDL model has instantly ideally become researchers in pass-through study.

The NARDL model requires the partial sum decomposition of the cost-of-funds rates:

$$mr_t^+ = \sum_{j=1}^{t} \Delta\, mr_j^+ = \sum_{j=1}^{t} \max(\Delta mr_j\,, 0),\;\; mr_t^- = \sum_{j=1}^{t} \Delta mr_j^- = \sum_{j=1}^{t} \min(\Delta mr_j\,, 0) \quad (2)$$

where $mr_t = mr_0 + mr_t^+ + mr_t^-$ and mr_t is either BB_t or CR_t in this analysis. These partial sum processes divide funding cost rises, mr_t^+, and funding cost cuts, mr_t^-. The

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

[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).

initial value mr_0 can be set to 0. An asymmetric long-run IRPT relationship in Eq. (1) is formalised as

$$br_t = \beta^+ mr_t^+ + \beta^- mr_t^- + u_t \quad (3)$$

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. (2) and (3) within an ARDL(p,q)

$$\Delta br_t = \mu + \rho br_{t-1} + \delta^+ mr_{t-1}^+ + \delta^- mr_{t-1}^- + \sum_{j=1}^{p-1} \lambda_{i,j}\, \Delta br_{t-j} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta mr_{t-j}^+ + \pi_j^- \Delta mr_{t-j}^-) + \varepsilon_t \quad (4)$$

where all variables are as defined above. 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 long-run asymmetry parameters of *BB* and *CR* are given by $\beta_i^+ = -\delta_i^+/\rho_i$ and $\beta_i^- = -\delta_i^-/\rho$. 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 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 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, …, 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. (4):

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial br_{t+j}}{\partial mr_t^+}, \quad m_h^- = \sum_{j=0}^{h} \frac{\partial br_{t+j}}{\partial mr_t^-} \quad with\ h = 0, 1, 2, \dots \quad (5)$$

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.

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 surge in outstanding mortgage debt as a percentage of GDP from nearly 30 percent in 1997 to 105 percent in Dec 2016 (Author's calculation from database of APRA 2017; ABS 2017a, b). 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, allowing for capturing potential market structural changes.

A novel bank-level dataset of weekly effective interest rates on variable home-loans is created from 20 anonymous commercial banks. The banks provide approximately 90 percent of the total outstanding mortgages over the sample period (author's calculation). The selected sample thus is relatively well represented. The 20 out of the total 37 sampling banks 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 percent (author's calculation). It is thus expected to be heterogeneous mortgage price-setting practices.

The effective home-loan rate variable, ER_t, is constructed from the annual adjustable percentage rate of mortgages that covers all kinds of fees, synthesised into the motion "mortgage rate". 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 percent, but 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) acts as 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, while the US$ LIBOR is a benchmark rate for offshore issues only (Guttmann and Rodgers, 2015; RBA, 2006). Technically, using the BBSW eliminates possible calculation errors from currency converting. In this study, using the BBSW as the proxy for international funding costs is more appropriate.

RESULT ANALYSIS

Table 1 presents the asymmetric results of the NARDL estimations, using the foreign funds rate variable. Table 2 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 the well-specified NARDL model.

Table 1. Asymmetry results of the foreign funds rate by NARLD Eqn. (4).

NARLD(p, q)	(a) Long-run asymmetry SoA (ρ)	Long-run IRPT β^+	Long-run IRPT β^-	W_{LR} H_o: $\beta^+ = \beta^-$	(b) Short-run asymmetry Impact IRPT π_0^+	Impact IRPT π_0^-	W_{ISR} H_o: $\pi_0^+ = \pi_0^-$	Cumulative IRPT $\sum_{j=0}^{1}\pi_j^+$	Cumulative IRPT $\sum_{j=0}^{1}\pi_j^-$	W_{CSR} H_o: $\sum_{j=0}^{1}\pi_j^+ = \sum_{j=0}^{1}\pi_j^-$	(c) Diagnostics t_{BDM}	F_{PSS}	χ^2_{SC}
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: Region 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]

(1) Table 1 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 2. Asymmetry results of the cash rate by NARLD Eqn. (4).

