4. Monetary and financial conditions

The Hong Kong dollar softened during the review period, driven by increased interest rate carry trade activities amid the widening of the negative HIBOR-LIBOR spreads in the first half of 2022 and the lacklustre performance of the local stock market. While the weak-side Convertibility Undertaking (CU) was triggered 31 times from May to August and Hong Kong Interbank Offered Rate (HIBOR) increased, the monetary environment in Hong Kong remained accommodative. Overall, the Hong Kong dollar exchange and money markets continued to trade in a smooth and orderly manner. Looking ahead, fund flows may be subject to heightened volatilities amid elevated uncertainties on various fronts, including the pace of US monetary policy normalisation, the evolving pandemic developments and the lingering geopolitical tensions. However, with the ample foreign reserves position and a robust financial system, Hong Kong is able to withstand outflows without jeopardising monetary and financial stability.

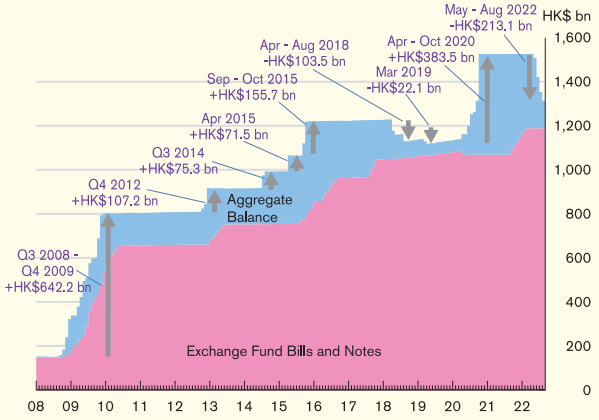
4.1 Exchange rate and capital flows

The Hong Kong dollar has softened since late April, driven by increased interest rate carry trade activities amid the widening of the negative HIBOR-LIBOR spreads in the first half of 2022 and the lacklustre performance of the local stock market. During the review period, the Hong Kong dollar traded within a range between 7.814 and 7.850 against the US dollar (Chart 4.1), with the weak-side CU being triggered 31 times. Since the first triggering of the weak-side CU on 11 May (US time), the HKMA has purchased a total of HK$213.1 billion (as at the end of August) at the request of banks in accordance with the design of the Linked Exchange Rate System (LERS). As a result of these purchases, the Aggregate Balance of the banking system declined from HK$337.6 billion at the end of February to HK$125.0 billion at the end of August (Chart 4.2).

Chart 4.1
Hong Kong dollar exchange rate

Source: HKMA.

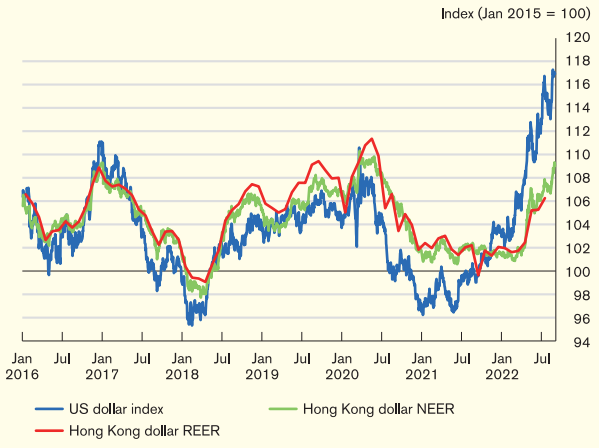
Chart 4.2
Aggregate Balance and Exchange Fund Bills and Notes (EFBNs)



Source: HKMA.

Broadly tracking the movements of the US dollar, the Hong Kong dollar nominal effective exchange rate index (NEER) strengthened during the review period (Chart 4.3). The Hong Kong dollar real effective exchange rate index (REER) generally followed the movement of the NEER.

Chart 4.3
NEER and REER



Note: The REER is seasonally adjusted and available only on a monthly basis.
Sources: CEIC, C&SD and HKMA staff estimates.

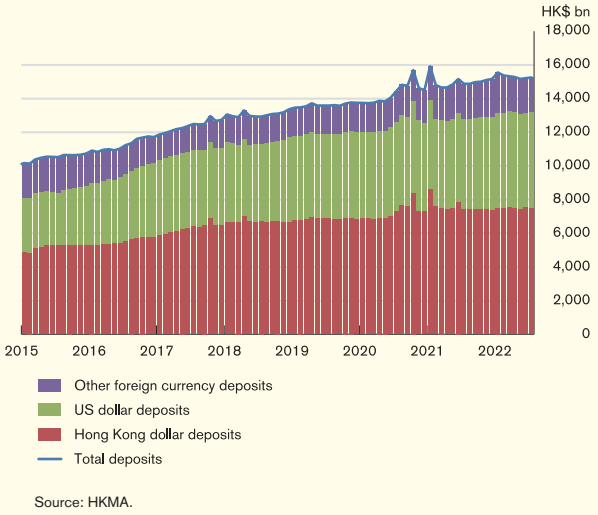
The fund flows may be subject to heightened volatilities in the period ahead due to the elevated uncertainties on various fronts, including the pace of US monetary policy normalisation, the evolving pandemic situation, and lingering geopolitical tensions. As the differentials between the higher US dollar interbank rates and the lower Hong Kong dollar interbank rates widen, there would be more carry trades in the market. According to the design and operation of the LERS, with the triggering of the weak-side CU, funds flow out from the Hong Kong dollar system and the interest rate automatic adjustment mechanism will kick in. The Hong Kong dollar interbank rates will gradually rise, offsetting the incentives for interest rate carry trades, slowing down fund outflows from the Hong Kong dollar market and stabilising the Hong Kong dollar exchange rate within the 7.75–7.85 Convertibility Zone. Over the years, the HKMA has built up strong buffers and resilience in the financial and banking systems. With ample foreign reserves, the HKMA has the capability and resolve to maintain the LERS and Hong Kong's monetary and financial stability.

4.2 Monetary environment and interest rates

Despite the triggering of the weak-side CU and the purchase of Hong Kong dollars at the request of banks, Hong Kong's monetary environment remained accommodative during the review period, with the Hong Kong dollar Monetary Base remaining sizeable at HK$1,930.3 billion at the end of August 2022.

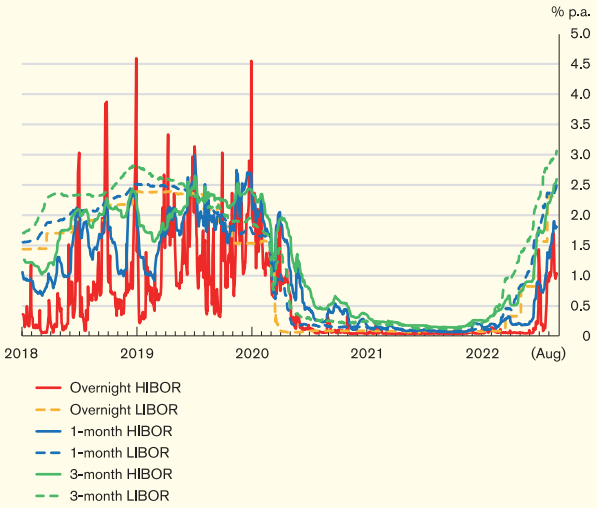
In the first seven months of 2022, total deposits with AIs increased modestly by 0.6%, with Hong Kong dollar deposits increasing by 1.6% while foreign currency deposits edged down by 0.3% (Chart 4.4). It should be noted, however, that monetary statistics are subject to volatility due to a wide range of transient factors, such as seasonal and initial public offering (IPO) related funding demand as well as business and investment-related activities. Therefore it is more appropriate to observe the longer-term trends.

Chart 4.4
Deposits with Authorized Institutions (AIs) by currency



Source: HKMA.

