HONG KONG MONETARY AUTHORITY

DOES THE RENMINBI EXCHANGE RATE AFFECT EQUITY FLOWS?
## – EVIDENCE FROM THE STOCK CONNECT PROGRAMMES

Key points:

- *The Stock Connect programmes established in 2014 offer both international and Mainland Chinese investors a new channel for diversifying their equity investment portfolios into the Mainland and Hong Kong markets. However, fluctuations in the renminbi have been more apparent since the exchange rate reform in August 2015, raising concerns this may have an impact on currency-adjusted returns in investors' portfolios and so influence their decisions on whether to participate in the programmes.*

- *Against this background, this study empirically tests whether the equity flows to the Mainland and Hong Kong markets are affected by the renminbi exchange rate, based on firm level flows under the Stock Connect programmes. Given the granular data publicly available, we opt for the machine learning (ML) technique as it efficiently handles multi-dimensional and multi-variety data.*

- *Empirical results show that movements in the offshore renminbi exchange rate have a very limited impact on decisions about investing in the cross-border stock markets via the Stock Connect programmes for both international and Mainland investors. This may be due to the fact that the currency risk arising from renminbi fluctuations can be hedged effectively by a diversified suite of renminbi exchange rate instruments available in the markets.*

- *Among other selected factors for comparison, global stock volatility was found to have the strongest impact on equity flows for both northbound and southbound trades. This implies that with continued growth in these trades through the Stock Connect programmes, potential global market spillovers will become more noteworthy. As such, investors should be mindful of sudden cross-border equity flows triggered by escalating global market uncertainty.*

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1.   INTRODUCTION

Since 2014, the Stock Connect programmes have offered both international and Mainland Chinese investors a new channel for diversifying their equity investment portfolios into the Mainland and Hong Kong markets. However, the renminbi fluctuation has been more apparent since the exchange rate reform in August 2015 (Chart 1), raising concerns that the fluctuations may impact the currency-adjusted returns on investors' portfolios. Therefore, will these fluctuations influence investors' decisions on their participation in the programmes?[1]

Chart 1: Movements of the offshore renminbi exchange rate

Source: Bloomberg
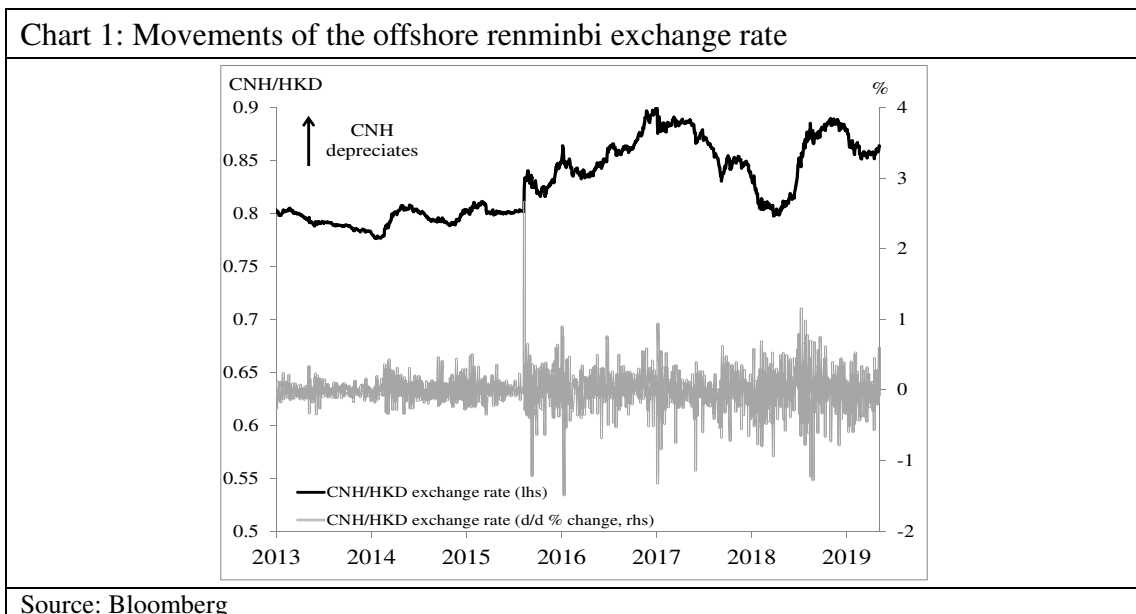
Against this background, our study tests whether the cross-border equity flows between the Mainland and Hong Kong are linked with movements in the offshore renminbi exchange rate (CNH), based on the equity flows under the Stock Connect programmes. Our test is based on firm level information, with goals of assessing both the effects of the CNH movement on equity flows to firms as a whole, and identifying firms that could be facing a larger impact. Given the granular data publicly available, we opt for three popular machine learning (ML) techniques, Random Forest (RF), Support Vector Machine (SVM) and Artificial Neural Network (ANN),[2] as these techniques are good at handling multi-dimensional and