NARLD(p,q)	(a) Long-run asymmetry				(b) Short-run asymmetry						(c) Diagnostics		
	SoA (ρ)	Long-run IRPT		W_{LR} H_o: $\beta^+ = \beta^-$	Impact IRPT		W_{ISR} H_o: $\pi_0^+ = \pi_0^-$	Cumulative IRPT		W_{CSR} H_o: $\sum_{j=0}^{1}\pi_j^+ = \sum_{j=0}^{1}\pi_j^-$	t_{BDM}	F_{PSS}	χ_{SC}^2
		β^+	β^-		π_0^+	π_0^-		$\sum_{j=0}^{1}\pi_j^+$	$\sum_{j=0}^{1}\pi_j^-$				
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: Region 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]

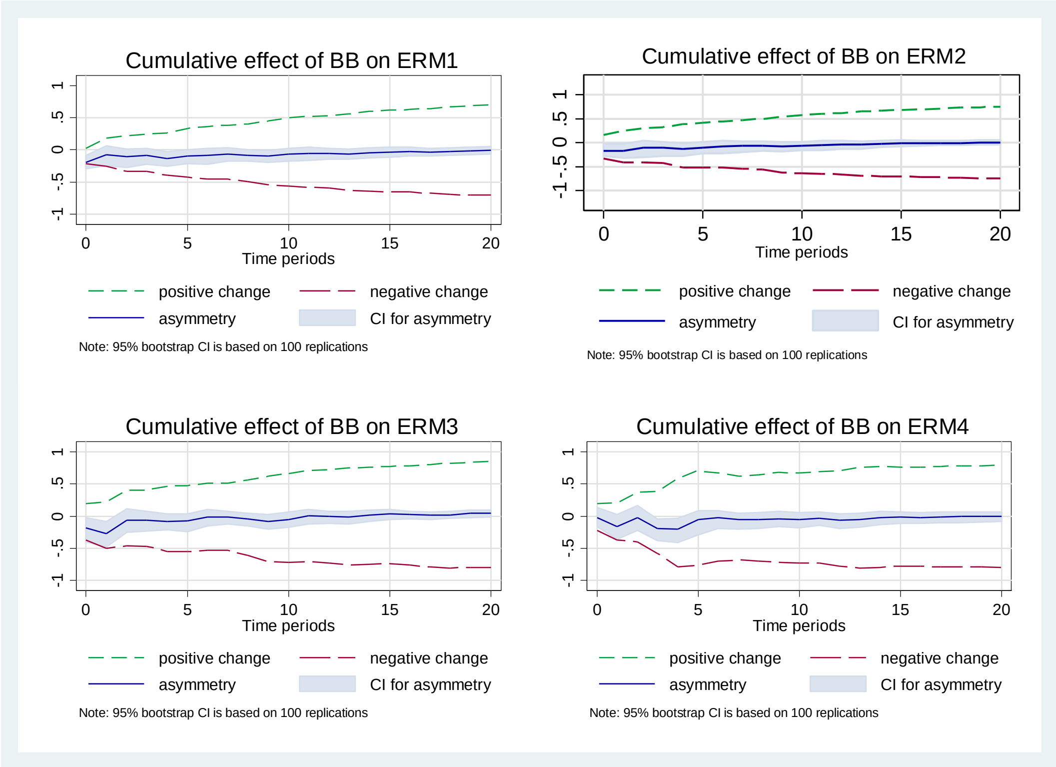
(1) This table reveals the results of the optimal NARDL estimations for the responsiveness of the mortgage rates to cash rate changes each bank of the three sampled groups in the corresponding panels. (2) The remainders are similar to Table 1.

We 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}, signifying a positive asymmetry. This finding is consistent with Apergis and Cooray (2015). The long-run effect in absolute values of the funding cost rises are 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.

The cash rate results are reported in Table 2. All 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 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 with regards to 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 funding cost rises, but are quiet to immediately respond to cost cuts. Our downward sluggish and heterogeneous findings are consistent with Fuertes et al. (2010) regarding the UK mortgage market with the explanations for these negligible degrees of the negative impacts that are 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.

