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Funding cost pass-through to mortgage rates

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NON-TECHNICAL SUMMARY

Prior to the global financial crisis (GFC), there was a relatively stable relationship between the Official Cash Rate (OCR) and retail mortgage rates. Changes in the OCR were typically accompanied by a proportional change in floating mortgage rates. However, this relationship has deteriorated since the GFC and the OCR on its own has not been a good proxy for bank funding costs. This paper examines the change in the transmission of the OCR, and the role of other funding costs for retail mortgage rates since the GFC.

Banks now place greater reliance on more stable (but more costly) sources of funding. They rely on domestic deposits and long-term wholesale funding more, and less on short-term wholesale funding. This has resulted in a wider and more volatile spread between mortgage rates and the OCR. Not all changes in the OCR have passed through one-for-one into floating mortgage rates, as funding costs from other sources have sometimes been offsetting.

We construct a comprehensive estimate of bank funding costs using a weighted average of the cost of domestic deposits, short-term wholesale funding and long-term wholesale funding. This weighted-average measure is further decomposed into a monetary policy rate component and a funding spread component. We use an error correction framework to measure the relative contributions of the policy rate and funding spreads to the level of mortgage rates in New Zealand, and estimate the speed of pass-through to mortgage rates from changes in funding costs.

Our results suggest that funding spreads have been larger post-GFC, and have had a larger impact on the level of fixed-rate mortgages than on floating rates. There has also been a significant slowdown in the pass-through from policy and funding spreads to the floating mortgage rate. The speed of pass-through to fixed-rate mortgages has slowed only slightly.

1. Introduction[1]

The Official Cash Rate (OCR) has historically been a reasonable proxy for short-term funding costs for banks. But, since the GFC, banks have funded a larger share of their borrowing from stable sources such as retail deposits and long-term wholesale markets, in part reflecting regulatory changes. As a result, a more complete measure of funding costs is needed to understand the transmission of OCR changes.

Wong (2012) provides a comprehensive discussion of the change in the composition of bank funding and an indicative measure of new funding costs. This note extends on this analysis in two dimensions.

a) We construct more up-to-date and comprehensive estimates of new funding costs using information from the Reserve Bank's liquidity survey of bank funding behaviour.
b) We empirically test for changes in the transmission from funding costs to retail mortgage rates.

2. Measuring new funding costs

To better understand the impact of bank funding pressures on mortgage rates, we first need a measure of bank funding costs that takes into account the wide range of funding markets banks participate in. Banks' funding base broadly consists of capital, retail and commercial deposits, short-term wholesale debt (i.e. maturing within one year) and long-term wholesale debt (maturing beyond one year). Additional complexities arise because banks typically hedge the interest rate mismatch caused by funding and lending at different terms, as well as currency exposures from funding in offshore markets. The costs and benefits involved with hedging interest rate and currency risks need to be incorporated into measures of total bank funding costs (see Wong 2012 for discussion).

Before the GFC, simple proxies of bank funding costs based on wholesale rates (bank bill or swap rates) typically worked well due to relative stability in the composition of funding. Banks also relied heavily on short-term wholesale funding, the cost of which was strongly influenced by the OCR, given its role in anchoring the term structure of domestic interest rates. As a result, the relationship between the OCR and the floating mortgage rate was relatively stable prior to the GFC (figure 1). The same was true for fixed mortgage rates

[1] Thanks to colleagues at the Reserve Bank for helpful comments, especially Yuong Ha, Enzo Cassino, Benjamin Wong, Chris McDonald, and Adam Richardson.

when compared to market-implied expectations of the OCR over an equivalent term (figure 2).[2]

Figure 1: Floating mortgage spread to OCR

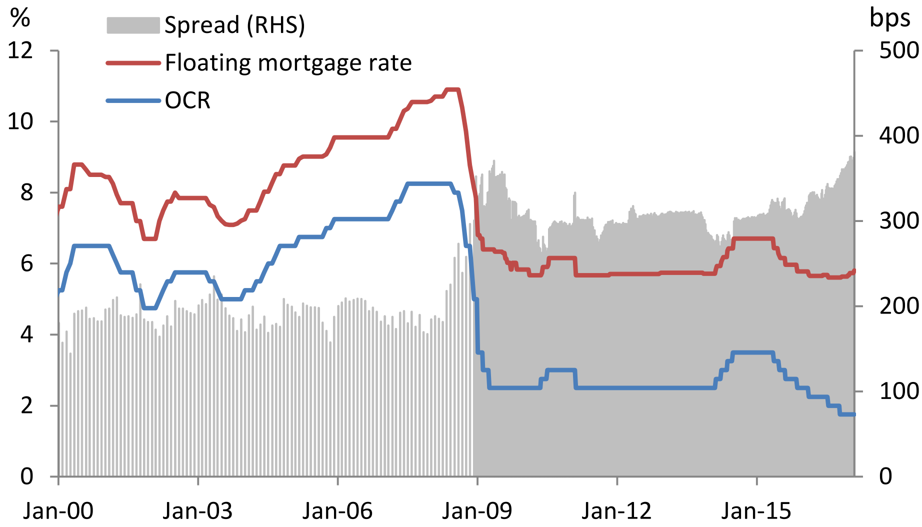
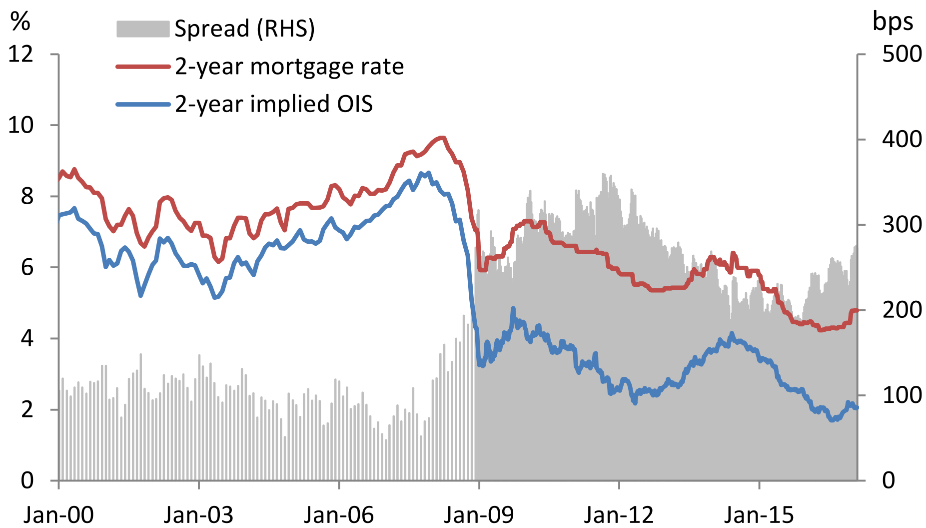


Figure 2: 2-year fixed rate mortgage spread



However, the GFC exposed vulnerabilities that come from relying too heavily on short-term wholesale funding markets. Short-term markets became illiquid as key investors in money markets reduced their exposure to banks, or they withdrew from the market entirely. The high cost required by banks to roll over short-term funding caused the market to effectively freeze up. Market participants were forced to reassess the roll-over risks involved with frequent refinancing of short-term debt.