Chart 4.5
Hong Kong dollar and US dollar interbank interest rates



Sources: CEIC and HKMA.

Overall, Hong Kong's interbank market continued to trade in a smooth and orderly manner. Against the background of continued US rate hikes, HIBORs increased, with the negative HIBOR-LIBOR spread narrowing more recently (Chart 4.5). The average lending rate for new mortgages increased from 1.56% in January 2022 to 2.31% in July 2022, mainly reflecting the increase in HIBOR. After the Fed hiked its policy rate in September, some banks raised their Best Lending Rates by 12.5 basis points, marking the first increase since 2018. Some banks also increased the cap on HIBOR-based mortgage rates of newly approved mortgage loans in recent months.

Looking ahead, as the Fed is expected to continue its monetary policy normalisation at a fast pace, the HKMA may purchase more Hong Kong dollars at the request of banks and the Aggregate Balance may decline further, in line with the design and expectations of the LERS. While the Hong Kong dollar interbank rates will generally track the US dollar interest rates, the speed and the magnitude of the HIBORs' catching up with their US dollar counterparts will still be subject to the supply and demand for Hong Kong dollar funding in the local market. For banks' commercial interest rates, it will be up to the banks to decide whether to adjust the rates, when to adjust them and by how much, having regard to their own funding cost structures and other relevant considerations.

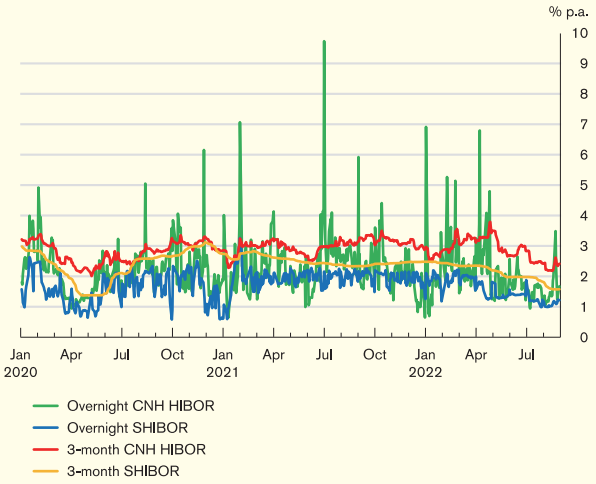
Offshore renminbi banking business

Liquidity conditions in the offshore renminbi (CNH) interbank market continued to be stable during the review period.[24] While the overnight CNH HIBOR saw brief fluctuations due to occasional funding needs for foreign exchange settlement and seasonal liquidity demand, it mostly traded below 4% (Chart 4.6). On the

[24] See Chapter 2.2 for the development of offshore and onshore renminbi exchange rates.

other hand, the three-month CNH HIBORs remained relatively steady and hovered around 3% throughout the review period.

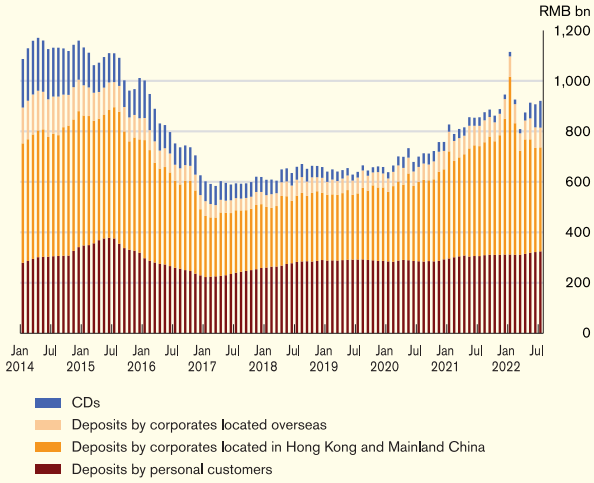
Chart 4.6
The overnight and the three-month CNH HIBOR fixings



Source: CEIC.

Hong Kong's CNH liquidity pool consolidated during the review period. In the year to end-July, total outstanding renminbi customer deposits and certificates of deposit (CDs) decreased by 2.6% to RMB919.9 billion (Chart 4.7 and Table 4.A). Largely driven by fund flows of corporates, renminbi customer deposits fell by 12.2%. On the other hand, outstanding CDs expanded by 494.0% along with the rise in renminbi CD issuance during the same period.

Chart 4.7
Renminbi deposits and CDs in Hong Kong



Source: HKMA.

Table 4.A
Offshore renminbi banking statistics

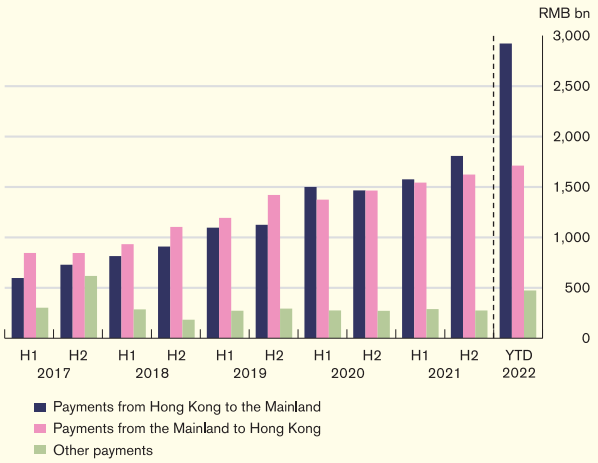
	Dec 2021	Jul 2022
Renminbi deposits & CDs (RMB bn)	944.7	919.9
Of which:		
Renminbi deposits (RMB bn)	926.8	813.7
Share of renminbi deposits in total deposits (%)	7.5	6.2
Renminbi CDs (RMB bn)	17.9	106.2
Renminbi outstanding loans (RMB bn)	163.6	172.5
Number of participating banks in Hong Kong's renminbi clearing platform	212	211
Amount due to overseas banks (RMB bn)	102.9	117.4
Amount due from overseas banks (RMB bn)	100.4	130.0
	Jan – Jul 2022	
Renminbi trade settlement in Hong Kong (RMB bn)	5,090.0	
Of which:		
Inward remittances to Hong Kong (RMB bn)	1,705.9	
Outward remittances to Mainland China (RMB bn)	2,913.8	
Turnover in Hong Kong's RMB real time gross settlement (RTGS) system (Daily average during the period; RMB bn)	1,669.5	

Source: HKMA.

Despite the consolidation in the renminbi liquidity pool, other aspects of the CNH banking business continued to grow. The outstanding amount of renminbi loans grew by 5.4% in the first seven months of 2022. Hong Kong's renminbi trade settlement also continued to pick up. Transactions handled by banks in Hong Kong amounted to RMB5,090.0 billion in the first seven months of 2022 (Chart 4.8), up by 26.6% compared with RMB4,020.0 billion during the same period last year. The renminbi liquidity pool in Hong Kong continued to support a large

amount of renminbi payments and financing transactions. During the first seven months of 2022, the average daily turnover of the renminbi RTGS system stayed high at RMB1,669.5 billion, compared with RMB1,531.2 billion in the same period in 2021.

Chart 4.8
Flows of renminbi trade settlement payments



Source: HKMA.

Going forward, the enhanced Currency Swap Agreement with the PBoC, as well as the enhancement to the HKMA's renminbi liquidity facility, will further support and deepen Hong Kong's renminbi liquidity pool. At the same time, the continuous enhancement to the mutual market access schemes with the Mainland, including the recently announced Swap Connect, the two-way Stock, Bond, and Cross-boundary Wealth Management Connects, and the planned modernisation of the CMU into a major international central securities depository (ICSD) in Asia, will provide a convenient and secure channel for overseas investors to trade renminbi assets through a connection between infrastructure institutions in the two centres. With these initiatives, Hong Kong stands ready to capture opportunities brought by the continuing liberalisation of Mainland's capital account and the deepening regional economic and financial co-operation under the Belt and Road and the Guangdong-Hong Kong-Macao Greater Bay Area initiatives.