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



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

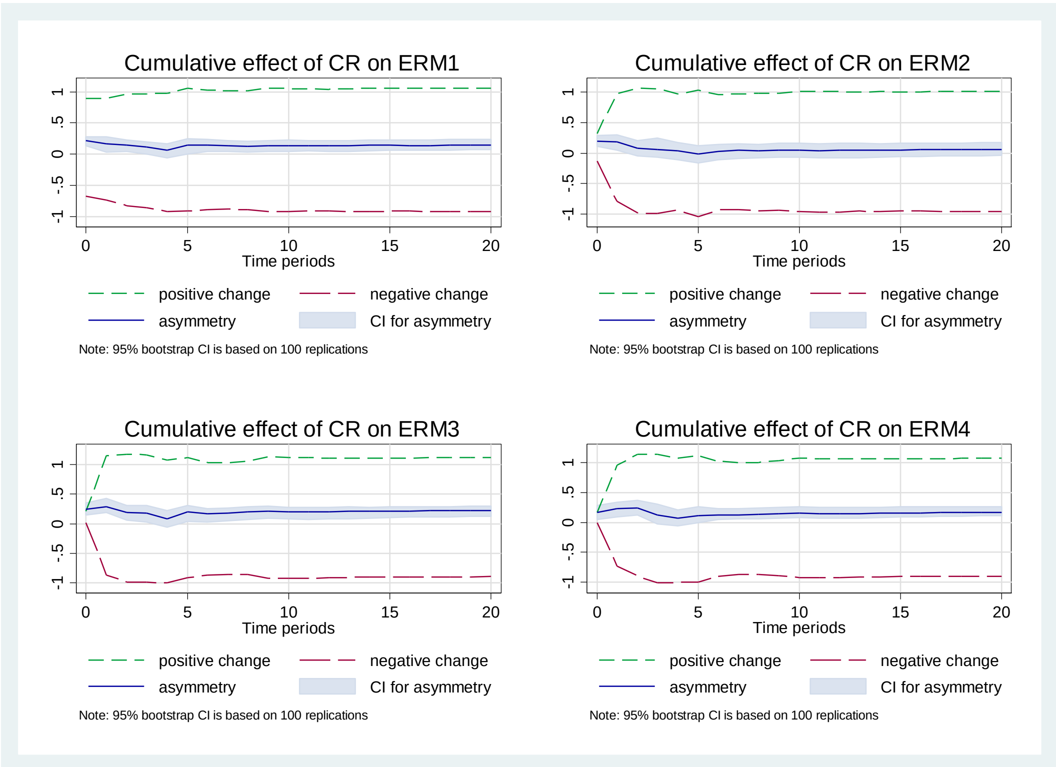
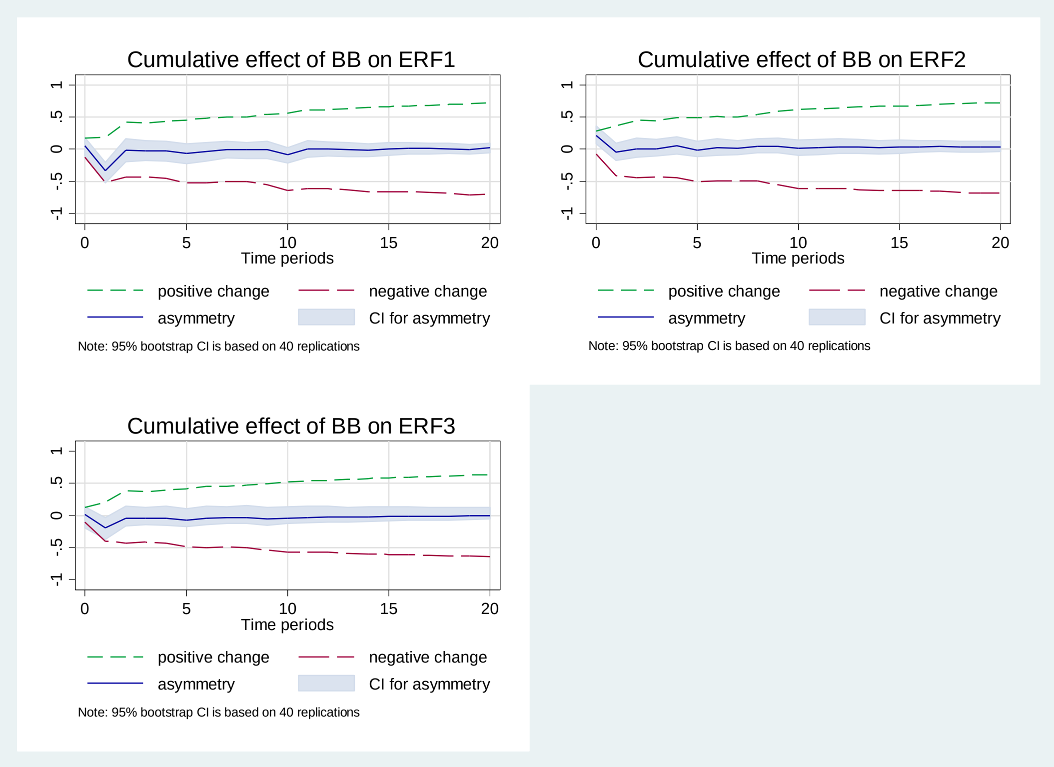


