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Bank competition, interest rate pass-through and the impact of the global financial crisis: evidence from Hong Kong and Macao

Jingya Li
BNU-HKBU United International College, Zhuhai, China
Zongyuan Li
Dalian Maritime University, Dalian, China, and
Ming-Hua Liu
University of Macau, Macao, China

Abstract

Purpose – The authors examine the interest rate pass-through in Hong Kong (HK) and Macao both in the long term and short term.
Design/methodology/approach – The authors use time series methodology, i.e. unit root, cointegration and error correction models.
Findings – The results show that in the post-global financial crisis (GFC) period, both the long-run and short-run interest rate pass-through from policy rates to prime rates have disappeared in Macao and are weakened significantly in Hong Kong. The long-term relationship between deposit rates and policy rates no longer exists in either market while the short-term relationship has been reduced significantly.
Research limitations/implications – The results indicate that the effectiveness of monetary policy in HK and Macao has been seriously undermined in the post-GFC period. New tools are needed in both regions.
Practical implications – Monetary policy transmission via bank interest rates in both HK and Macao are no longer effective after the outbreak of the GFC.
Social implications – Effort to stimulate the economy and/or control inflation will be hampered.
Originality/value – To the best of the authors' knowledge, this is the first study to examine the impact of the GFC on the effectiveness of monetary policy transmission in HK and Macao.

Keywords Error correction model, Monetary policy transmission, Hong Kong banks, Interest rate pass-through, Macao banks

Paper type Research paper

1. Introduction

The existence of the transmission of monetary policy through commercial banks' interest rates has been well-documented in the literature (Chong *et al.*, 2006; Cottarelli and Kourelis, 1994; De Bondt, 2005; Sander and Kleimeier, 2004; Van Leuvensteijn *et al.*, 2013). An increase (decrease) in the policy rate lifts up (brings down) the borrowing cost, which subsequently increases (reduces) bank lending rates and boosts (reduces) the demand of bank loans (Gambacorta, 2008). Similarly, since bank deposits and government securities are both safe assets and close substitutes, an increase in the policy rate directly affects the yield of government securities, and puts upward pressure on deposit rates (Egert *et al.*, 2007), and vice versa.

Interest rate pass-through is of particular concern in countries and regions where capital markets are not well-developed and companies rely on bank credit for financing, e.g. in the Euro zone. It is well-known that monetary policy operates with a time lag. The pass-through of monetary policy rates to lending and deposit rates is not immediate. Furthermore, interest

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rate pass-through may be asymmetric (i.e. lending (deposit) rates are fast (slow) to go up but slow (fast) to come down), depending on the competitiveness of the banking industry.

There are several reasons for this. First, banks are able to exploit extra economic rents, as they have private information about their long-term customers (e.g. Chemmanur and Fulghieri, 1994; Petersen and Rajan, 1994). This means that even if banks do not cut lending rates in response to a sudden decline in the policy rates, their customers are less likely to switch to other banks because of the substantial searching cost and matching frictions. Second, Stiglitz and Weiss (1981) and Jaffee and Russell (1976) argue that banks offer relatively stable (rigid) lending rates to shield their consumers from interest rate fluctuations. Finally, Hannan and Berger (1991) note that the rigidity of deposit rates is negatively correlated with market competition and the customer base. Kopecky and Van Hoose (2012) also show that greater competition in commercial markets leads to speedy interest pass-through by enhancing contemporaneous effects and reducing the lagged effect.

More recent studies focused on the impact of GFC on the interest rate pass-through (Hansen and Welz, 2011; Hristov *et al.*, 2014; Karagiannis *et al.*, 2010). The results show that interest rate pass-through has been impaired since the GFC as a result of changes in the banking industry as well as the economy.

Theoretical studies have shown that the introduction of the Basel III framework, introduced by the Bank for International Settlements after the outbreak of the GFC, could permanently alter the influence of monetary policy on interest rates (Bech and Keister, 2017) and compromise the efficacy of monetary policy (Rubio and Carrasco-Gallego, 2016). The tightened capital and liquidity requirements have changed lending and financing behaviors among banks. For example, banks have substituted short-term wholesale funds with more stable core deposits (Banerjee and Mio, 2018) and increased the share of high-quality liquid assets (King, 2013) to meet the post-GFC regulatory requirements.

Moreover, the prolonged low interest rate environment in the last decade further complicates the transmission mechanism of monetary policy (Altavilla *et al.*, 2021; Wright, 2012). On the one hand, the low interest rate environment weakens the interest rate pass-through from policy rates to deposit rates because retail deposit rates have a zero lower bound and cannot be negative even when policy rates become negative, e.g. in the Euro zone, Japan and some other countries [1]. If banks cannot reduce their deposit rates further, any cuts in lending rates would reduce the net interest margin, the bread and butter of commercial banking, and erode banks' profitability and equity [2]. Banks become less willing to lend. As a result, interest rate pass-through will become less complete as the connection between policy rates and lending rates loosens (Ulate, 2021).

Most studies on interest rate pass-through examined the relationship between lending rates and policy rates or money market rates, but ignored deposit rates. However, the analysis of pass-through to deposit rates is essential in order to understand the pass-through to lending rates. Banks tend to not adjust their lending rates if their net interest rate margin is not at risk. When the cost of funds increases, banks will pass the extra funding cost to borrowers, and vice versa, in a competitive banking industry.

In the literature, it is also well documented that banks became more conservative in their lending after the outbreak of GFC as they tightened lending standards and reduced financial leverage by increasing regulatory capital (Hristov *et al.*, 2014; Liu *et al.*, 2016; RBA, 2010, 2011).

Combining the arguments above, we therefore expect that competition and interest rate pass-through will be reduced in the aftermath of the GFC. However, bank competition tends to follow the business cycle. Bank lending tends to be pro-cyclical. When the economy is booming, income will rise, and collateral value will increase. Banks tend to compete more aggressively for loans and other businesses. Therefore, the degree of reduction in interest rate pass-through in the post-GFC period is an empirical question.

In this study, we investigate the impact of GFC on the interest rate pass-through from policy rates to bank administered rates in Hong Kong (HK) and Macao. Specifically, we examine (1) the degree of interest rate pass-through in the long term and whether there has been a significant change during the post-GFC sub-period; (2) the short-term dynamics between lending rates and policy rates and between deposit rates and policy rates. We further analyze if there is a significant change in the short-term pass-through after the outbreak of the GFC and (3) the asymmetric adjustment speed and/or asymmetric short-term pass-through.

Despite the rich literature related to the impact of the post-GFC changes on interest rate pass-through (for such a review, see Gregor *et al.*, 2021), most previous studies focus on a handful of advanced economies, such as US and European Union countries (e.g. Hristov *et al.*, 2014; Karagiannis *et al.*, 2010; Kleimeier and Sander, 2006). These studies are subject to the endogeneity problem that both administered rates (i.e. lending and borrowing rates) and monetary policy rates are influenced by local economic conditions. On the contrary, both HK and Macao have adopted the currency-board system since the early 1980s; thus, their policy rates are immune from domestic economic conditions. This mitigates the above-mentioned concern. Furthermore, this study is also an extreme case of spillovers from the US monetary policy, which provides policy implications for other small and open economies. Furthermore, neither HK nor Macao has adopted negative interest rates in their monetary policy, which rules out the possible explanation that the negative interest rate policy causes changes in interest rate pass-through.

Moreover, the difference in market structure between HK and Macao banking industries provides us with a quasi-natural experiment about the influence of market competition on interest rate pass-through. The GFC had little impact on the banking structure in both markets. However, in other countries, the banking structure may have gone through significant changes. For example, the vast majority of US banks that failed during the GFC, such as the Washington Mutual Bank, have been sold to other healthy banks (Wheelock, 2011). The post-GFC regulations have further facilitated mergers and acquisitions among just-below-regulatory-threshold US banks (Bindal *et al.*, 2020) and other small banks (Leledakis and Pyrgiotakis, forthcoming). Therefore, it would be difficult to separate those impacts from the impact of GFC.

By analyzing HK and Macao interest rates, we are effectively using city-level data, which further contributes to the existing literature. Most previous studies (e.g. Hristov *et al.*, 2014; Karagiannis *et al.*, 2010) use national level data which ignore the regional variations in bank competition and, therefore, interest rate pass-through. For example, competition may be higher in cities than in rural areas. It may also be higher in big cities in coastal areas than in small towns in inland areas.