[2] See Choy (2003) for a more comprehensive discussion on Overnight Indexed Swaps.

Banks began to shift their funding composition towards more stable (and costly) sources of funding, such as deposit and long-term wholesale markets. This shift was encouraged by the Reserve Bank, which introduced minimum requirements on banks' funding composition via its core funding ratio (CFR)[3]. The reliance on short-term wholesale funding diminished, with the stock of total funding sourced from these markets falling from above 50 percent in 2008 to around 30 percent currently.[4] The spread between the OCR and mortgage rates widened (grey area in figures 1 and 2), partially reflecting the additional costs involved with deposit and long-term wholesale funding. A similar, albeit more gradual, trend has been seen over recent years, as rapid credit growth has put pressure on banks to compete more aggressively for a limited pool of domestic deposits.

The shift towards higher cost deposit and long-term wholesale funding has contributed to higher mortgage rates relative the OCR. To assess the extent of this increase in costs, we construct a measure of funding costs that uses the same underlying framework as that used by Wong (2012). The measure is a volume-weighted average cost of new funding that covers retail and corporate deposits, domestic long-term wholesale, foreign short-term and long-term wholesale funding (see table A1 in the Appendix for details).[5]

We improve upon the measure used by Wong (2012) in three key ways:

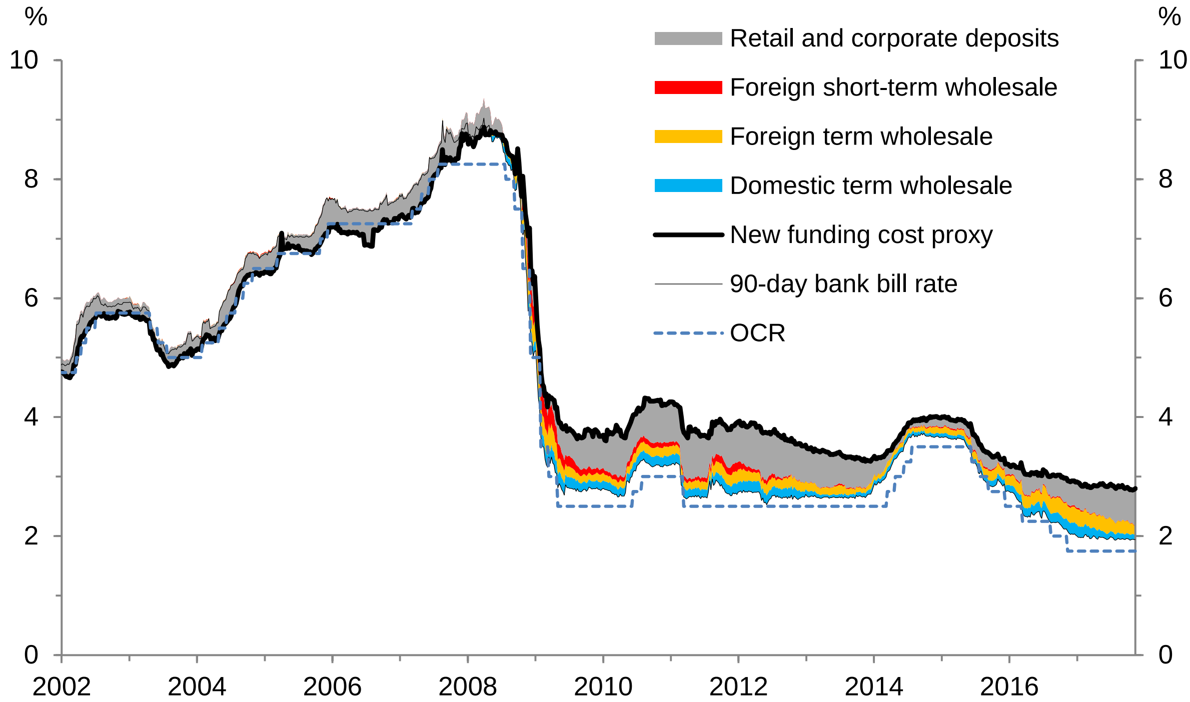
1. We increase the sophistication of foreign funding and hedging costs by (1) using Bloomberg fair value indices for AA-rated financial institutions as proxies for NZ banks' cost of funding, (2) for comparability we transform these costs into 3-month resetting cash flows where necessary (via interest rate swaps), and (3) we swap the cash flows into NZD via foreign exchange swaps or cross-currency basis swaps depending on the term of funding.[6]
2. We use a dynamic weighting scheme, based on information in the Reserve Bank's liquidity survey, to incorporate banks' changing funding behaviour.
3. We broaden the range of deposit accounts to allow for diverging competitive pressures between on-call savings accounts and bonus savings products.

We calibrate our measure of new funding costs (NFC) to match two terms: a 3-month floating rate (figure 3) and 2-year fixed mortgage rate, since the vast majority of mortgages

[3] See Richardson et al (2009) for more details on core funding ratios.
[4] Figures are based on bank data provided in the Reserve Bank's Standard Statistical Returns (SSR).
[5] We expect that the impact of core funding requirements imposed by the Reserve Bank in April 2010 will be captured by our funding cost measures.
[6] This method produces measures of EUR and USD long-term wholesale costs that are comparable to a proxy based on Australian banks' average CDS spreads, as used by Wong (2012).

in New Zealand are either floating or fixed-rate contracts at the 2-year term or less.[7] The proportion of loans across these categories varies significantly over the cycle, with borrowers typically fixing at the lowest rate on offer.

Figure 3: Banks' new funding costs (3-month floating rate) and contributions



3. Has the pass-through of funding costs changed since the GFC?

To assess the contributions of the policy rate to the level of mortgage rates, we separate the NFC measures into a *policy rate* component and a *funding spread* component (see table A2 in the Appendix for details). We follow the approach used by Darracq Paries et al. (2014), extending standard pass-through models using the following specification:[8]

$$\Delta r_t = \sum_{k=0}^{K} \delta_k \Delta pr_{t-k} + \sum_{j=1}^{L} \lambda_k \Delta r_{t-j} + \sum_{j=1}^{M} \gamma_k \Delta fs_{t-j} + \alpha (r_{t-1} - \beta_1 pr_{t-1} - \beta_2 fs_{t-1} - c) + \varepsilon_t \qquad (1)$$

where r_t is the mortgage rate (floating or fixed), pr_t is either the OCR or 2-year implied overnight indexed swap (OIS) rate, and fs_t is the weighted average funding spread. The term in the brackets represents the long-run cointegrating relationship, β_1 represents the long-run pass-through of the policy rate to the relevant mortgage rate and β_2 the long-run

[7] The 2-year new funding cost proxy is equal to the 3-month new funding cost plus the cost of transforming the maturity to two years by paying the fixed leg of a 2-year interest rate swap and receiving the 3-month (floating) leg.
[8] Whereas Darracq Paries et al. (2014) focus on banks' reference rate as a proxy for cost of funding, we split this into policy rate and funding spread components.

pass-through of the funding spread. The speed of adjustment towards equilibrium α should be negative if there is convergence to the long-run relationship.