Asset markets

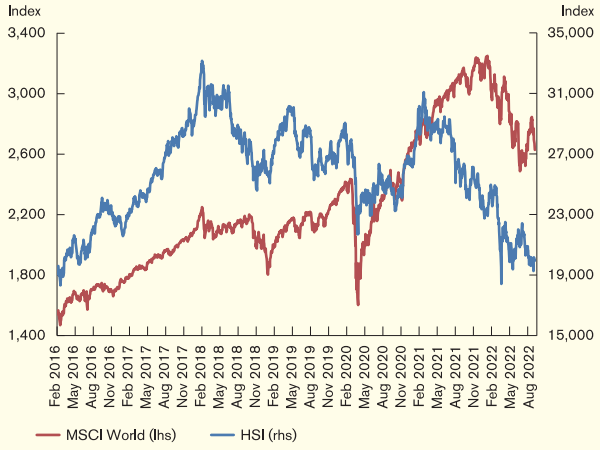
Along with the decline in global equity markets, the Hong Kong equity market dropped to a six-year low in March 2022 and remained volatile throughout the review period amid lingering threats of the pandemic, front-loaded monetary tightening in the US, and impacts of the Russia-Ukraine conflict on the global economy. Despite the volatile market condition, the Hong Kong dollar and offshore renminbi debt markets in Hong Kong continued to expand in the first half of 2022. After experiencing some stabilisation in the second quarter, the residential property market softened recently as market sentiment turned cautious amid rising interest rates.

4.3 Equity market

Along with the decline in global equity markets, the Hong Kong equity market plummeted in March 2022 and reached a six-year low of 18,415 points on 15 March (Chart 4.9). Major and local equity markets remained volatile throughout the review period amid lingering threats of the pandemic, front-loaded monetary tightening in the US, and impacts of the Russia-Ukraine conflict on the global economy. The option-implied volatilities of the S&P 500 Index and the Hang Seng index both moved to a high level relative to the average level during the past ten years (Chart 4.10). Reflecting investors' willingness to pay for downside protection, the SKEW index rose and reached its recent peak in April 2022, before trending down afterwards.[25]

Overall, the Hang Sang Index dropped by 12.1% from the end of February to the end of August 2022, while the MSCI World Index recorded a 11.8% decline in the same period.

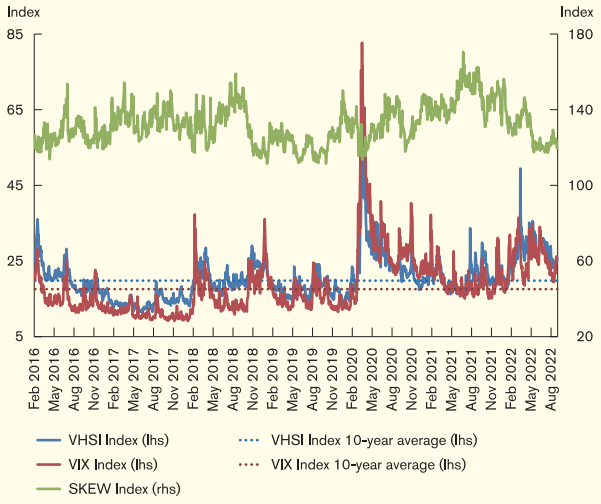
Chart 4.9
The Hang Seng Index and the MSCI World Index



Source: Bloomberg.

[25] The SKEW Index is calculated by the Chicago Board Options Exchange from the prices of the S&P 500 out-of-the-money options. An index value of 100 means that the probability of outlier negative returns on a 30-day horizon is negligible. As the SKEW Index rises above 100, the left tail of the S&P 500 returns distribution acquires more weight, suggesting that the probability of outlier negative returns has become more significant. For details, see https://www.cboe.com/products/vix-index-volatility/volatility-indicators/skew.

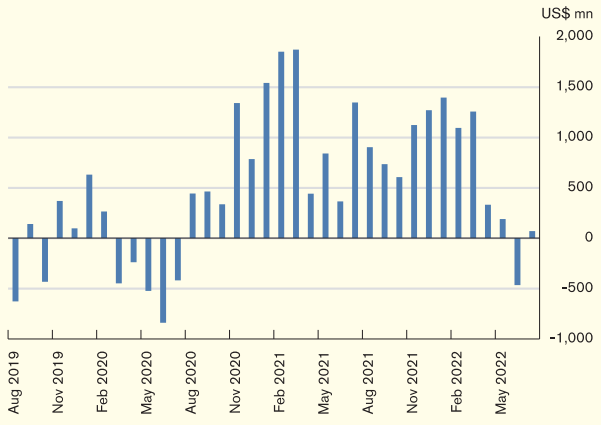
Chart 4.10
Option-implied volatilities of the Hang Seng Index and the S&P 500 Index, and the SKEW Index



Source: Bloomberg.

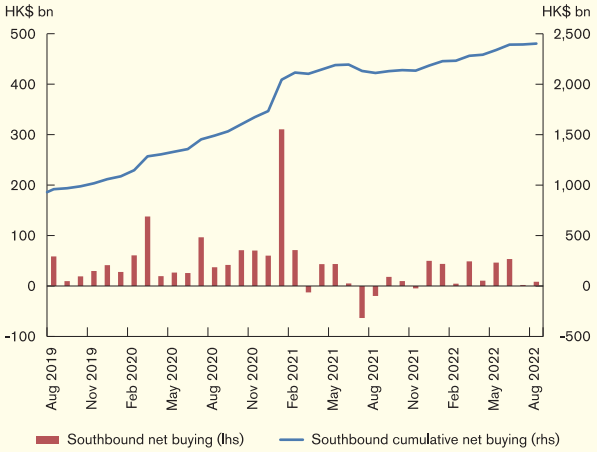
The volatility in the local equity market was accompanied by a slowdown in net inflows through the equity market funds (Chart 4.11), with the amount of inflows totaled US$2,469.7 million between February and July 2022. Meanwhile, buying interest through the southbound Stock Connects stayed relatively stable, and registered a net inflow of HK$169.6 billion between the end of February and the end of August 2022. During the review period, the cumulative net buying amount increased by 7.6% to HK$2,402.6 billion (Chart 4.12).

Chart 4.11
Equity market fund flows into Hong Kong



Source: EPFR Global.

Chart 4.12
Net buying through southbound Stock Connect over time

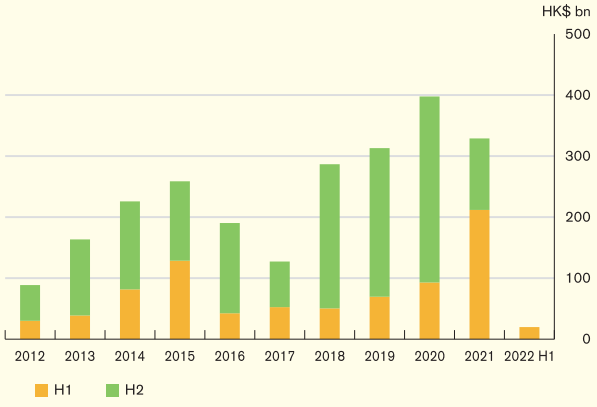


Note: Southbound net buying is the sum of such buying on the Shanghai-Hong Kong Stock Connect and the Shenzhen-Hong Kong Stock Connect.

Sources: CEIC and HKMA staff estimates.