Our study is also timely and interesting in light of the growing importance of the Greater Bay Area of China and increasing integration of HK and Macao with mainland China, in general, and Guangdong province, in particular. To deepen the economic cooperation in the region, the central government recently announced that Macao and Guangdong province would jointly manage and develop the Hengqin Cooperation Zone and that HK and the Guangdong province would jointly manage and develop the Qianshan Cooperation Zone. Therefore, an understanding of the competitiveness of the banking system and monetary policy transmission in both markets would be necessary and beneficial.

Our results show that both the long-run and short-run interest rate pass-through in HK and Macao has been seriously impaired in the post-GFC period. In particular, both the long-run and short-run interest rate pass-through from policy rates to prime rates have disappeared in Macao, and they are also weakened in the relatively competitive HK market. Similarly, the long-term relationship between deposit rates and policy rates no longer exists in both markets, and the extent of the short-term relationship has been reduced significantly. Additionally, after the GFC, both HK and Macao banks charge higher markups for lending rates but lower markdowns for deposit rates. The empirical results imply that the change in

banking regulations and bank behavior in the post-GFC period has impaired the efficacy of monetary policy, especially in the lending market.

The rest of the paper is organized as follows. Section 2 reviews the exchange rate systems and institutional background in HK and Macao. Sections 3 describes the methodology. Section 4 reports the data and analyzes the empirical results. Section 5 concludes.

2. Background review

2.1 Currency board system and policy rate

Both HK and Macao adopt the currency board system. The currency board in HK has evolved slightly over time.

In October 1983, HK established the Linked Exchange Rate System, which effectively pegged the HK dollar (HKD) to the US dollar (USD) at the rate of HKD7.8 per USD (Hong Kong Monetary Authority, 2013). Three note-issuing banks—namely the Hong Kong and Shanghai Banking Corporation Limited (since 1865), the Bank of China (HK) Limited (since 1994) and the Standard Charted Bank Limited (since 1862)—obtained authorization from the HK government to issue or redeem banknotes as currency notes in HK. To issue new HKD banknotes, note-issuing banks need to deposit the equivalent amount of USD to the Exchange Fund at a specific rate of HKD7.80 per USD. As all HKD notes issued are fully backed by foreign exchange reserves held by the Exchange Fund, the HK government could commit to converting HKD into USD without intervening in the foreign exchange market.

In September 1998, to strengthen the Linked Exchange Rate System, the Hong Kong Monetary Authority (HKMA) introduced a clear weak-side convertibility undertaking (CU) at the rate of 7.75 HKD per USD (Genberg and Hui, 2011). Under this weak-side CU, the HKMA committed to purchasing HKD at the rate of 7.75 HKD per USD upon request by licensed banks. The weak-side CU gradually shifted from 7.75 to 7.80 HKD per USD from 1990 to 2000.

In May 2005, the HKMA finalized "Three Refinements," which further reduced uncertainties and increased the transparency of the Linked Exchange Rate System. The three refinements are as follows: (1) introducing a strong-side CU at the rate of 7.75 HKD per USD; (2) moving the weak-side CU from 7.80 to 7.85 HKD per USD and (3) creating a convertibility zone between 7.75 and 7.85 HKD per USD and allowing the HKMA to conduct market operations within this zone (Yam, 2005).

In Macao, the government has adopted a similar currency board system since 1989. Macao pataca (MOP) is the legal tender in Macao and has been pegged to HKD at a fixed rate of 1.03 MOP per HKD. As in the case of HK, all MOP notes issued are fully backed by the equivalent amount of foreign reserves. The note-issuing banks in Macao are Banco Nacional Ultramarino (since 1906) and Bank of China (Macau Branch) (since 1995). The Monetary Authority of Macao has the responsibility to manage the foreign exchange reserve fund (Scott, 1997).

By adopting the currency board system, the HK and Macao governments gave up their independent monetary policy (Schwartz, 1993). As mentioned previously, the HKD is pegged to the USD, and the MOP is pegged directly to the HKD and indirectly to the USD. Therefore, both policy rates in HK and Macao closely track those in the USA.

Table 1 shows that the correlation coefficients between the HK policy rates (HKD discount window base rate) and the US policy rates (effectively, the Federal Fund rate) is 0.981 and that

Table 1. Correlation matrix between policy rates (December 1999–June 2021)

	HK policy rate	MO policy rate	US policy rate
HK policy rate	1		
MO policy rate	0.999	1	
US policy rate	0.981	0.982	1

between the Macao policy rates and the US policy rates is 0.982. Policy rates in HK and Macao are, therefore, not necessarily related to their local economic conditions. For example, between 2015 and 2016, the Macao government continuously raised policy rates because of rising Federal Fund rates, while the local economy experienced a contraction (see Figure 1).

2.2 Institutional background

As an international financial center, HK has a large and open banking industry. HK has maintained a three-tier system of authorized (deposit-taking) institutions, which includes 152 licensed banks, 18 restricted license banks and 16 deposit-taking companies by the end of 2018 (Hong Kong Monetary Authority, 2018). The size of the banking industry (measured as the total assets of all authorized deposit-taking institutions) was more than eight times HK's GDP in 2018.

To strengthen HK's status as an international financial center, the HK government lifted the "three-building" restriction on the foreign banks' size in November 2001 and relaxed restrictions on the foreign banks' entry barrier in May 2002 (Hall *et al.*, 2012). As a result, foreign banks have a strong presence in HK (International Monetary Fund, 2014). Among 152 fully licensed banks, 130 of them are incorporated outside HK and 14 of them are foreign subsidiaries (Hong Kong Monetary Authority, 2018). Additionally, HKMA is designated as the lead resolution authority for 25 out of 29 global systemically important banks (G-SIBs) identified by the Financial Stability Board in December 2018.

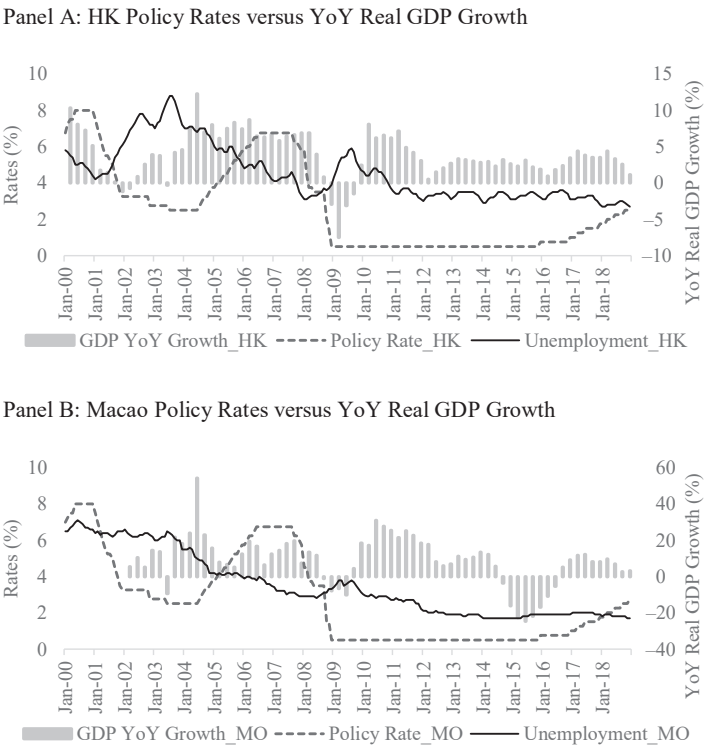

Figure 1.
Policy rates and year-on-year (YoY) real GDP growth

Regarding interest rate restrictions, the HKMA gradually removed deposit rate caps between 1994 and 2001. After this interest rate liberalization, the spreads between bank deposit rates and the corresponding interbank rates decreased by a third (Chong, 2010). Benchmark interbank rates, i.e. Hong Kong Interbank Offered Rate (HIBOR), are released by the Hong Kong Association of Banks each trading day at 11:15 a.m., based on designated banks' quotations. Individual banks could freely set their individual best lending rates (prime rates), but their best lending rates are commonly tied to HIBOR (Hong Kong Monetary Authority, 1994a).