The model is estimated using weekly data over the period from 13 September 2002 to 3 March 2017. We split data into pre- and post-GFC periods (and exclude the period July 2008 to April 2009 during the GFC when there was a levels shift in rates) to assess how the coefficient estimates have changed over time. Specifically, we test for statistical differences in the β and α coefficients pre- and post-GFC (i.e. $\beta_{preGFC} = \beta_{postGFC}$ and $\alpha_{preGFC} = \alpha_{postGFC}$) and whether the long-run pass-through is complete (i.e. when changes in policy rates and funding spreads are proportional to changes in mortgage rates the β coefficients should equal one).

All rates are non-stationary over the relevant samples (Table A3 in Appendix) and rejection of the unit root null of the residual of the long-run relationship suggests that there is evidence of cointegration between the three variables in the benchmark model (Table 1).[9] Wald tests reject the null of equality in β coefficients across the pre- and post-GFC periods. The stable long-run relationship during the pre-GFC period breaks down after the GFC for floating mortgage rates, while the results based on monthly data in Appendix B (Table B1) suggest the magnitude of policy rate coefficient falls post-GFC and the fit of the model deteriorates. For 2-year rates, the estimate rises post-GFC.[10] For both floating and 2-year mortgage rates, the null hypothesis that long-run pass-through is complete is rejected by Wald tests.

We interpret these results as suggesting that, for the long-run relationships, floating mortgage rates have become less responsive to changes in the policy rate since the GFC, while the pass-through to 2-year rates has not changed dramatically. For the purposes of monetary policy, it is important to note that the portion of mortgages on floating mortgages (vs. fixed-rate mortgages) has declined to just 20 percent over recent years.

[9] Note evidence of cointegration for the post-GFC sample for the floating rate model is sensitive to the lag order used. Model selection criteria used for cointegration tests generally favoured the benchmark specification when using higher lag orders (i.e. an Engle-Granger z-statistic of -30.51 (p-value of 0.02) based on AIC criterion), while at low lag orders the existence of cointegration is rejected (as in Table 1).

[10] Some papers consider whether the zero lower bound may have affected the setting of bank lending rates as banks could become unable to pass on low rates to depositors because it would result in deposit loss (see for example Borio and Hoffmann 2017). In this paper, we control for the cost of new funding, which would tend to rise if the spread between deposit rates and the 3 month bank bill widens.

Table 1: Change in pass-through estimates post-GFC (weekly data)

	Floating mortgage rate				2-year mortgage rate			
	Pre-GFC		Post-GFC		Pre-GFC		Post-GFC	
Policy rate (β_1)	1.050	***	0.686	***	0.912	***	1.158	***
	(0.015)		(0.015)		(0.032)		(0.034)	
Funding spread (β_2)	0.238	***	-0.071	**	1.189	***	1.282	***
	(0.072)		(0.035)		(0.177)		(0.080)	
ECM (α)	-0.240	***	-0.025	***	-0.137	***	-0.079	***
	(0.033)		(0.010)		(0.025)		(0.0128)	
Adjusted R^2	0.99		0.75		0.93		0.94	
ADF: residual	-7.45	***	-2.82	*	-7.45	***	-2.82	**
p-value	0.000		0.06		0.000		0.000	
Engle-Granger Cointegration test	-96.43	***	-11.26		-26.41	**	-45.72	***
Wald: β_1=1	72.57	***	152.78	***	35.33	***	109.59	***
Wald: β_2=1	531.52	***	996.89	***	6.77	***	64.28	***
Wald: β_1=β_2	528.35	***	703.35	***	14.03	***	12.55	***
Wald: $\beta_{1,\ preGFC}=\beta_{1,postGFC}$			205.92	***			266.26	***
Wald: $\beta_{2,\ preGFC}=\beta_{2,postGFC}$			78.43	***			7.03	***
Wald: $\alpha_{preGFC}=\alpha_{postGFC}$			431.31	***			20.41	***

Note: Pre-GFC is September 2002 to June 2008, Post-GFC is May 2009 to March 2017. Newey West standard errors are reported in brackets and ADF and Engle-Granger z-statistic p-values are based on MacKinnon (1996) with a maximum lag length of one, α estimates are from the short adjustment equation and Wald test F-statistics reported.

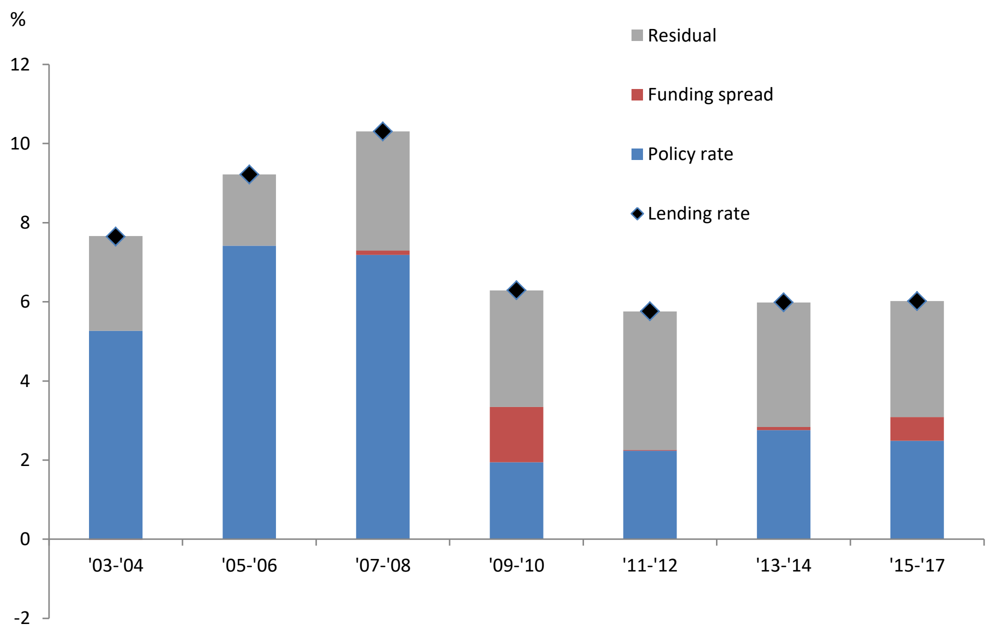
The negative post-GFC coefficient on the funding spread for floating rates appears to have been driven by the period from 2012 to mid-2014 when funding spread declined materially, while mortgage rates remained stable. The lack of pass-through from funding spreads could be caused by banks recouping margins after they were eroded during the GFC, although there are a number of other possible explanations. Banks could be taking their entire mortgage book into account when setting mortgage rates, rather than on a term-by-term basis. For example, banks could use fixed rate mortgages as a “loss-leader” to gain market share, while partially cross-subsidising them with higher floating rates. Consistent with increased competition for fixed-rate mortgages during this period, the proportion of borrowers on floating-rate loans fell sharply from above 60 percent to 30 percent. There were also regulatory changes around this time that required banks to hold more capital against home lending. This would have slightly increased the cost of funding beyond that shown in the funding spread. Despite this slightly odd result, Table B1 in the appendix shows that, when measured at a monthly frequency, the coefficient is positive (albeit still significantly different from one).