The uncertainties surrounding the geopolitical and global macro-economic environments have also slowed down primary market activities worldwide. In Hong Kong, the amount raised through IPO in the first half of 2022 dropped by 90.7% compared with the first half of 2021, mainly reflecting the base effect due to the strong IPO activities recorded in the first half of 2021 (Chart 4.13). Nevertheless, the demand for listing in Hong Kong has not slowed, with the Stock Exchange of Hong Kong processing 189 listing applications as at the end of June 2022.

Chart 4.13
Initial public offering market in Hong Kong

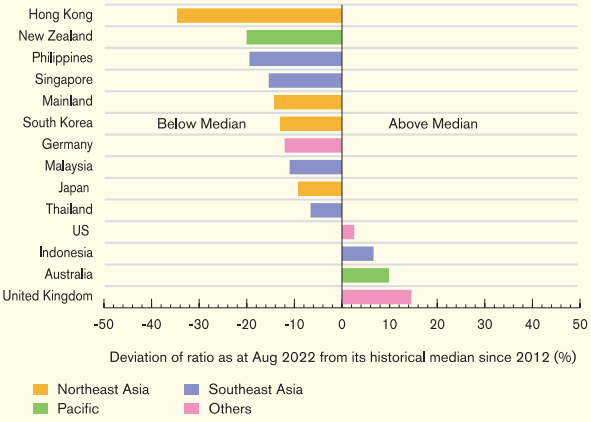


Source: HKEX.

The outlook for the local equity market is subject to headwinds in the external environment. Lingering geopolitical tensions, concerns over global economic growth slowdown and inflationary pressure as well as the tightening monetary policies of major central banks may hurt the long-term prospects of corporates' earnings. Persistent strength of the US dollar, which has stayed at a high level after reaching a 20-year high in July 2022, could add further pressure on the debt-servicing burdens of corporates with large US dollar debt. On the domestic front, uncertainties over the epidemic situation in Hong Kong remains one risk factor going forward.

On a positive note, monetary and fiscal policy support to the Mainland economy, and the inclusion of eligible exchange-traded funds (ETFs) in the Stock Connect scheme since 4 July 2022 may improve the Hong Kong equity market sentiment. The more favourable valuation of the Hong Kong equity market compared to both historical levels and major equity markets, as reflected by a lower cyclically-adjusted price-to-earnings ratio, may help lessen the impact of future headwinds to some extent (Chart 4.14).

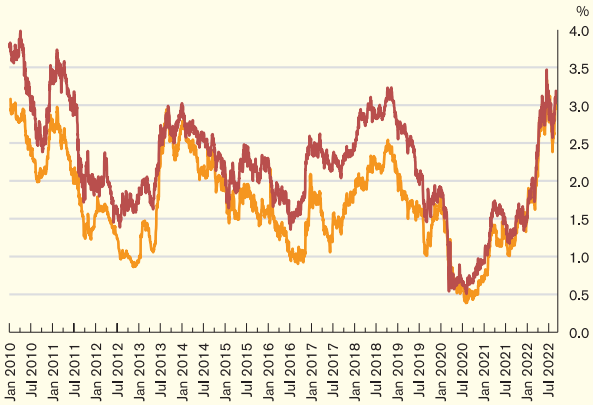
Chart 4.14
Cyclically-adjusted price-earnings ratios of Asia Pacific and other major markets



4.4 Debt market

The Hong Kong dollar debt market grew mildly in the first half of 2022 amid surges in bond yields. The interest rate hikes in the US in light of the inflationary pressure sent the US 10-year Treasury yield to an 11-year high on 14 June 2022. The US Treasury yield continued to hover around the recent high level as inflationary pressure persisted while concerns over US economic growth slowdown emerged. In tandem with the movements in the US 10-year Treasury yield, the yield of the Hong Kong dollar 10-year Government Bond rose to an all-time high of 3.34% on 15 June 2022 and remained volatile afterwards (Chart 4.15).

Chart 4.15
10-year Hong Kong Government Bond and US Treasury yield

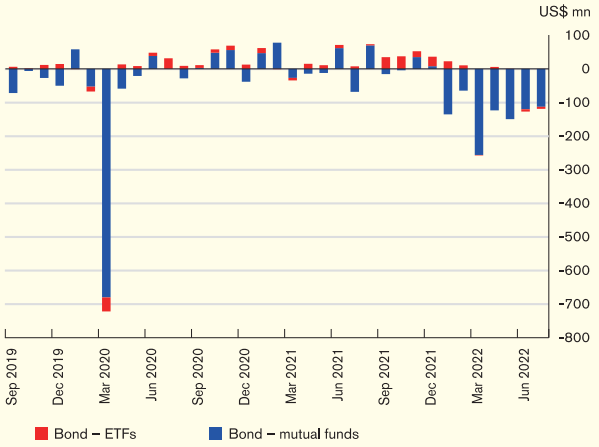


Note: Daily figures of the Hong Kong 10-year Government Bond yield under the Institutional Bond issuance program is available since 11 January 2010.

Sources: Bloomberg and HKMA.

The bond yields rose along with net bond fund outflows from Hong Kong. Between February and July 2022, bond funds as a whole registered a net outflow of US$825.3 million from Hong Kong (Chart 4.16), driven by outflows of bond mutual funds.

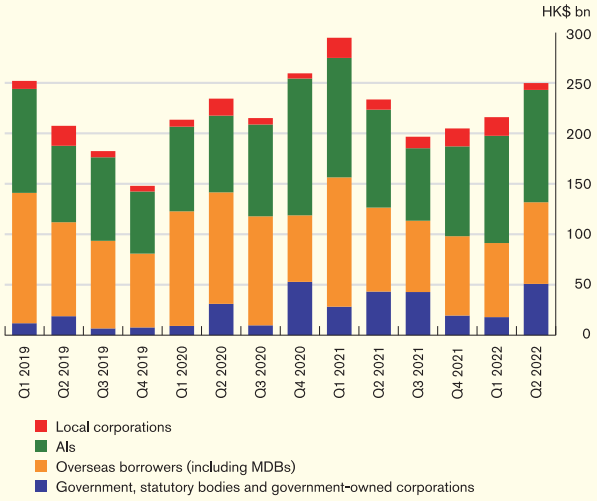
Chart 4.16
Flows of bond ETFs and mutual funds into Hong Kong



Source: EPFR Global.

The total issuance of Hong Kong dollar debt in the first half of 2022 increased by 8.4% year-on-year to HK$2,352.6 billion, contributed mainly by the 14.9% rise in the issuance of EFBNs. For non-EFBNs, bonds issued by government and statutory bodies, which include the HK$20 billion inaugural retail green bond of the Hong Kong Government issued on 18 May 2022, stayed relatively stable at HK$68.7 billion during the first half (Chart 4.17). The Hong Kong dollar debts issued by AIs and local corporations also remained steady while the issuance by overseas borrowers dropped noticeably in the first half of 2022, compared with the same period last year.

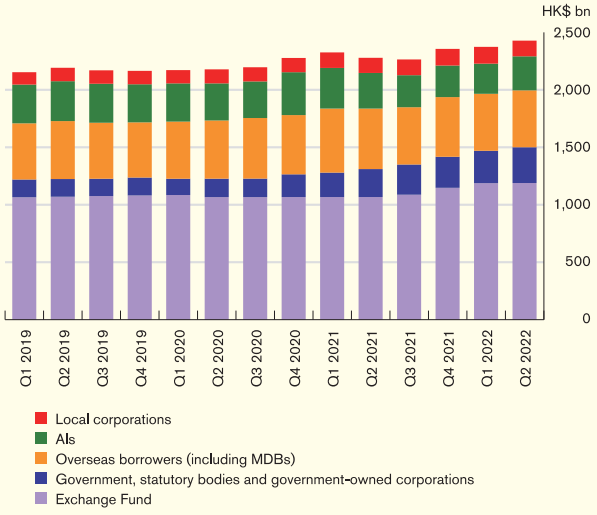
Chart 4.17
New issuance of non-EFBN Hong Kong dollar debt



Sources: HKMA staff estimates based on data from Bloomberg, CMU, Dealogic and Reuters.