Compared with the banking industry in HK, the Macao banking industry is much smaller and more concentrated. As at the end of 2018, there were 29 banks in Macao, 18 of which were branches of foreign banks, and the remaining 11 were locally incorporated banks. Together, they operated 213 banking branches and employed 6,456 people, or about 1% of Macao's 670,000 population. With 1,700 automatic teller machines (ATMs), Macao has the highest ATM density in the world. This is because of the cash nature of the gaming business that dominates Macao's economy. Annual gaming revenue in Macao was more than six times that of Las Vegas.

Total bank assets were about four times that of the local gross domestic product (GDP) in 2018. As at the end of 2018, the five largest banks, namely, the Bank of China (Macau Branch), Industrial and Commercial Bank of China (Macau) Limited, Luso International Banking Limited, Tai Fung Bank Limited and Banco Nacional Ultramarino, together accounted for 86.88% of total deposits [3].

In addition, as the Bank of China controls 50.35% of shares of Tai Fung Bank Limited, it enables the Banks of China to hold around 40% of market shares in deposits through the Bank of China (Macau Branch) and Tai Fung Bank Limited. The Industrial and Commercial Bank of China (Macau) controls about another 10%. According to IMF (2011), Macao's banking industry is moderately concentrated with the Herfindahl-Hirschman Index (HHI) of 1314, based on bank assets, in 2008.

The Macao government has no explicit interest rate restrictions. The Macao Association of Banks provides the reference rate for saving deposits denominated in MOP and HKD (Macao Association of Banks, 2019), but individual banks still have the discretion to choose their own deposit rates and prime lending rates (China Briefing, 2004, p. 563). Even though the legal tender of Macao is MOP, HKD is also acceptable in Macao. Residents could withdraw both HKD and MOP notes through local ATMs. According to Autoridade Monetária de Macau (AMCM), in December 2018, HKD consisted of 42.33% of the M1 money supply and MOP consisted of 56.01% of the M1 money supply.

As there are no capital markets in Macao, banks' balance sheets are quite simple. They mainly take deposits, make loans and operate the payment system. Stock brokerage service is provided to investors who trade shares that are listed on the Hong Kong Exchange. Currency transactions are carried out on behalf of customers. Propriety trading by the banks themselves is very limited (IMF, 2011).

Table 2 shows that Macao banks have higher financial leverage than HK banks, especially after the GFC. The average leverage ratio, i.e. total assets to equity, for HK banks has decreased from 15.42 in 2009 to 8 in 2018, while that for Macao banks is always above 20. Furthermore, while the average loan-to-deposit ratio for HK banks is relatively stable over time, that for Macao banks has more than doubled from 48.1% in 2009 to 90.04% in 2018. Regarding profitability, although HK banks, on average, have higher return on assets (ROA) than Macao banks, HK banks have lower return on equity (ROE) than Macao Banks in 14 out of 19 years between 2000 and 2018 due to the higher equity multiplier or financial leverage of Macao banks. Finally, HK banks have had higher nonperforming loan ratio and a more volatile net interest margin than Macao banks since 2007. The above results further imply that HK banks tend to take more credit risk than Macao banks.

Year	ROA (%)	ROE (%)	Leverage	Equity to assets ratio (%)	Nonperforming loan ratio (%)	Net interest margin (%)	Loan to deposit ratio (%)
Panel A: Financial performance of HK banks							
2000	0.49	4.42	9.02	11.09	5.37	1.88	71.54
2001	0.34	5.72	16.82	5.94	4.09	1.60	68.58
2002	1.03	3.14	3.05	32.80	3.95	4.66	66.66
2003	0.96	2.11	2.20	45.50	3.16	2.30	62.45
2004	2.63	52.81	20.08	4.98	1.62	3.19	58.84
2005	1.40	26.23	18.74	5.34	1.40	1.23	58.57
2006	1.63	24.18	14.83	6.74	1.10	1.45	55.19
2007	1.57	21.88	13.94	7.18	0.80	2.65	49.43
2008	1.18	19.34	16.39	6.10	1.23	2.69	47.97
2009	1.18	18.20	15.42	6.48	1.58	2.35	49.08
2010	1.24	17.38	14.02	7.13	0.83	2.20	54.58
2011	1.16	16.66	14.36	6.96	0.69	2.07	61.75
2012	1.16	16.64	14.34	6.97	0.60	0.97	62.85
2013	1.34	17.40	12.99	7.70	0.54	0.80	63.32
2014	0.98	11.16	11.39	8.78	0.51	0.72	66.12
2015	2.26	24.67	10.92	9.16	0.73	2.87	63.39
2016	1.22	13.15	10.78	9.28	0.85	1.46	58.03
2017	1.35	14.25	10.56	9.47	0.67	1.55	60.59
2018	1.23	10	8.00	12.50	0.55	1.67	74.26
Panel B: Financial performance of Macao banks							
2000	0.53	15	27.3	3.7	22	2.80	48.50
2001	0.41	12	29.0	3.4	20.2	2.46	42.78
2002	0.60	12	20.8	4.8	16.67	2.33	36.03
2003	0.62	13	20.2	5.0	11.6	2.25	31.22
2004	0.82	14	17.3	5.8	3.5	2.33	29.38
2005	1.40	25	17.9	5.6	1.8	1.98	30.87
2006	1.48	27	18.4	5.4	1.1	2.20	30.70
2007	1.22	25	20.4	4.9	0.6	2.13	34.07
2008	0.93	19	20.8	4.8	1.1	2.15	43.44
2009	0.82	18	22.2	4.5	0.6	1.50	48.10
2010	0.72	16	22.5	4.4	0.4	1.36	51.08
2011	0.77	18	23.1	4.3	0.4	1.31	55.57
2012	0.79	19	24.4	4.1	0.2	1.04	55.36
2013	0.86	21	25.1	4.0	0.09	1.55	56.97
2014	0.94	26	28.1	3.6	0.12	1.57	65.50
2015	0.96	25	25.8	3.9	0.12	1.84	77.62
2016	1.02	22	21.7	4.6	0.2	1.35	82.94
2017	0.97	21	21.9	4.6	0.2	1.40	80.50
2018	0.90	19	21.2	4.7	0.2	1.20	90.04

Table 2.
Financial performance of HK and Macao banks

Source(s): HKMA annual reports, AMCM annual report and the World Bank (https://data.worldbank.org/indicator/FB.BNK.CAPA.ZS) and the Global Economy database (https://www.theglobaleconomy.com/Hong-Kong/bank_credit_to_deposits

3. Methodology

In this paper, we examine whether the GFC has affected the long-term and short-term interest rate pass-through from policy rates to prime rates and to deposit rates. We first carry out unit root tests to check if the various interest rate series are nonstationary. We then carry out cointegration tests to see if there exists a long-term relationship between the policy rates and bank interest rates. After confirming that the series are cointegrated, we proceed to estimate the long-term relationship and short-term dynamics.

The long-term relationship between policy rates and administered rates (i.e. prime rates and deposit rates) is specified as follows:

$$y_t = \alpha_0 + \alpha_1 D_t + \alpha_2 x_t + \alpha_3 D_t x_t + \varepsilon_t \quad (1)$$

where y_t represents the prime rate (commercial bank lending rate) or deposit rate (commercial bank borrowing rates) for HK or Macao at time t; x_t denotes the corresponding policy rate at time t; ε_t is the error term; α_0 and α_2 capture the markup and the degree of long-term pass-through, respectively (as in Rousseas, 1985) [4]. D_t is a dummy variable, which equals 0 before September 2008 (i.e. the collapse of Lehman Brother and the outbreak of the GFC), and 1 otherwise. Therefore, α_1 and α_3 are used to measure structural changes in the markup and the long-term interest rate pass-through, respectively.

Second, following Liu *et al.* (2011), we employ a standard error correction model (ECM) to investigate the short-term dynamics of administered rates in response to changes in policy rates:

$$\Delta y_t = \beta_1 \Delta x_t + \beta_2 \Delta x_{t-1} + \beta_3 D_t \Delta x_t + \beta_4 D_t \Delta x_{t-1} + \beta_5 \widehat{\varepsilon}_{t-1} + \mu_t \quad (2)$$

where Δ is the first difference operator, and μ_t is the disturbance term. β_1 measures the contemporaneous short-term interest rate pass-through, and β_2 evaluates the lagged effect. β_3 and β_4 reflect structural changes in the previous two effects. The residual term from Equation (1), $\widehat{\varepsilon}_{t-1} = y_{t-1} - (\alpha_0 + \alpha_1 D_{t-1} + \alpha_2 x_{t-1} + \alpha_3 D_{t-1} x_{t-1})$, captures the extent of short-term deviation from a long-run equilibrium relationship. β_5 reflects how fast commercial banks adjust their prime or deposit rates toward the long-run equilibrium relationship with the policy rate.