3.1 Contributions to mortgage rates

To illustrate that funding spreads have had an important influence on mortgage rates over specific periods since the GFC, we next look at the contributions of the policy rate and funding spreads to the level of mortgage rates. Figures 4 and 5 plot the combined short- and long-run contributions to the level of mortgage rates. We split data into seven sub-periods and run separate regressions to assess how these contributions have changed over time.[11]

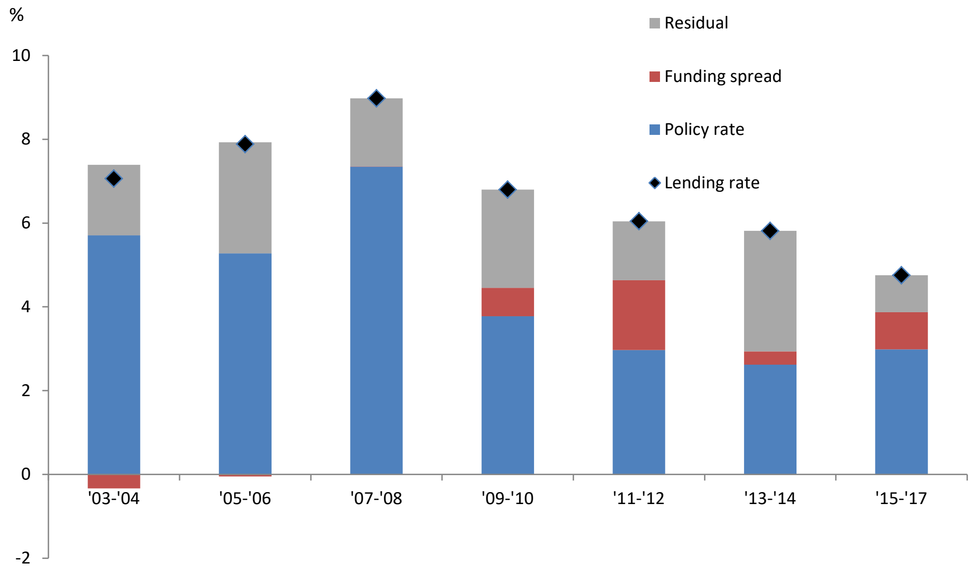
The figures suggest that lower policy rates following the GFC put downward pressure on mortgage rates (blue bars shrink). However, declines in the policy rate were offset by an increase in bank funding spreads from 2009 (red bars grow). Funding spreads have widened over recent years, preventing mortgage rates from falling, although funding spreads have not risen to the extent seen immediately following the GFC.[12]

Figure 4: Floating mortgage rates with contributions



[11] Contributions are calculated as the product of sub-sample averages and the estimated sub-sample coefficients.
[12] In the case of floating rates, the funding spread was volatile during the 2011-2012 sub-sample, while floating rates fell, and consequently floating rates have a very small coefficient estimate during for that subsample.

Figure 5: 2-year mortgage rates with contributions



There are other factors unrelated to policy and wider funding conditions that can influence mortgage rates, including asset quality, macro-economic risks, and bank margins over the cost of funding. In the benchmark specification, such factors will be captured in the residual (grey bars). The benchmark results suggest that the unexplained portion of floating mortgage rates has been relatively stable over recent years, while it has fallen in the case of fixed rates. In Appendix C, we test whether factors such as sovereign bond spreads, credit spreads, or asset quality can account for the observed spread between the OCR and mortgage rates. We do not find strong evidence that risk factors can account for the change in transmission to market rates.

Darracq Paries et al. (2014) suggest that there has also been some weakening in the pass-through from monetary policy to mortgage rates in the euro area, although they find that risk factors have played a material role in determining mortgage rates since the GFC.[13] Kapuściński and Stanisławska (2016) also find similar a result for Poland.[14]

[13] In a follow up article, the ECB (2017) suggests that standard pass-through models perform poorly at forecasting lending rate changes in the low rate environment of the post-GFC euro zone. On the other hand, Krippner et al (2015) use a FAVAR approach instead and find that the pass-through of conventional policy has not changes after the crisis. Using an ECM framework, Mandsberg et al. (2016) find that deposit rate pass-through has changed post-GFC in Denmark, but do not find any significant change in the relationship for lending rates.

[14] Also for Poland, Stanisławska (2014) looks at individual bank lending rates and does not find significant evidence that heterogeneity in interest rate pass-through across banks reflects individual bank risk characteristics. Borio and Gambacorta (2017) perform the same type of analysis on large international banks post-GFC and find weaker transmission of rate cuts to lending rates at low levels, and the results hold when controlling for bank risk characteristics.

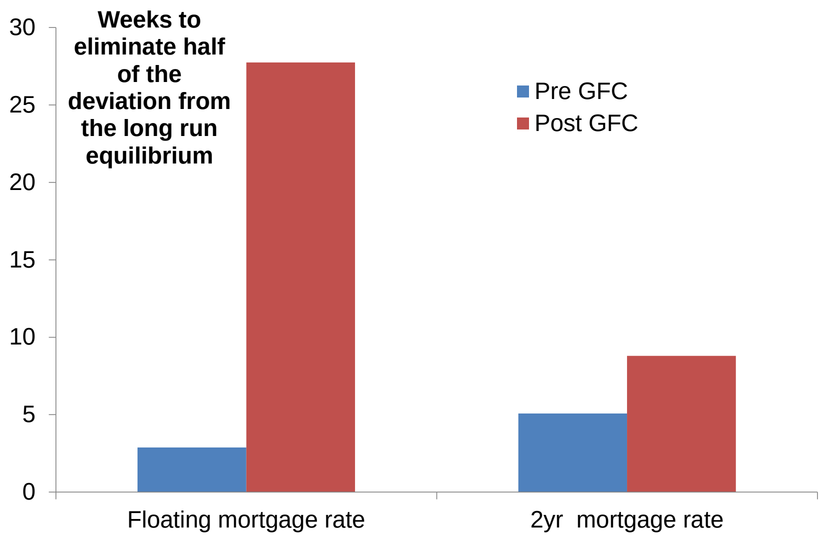
3.2 Change in the speed of funding cost pass-through post-GFC

The speed of pass-through has also slowed since the GFC. Table 1 shows that estimates of the adjustment coefficient α have become much less negative post-GFC, indicative of less reversion to the long-run equilibrium. For example, in the case of floating rates, the estimates suggest that 24 percent of any gap between 3-month funding costs and floating mortgage rates was eliminated each week pre-GFC, while that has declined to only 2.5 percent each week post-GFC. Wald tests reject the equality of α estimates pre- and post-GFC for both floating and fixed rates.