At the end of June 2022, the outstanding Hong Kong dollar debt grew by 6.5% year-on-year to HK$2,428.6 billion (Chart 4.18). The amount was equivalent to 29.5% of Hong Kong dollar M3, and to 24.1% of the Hong Kong dollar-denominated assets of the banking sector. Within the government sector, the outstanding non-EFBN debt increased by 27.9% year-on-year to HK$311.2 billion, while the outstanding EFBN debt increased by 11.4% to HK$1,190.4 billion.

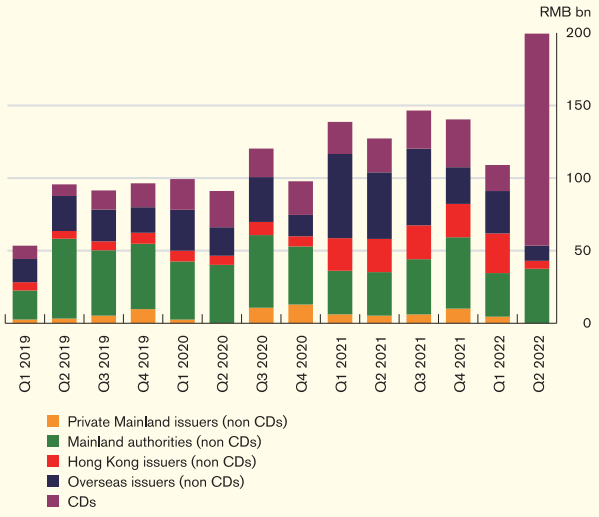
Chart 4.18
Outstanding Hong Kong dollar debt by issuer



Sources: HKMA staff estimates based on data from Bloomberg, CMU, Dealogic and Reuters.

The CNH debt market in Hong Kong continued to expand in the first half of 2022. New issuance increased by 16.4% year-on-year to RMB 309.5 billion in the first half of 2022 (Chart 4.19). The growth was mainly driven by a surge in CDs issuance in the second quarter of 2022, which increased by five times to RMB 146.0 billion compared with the second quarter of 2021. The increase in CDs issuance offset the noticeable slowdown in non-CDs issued by private issuers during the same quarter. Meanwhile, non-CDs issued by the Mainland authorities increased by 12.5% year-on-year to RMB 67.5 billion in the first half of 2022.

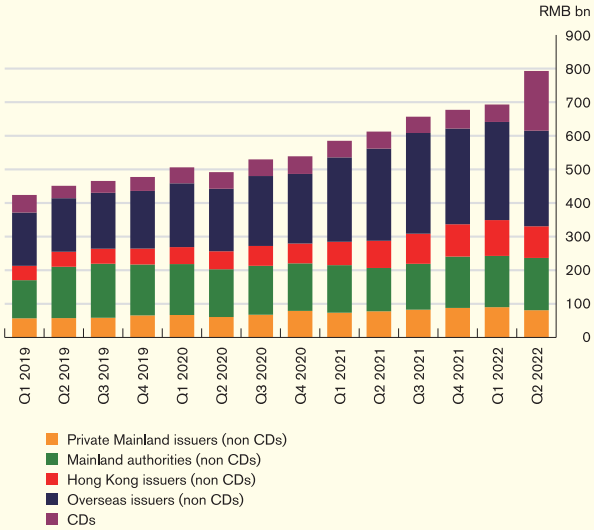
Chart 4.19
New issuance of CNH debt securities in Hong Kong



Sources: HKMA staff estimates based on data from Bloomberg, CMU, Dealogic and Reuters.

As a result, total outstanding CNH debt securities recorded a 29.4% year-on-year growth and reached RMB 792.8 billion at the end of June 2022 (Chart 4.20).

Chart 4.20
Outstanding CNH debt in Hong Kong



Sources: HKMA staff estimates based on data from Bloomberg, CMU, Dealogic and Reuters.

Looking ahead, the debt market in Hong Kong will be subject to a number of challenges. Sharp interest rate hikes by major central banks and concerns over global economic growth slowdown could make corporates more cautious in raising debt. Meanwhile, downward pressure on the Mainland economy, volatility in the CNH exchange rate and lingering risks of rising bond defaults may cast uncertainties over the outlook for the CNH debt market, even though the monetary and fiscal policy support to the Mainland economy could help lift market sentiment.

During the review period, policy initiatives were introduced to foster the development of Hong Kong's bond market. In particular, the Financial Secretary announced in the 2022-23 Budget plans to develop the CMU into a major international central securities depository in Asia. The development includes the HKMA's three-year enhancement programme plan to upgrade the CMU system and services, which will help strengthen Hong Kong's position as a bond hub.[26]

[26] For details, please refer to the inSight articles "Developing the CMU to reinforce Hong Kong's status as an IFC" on 13 June 2022 and "New Impetus for Hong Kong Offshore Renminbi Business" on 4 July 2022.

In addition, the recent successful debut of the Government's retail green bond has broadened the variety of green financial products in Hong Kong, reinforcing Hong Kong's position as a premier green finance hub. The vibrant development of Hong Kong's bond market will help maintain Hong Kong's leading position as an international financial centre.

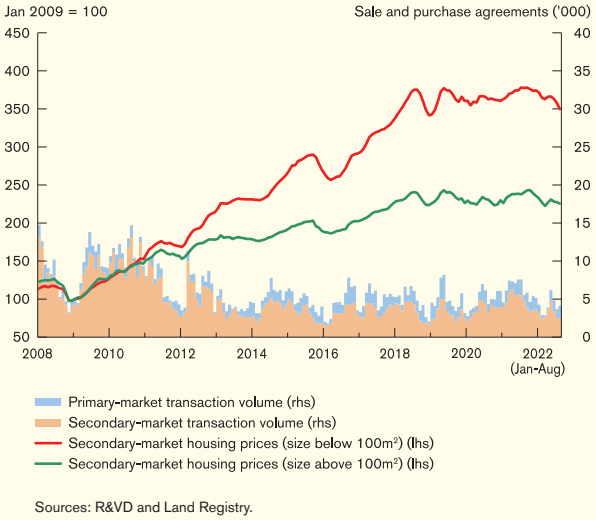
4.5 Property markets

Residential property market

The residential property market stabilised in the second quarter following a moderation in the first quarter. As the fifth wave of the local epidemic receded, flat viewing and transaction activities bounced back alongside improving market sentiment and pent-up demand. Property developers also resumed the launch of new projects with competitive pricing strategies to boost sales. As a result, the average monthly transactions picked up to 4,975 units in the second quarter from a low of 3,352 units in the first quarter (Chart 4.21). More recently, market sentiment again turned cautious amid concerns over rising interest rates, and average monthly housing transactions fell back to 3,904 units in July–August.

Secondary-market housing prices edged up by 0.2% in the second quarter following a 3.2% decline in the first quarter. Analysed by size, prices of large flats (with a saleable area of at least 100m^2) increased faster than that of small and medium-sized flats (with a saleable area of less than 100m^2), partly reflecting local families' upgrading demand (Chart 4.21). More timely market data indicated that flat prices softened again in July and August.