Since the adjustment speed for positive and negative deviations could be asymmetric (Chong *et al.*, 2006; Chong, 2010), we further adopt the following asymmetric short-term dynamic equation:

$$\Delta y_t = \beta_1 \Delta x_t + \beta_2 \Delta x_{t-1} + \beta_3 D_t \Delta x_t + \beta_4 D_t \Delta x_{t-1} + \beta_5^+ \widehat{\varepsilon}_{t-1}^+ + \beta_5^- \widehat{\varepsilon}_{t-1}^- + \mu_t \quad (3)$$

where $\widehat{\varepsilon}_{t-1}^+$ equals $\widehat{\varepsilon}_{t-1}$ when y_{t-1} is above the long-run equilibrium relationship level specified in Equation (1) (that is, $\widehat{\varepsilon}_{t-1} > 0$), and zero otherwise. Similarly, $\widehat{\varepsilon}_{t-1}^-$ equals $\widehat{\varepsilon}_{t-1}$ when $\widehat{\varepsilon}_{t-1} \leq 0$, and zero otherwise. β_5^+ and β_5^- capture commercial banks' adjustment speed for positive and negative deviations, respectively. To see whether commercial banks adjust their interest rates toward the equilibrium level asymmetrically, we employ the Wald tests to check whether β_5^+ is statistically different from β_5^-.

Finally, we test whether the contemporary short-run interest rate pass-through from policy rates to administered rates is also asymmetric using the following equation:

$$\Delta y_t = \delta_1^+ \Delta x_t^+ + \delta_1^- \Delta x_t^- + \delta_2^+ D_t \Delta x_t^+ + \delta_2^- D_t \Delta x_t^- + \delta_3 \widehat{\varepsilon}_{t-1} + \eta_t \quad (4)$$

where Δx_t^+ equals the policy rate change for HK or Macao at time t (Δx_t) if the policy rates increase ($\Delta x_t > 0$), and zero otherwise. Similarly, Δx_t^- equals Δx_t if $\Delta x_t \leq 0$, and zero otherwise. δ_1^+ and δ_1^- measure the short-term interest rate pass-through for positive and negative policy rate changes, respectively. Again, δ_2^+ and δ_2^- reflect the impact of the GFC on the last two short-term interest rate pass-through channels, respectively.

4. Data and empirical results

4.1 Data

The monthly time series data of interest rates for HK and Macao were downloaded from Datastream. They are prime lending rates, one-month fixed deposits rates and policy rates of

both HK and Macao. The same data can also be downloaded from International Financial Statistics, which the International Monetary Fund published. They can be extracted from Lines 60P, 60L and 60R, respectively.

The HK deposit and lending rates are also available on the HKMA's website. The one-month fixed deposit rates are for deposits up to HKD 100,000. All rates are the month's average rates.

The policy rates of Macao are the base rates of the Monetary Authority of Macau, AMCM, but they are only available from December 1999 when Macao was handed over to mainland China by Portugal. Hence, our sample period starts from December 1999 and ends in June 2021. The sample comprises 259 monthly observations. Figure 2 shows the times series data of the various interest rates for HK (Panel A) and Macao (Panel B).

Panel A of Table 3 reports definitions of the main variables used in this paper, and Panel B exhibits the summary statistics of those variables. The average and median of Macao's prime rates are higher than those of HK. Similarly, the average and median of Macao's one-month fixed deposit rates are also slightly higher than those of HK. However, the average spread between prime rates and the one-month fixed deposit rates is 5.21% for Macao, which is

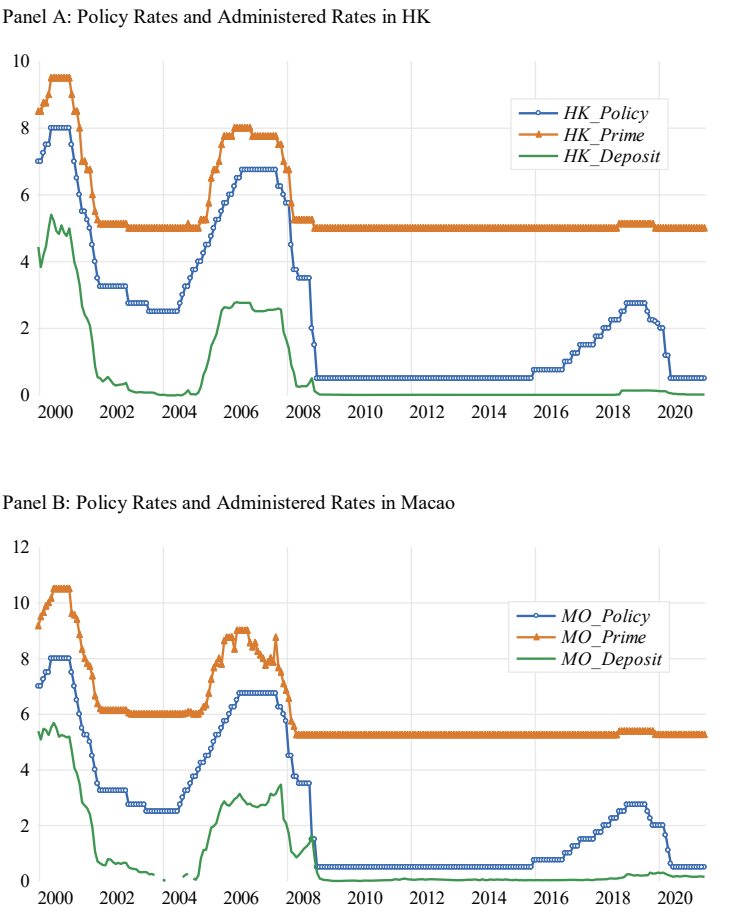

Figure 2.
Policy rates and administered rates in HK and Macao

Panel A: variable definitions

Variables	Definitions
HK_Policy (%)	Monthly average policy rate in HK
HK_Prime (%)	Monthly average HKD primary lending rate in HK
HK_Deposit (%)	Monthly average HKD deposit rate for one-month time deposits
MO_Policy (%)	Monthly average discount window base rate in Macao
MO_Prime (%)	Monthly average MOP primary lending rate in Macao
MO_Deposit (%)	Monthly average MOP deposit rate for one-month time deposits

Panel B: Summary statistics

	Mean	Median	Maximum	Minimum	Std. dev.	Observations
HK_Policy	2.54	2.00	8.00	0.50	2.33	259
HK_Prime	5.64	5.00	9.50	5.00	1.25	259
HK_Deposit	0.70	0.02	5.41	0.00	1.32	259
MO_Policy	2.53	2.00	8.00	0.50	2.33	259
MO_Prime	6.11	5.26	10.50	5.25	1.43	259
MO_Deposit	0.90	0.16	5.69	0.01	1.46	259

Note(s): This table reports definitions and summary statistics of variables used in analysis. The sample period is between December 1999 and June 2021. Interest rates are the annualized average rates on a monthly basis

Table 3.
Variable definitions and summary statistics

higher than that of HK (4.94%). The median spread is also higher in Macao (5.1%) than in HK (4.98%). These statistics indicate that bank competition in HK is more intense than that in Macao.

4.2 Long-term relationships and structural changes

Before analyzing the long-term pass-through from policy rates to administered rates (prime rates and deposit rates), we conducted the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests. The results are reported in Table 4. Our results show that some interest rate series are *I*(0) variables, i.e. deposit rates in both HK and Macao, while other series are *I*(I) variables.

Next, we test whether stable long-term relationships exist between policy rates and administered rates in our sample period. Since the unit root test results in Table 4 show that not all the variables are *I*(1), standard cointegration tests such as Engle–Granger (EG) and Phillips–Ouliaris (PO) residual-based tests cannot be used. Instead, we apply the autoregressive-distributed lag (ARDL) bounds test.