Figure 6 summarises the speed of adjustment to the long-run relationship in the benchmark specification for mortgage rates.[15] Post-GFC, the speed of adjustment to the long-run relationship slowed dramatically for floating rates but slowed more moderately in the case of fixed rates. Pre-GFC, the speed of adjustment for floating rates is estimated to have been slightly faster than that of the 2-year rate. However, the slowing in pass-through following the GFC means that floating rates are materially slower than that of the 2-year rate.[16] It is possible that slow pass-through could reflect a departure by banks from marginal-cost pricing.[17] But given the volatility in marginal funding costs, it may also reflect smoothing of advertised mortgage rates to protect market share.

[15] Half-life measures the number of periods taken to eliminate half of any deviation from the estimated long-run equilibrium. Figure B2 in Appendix B shows that estimates are similar when based on monthly data instead.
[16] The GFC period has been excluded from these sub-samples, as in Table 1.
[17] In the short term, this could reflect a range of factors, including weak competitive pressure for market share, menu costs or switching cost considerations (lock-in periods or break penalties). See Cassino (2012) for a brief discussion of the literature on the relationship between retail lending rates and bank funding costs.

Figure 6: Half-life estimates based on weekly data



Note: Pre-GFC is September 2002 to June 2008, Post-GFC is May 2009 to March 2017

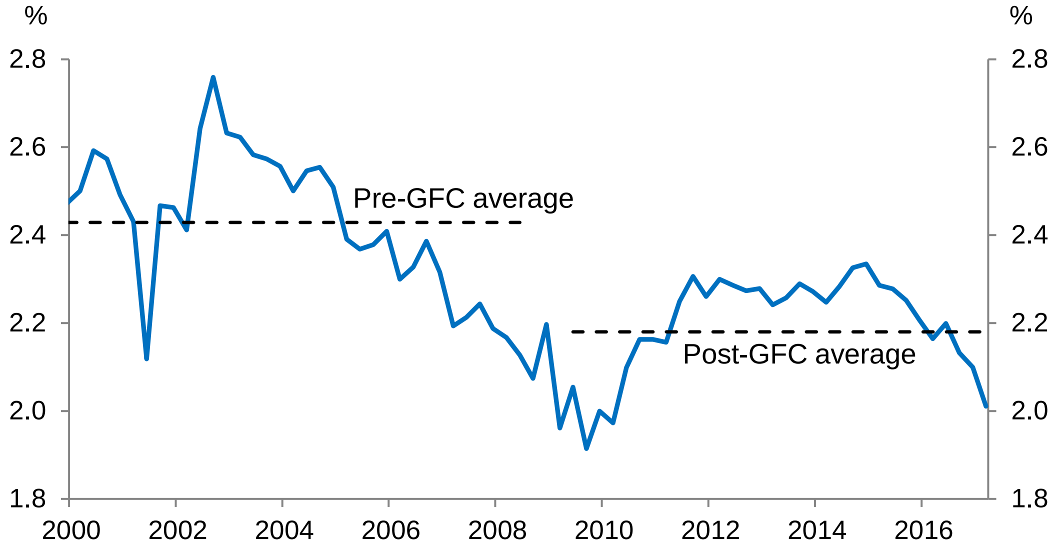
Together with the results in Table 1, this suggest that changes to the OCR and funding spreads have had a weaker long-run impact on floating mortgage rates post-GFC and it has taken longer for the full effects to be transmitted. For 2-year rates, the pass-through is still estimated to be closer to complete and the speed of adjustment has slowed only slightly.

3.3 Possible explanations for the change in bank behaviour

It is not obvious why banks' rate-setting behaviour should differ so dramatically for floating- and fixed-rate mortgage markets after the GFC. One possibility is that competition may differ across these markets. For instance, when a bank adjusts the interest rate it charges on a fixed-term mortgage, only new mortgages and those being reset at this term will be affected. In contrast, an adjustment to the floating mortgage rate will reset a bank's entire floating mortgage book within one month. This difference would mean that banks are more likely to compete for market share via fixed-rate mortgages compared to the market for floating-rate mortgages, where a decrease in rates would impact profitability more quickly.

If bank profitability is more sensitive to changes in floating mortgage rates, banks may also use them to slow a decline in interest rate margin. Figure 7 shows that declines in net interest margin (NIM) occurred during the GFC and the period since early-2015, which coincides with the rise in mortgage spreads from figures 1 and 2. These declines in NIM, along with the fact that NIMs are on average 25bps lower in the post-crisis period, could help to explain the change in banks' rate setting behaviour. Unfortunately, the low frequency of NIM data prohibits its use in the analysis in earlier sections.[18]

Figure 7: Retail banks' net interest margin (quarterly annualised)



Note: Net interest margin is net interest income relative to interest-earning assets. Source: Registered banks' Disclosure Statements.

Another possible explanation for our findings is asymmetries in pass-through, where banks pass on funding-cost increases more quickly than decreases (with the pre-GFC period dominated by rate hikes while the post-GFC period dominated by rate cuts).[19] It is also possible that banks only periodically adjust mortgage rates, waiting for small changes in funding to accumulate. If there are such asymmetries, the models of the type used in the other sections could be misspecified. To consider the possibility of asymmetries in the pass-through to mortgage rates, we use the approach of Enders and Siklos (2001) that permits assessment of the non-linear impacts of differences in the direction of funding costs on mortgage rates. However, we find no asymmetries in the adjustment of mortgage rates (see Appendix D for details).

4. Conclusion

We construct a comprehensive estimate of new funding costs, and empirically test for changes in the transmission from policy and funding spreads to retail mortgage rates.

[18] Net interest margin is quarterly and so cannot be added to our model as it relies on weekly data.
[20] Note that for the pre-GFC sample for the floating rate model, model selection criteria generally favoured the benchmark specification for low lag orders, but for longer lag orders the existence of cointegration is rejected, raising concerns over the appropriateness of the modelling framework for this sub-sample.

Our estimates suggest funding spreads are larger post-GFC and have had a larger impact on the level of fixed-rate mortgages than on floating rates as their variation increased.

We find that the relative contributions of the policy rate and funding spreads to mortgage rates have changed since the GFC. This change was especially notable for floating mortgage rates, where the previously stable long-run relationship has broken down as lending rates have become less sensitive to policy and funding spreads post-GFC.