Chart 4.21
Residential property prices and transaction volumes



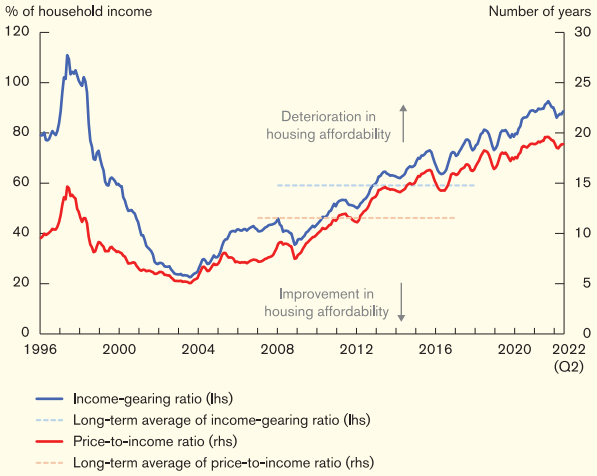
Sources: R&VD and Land Registry.

Housing affordability remained stretched, despite improving somewhat during the first half of the year. Compared to the final quarter of 2021, the housing price-to-income ratio eased to a still-high level of 18.8 in the second quarter of 2022, which was still higher than the peak value of about 15 in 1997. The income-gearing ratio also retreated to 87.9, but still remained well above the long-term average (Chart 4.22).[27] On the other hand, housing rentals zigzagged upwards by 1.4% during May–August (Chart 4.23) after declining by about 4% in the seven months through April.[28] Residential rental yields stayed low at 2.0–2.5% in July.

[27] The price-to-income ratio measures the average price of a typical 50m^2 flat relative to the median income of households living in private housing. Alternately, the income-gearing ratio compares mortgage payment for a typical 50m^2 flat (under a 20-year mortgage scheme with a 70% loan-to-value ratio (LTV) ratio) to the median income of households living in private housing. The income-gearing ratio is not the same as a borrower's actual debt-servicing ratio, which is subject to a maximum cap under HKMA prudential measures.

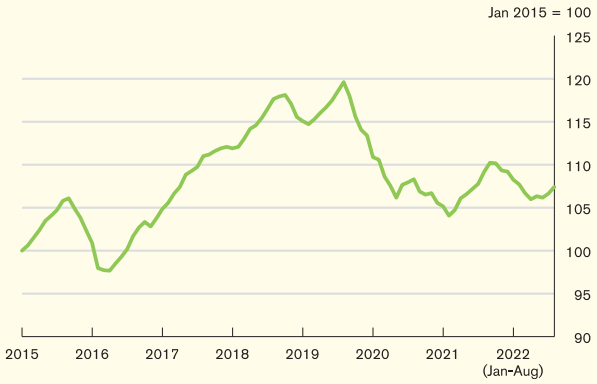
[28] Market information suggests that the leasing market was partly supported by demand from Mainland students.

Chart 4.22
Indicators of housing affordability



Sources: R&VD, C&SD and HKMA staff estimates.

Chart 4.23
Residential property rental index



Source: R&VD.

With an uptick in the one-month HIBOR, local mortgage interest rates have picked up since June, adding to the repayment burden on borrowers (see also section 4.2). In response to the higher costs of liquidity, some banks also raised the cap on their HIBOR-based mortgage rates in recent months and their Best Lending Rates in September. The public should carefully assess and manage the relevant risks when buying property, arranging mortgages or making other relevant decisions. [29] However, the macro-prudential measures implemented by the HKMA since 2009 have helped contain household leverage and strengthen banks' risk management for mortgage loans, thereby improving their resilience to interest rate and property market shocks. The average loan-to-value (LTV) ratio for new mortgages was about 56% in July 2022, still below the prevailing ratio of 64% before the measures were first introduced. The debt-servicing ratio (DSR) also stayed at a low level of around 37%, and borrowers are stress-tested to ensure their ability to withstand rising interest rates.[30] In addition, over half of the private housing units did not have any outstanding mortgages at the end of 2021.[31] Box 3 explores the use of machine learning techniques to predict credit deterioration in RMLs in view of the upward pressures on mortgage rates.

The residential property market outlook is subject to a number of uncertainties and risks as discussed in the previous chapters. In particular, a prolonged local epidemic, coupled with higher mortgage interest rates, could suppress housing demand, while concerns about the global economic prospects and the uncertainty over the pace of US rate hikes will continue to cloud housing market sentiment. Over the longer

[29] The HKMA has also reminded homebuyers to be aware of property price or interest rate adjustment risks when buying first-hand, incomplete flats via stage payment schemes. In particular, when these buyers arrange mortgage later on, they may face more conservative property valuations or may not pass the stress test amid rising interest rates.

[30] Taking into account the prevailing interest rate environment, the trend of mortgage rates and their long-term historical average, the HKMA considers it appropriate to lower the interest rate stress testing requirement for property mortgage lending from 300 basis points to 200 basis points, with immediate effect on 23 September 2022. This level is considered to be sufficiently prudent from the perspective of effective risk management of the banks' property lending business. For more details, see the press release "Property Mortgage Lending" issued by the HKMA on 23 September 2022.

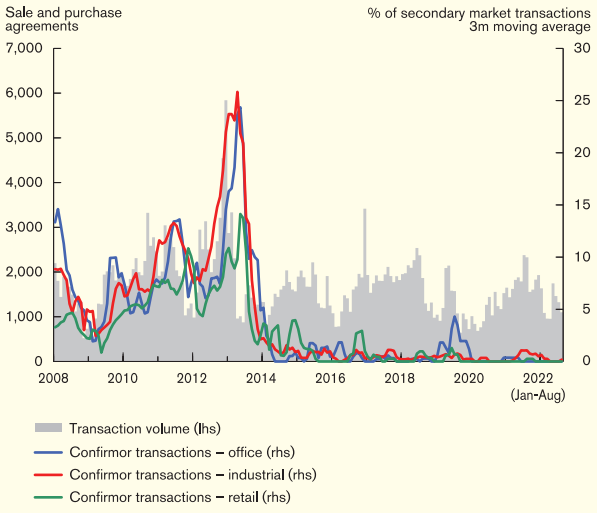
[31] See "Box 4: Using transactional big data to monitor Hong Kong's residential mortgage loans offered by non-bank institutions", *HKMA Half-yearly Monetary and Financial Stability Report*, March 2022. The 2021 Population Census data also show that 66% of owner-occupier households did not have any mortgage.

term, the outlook for the housing market will depend on the supply-demand gap. The Government projects that private housing supply will remain high in the coming years.[32]

Non-residential property market

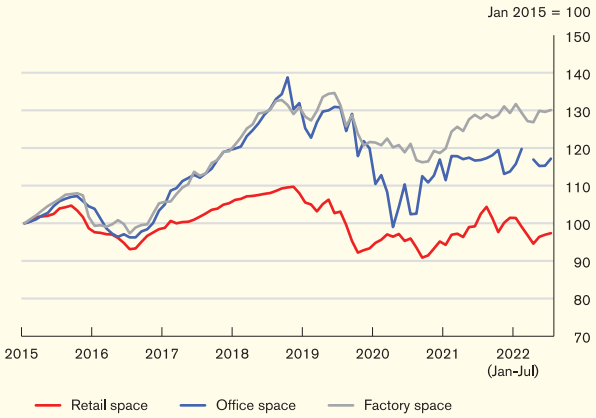
Amid the fifth wave of the local epidemic and the resultant restrictive measures, the non-residential property market consolidated in the first half of the year. Average monthly transactions declined to about 1,300 units during the period, while speculative activities remained muted (Chart 4.24). The price of retail premises softened again amid a challenging business environment, while the price of office spaces and flatted factories zigzagged sideways (Chart 4.25). In the leasing market, rentals of commercial properties remained soft (Chart 4.26). Rental yields across the segments stayed low at 2.5–2.9% in July.

Chart 4.24
Transactions in non-residential properties



Sources: Land Registry and Centaline Property Agency Limited.