	Level			1st difference	
	ADF test *p*-value	P–P test *p*-value		ADF test *p*-value	P–P test *p*-value
HK_Policy	0.189	0.329	Δ*HK_Policy*	0.000	0.000
HK_Prime	0.002	0.100	Δ*HK_Prime*	0.000	0.000
HK_Deposit	0.010	0.054	Δ*HK_Deposit*	0.000	0.000
MO_Policy	0.186	0.328	Δ*MO_Policy*	0.000	0.000
MO_Prime	0.001	0.171	Δ *MO_Prime*	0.002	0.000
MO_Deposit	0.060	0.031	Δ *MO_Deposit*	0.000	0.000

Note(s): This table presents the results of unit root tests of levels and first differences of interest rates. ADF test is the Augmented Dickey–Fuller test, and P–P test denotes the Phillips–Perron test

Table 4.
Unit root tests

The results, reported in Table 5, show that all four series, i.e. HK prime rates, HK deposit rates, Macao prime rates and Macao deposit rates, are cointegrated with their corresponding policy rates.

As cointegration tests confirm that there exists a long-term relationship between bank interest rates and policy rates, we investigate the long-term relationships using the fully modified (Phillips–Hansen) ordinary least-square regression (FM-OLS) one by one. The results are reported in Table 6.

In the pre-GFC period, the long-term pass-through from policy rates to prime rates and deposit rates (α_2, the coefficient of *HK_Policy* in Columns (1) and (2) and the coefficient of *MO_Policy* in Columns (3) and (4)) are 82.5 and 84.6%, respectively, for HK and 78.3 and 88.8%, respectively, for Macao. The markup (α_0) for lending rates and deposit rates is 2.53% and −2.452% per annum, respectively, for HK banks and 3.576% and −2.367%, respectively, for Macao banks.

The above results further indicate that banks in HK are more competitive than those in Macao. A more (less) competitive banking industry is associated with more (less) complete interest rate pass-through (Sander and Kleimeier, 2004) and lower (higher) markup for lending rates but higher (lower) markup, in absolute values, for deposit rates.

In the post-GFC period, the long-term interest rate pass-through is weakened in all four cases (α_3, the coefficient of *HK_Policy* × *D* in Columns (1) and (2) and the coefficient of *MO_Policy* × *D* in Columns (3) and (4) are negative and statistically significant at the 1% level). For relatively more competitive HK banks, the long-term relationship between policy rates and prime lending rates is slightly positive and statistically significant at the 1% level (with Wald test chi-statistic = 14.622). However, for Macao, the relationship no longer exists as the sum of α_2 and α_3 is not significantly different from zero even at the 10% level. Both markups for HK prime rates and Macao prime rates increased to 4.975% (2.530% + 2.445%) and 5.228% (3.576% + 1.652%), while the markups (markdowns) for HK deposit rates and Macao deposit rates increased (decreased) to 0.005% (−2.432% + 2.437%) and 0.02% (−2.432% + 2.387%), respectively.

Changes in long-term pass-through and markups during the post-GFC period can be attributed to changes in banking regulations. After the GFC, banks were required to fulfill new funding and liquidity requirements by substituting short-term wholesale funds or hot money with more stable core deposits (Banerjee and Mio, 2018), which leads to more

	(1) *HK_Prime*	(2) *HK_Deposit*	(3) *MO_Prime*	(4) *MO_Deposit*
Bounds test *F*-statistic	4.911**	5.062**	5.063**	6.253***
Critical values of ARDL bounds tests				
		Lower bound		Upper bound
10%		3.02		3.51
5%		3.62		4.16
1%		4.94		5.58

Note(s): This table reports the results of autoregressive-distributed lag (ARDL) bounds test. The null hypothesis of all three tests is as follows: the two series, i.e. policy rates and bank lending/deposit rates, are not cointegrated. It is also worth noting that, unlike the other cointegration tests, there are three possible conclusions for bounds tests. The null hypothesis is rejected when *F*-Statistic of bounds test exceeds the upper critical bound value, whereas the null hypothesis is accepted when *F*-statistic is below the lower critical bound value. If *F*-statistic is between upper and lower bound values, the result is inconclusive. ***, ** and * denote 1% level, 5 and 10% level of significance, respectively

Table 5.
Cointegration tests

Table 6.
Long-term relationship

		(1) *HK_Prime*	(2) *HK_Deposit*	(3) *MO_Prime*	(4) *MO_Deposit*
HK_Policy(*t*)	α_2	0.825*** (34.628)	0.846*** (25.081)		
MO_Policy(*t*)	α_2			0.783*** (19.828)	0.888*** (22.722)
HK_Policy(*t*) × *D*	α_3	−0.785*** (−13.973)	−0.801*** (−10.075)		
MO_Policy(*t*) × *D*	α_3			−0.746*** (−7.950)	−0.819*** (−9.443)
Constant × *D*	α_1	2.445*** (17.848)	2.437*** (12.537)	1.652*** (7.284)	2.387*** (10.457)
Constant	α_0	2.530*** (20.504)	−2.452*** (−14.039)	3.576*** (17.530)	−2.367*** (−11.298)
Adjusted R^2		0.968	0.946	0.933	0.938
Wald tests (Chi-square)					
$\alpha_2 + \alpha_3 = 0$		14.622***	0.386	0.189	0.783

Note(s): This table reports the regression results of fully modified least-squares (FM-OLS) estimates. Long-run relationship between commercial bank (lending or borrowing) rates and policy rates is defined in Equation (1): $y_t = \alpha_0 + \alpha_1 D_t + \alpha_2 x_t + \alpha_3 D_t x_t + \varepsilon_t$, where y_t denotes prime rate or deposit rate for HK or Macao at time t, x_t is policy rate at time t and D_t is the GFC dummy variable. It equals 0 if time t is before September 2008 (the collapse of Lehman Brothers), and 1 otherwise. t-statistics are reported in parentheses. *** denotes significance at 1% level

competition for core deposits. Since the loan-to-deposit ratio is a key regulatory indicator (Hong Kong Monetary Authority, 1994b), banks need to attract more deposits in order to make more loans.

As banks competed more aggressively for core deposits, any increase in deposit rates will adversely impact the bottom line of banks. To maintain profitability and protect their net interest margin, commercial banks in both HK and Macao responded by increasing their margin for bank loans and reducing the long-term pass-through of policy rates to prime rates.

4.3 Short-term relationships

We estimated the symmetric ECM, as in Equation (2), to study the short-term interest rate pass-through and adjustment speed. Table 7 presents the regression results. The contemporaneous pass-through from policy rates to prime rates and to deposit rates (β_1) are 73.9 and 52%, respectively, for the relatively more competitive HK banking industry and are 46.3 and 47.1%, respectively, for Macao. However, the Macao banking industry has significantly delayed its response to changes in policy rates (β_2), while the aggregate short-term pass-through in the first two months ($\beta_1 + \beta_2$) for Macao commercial banks is slightly higher than that for HK commercial banks. The sum of contemporaneous and lagged short-term pass-through ($\beta_1 + \beta_2$) from policy rates to prime rates and to deposit rates are 0.791 and 0.708 for HK banks and are 0.849 and 0.762 for Macao banks.

In the post-GFC period, short-term interest pass-through from policy rates to prime rates and to deposit rates (β_3 and β_4 for post-crisis changes in contemporaneous and lagged short-term interest rate pass-through, respectively) are significantly weakened in both HK and Macao, especially for lending rates. This is consistent with what we have observed in long-term interest rate pass-through. Based on Wald tests ($H_0 : \beta_1 + \beta_2 + \beta_3 + \beta_4 = 0$), in the post-GFC period, changes in policy rates barely affected lending rates in the short run and have reduced the impact on deposit rates. These results also show that the efficacy of monetary policy has impaired in both HK and Macao, and banks in both HK and Macao tend to compete more for deposits than loans in the short term in the post-crisis period.

Both HK and Macao banking industries display greater price rigidity on lending rates (prime rates) than on deposit rates. The difference between prime rate rigidity and deposit rate rigidity could be caused by relatively higher searching and switching costs in the loan market compared with the deposit market. As bank deposits are close substitutes, depositors could easily switch to another bank with little or no searching and switching costs. On the contrary, due to information asymmetries (e.g. Stiglitz and Weiss, 1981; Jaffee and Russell, 1976) between borrowers and lenders (i.e. banks in this case), banks tend to offer favored lending rates to their long-time customers (Chemmanur and Fulghieri, 1994; Petersen and Rajan, 1994). Consequently, borrowers could face difficulties and higher borrowing costs when they switch to new banks. Banks, therefore, are able to maintain relatively uncompetitive lending rates for a longer period of time.