We also find that the speed of adjustment of floating mortgage rates to policy and funding changes has slowed post-GFC, while we find that transmission to fixed rates has slowed only slightly. We do not find evidence of asymmetries in the adjustment process or that macroeconomic risk factors can explain the change in rate setting behaviour.

These results emphasise the role of wider funding costs, not just monetary policy, for how banks set their mortgage rates. This is particularly the case for fixed-rate mortgages, given increased variability in funding costs and the composition of bank funding.

Future analysis could try to incorporate additional explanatory factors, such as the impact of regulatory changes and bank competition.

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Appendix A

Table A1: New funding cost (NFC) components

Funding spread*	Additional currency hedging cost	Source
Domestic deposits		
Non-interest bearing over 3-month bank bill		
Bonus saving rate over 3-month bank bill		Interest.co.nz
On-call savings rate over 3-month bank bill		Interest.co.nz
Retail and corporate 6-month term deposit over 6-month bank bill		Interest.co.nz
Short-term wholesale		
USD 3-month corporate paper over 3-month USD LIBOR	Currency hedged via 3-month NZD FX swap	Bloomberg fair value index
EUR 3-month corporate paper over 3-month EUR LIBOR	Currency hedged via 3-month EUR and NZD FX swaps	Bloomberg fair value index
Long-term wholesale		
NZD 5-year AA financial corporate spread over 5-year NZD swap		Bloomberg fair value index
USD 5-year AA financial corporate spread over 5-year USD swap	Currency hedged via 5-year NZD cross-currency swap	Bloomberg fair value index
EUR 5-year AA financial corporate spread over 5-year EUR swap	Currency hedged via 5-year EUR and NZD cross-currency swaps	Bloomberg fair value index

Note: Funding spreads represent the cost of funding inclusive of interest rate hedging. We assume that banks swap all liabilities into a comparable term - in this case a 3-month term.

Table A2: Market reference rate, risk factors and spreads

Lending rate	Policy rate	Funding spread	Risk factors
Floating mortgage rate	Official cash rate	Weighted average cost of new funding (3-month) less overnight indexed swap rate (3-month)	Deposit to credit gap (NZ$bn) 10-year sovereign spread (NZ-US) Non-performing loan ratio (housing)
2-year mortgage rate	2-year OIS rate	Weighted average cost of new funding (2-year) less overnight indexed swap rate (2-year)	Deposit to credit gap (NZ$bn) 10-year sovereign spread (NZ-US) Non-performing loan ratio (housing)

Note: We use the OCR as our policy rate in the floating mortgage rate models because banks typically adjust floating rates after a change in policy, rather than in anticipation of a policy change. The 2-year OIS rate provides us with a measure of the average expected policy rate over the next two years.

Table A3: Unit root tests (levels)

	Floating mortgage		**2-year mortgage**	
	Pre-GFC	Post-GFC	Pre-GFC	Post-GFC
Mortgage rate	0.88	-1.60	-0.33	-1.18
p-value	1.00	0.48	0.92	0.68
Policy rate	-0.50	-0.32	-1.14	-0.89
p-value	0.89	0.92	0.70	0.79
Funding spread	-1.20	-1.93	-0.81	-2.24
p-value	0.68	0.32	0.81	0.19

Note: Pre-GFC is September 2002 to June 2008, Post-GFC is May 2009 to March 2017. MacKinnon (1996) p-values.

Appendix B

The benchmark results based on monthly data are reported in Table B1. The results support the benchmark specification used above, with the policy rate and funding spreads statistically significant on a consistent basis.[20] Over the long-run, an increase in the policy rate and funding spread are both reflected in higher floating and fixed mortgage rates, although the post-GFC impacts are larger for fixed rates than for floating.

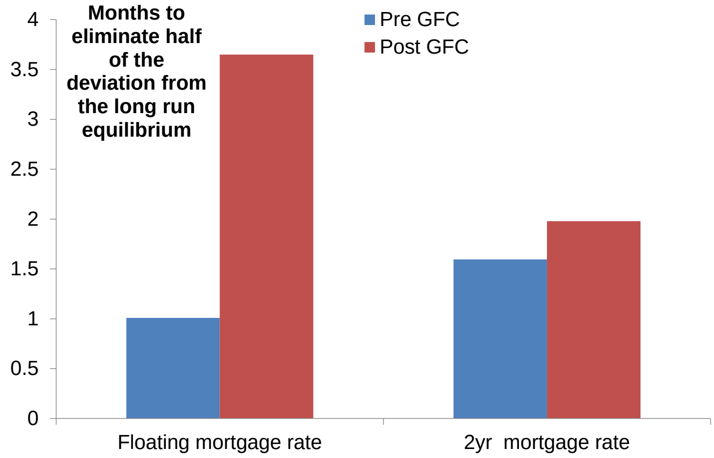
Table B1: Change in pass-through estimates post-GFC (monthly data)

	Floating mortgage rate				**2-year mortgage rate**			
	Pre-GFC		Post-GFC		Pre-GFC		Post-GFC	
Policy rate (β_1)	1.07	***	0.78	***	0.95	***	0.97	***
	(0.013)		(0.060)		(0.034)		(0.028)	
Funding spread (β_2)	0.21	**	0.18	**	0.96	***	0.77	***
	(0.102)		(0.082)		(0.227)		(0.091)	
ECM (α)	-0.69	***	-0.19	***	-0.43		-0.35	
	(0.167)		(0.053)		(0.108)		(0.068)	
Adjusted R^2	0.99		0.85		0.95		0.95	
ADF: residual	-6.72	***	-3.17	**	-4.98	***	-4.54	***
p-value	0.00		0.02		0.00		0.00	
Engle-Granger Cointegration test	-57.89	***	-35.68	***	-51.72	***	-34.12	***
Wald: β_1=1	38.76	***	34.88	***	3.72	*	1.14	
Wald: β_2=1	191.31	***	278.80	***	0.072		17.31	***
Wald: β_1=β_2	192.64	***	212.29	***	0.014		13.58	***
Wald: $\beta_{1,\ preGFC}=\beta_{1,postGFC}$			60.49	***			1.29	
Wald: $\beta_{2,\ preGFC}=\beta_{2,postGFC}$			0.32				12.28	***
Wald: $\alpha_{preGFC}=\alpha_{postGFC}$			85.46	***			1.62	

Note: Pre-GFC is September 2002 to June 2008, Post-GFC is May 2009 to March 2017. Newey West standard errors are reported and ADF and Engle-Granger z-statistic p-values are based on MacKinnon (1996) with a maximum lag length of one, α estimates are from the short adjustment equation and Wald test F-statistics reported.

[20] Note that for the pre-GFC sample for the floating rate model, model selection criteria generally favoured the benchmark specification for low lag orders, but for longer lag orders the existence of cointegration is rejected, raising concerns over the appropriateness of the modelling framework for this sub-sample.