Figure 2. Dynamic multipliers for major-bank mortgage rates. This figure plots the cumulative dynamic multiplier effect of respectively a 1% increase or decrease of the cost-of-funds rates on the bank effective mortgage rates in percentage points on the vertical axis. Weekly intervals are on the horizontal axis.

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



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

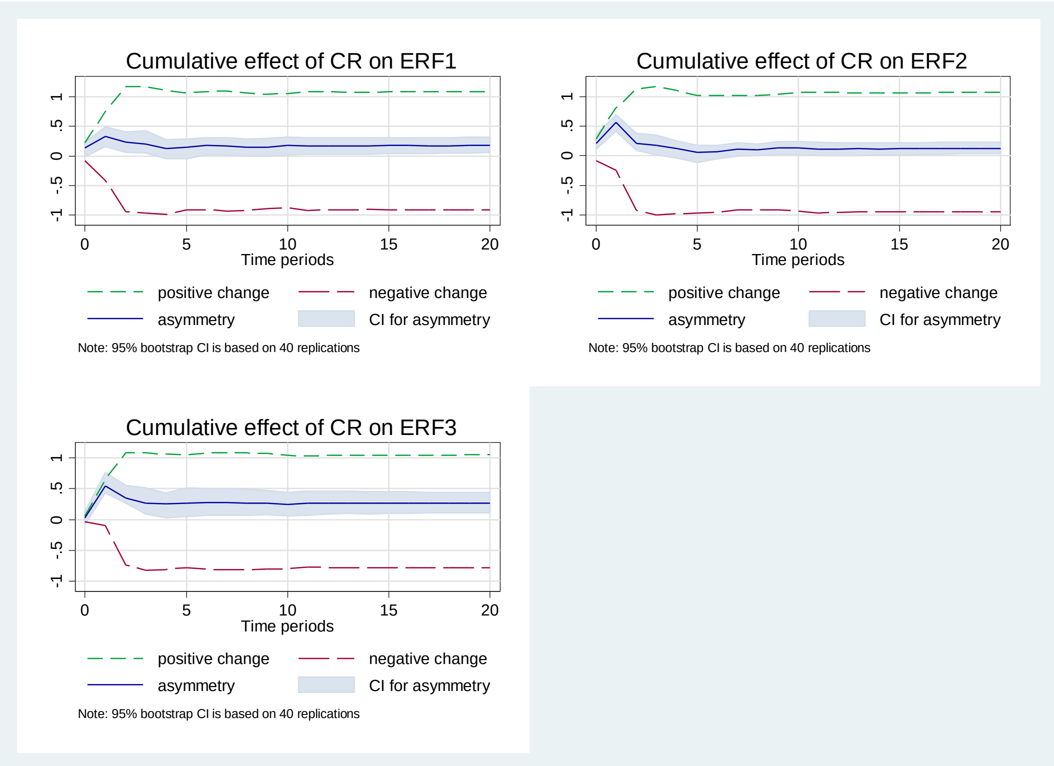


Figure 3. Dynamic multipliers for foreign-bank mortgage rates. The rest are similar to Figure 2.