Furthermore, a smooth lending rate (a rigid lending rate) also serves as implicit interest rate insurance for borrowers (Fried and Howitt, 1980; Berger and Udell, 1992). That is, banks and borrowers form an "implicit contract" that banks offer above-market rates when market rates are low and below-market rates when market rates are high. By doing so, banks insure their risk-averse borrowers against interest rate fluctuations.

The coefficients of the error correction term (β_5) are always negative and statistically significant across Columns (1) to (4) of Table 7. This is in line with our expectation that administered rates display mean-reverting properties and tend to revert toward their long-term equilibrium relationship with policy rates.

Table 7. Short-term dynamics between policy rate and commercial bank rates

		(1) ΔHK_Prime	(2) ΔHK_Deposit	(3) ΔMO_Prime	(4) ΔMO_Deposit
Degree of short-term pass-through					
$\Delta HK\_Policy(t)$	β_1	0.739*** (16.210)	0.520*** (11.281)		
$\Delta HK\_Policy(t-1)$	β_2	0.052 (1.139)	0.188*** (4.061)		
$\Delta MO\_Policy(t)$	β_1			0.463*** (7.519)	0.471*** (8.127)
$\Delta MO\_Policy(t-1)$	β_2			0.386*** (6.325)	0.291*** (5.034)
$\Delta HK\_Policy(t) \times D(t)$	β_3	−0.724*** (−11.435)	−0.541*** (−8.424)		
$\Delta HK\_Policy(t-1) \times D(t-1)$	β_4	0.009 (0.146)	−0.058 (−0.913)		
$\Delta MO\_Policy(t) \times D(t)$	β_3			−0.436*** (−5.292)	−0.532*** (−6.772)
$\Delta MO\_Policy(t-1) \times D(t-1)$	β_4			−0.384*** (−4.661)	−0.055 (−0.720)
Speed of adjustments					
$\widehat{\varepsilon}_{t-1}$	β_5	−0.103*** (−3.652)	−0.057*** (−2.722)	−0.067*** (−2.771)	−0.113*** (−4.561)
Adjusted R^2		0.606	0.523	0.401	0.470
Wald tests (Chi-square)					
$\beta_1 + \beta_2 = 1$		22.288***	42.011**	5.441**	15.098***
$\beta_1 + \beta_2 + \beta_3 + \beta_4 = 0$		1.886	3.889**	0.147	5.872**

Note(s): This table exhibits regression results of Equation (2). Dynamics of short-term adjustments of commercial bank rates in response to changes in policy rates are expressed as $\Delta y_t = \beta_1 \Delta x_t + \beta_2 \Delta x_{t-1} + \beta_3 D_t \Delta x_t + \beta_4 D_t \Delta x_{t-1} + \beta_5 \widehat{\varepsilon}_{t-1} + \mu_t$, where Δ is the first difference operator and μ_t is the disturbance term, and $\widehat{\varepsilon}_{t-1}$ is estimated residual of long-term equilibrium given by Equation (1). y_t denotes prime rate or deposit rate at time t, x_t is policy rate at time t, and D_t equals 0 if time t is before September 2008 (the collapse of Lehman Brothers), and 1 otherwise. t-statistics are reported in parentheses. ** and *** denote significance at 5 and 1% levels, respectively

4.4 Asymmetric speed of adjustments and interest rate pass-through

In Table 8, we further allow the adjustment speed to be asymmetric. Comparing the coefficients of $\widehat{\varepsilon}_{t-1}^{+}$ and $\widehat{\varepsilon}_{t-1}^{-}$, the downward adjustment speed ($|\beta_5^{+}|$) is always faster than the upward adjustment speed ($|\beta_5^{-}|$) in all four cases. However, the difference between the two is not statistically significant (as shown by the results of the Wald tests), even at the 10% level. In other words, there was no evidence that banks in HK or Macao adjust their administered rates upwards differently from downwards, even though it can exist in other markets, e.g. in the USA (Neumark and Sharpe, 1992), Australia (Liu *et al.*, 2011) and Singapore (Chong *et al.*, 2006).

Finally, in Table 9, we test whether banks adjust their administered rates in response to positive and negative monetary policy shocks asymmetrically. The regression results, in general, show that in the pre-GFC period, commercial banks in HK are faster in reducing prime rates following reduced policy rates than in increasing prime rates following increased policy rates. The difference is statistically significant at the 1% level. For the other three series, there is no significant difference. This phenomenon observed in HK implies that HK banks were more competitive in making loans that could erode bank profitability. In the post-GFC period, we no longer observe any statistically significant difference for any of the contemporaneous short-term pass-through. It indicates that in the post-GFC period, bank competition has decreased and monetary policy transmission via a bank administered interest rate channel is no longer effective.

4.5 Robustness test

To see whether our results are robust, we analyzed other time series data of HK fixed deposit rates, namely, three-month, six-month and one-year rates, in addition to the one-month fixed deposit rates used in our sample. We downloaded the data from the HKMA's website.

The regression results were consistent with those obtained from the one-month deposit rates [5]. This is not surprising because the fixed deposit rates with different maturities track each other very closely (see Figure 3). The pairwise correlation coefficients among the series range from 99.01 (between one-month and one-year rates) to 99.94 (between three-month and six-month rates).

We also conducted principal component analysis (PCA) with the deposit rates data, and the results in Table 10 show that the first principal component accounts for 99.7% of the variations in the data, further confirming that our HK results based on the one-month fixed deposit rates are robust. In other words, all fixed deposit rates in HK move in the same direction and almost by the same amount when commercial banks adjust them in response to changes in policy rates and/or market interest rates.

5. Conclusion

Since the collapse of Lehman Brothers and the outbreak of the GFC, the monetary policy all over the world has gone through significant adjustments. In this paper, we examined the interest rate pass-through in HK and Macao, and our results show that in the post-GFC period, the effectiveness of monetary policy has been seriously undermined in both markets.

For the prime rates, the long-term interest pass-through has decreased significantly in HK and completely disappeared in Macao while the short-term pass-through has disappeared in both. For the deposit rates, the long-term interest rate pass-through has disappeared in both HK and Macau while the short-term pass-through has decreased significantly in both markets. Although commercial banks compete more aggressively for core deposits, they nearly double the markups in their lending rates.

Our results also show that there is a positive link between competition and interest rate pass-through. The long-term interest rate pass-through from policy rates to prime rates is

Table 8. Asymmetric short-term adjustments

		(1) ΔHK_Prime	(2) $\Delta HK\_Deposit$	(3) ΔMO_Prime	(4) $\Delta MO\_Deposit$
Degree of short-term pass-through					
$\Delta HK\_Policy(t)$	β_1	0.736*** (16.065)	0.510*** (10.090)		
$\Delta HK\_Policy(t-1)$	β_2	0.051 (1.118)	0.188*** (4.076)		
$\Delta MO\_Policy(t)$	β_1			0.455*** (7.333)	0.465*** (7.954)
$\Delta MO\_Policy(t-1)$	β_2			0.381*** (6.211)	0.294*** (5.078)
$\Delta HK\_Policy(t) \times D(t)$	β_3	−0.723*** (−11.387)	−0.533*** (−8.251)		
$\Delta HK\_Policy(t-1) \times D(t-1)$	β_4	0.009 (0.882)	−0.063 (−0.978)		
$\Delta MO\_Policy(t) \times D(t)$	β_3			−0.434*** (−5.264)	−0.532*** (−6.767)
$\Delta MO\_Policy(t-1) \times D(t-1)$	β_4			−0.379*** (−4.582)	−0.070 (−0.892)
Speed of adjustments					
$\widehat{\varepsilon}^{+}_{t-1}$	β_5^{+}	−0.117*** (−2.741)	−0.084*** (−2.740)	−0.098** (−2.277)	−0.136*** (−3.902)
$\widehat{\varepsilon}^{-}_{t-1}$	β_5^{-}	−0.092** (−2.426)	−0.033 (−1.138)	−0.052* (−1.748)	−0.091** (−2.588)
Adjusted R^2		0.606	0.525	0.402	0.472
Wald test (Chi-square)					
$\beta_5^{+} = \beta_5^{-}$		0.195	1.461	0.751	0.870