Figure B2: Half-life estimates based on monthly data (benchmark model)



Note: Pre-GFC is September 2002 to June 2008, Post-GFC is May 2009 to January 2017.

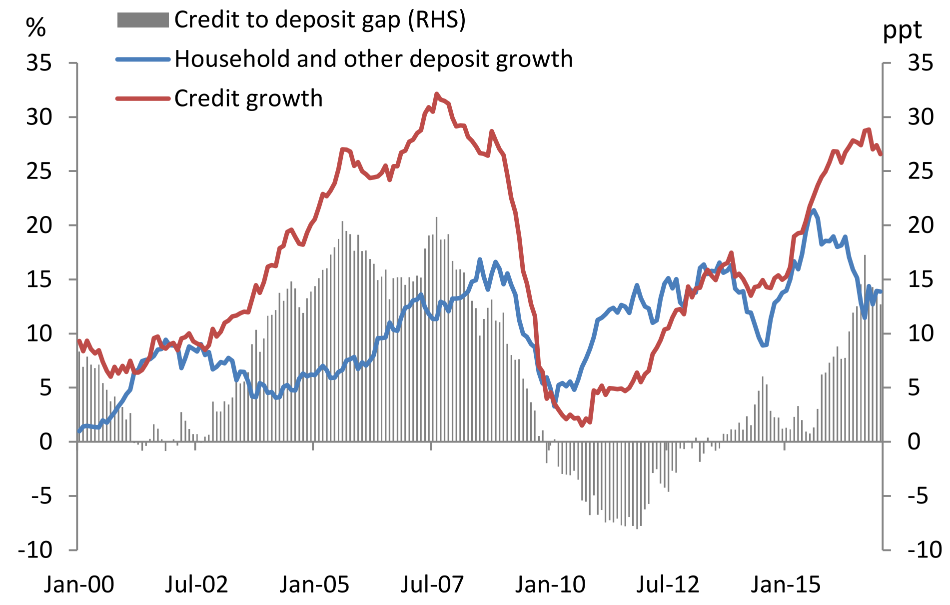
Appendix C: Can risk factors explain the observed residual between mortgage rates and funding costs?

We extend the benchmark model further to include a number of risk factors where data is available:[21]

- Rapid credit growth in excess of banks' deposit growth, defined here as *credit gap* (figure C1), could see banks raise their lending rates (above levels consistent with monetary policy and funding conditions) to reflect a preference to limit their dependence on offshore term wholesale markets.
- Rising New Zealand *sovereign risk* (New Zealand sovereign 10-year bond yield premium over the equivalent US yield) could see investors require a higher premium to invest in New Zealand banks, because the sovereign may be less able to support the banks if called upon.
- The proportion of *Non-performing loans* (for housing) is used to determine whether deteriorating asset quality causes banks to lift their lending rates to offset the impact of asset write-downs. Unfortunately, this series is only available for the post-GFC period, so models that include this explanatory variable are only estimated over a sub-sample beginning post-GFC.

[21] Data constrains prevent us from formally considering the impacts of Loan- or competition for mortgages.

Figure C1: Retail funding and credit growth (annual growth)



Each *risk factor* is added separately via the variable rf_t in equation 2. The expanded model is based on monthly data and therefore does not provide sufficient data points for sub-sample estimation.[22] The model specification is the same for all estimated models.

$$\Delta r_t = \sum_{k=0}^{2}\delta_k \Delta pr_{t-k} + \sum_{j=1}^{1}\lambda_k \Delta r_{t-j} + \sum_{j=1}^{1}\gamma_k \Delta fs_{t-j} + \sum_{j=1}^{1}\psi_k \Delta rf_{t-j} + \alpha(r_{t-1} - \beta_1 pr_{t-1} - \beta_2 fs_{t-1} - \beta_3 rf_{t-1} - c\ ) + \varepsilon_t \quad (2)$$

Tables B2 and B3 summarise the results of adding risk variables to the benchmark model. For the floating rate models, the null of no cointegration is always rejected and the modelling approach therefore not valid. In the case of fixed rates, while there is evidence of cointegration and that some risk variables are statistically significant, risk variable coefficients are generally extremely small and their significance sensitive to the sample period selected.[23] In the case of credit risk, for example, its coefficient is negative, contrary to expectation. There is, however, some evidence that the extent of non-performing loans can help explain the level of fixed mortgage rates since the GFC.

[22] The estimated contributions of the policy rate and funding spread are similar, whether measured using weekly or monthly data.
[23] The results of cointegration tests are not sensitive to lag selection.

Table C2: Long-run estimates by explanatory factor (floating mortgage rate, post-GFC)

Policy rate	0.907	***	0.754	***	0.763	***	0.840	***
	(0.074)		(0.053)		(0.048)		(0.040)	
Funding spread	0.363	***	0.136	**	0.139		0.215	***
	(0.135)		(0.060)		(0.088)		(0.073)	
Credit gap	0.013	**					0.020	***
	(0.135)						(0.002)	
Sovereign spread			0.031				0.129	**
			(0.045)				(0.049)	
Housing NPLs					0.033		0.068	
					(0.063)		(0.086)	
ECM (α)	-0.326	***	-0.208	***	-0.212	***	-0.324	***
	(0.064)		(0.058)		(0.057)		(0.073)	
Adjusted R2	0.88		0.85		0.85		0.91	
ADF: residual	-3.18	**	-3.13	**	-3.16	**	-3.29	**
p-value	0.02		0.03		0.03		0.02	
Engle-Granger Cointegration test	-18.38		-15.06		-15.09		-22.13	

Note: Post-GFC is May 2009 to January 2017. Newey West standard errors are reported and ADF and Engle-Granger z-statistic p-values are based on MacKinnon (1996) with a maximum lag length of one, α estimates are from the short adjustment equation and Wald test F-statistics reported.

Table C3: Long run estimates by explanatory factor (2-year mortgage rate, post-GFC)

Policy rate	0.931	***	0.932	***	0.833	***	0.915	***
	(0.039)		(0.061)		(0.054)		(0.068)	
Funding spread	0.687	***	0.701	**	0.392	***	0.583	***
	(0.085)		(0.105)		(0.141)		(0.200)	
Credit gap	-0.010	**					-0.010	
	(0.005)						(0.008)	
Sovereign spread			0.074				-0.105	**
			(0.086)				(0.084)	
Housing NPLs					0.400	***	0.216	
					(0.138)		(0.265)	
ECM (α)	-0.282		-0.307		-0.281		-0.293	
	(0.069)		(0.069)		(0.069)		(0.265)	
Adjusted R2	0.95		0.95		0.95		0.95	
ADF: residual	-6.05	***	-4.48	***	-4.43	***	-4.86	**
p-value	0.00		0.00		0.00		0.00	
Engle-Granger Cointegration test	-36.71	***	-33.28	**	-33.03	**	-38.36	*

Note: Post-GFC is May 2009 to January 2017. Newey West standard errors are reported and ADF and Engle-Granger z-statistic p-values are based on MacKinnon (1996) with a maximum lag length of one, α estimates are from the short adjustment equation and Wald test F-statistics reported.