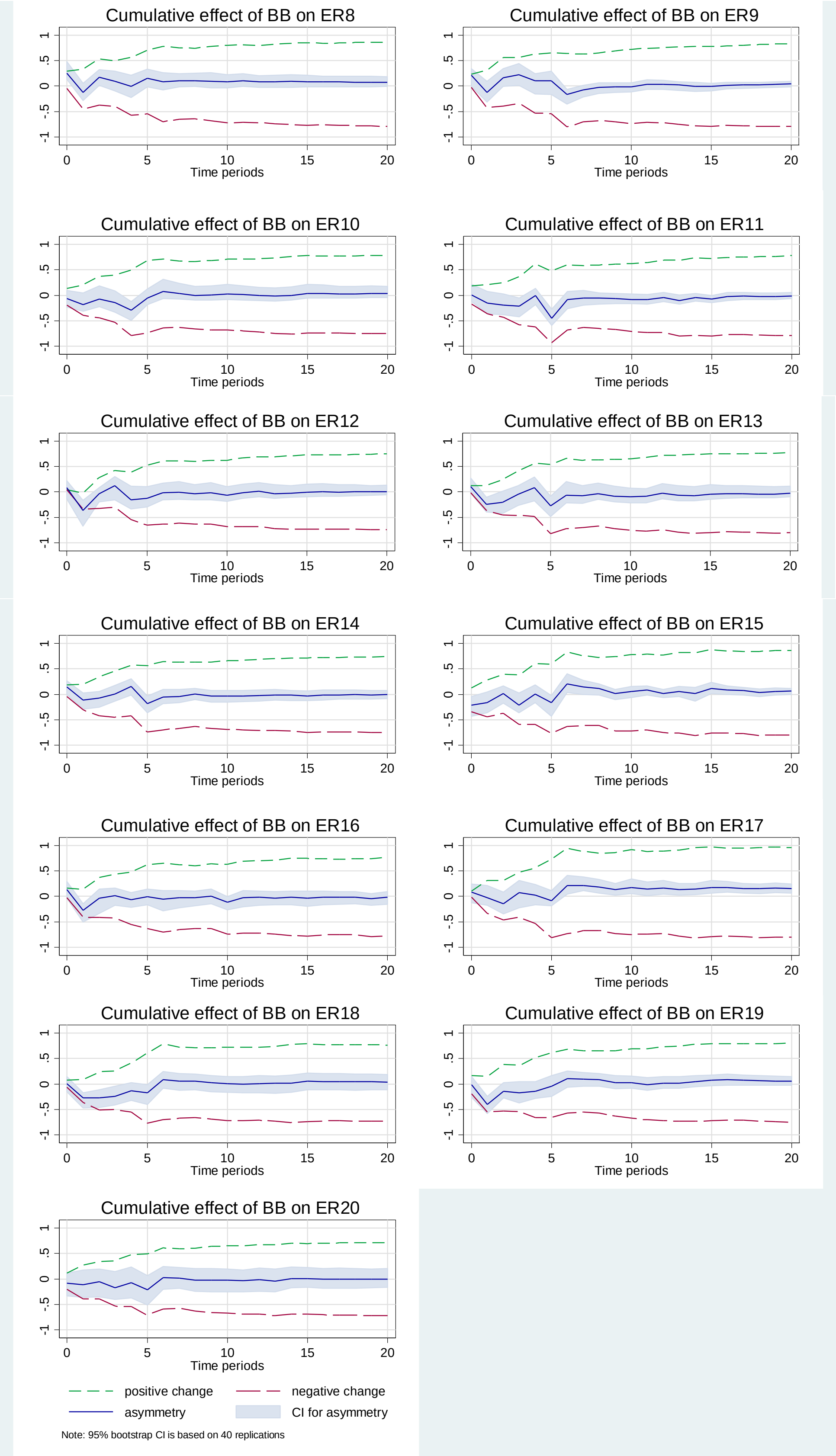


Figure 4. Dynamic multipliers for region-bank mortgage rates and the foreign funds rate.