Note(s): This table reports regression results of asymmetric error correction models (ECMs). In Equation (3), $\Delta y_t = \beta_1 \Delta x_t + \beta_2 \Delta x_{t-1} + \beta_3 D_t \Delta x_t + \beta_4 D_t \Delta x_{t-1} + \beta_5^{+} \widehat{\varepsilon}^{+}_{t-1} + \beta_5^{-} \widehat{\varepsilon}^{-}_{t-1} + \mu_t$, we allow commercial banks to respond to positive and negative deviations differently. y_t denotes prime rate or deposit rate at time t, x_t is policy rate at time t and D_t equals 0 if time t is before September 2008 (the collapse of Lehman Brothers), and 1 otherwise. Δ is the first difference operator, and μ_t is the disturbance term. Finally, $\widehat{\varepsilon}^{+}_{t-1}$ ($\widehat{\varepsilon}^{-}_{t-1}$) equals estimated residual from Equation (1) when $\widehat{\varepsilon}_{t-1}$ is positive (negative). t-statistics are reported in parentheses. *, ** and *** denote significance at 10, 5 and 1% levels, respectively

Table 9.
Asymmetric short-term pass-through

		(1) ΔHK_Prime	(2) $\Delta HK\_Deposit$	(3) ΔMO_Prime	(4) $\Delta MO\_Deposit$
Degree of short-term pass-through					
$\Delta HK\_Policy^{+}(t)$	δ_1^{+}	0.552*** (6.777)	0.586*** (6.078)		
$\Delta HK\_Policy^{-}(t)$	δ_1^{-}	0.826*** (18.918)	0.628*** (13.489)		
$\Delta MO\_Policy^{+}(t)$	δ_1^{+}			0.579*** (4.613)	0.684*** (5.277)
$\Delta MO\_Policy^{-}(t)$	δ_1^{-}			0.648*** (9.634)	0.584*** (9.322)
$\Delta HK\_Policy^{+}(t) \times D(t)$	δ_2^{+}	−0.555*** (−3.612)	−0.541*** (−3.282)		
$\Delta HK\_Policy^{-}(t) \times D(t)$	δ_2^{-}	−0.793*** (−12.706)	−0.621*** (−9.294)		
$\Delta MO\_Policy^{+}(t) \times D(t)$	δ_2^{+}			−0.531** (−2.247)	−0.656*** (−2.871)
$\Delta MO\_Policy^{-}(t) \times D(t)$	δ_2^{-}			−0.624*** (−6.847)	−0.646*** (−7.500)
Speed of adjustments					
$\widehat{\varepsilon}_{t-1}$	δ_3	−0.107*** (−3.839)	−0.072*** (−3.322)	−0.066*** (−2.525)	−0.160*** (−6.202)
Adjusted R^2		0.614	0.477	0.306	0.376
Wald tests					
$\delta_1^{+} = \delta_1^{-}$		8.750***	0.177	0.238	0.486
$(\delta_1^{+} + \delta_2^{+}) = (\delta_1^{-} + \delta_2^{-})$		0.066	0.069	0.013	0.209

Note(s): This table reports regression results of asymmetric short-term pass-through. In Equation (4), $\Delta y_t = \delta_1^{+}\Delta x_t^{+} + \delta_1^{-}\Delta x_t^{-} + \delta_2^{+}D_t\Delta x_t^{+} + \delta_2^{-}D_t\Delta x_t^{-} + \delta_3\widehat{\varepsilon}_{t-1} + \eta_t$, we allow short-term interest rate pass-through to be asymmetric. y_t denotes prime rate or deposit rate at time t. Δx_t^{+} (Δx_t^{-}) equals change in policy rate at time t if $\Delta x_t > 0$ ($\Delta x_t \leq 0$), and zero otherwise. D_t equals 0 if time t is before September 2008 (the collapse of Lehman Brothers), and 1 otherwise. Δ is the first difference operator, and η_t is the disturbance term. $\widehat{\varepsilon}_{t-1}$ is estimated residual of long-term equilibrium given by Equation (1). t-statistics are reported in parentheses. ** and *** denote significance at 5 and 1% levels, respectively

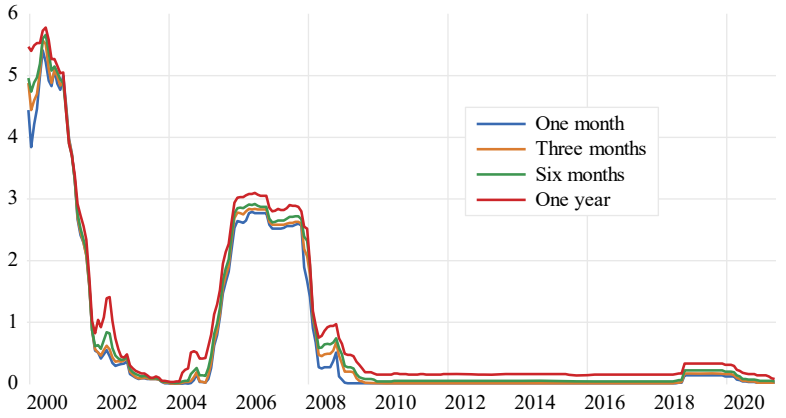

Figure 3.
Hong Kong fixed deposits rates of various maturities

Number	Eigen value	Proportion	Cumulative proportion
1	3.989	0.997	0.997
2	0.009	0.002	1.000
3	0.001	0.000	1.000
4	0.000	0.000	1.000

Table 10.
Eigenvalues of HK fixed deposit rates (December 1999–June 2021)

higher in HK than in Macao due to more intense competition. In the pre-GFC period, HK banks were quicker (slower) to reduce (increase) their lending rates when policy rates were decreasing (increasing). In Macao, there was no such evidence. In the post-GFC period, the long-term relationship between policy rates and prime rates disappeared in Macao, but was still positive in HK. In the relatively concentrated Macao banking industry, prime rates are no longer sensitive to changes in policy rates in the long or short term.

Our study shows that after the outbreak of the GFC, monetary policy transmission via bank deposit and lending rates no longer works well in either HK or Macao. Monetary authorities in both HK and Macao need to find alternative tools to conduct the monetary policy. For example, the reserve requirement ratio can be utilized as an instrument to control bank credit in the economy. More importantly, the regulatory authority needs to take measures to increase bank competition, especially in Macao.

Notes

1. In theory, retail deposit rates can become negative. However, in practice, it has not been done in any country for fear of cash hoarding by depositors, which would reduce the amount of deposits banks have to make loans.
2. In theory, if banks could not reduce deposit rates to negative, banks could then substitute core deposits with wholesale interbank borrowing to make loans. However, wholesale funds are hot money and short term in nature. Banks also need to meet the core-deposit funding requirements imposed by regulators.
3. Data for total deposits of the banking industry are published by the Monetary Authority of Macao in its annual reports.
4. For deposit rates, the constant is usually negative as banks' retail deposit rates are lower than policy rates and wholesale money market rates. In this case, the term "markdown" is more appropriate and appealing.

5. To save space, the results not reported in the paper. Fixed deposit rates of other maturities in Macao were not available. Data on other lending rates are not available.

References

Altavilla, C., Brulon, L., Giannetti, M. and Holton, S. (2021), "Is there a zero lower bound? The effects of negative policy rates on banks and firms", *Journal of Financial Economics*, Forthcoming.

Banerjee, R.N. and Mio, H. (2018), "The impact of liquidity regulation on banks", *Journal of Financial Intermediation*, Vol. 35 No. Part B, pp. 30-44.

Bech, M. and Keister, T. (2017), "Liquidity regulation and the implement of monetary policy", *Journal of Monetary Economics*, Vol. 92, pp. 64-77.

Berger, A.N. and Udell, G.F. (1992), "Some evidence on the empirical significance of credit rationing", *Journal of Political Economy*, Vol. 100 No. 5, pp. 1047-1077.

Bindal, S., Bouwman, C.H.S., Hu, S. and Johnson, S.A. (2020), "Bank regulatory size thresholds, merger and acquisition behavior, and small business lending", *Journal of Corporate Finance*, Vol. 62, 101519.

Chemmanur, T.J. and Fulghieri, P. (1994), "Reputation, renegotiation, and the choice between loans and publicly traded debt", *Review of Financial Studies*, Vol. 7 No. 3, pp. 475-506.