Appendix D

Based on the approach of Enders and Siklos (2001), we use the residuals u_t from the long-run relationship between mortgage rates, the policy rate and the funding spread (i.e. the contents of the brackets in equation 1) in the following equation:

$$\Delta u_t = I_t \rho_1 u_{t-1} + (1 - I_t)\rho_2 u_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta u_{t-1} + \varepsilon_t \qquad (2)$$

Where I_t is an indicator variable that, depending on a threshold (τ), takes one of the following values:

$$T_t = \begin{cases} 1 & if \quad u_{t-1} \geq \tau \\ 0 & if \quad u_{t-1} < \tau \end{cases} \qquad (3)$$

$$M_t = \begin{cases} 1 & if \quad \Delta u_{t-1} \geq \tau \\ 0 & if \quad \Delta u_{t-1} < \tau \end{cases} \qquad (4)$$

depending on whether a threshold autoregressive (TAR) model or a momentum threshold autoregressive (MTAR) model is estimated. The former captures deviations from the estimated equilibrium level, while the latter captures the possibility of momentum in a specific direction (i.e whether deviations of mortgage rates from their long run equilibrium are rising or falling). The threshold value can either be set or estimated. If Δu_{t-1} is above this threshold, the adjustment is given by $\rho_1 u_{t-1}$, or $\rho_2 u_{t-1}$ if Δu_{t-1} is below this threshold. There is evidence of asymmetric cointegration if the null hypothesis that $\rho_1 = \rho_2 = 0$ can be rejected. The adjustment is asymmetric if the null hypothesis that $\rho_1 = \rho_2$ is rejected. In the case of TAR models, when $0 > \rho_1 > \rho_2 > -1$, positive changes in u_t will tend to be more persistent than equally-sized negative shocks. In the case of MTAR models, when $|\rho_1| < |\rho_2|$ higher mortgage rate increases are persistent, while decreases dissipate more quickly. While TAR models consider whether the size of the deviation from equilibrium matters for the mortgage rate reaction to positive or negative shocks, MTAR models test whether the adjustment speed of mortgage rates is faster for positive or negative shocks.

Table 3 shows that the joint F test rejects the null of no cointegration for all sub-periods for 2 year fixed mortgage rates, while for floating rates, there is only evidence of cointegration for the pre-GFC period. Moving on to testing for asymmetric adjustment, the null of symmetric impacts is not rejected by the equality test in most models at conventional levels of statistical significance. The only exceptions are the MTAR models of floating rates for the pre-GFC period. For these models, the necessary condition for convergence (i.e. that $\rho_1 < 0, \rho_2 < 0$) is not met, however.[24] The results imply that there are no asymmetries in the adjustment of mortgage rates.[25]

Table 3: Estimates of TAR and MTAR co-integration (weekly data)

Floating rates

	TAR				TAR				MTAR				MTAR			
	Pre-GFC		Post-GFC		Pre-GFC		Post-GFC		Pre-GFC		Post-GFC		Pre-GFC		Post-GFC	
ρ_1	-0.273		-0.019		-0.320		-0.016		-0.390		-0.039		-0.390		-0.050	
	(0.079)		(0.012)		(0.083)		(0.010)		(0.068)		(0.015)		(0.068)		(0.018)	
ρ_2	-0.249		-0.023		-0.218		-0.044		0.028		-0.006		0.028		-0.007	
	(0.076)		(0.017)		(0.074)		(0.026)		(0.087)		(0.013)		(0.087)		(0.012)	
Lags	6		3		4		3		6		3		6		3	
τ (threshold value)	0		0		0.008		-0.028		0		0		-0.001		0.000	
F-joint (ϕ)	7.961	**	1.987		8.637	*	2.470		22.699	***	3.215		19.896	***	3.870	
	[7.098]		[9.569]		[7.131]		[10.718]		[11.732]		[10.025]		[11.883]		[12.294]	
F-equal (ρ_1=ρ_2)	0.071		0.041		1.352		0.998		19.855	***	2.474		22.699	***	3.771	
	[2.358]		[4.179]		[9.472]		[9.055]		[11.969]		[6.747]		[12.112]		[11.700]	

2 Year fixed rates

	TAR				TAR				MTAR				MTAR			
	Pre-GFC		Post-GFC		Pre-GFC		Post-GFC		Pre-GFC		Post-GFC		Pre-GFC		Post-GFC	
ρ_1	-0.161		-0.118		-0.202		-0.129		-0.176		-0.112		-0.215		-0.122	
	(0.046)		(0.035)		(0.052)		(0.033)		(0.047)		(0.033)		(0.040)		(0.0265)	
ρ_2	-0.173		-0.108		-0.146		-0.097		-0.159		-0.111		-0.071		-0.074	
	(0.046)		(0.031)		(0.042)		(0.032)		(0.045)		(0.032)		(0.055)		(0.050)	
Lags	4		2		5		2		4		2		4		2	
τ (threshold value)	0		0		0.033		-0.025		0		0		-0.005		-0.015	
F-joint (ϕ)	11.356	***	10.888	***	11.760	***	11.132	***	11.379	***	10.865	***	13.999	***	11.257	***
	[9.785]		[9.567]		[10.427]		[10.427]		[10.427]		[10.080]		[12.190]		[12.001]	
F-equal (ρ_1=ρ_2)	0.034		0.047		0.784		0.509		0.077		0.001		4.941		0.745	
	[10.427]		[4.415]		[10.427]		[8.914]		[6.641]		[6.670]		[11.717]		[11.888]	

Standard errors are in parenthesis. ***, **, * represent statistical significance at the 1%, 5% and 10% significance levels respectively based on critical values (square brackets) based on 10000 Monte Carlo simulations. Lag selection is based on AIC. Following Enders and Siklos (2001), all rates are expressed in logarithms.

[24] As recommended by Enders and Siklos (2001), when either ρ_1 or ρ_2 are positive, *t*-Max tests fail to reject the null no cointegration. The t-Max statistics are -0.365 and 0.31619 for columns 5 and 7 for the floating rate results, with critical values at 1 percent significance of -2.675 and -2.728, respectively. The negative coefficients on ρ imply that when there is a shock there is convergence to the long-run equilibrium. In the case of the first TAR model for floating rates, the estimated speed of adjustment is 27.3 percent per week in the case of positive deviations, compared to 24.9 percent per week for negative deviations.

[25] These results contradict those of an earlier study for New Zealand by Liu, Margaritis and Tourani-Rad (2008), who find no evidence of asymmetries in lending rate adjustment for a sample between 1989 and 2009.