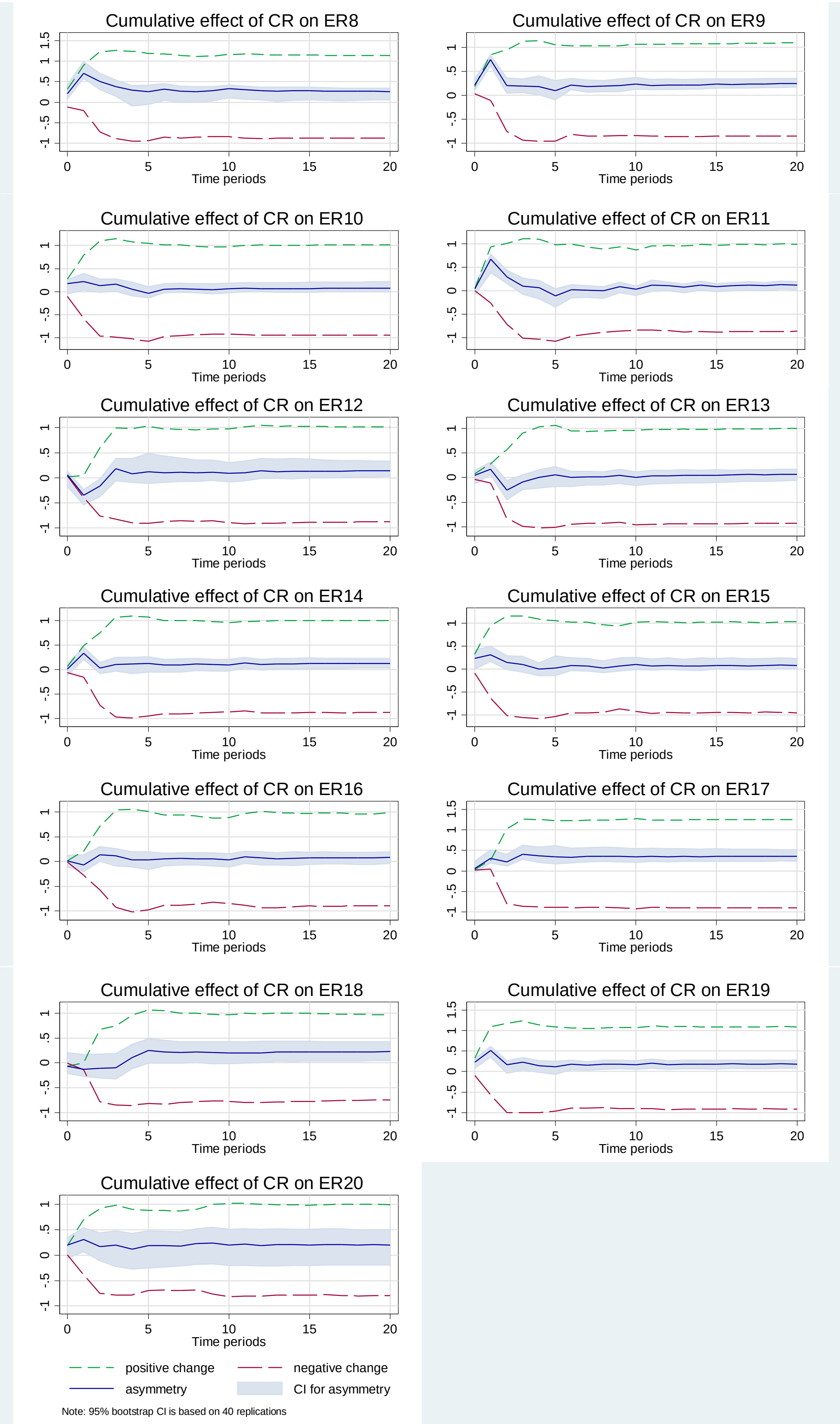


Figure 5. Dynamic multipliers for region-bank mortgage rates and the cash rate.

Figures 2 to 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 1 and 2. We focus on four key findings and the 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. 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). Our findings indicate the higher competitive pressure for banks 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 our 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 in determining what factors cause the heterogeneous asymmetry.

CONCLUSIONS

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 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 interest 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 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, our findings provide convincing evidence of the strong influence of foreign funding costs on mortgage rates. This empirical evidence is of practical use to the Australian Prudential Regulation Authority (APRA) and Reserve Bank of Australia (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 cost that is 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 Australian Competition & Consumer Commission (ACCC) to implement. Banks have greatly passed on funding cost rises to their mortgage borrowers by setting higher rates on new lending, 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 number of unaffordable borrowers subsequent to increased credit losses for banks.

REFERENCES

Apergis, N. and Cooray, A. (2015) Asymmetric interest rate pass-through in the U.S., the U.K. and Australia: New evidence from selected individual banks. *Journal of Macroeconomics*, 45, 155–172.

APRA. (2017) Monthly banking statistics. Australian Prudential Regulation Authority Publishing APRAWeb. http://www.apra.gov.au/adi/Publications/Pages/monthly-banking-statistics.aspx

Aristei, D. and Gallo, M. (2014) Interest rate pass-through in the Euro area during the financial crisis: A multivariate regime-switching approach. *Journal of Policy Modeling*, *36*, 273–295.

Australian Bureau of Statistics (ABS). (2017a) *Australian National Accounts: Finance and Wealth, Dec 2016 (5232.0)*. Canberra.

Australian Bureau of Statistics (ABS). (2017b) *Australian National Accounts: Housing Finance, May 2017 (5609.0)*. Canberra.

Bailey, O. Uffelen, L. Van, and Wood, K. (2012) International activities of Australian banks. *RBA Monthly Bulletin*, December, 47–56.