China Briefing (2004), *Business Guide to the Greater Pearl River Delta*, China Briefing Media.

Chong, B.S. (2010), "Interest rate deregulation: monetary policy efficacy and rate rigidity", *Journal of Banking and Finance*, Vol. 34, pp. 1299-1307.

Chong, B.S., Liu, M.H. and Shrestha, K. (2006), "Monetary transmission via the administered interest rate channel", *Journal of Banking and Finance*, Vol. 30 No. 5, pp. 1467-1484.

Cottarelli, C. and Kourelis, A. (1994), "Financial structure, bank lending rates, and the transmission mechanism of monetary policy", *IMF Staff Reports*, Vol. 41 No. 4, pp. 587-623.

De Bondt, G.J. (2005), "Interest rate pass-through: empirical results for the euro area", *German Economic Review*, Vol. 6 No. 1, pp. 37-78.

Egert, B., Crespo-Cuaresma, J. and Reininger, T. (2007), "Interest rate pass-through in central and Eastern Europe: reborn from ashes merely to pass away?", *Journal of Political Modeling*, Vol. 29 No. 2, pp. 209-225.

Fried, J. and Howitt, P. (1980), "Credit rationing and implicit contract theory", *Journal of Money, Credit and Banking*, Vol. 12 No. 3, pp. 471-487.

Gambacorta, L. (2008), "How do banks set interest rates?", *European Economic Review*, Vol. 52 No. 5, pp. 792-819.

Genberg, H. and Hui, C. (2011), "The credibility of the Hong Kong's link from the perspective of modern financial theory", *Journal of Money, Credit and Banking*, Vol. 43 No. 1, pp. 185-206.

Gregor, J., Melecky, A. and Melecky, M. (2021), "Interest rate pass-through: a meta-analysis of the literature", *Journal of Economic Surveys*, Vol. 35 No. 1, pp. 141-191.

Hall, M.J.B., Kenjegalieva, K.A. and Simper, R. (2012), "Environmental factors affecting Hong Kong banking: a post-Asian financial crisis efficiency analysis", *Global Finance Journal*, Vol. 23 No. 3, pp. 184-201.

Hannan, T.H. and Berger, A.N. (1991), "The rigidity of prices: evidence from the banking industry", *American Economic Review*, Vol. 81 No. 4, pp. 938-945.

Hansen, N.-J.H. and Welz, P. (2011), *Interest Rate Pass-Through during the Global Financial Crisis: The Case of Sweden*, OECD Economics Department Working Papers 855, OECD Publishing.

Hong Kong Monetary Authority (1994a), "The interest rate structure in Hong Kong", *HKMA Quarterly Bulletin*, pp. 8-14.

Hong Kong Monetary Authority (1994b), "New regime for the supervision of liquidity", *HKMA Quarterly Bulletin*, pp. 20-24.

Hong Kong Monetary Authority (2013), "Monetary operations under the currency board system: the experience of Hong Kong", *Market Volatility and Foreign Exchange Intervention in EMEs: What Has Changed? (BIS Paper No. 73)*, Bank for International Settlements, Basel, pp. 145-154.

Hong Kong Monetary Authority (2018), "HKMA 2018 annual report", available at: https://www.hkma.gov.hk/eng/data-publications-and-research/publications/annual-report/2018/ (accessed 24 August 2020).

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 and Finance*, Vol. 48, pp. 104-119.

IMF (2011), *Macao Special Administrative Region of the People's Republic of China: Financial Sector Stability Assessment*, IMF Country Report No. 11/264.

IMF (2014), *Financial Sector Assessment Program: People's Republic of China—Hong Kong Special Administration Region*, IMF Country Report No. 14/207.

Jaffee, D.M. and Russell, T. (1976), "Imperfect information, uncertainty, and credit rationing", *Quarterly Journal of Economics*, Vol. 90 No. 4, pp. 651-666.

Karagiannis, K., Panagopoulos, Y. and Vlamis, P. (2010), "Interest rate pass-through in Europe and the US: monetary policy after the financial crisis", *Journal of Policy Modeling*, Vol. 32 No. 3, pp. 323-338.

King, M.R. (2013), "The Basel III net stable funding ratio and bank net interest margins", *Journal of Banking and Finance*, Vol. 37 No. 11, pp. 4144-1456.

Kleimeier, S. and Sander, H. (2006), "Expected versus unexpected monetary policy impulses and interest rate pass-through in euro-zone retail banking markets", *Journal of Banking and Finance*, Vol. 30 No. 7, pp. 1839-1870.

Kopecky, K.J. and Van Hoose, D.D. (2012), "Imperfect competition in bank retail markets, deposit and loan rate dynamics, and incomplete pass through", *Journal of Money, Credit and Banking*, Vol. 44 No. 6, pp. 1185-1205.

Leledakis, G.N. and Pyrgiotakis, E.G. (forthcoming), "U.S. Bank M&As in the Post-Dodd-Frank act era: do they create value?", *Journal of Banking and Finance*.

Liu, M.H., Margaritis, D. and Tourani-Rad, A. (2011), "Asymmetric information and price competition in small business lending", *Journal of Banking and Finance*, Vol. 35 No. 9, pp. 2189-2196.

Liu, M.H., Margaritis, D. and Qiao, Z. (2016), "The global financial crisis and retail interest rate pass-through in Australia", *Review of Pacific Basin Financial Markets and Policies*, Vol. 19 No. 4, pp. 1-32.

Macao Association of Banks (2019), "Instruction of the Macao association of banks", available at: http://www.abm.org.mo/uploadfile/2019/0807/20190807040836201.pdf (accessed 25 August 2020).

Neumark, G. and Sharpe, S.A. (1992), "Market structure and the nature of price rigidity: evidence from the market for consumer deposits", *Quarterly Journal of Economics*, Vol. 107, pp. 657-680.

Petersen, M.A. and Rajan, R.G. (1994), "The benefits of lending relationships: evidence from small business data", *Journal of Finance*, Vol. 49 No. 1, pp. 3-37.

RBA (Reserve Bank of Australia) (2010), *Senate Economics References Committee Inquiry into Competition within the Australian Banking Sector*.

RBA (Reserve Bank of Australia) (2011), *Parliamentary Joint Committee on Corporations and Financial Services Inquiry into Access for Small and Medium Business to Finance*.

Rousseas, S. (1985), "A markup theory of bank loan rates", *Journal of Post Keynesian Economics*, Vol. 8, pp. 135-144.

Rubio, M. and Carrasco-Gallego, J.A. (2016), "The new financial regulation in Basel III and monetary policy: a macroprudential approach", *Journal of Financial Stability*, Vol. 26, pp. 294-305.

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*, Vol. 23 No. 3, pp. 461-492.

Schwartz, A.J. (1993), "Currency boards: their past, present, and possible future role", *Carnegie-Rochester Conference Series on Public Policy*, Vol. 39, pp. 149-187.

Scott, R.H. (1997), "Pegged exchange rate systems in Macau and Hong Kong", *Multinational Finance Journal*, Vol. 1 No. 2, pp. 153-168.

Stiglitz, J.E. and Weiss, A. (1981), "Credit rationing in markets with imperfect information", *American Economic Review*, Vol. 71 No. 3, pp. 393-410.

Ulate, M. (2021), "Going negative at the zero lower bound: the effects of negative nominal interest rates", *American Economic Review*, Vol. 111 No. 1, pp. 1-40.

Van Leuvensteijn, M., Sörensen, C.K., Bikker, J.A. and van Rixtel, A.A. (2013), "Impact of bank competition on the interest rate pass-through in the euro area", *Applied Economics*, Vol. 45 No. 11, pp. 1359-1380.

Wheelock, D.C. (2011), "Have acquisitions of failed banks increased the concentration of U.S. Banking markets?", *Federal Reserve Bank of Stand Louis Review*, Vol. 93 No. 3, pp. 155-168.

Wright, J.H. (2012), "What does monetary policy due to long-term interest rates at the zero lower bound?", *Economic Journal*, Vol. 122 No. 564, pp. F447-F466.

Yam, J. (2005), "The convertibility zone. Hong Kong monetary authority viewpoint", 26 May 2005, available at: https://www.hkma.gov.hk/eng/news-and-media/insight/2005/05/20050526/ (accessed 21 August 2020).

Corresponding author
Ming-Hua Liu can be contacted at: mhliu@umac.mo