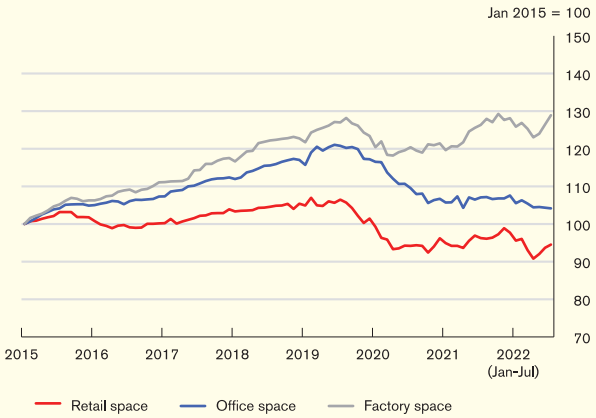
Chart 4.25
Non-residential property price indices



Note: The price index of office space cannot be compiled in March 2022 due to insufficient transactions for analysis.

Source: R&VD.

Chart 4.26
Non-residential property rental indices



Source: R&VD.

The outlook for the non-residential property market remains challenging in the near term. For example, while the disbursement of the government's consumption vouchers should stimulate local consumption and thereby provide some support to the retail segment, subdued inbound tourism continues to be a drag. The rental and capital values of office spaces may remain under pressure due to the high vacancy rate and more new supply in the upcoming years.

[32] Total private supply of first-hand flats in the coming three to four years will remain at a high level of 98,000 units as estimated by the Housing Bureau at end-June 2022. To expedite land and housing supply, the Government also set up the "Steering Committee on Land and Housing Supply" and the "Task Force on Public Housing Projects" in July 2022 with the aim of streamlining development-related procedures and unleashing the development potential of land.

Box 3
Using data science to assess banks' mortgage credit risks

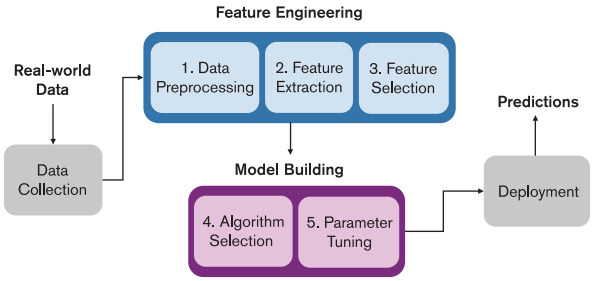
Introduction

In Hong Kong, RML is a significant area of loan exposure for banks and borrowers, accounting for 24% of the loans for use in Hong Kong and 70% of local household debts as of June 2022. While the residential mortgage delinquency ratio has remained at a very low level of around 0.01% to 0.05% following several rounds of macroprudential measures implemented by the HKMA since 2009, it is still imperative for regulators to closely monitor the credit risks of RMLs, particularly in view of the upward pressures on mortgage rates amid the aggressive rate hike by the Fed. Against this background, this box explores the use of machine learning techniques to predict credit deterioration in RMLs to facilitate risk monitoring.

Data and Methodology

The HKMA initiated the Granular Data Reporting (GDR) programme in April 2019, under which participating AIs are required to report transaction-level RML data to the HKMA on a monthly basis. The programme was introduced in phases, and in July 2020 all the AIs covered by the HKMA's residential mortgage survey started reporting the transaction-level records of all their outstanding RMLs[33]. As of May 2022, the GDR dataset contained over 598,000 outstanding RMLs associated with around 678,000 borrowers. The dataset is highly granular with each reported RML carrying around 200 unique data fields.

Chart B3.1
Typical machine learning pipeline



Source: Elshawi et al. (2019).

We explore the use of machine learning techniques to build a model with the GDR dataset for predicting the technical delinquency of RMLs, which are identified to be overdue for more than 90 days using the information reported in the GDR dataset[34]. It should also be noted that the GDR dataset currently does not contain any information on principal moratorium. Hence, the technically delinquent loans identified using the GDR dataset may include those that are under the principal moratorium plan offered by AIs to help relieve borrowers' cash-flow pressure during the COVID-19 outbreak[35]. Building a high-quality machine learning model requires informed decisions to be made by researchers at each step of a typical machine learning pipeline outlined in Chart B3.1[36]. In particular, as no single machine learning method can perform best on all types of data and that the performance of

[33] The RMLs of the AIs covered in the GDR programme and the residential mortgage survey represent about 99% of all the RMLs in the banking sector.

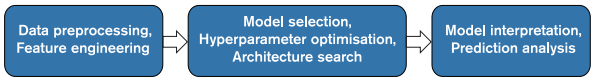
[34] We identify the technically delinquent RMLs by using the data field "number of days in arrears". For RMLs with missing information in this data field, we use their "beginning outstanding amount" and "closing outstanding amount" to infer whether the loan has been overdue for three consecutive months.

[35] For details on principal moratorium, see HKMA's press release "The HKMA and the banking sector join forces to help Hong Kong's economy overcome the outbreak of COVID-19" published on 3 April 2020, https://www.hkma.gov.hk/eng/news-and-media/press-releases/2020/04/20200403-4/.

[36] Elshawi R, Maher M, Sakr S (2019). "Automated Machine Learning: State-of-the-art and Open Challenges", *arXiv.org*, 1906.02287.

some methods rely heavily on hyperparameter tuning, researchers in applied machine learning are generally challenged with the need to select among a wide range of algorithms and to tune the hyperparameters of the selected model[37]. To tackle these challenges, this study uses a state-of-the-art approach, namely automated machine learning (AutoML), under which the process of algorithm selection and hyperparameter tuning would be automated. Depending on the choice of tools, a common AutoML pipeline would involve automating the three stages as illustrated in Chart B3.2, with each stage being optimised iteratively to obtain the best outcome[38&39].

Chart B3.2
Common AutoML pipeline



Source: Truong et al. (2019).

Regarding the data input, we use the GDR data reported during the period from July 2020 to May 2022. As with any other big data, the GDR data, especially those that were reported in the initial stage of the programme, do not come with perfect quality. Instead of relying completely on AutoML, we preprocess the data and perform some parts of the feature engineering steps by leveraging our domain knowledge in RML and the GDR dataset. First, we drop the data fields that either contain missing information for most of the RML transactions or cannot be imputed with a meaningful representation. Secondly, we impute the missing values or create new variables by combining the incomplete information reported in different but related data fields. After these data preparation steps, we are left with 37 variables which contain information on loan characteristics, the borrowers and the mortgaged properties. We also supplement the transaction-level information with some macroeconomic indicators. The explanatory variables used in our prediction model are listed in Table B3.1.

Table B3.1
List of explanatory variables in the prediction model

	Category	Data field/variable
GDR	Borrower information	DSR at origination, Employment status, Fixed income proportion*, Hong Kong connection*, Individual/corporate borrower*, Martial status, Mega corporate indicator, Number of borrowers/ guarantors*, Total monthly income*, Year of birth
	Loan characteristics	Approval basis, Closing outstanding amount, Co-financing indicator, Equitable mortgage indicator, Interest rate cap: reference rate, Interest rate type, Loan amount at origination (HKD equivalent), Latest updated LTV, LTV ratio at origination, Mortgage Insurance Programme (MIP) indicator*, Number of collateral*, Payment frequency, Reference rate, Remaining tenor, Staff loan indicator, Tenor at origination, Guarantee*, Other collateral*, Type of financing, Mortgage cash rebate
	Property characteristics	Car parking space, Collateral value, Intention of use, Original collateral (property) value, Rented out on origination date, Saleable area, Type of building
	Housing market indicators	Centaline leading index, Centa-salesman index, Centa-valuation index, Completions of private domestic, Midland 35 Estate Transactions, Property market sentiment index, R&VD residental property prices, R&VD residental property rentals, Ricacorp flat viewing appointment, Sales transactions of private domestic
	Macro-financial indicators	1-month HIBOR, Effective mortgage rate, Hang Seng Index, Hong Kong economic policy uncertainty index, HSI volatility index, Inflation rate, Median household income, PMI, Prime rate, Retail sales value and volume, Turnover value of Hong Kong stocks, Unemployment rate

Note: Data fields marked with * are created by combing information reported in different but related data fields.