Banerjee, A. Dolado, J. and Mestre, R. (1998) Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of Time Series Analysis*, 19(3), 267–283.

Beau, E. Hill, J. Hussain, T. and Nixon, D. (2014) Bank funding costs: what are they, what determines them and why do they matter? *Bank of England: Quarterly Bulletin*, 54(4), 370–384.

Berkelmans, L. and Duong, A. (2014) Developments in banks' funding costs and lending rates. *RBA Monthly Bulletin*, March, 69–76.

Cifarelli, G. and Paladino, G. (2016) Time-varying mark-up and the ECB monetary policy transmission in a highly non linear framework. *International Review of Economics & Finance*, 45, 247–262.

De Bondt, G. J. (2005) Interest rate pass-through: Empirical results for the Euro area. *German Economic Review*, 6(1), 37–78.

De Graeve, F. De Jonghe, O. and Vennet, R. Vander. (2007) Competition, transmission and bank pricing policies: Evidence from Belgian loan and deposit markets. *Journal of Banking & Finance*, 31(1), 259–278.

De Haan, L. and Sterken, E. (2011) Bank-specific daily interest rate adjustment in the Dutch mortgage market. *Journal of Financial Services Research*, 39(3), 145–159.

Freixas, X. and Rochet, J.C. (2008) *Microeconomics of Banking* (2nd ed.). MIT Press, Cambridge.

Fuertes, A. Heffernan, S. and Kalotychou, E. (2010) How do UK banks react to changing central bank rates? *Journal of Financial Services Research*, 37(2), 99–130.

Granger, C. W. and Yoon, G. (2002) Hidden Cointegration. *University of California*, 2002–2, 1–48.

Guttmann, R. and Rodgers, D. (2015) International banking and liquidity risk transmission: Evidence from Australia. *IMF Economic Review*, 63(3), 411–425.

Hannan, T. H. and Berger, A. N. (1991) The rigidity of prices: Evidence from the banking industry. *The American Economic Review*, 81(4), 938–945.

Hristov, N. Hülsewig, O. and Wollmershäuser, T. (2014) The interest rate pass-through in the Euro area during the global financial crisis. *Journal of Banking & Finance*, 48, 104–119.

Lim, G. C. Tsiaplias, S. and Chua, C. L. (2013) Bank and official interest rates: How do they interact over time? *Economic Record*, 89(285), 160–174.

Pesaran, M. H. Shin, Y. and Smith, R. J. (2001) Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16, 289–326.

RBA. (2006) Australian banks' global bond funding. *RBA Monthly Bulletin*, August, 1–6.

Robstad, Ø. (2018) House prices, credit and the effect of monetary policy in Norway: evidence from structural VAR models. *Empirical Economics*, 54(2), 461–483.

Rocha, M. D. (2012) Interest rate pass-through in Portugal: Interactions, asymmetries and heterogeneities. *Journal of Policy Modeling*, 34, 64–80.

Rousseas, S. (1985) A markup theory of bank loan rates. *Journal of Post Keynesian Economics*, 8(1), 135–144.

Sander, H. and Kleimeier, S. (2004) Convergence in euro-zone retail banking? What interest rate pass-through tells us about monetary policy transmission, competition and integration. *Journal of International Money and Finance*, 23(3), 461–492.

Sathye, M. (2013) Financial crisis and interest rate pass-through in Australia. *Review of Pacific Basin Financial Markets and Policies*, 16(4), 1–22.

Shin, Y. Yu, B. and Greenwood-Nimmo, M. (2014) *Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework*. In: Sickles, R. and Horrace, W. (Eds) Festschrift in Honor of Peter Schmidt: Econometric Methods and Applications. Springer, New York.

Stewart, C. Robertson, B. and Alexandra, H. (2013) Trends in the funding and lending behaviour of Australian banks. *Research Discussion Paper 2013/15,* Reserve Bank of Australia.

Turner, G. and Nugent, J. (2015) International linkages of the Australian banking system: Implications for financial stability. *The Finsia Journal of Applied Finance*, (3), 34–43.

Valadkhani, A. (2013) The pricing behaviour of Australian banks and building societies in the residential mortgage market. *Journal of International Financial Markets, Institutions and Money*, 26(1), 133–151.

Wilkins, K. Gardner, G. and Chapman, B. (2016) Developments in banks ' funding costs and lending rates. *RBA Monthly Bulletin*, March, 21–30.