To enable the machine to learn in a supervised way, we assign the label "delinquent" or "healthy" to each RML transaction based on whether it was delinquent three months following the reporting position date. After identifying all the technically delinquent RMLs, we randomly draw a subset of the healthy loans from the GDR dataset. The number of healthy loans drawn is four times that of the technically delinquent RMLs. This under-sampling step aims to address the imbalance between the two classes of loans in order to ensure that our model is able to capture the characteristics of the delinquent

[37] Feurer, M., Klein, A., Eggensperger, K., Springenberg, J., Blum, M., & Hutter, F. (2015). "Efficient and robust automated machine learning", In *Advances in neural information processing systems* (pp. 2962-2970).

[38] Truong, A., Walters, A., Goodsitt, J., Hines, K., Bruss, C. B., Farivar, R. (2019). "Towards Automated Machine Learning: Evaluation and Comparison of AutoML Approaches and Tools", *arXiv.org*, 1908.05557.

[39] Examples of AutoML tools include DataRobot, H2O AutoML, Auto-keras, Auto-Weka, Azure ML and Auto-sklearn.

loans. Overall, we include 56,212 unique RMLs with around 847,000 records spanning the entire sampling period. To ensure the trained model can perform well on unseen data, these sampled transactions are split into two groups, with 80% of the unique RMLs being used as the training set and the remaining as the testing set.

With the data ready, we initiate the AutoML pipeline under which the training set are used to train over 100 models using a pre-defined set of algorithms with each carrying a list of hyperparameters to be searched over[40]. The performance of each trained model is evaluated automatically using the testing data. Leveraging the computing power of the in-house Data Science Lab, the entire AutoML process can be completed in around 600 minutes.

Empirical results

Different evaluation metrics are generated to compare the performance of all the trained models. Given that the aim of our model is to tackle a binary classification problem (i.e. predicting whether an RML would become delinquent in three-month's time), the evaluation metric called the area under the curve of receiver operating characteristic (AUC) can be used to select the best model. Table B3.2 shows the evaluation metrics of the best trained model for each category based on AUC. As shown in the table, the best model is one of the stacked ensemble models which carries an AUC of 0.9388. According to the literature benchmark, the performance of this model can be considered as excellent[41].

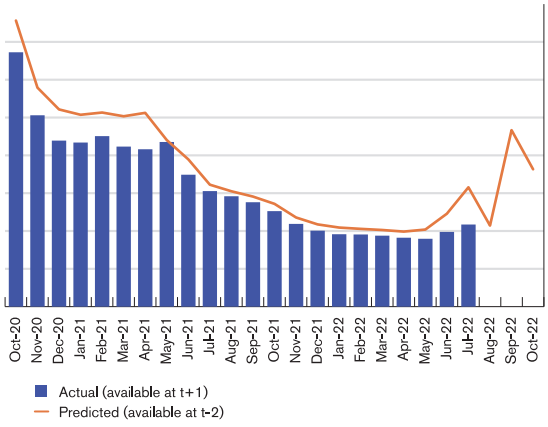
This selected model can be deployed to offer timely insights on the trend of credit risk in AIs' RMLs. Chart B3.3 compares the model predictions with the actual number of technical delinquency identified using the GDR data. As can be seen in the chart, the selected model performs fairly well in predicting the total number of technical delinquency with a three-month lead time. Amid the deteriorated economic condition caused by the fifth wave COVID-19 infections and the upward pressures on mortgage rates, the selected model predicts that the number of technical delinquency may increase but will still remain at a relatively low level.

Table B3.2
Key evaluation metrics of the best trained model for each category

Model Types	AUC	Precision-recall AUC
Deep neural network	0.8980	0.5785
Distributed random forest	0.9116	0.7123
Gradient boosting machine (GBM)	0.9322	0.7563
Generalised linear model	0.8184	0.4182
Stacked Ensemble Type 1	**0.9388**	**0.7837**
Stacked Ensemble Type 2	0.9373	0.7697
XGBoost GBM	0.9325	0.7587

Source: HKMA staff estimates.

Chart B3.3
Comparing model predictions with actual number of technical delinquency



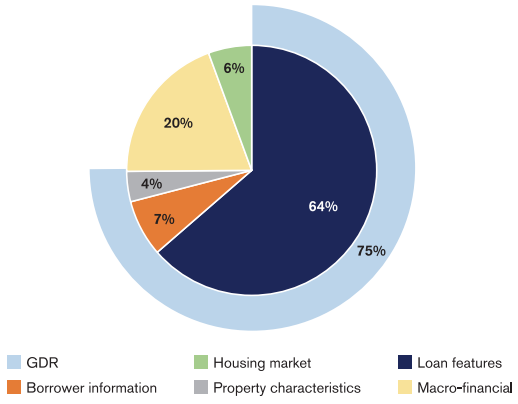
Source: HKMA staff estimates.

[40] Throughout the AutoML process, 100 base models are trained using five-fold cross validation and a number of machine learning algorithms, including distributed random forest, generalised linear model, gradient boosting machine (GBM), XGBoost GBM, and deep neural network. Several stacked ensemble models are also trained based on a subset of the 100 base models.

[41] In theory, a perfect model has an AUC of one. The literature suggested that a model with an AUC of 0.9 and 0.8 could respectively be considered as an excellent and a good model. For details, see Hosmer Jr, D. W., Lemeshow, S., Sturdivant, R. X. (2013). *Applied Logistic Regression* 398. John Wiley & Sons.

We also try to identify through reverse engineering the factors that are most influential to our model predictions. Our selected model highlights that 75% of the information used for predicting delinquency is provided by the GDR dataset (Chart B3.4). Among all the GDR variables, loan characteristics, such as LTV ratio, tenor and the outstanding amount of an RML are considered as important drivers. Other influential GDR variables highlighted by our model include DSR and borrower's employment and income information. As for the macro-financial data, effective interest rate is found to be the most important factor. Our finding is in line with a similar study conducted by the Bank of England in 2019[42]. Furthermore, by highlighting LTV ratio and DSR as part of the key drivers that could render a loan vulnerable to delinquency, our finding confirms that the HKMA's macro-prudential measures could help contain credit risks by setting limits on these ratios.

Chart B3.4
Importance of input variables grouped by category



Notes:
1. Variable importance is measured by using variable drop-out loss, which refers to the drop in model performance when a variable is removed from the model training process. A higher drop-out loss indicates greater importance of the variable.
2. Figures may not add up to 100% due to rounding.

Source: HKMA staff estimates.

Conclusion

To conclude, this box experiments the use of AutoML technique to develop a toolkit for facilitating risk monitoring of AIs' RML portfolio. In particular, we have trained a model capable of predicting RML technical delinquency three months ahead. Through reverse engineering, we also find that GDR data provides valuable information for predicting technical delinquency in RML, with loan features being the most important category of information.

Despite the reasonably good performance of our trained model, it is important to note that our exploratory model is not without its limitations. In particular, given the short timeframe of the GDR dataset and the imperfect data quality, our model may not be able to capture all the important contributing factors and the structural changes across different economic cycles. That said, the use of AutoML technique allows us to easily refine the model as the quality and the coverage of GDR data improve over time. The refined model can be used as a supplementary tool to provide an early warning signal to credit deterioration in RMLs.

[42] Bracke, P., Datta, A., Jungm C., Sen, S. (2019). "Machine Learning Explainability in Finance: an Application to Default Risk Analysis", *Bank of England Staff Working Paper No. 816*.