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[1] Imperfect foreign exchange risk hedging is the major reason why international equity flows should react to movements in exchange rates, as it would affect the returns of cross-border equity investments. In literature, empirical evidence is available for both a positive (i.e. more flows into foreign equities on foreign currency appreciation, see Brennan and Cao, 1997) and negative (i.e. less flows in foreign equities on foreign currency appreciation, see Hau and Rey, 2004) reaction to cross border equity flows when foreign currency appreciates
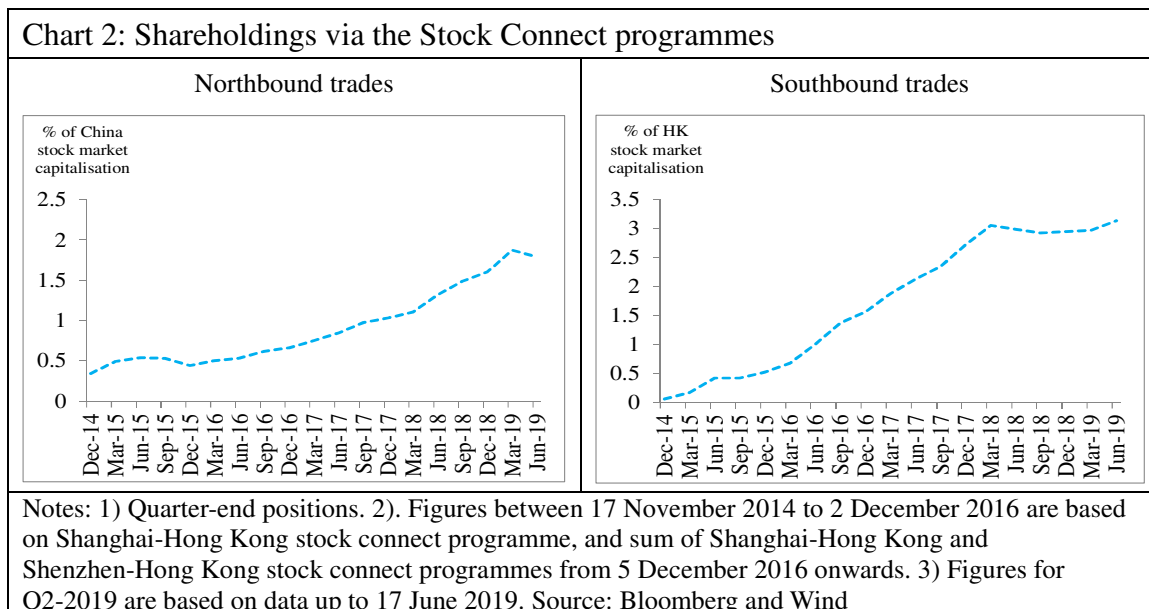
[2] Brief descriptions of these ML techniques are summarised in Appendix 1.

multi-variety data (Chakraborty and Joseph, 2017). Finally, we also separate the analysis of the northbound[3] (i.e. international investors investing in Mainland markets) from that of the southbound trades (i.e. Mainland Chinese investors investing in the Hong Kong market) to see whether the effects differ between these two groups of investors.

Our study is organised as follows. Sections 2 and 3 describe data and empirical methodology respectively. Section 4 discusses our empirical findings while the final section concludes.

2. DATA

In this study, equity flows refer to the net flows to eligible firms under the Stock Connect programmes. The net flows to each firm are measured by the net change in shareholdings (as percentage of a firm's market capitalisation) under the Stock Connect programmes, where a positive (negative) net flow indicates an inflow (outflow) to the firm. Chart 2 depicts the net flows of the northbound and southbound trades since the start of the programmes. As can be seen, these equity flows into the stock markets of both Mainland China and Hong Kong have accumulated steadily under the Stock Connect programmes.

Chart 2: Shareholdings via the Stock Connect programmes

Northbound trades

Southbound trades

Notes: 1) Quarter-end positions. 2). Figures between 17 November 2014 to 2 December 2016 are based on Shanghai-Hong Kong stock connect programme, and sum of Shanghai-Hong Kong and Shenzhen-Hong Kong stock connect programmes from 5 December 2016 onwards. 3) Figures for Q2-2019 are based on data up to 17 June 2019. Source: Bloomberg and Wind

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[3] This approach achieves an average improvement of 18% in terms of the prediction accuracy in this study, compared with the case where we estimate the effect using the traditional linear regression model.

Covering the sample period from 20 March 2017 to 30 April 2019,[4] our data sample consists of 1,522 actively traded firms under the Stock Connect programmes.[5] Among these firms, 1,110 are listed in Mainland stock markets (512 in Shanghai and 598 in Shenzhen, denoted as "northbound firms"), while the remaining 412 firms are listed in Hong Kong (denoted as "southbound firms"). The selected sample firms are highly representative, sharing about 90% and 94% respectively of the market capitalisation of all eligible northbound and southbound firms.

Several potential determinants of individual firms' equity flows are considered,[6] including:

(i)   the CNH movement, which is measured by the daily percentage change of the CNH exchange rate against the Hong Kong dollar (HKD);

(ii)   a firm's stock performance, which is measured by the foreign firm's daily excess return over the domestic stock market return from an investor's perspective, (i.e., dividing firm's return by the Hang Seng Composite Index one for international investors; and dividing by the CSI 300 Index one for Mainland Chinese investors);

(iii)   global market volatility, which is measured by the daily changes of the VIX index;

(iv)   funding cost,[7] which is measured by the 3-month CNH interbank interest rates (CNH HIBOR) and the 3-month Shanghai interbank offered rate (SHIBOR) for international and Mainland Chinese investors respectively; and

(v)   the lagged term of net equity flows of the firm.

Appendix 2 provides some summary statistics of the above determinants. During the sample period, the daily net flows were more volatile for the southbound firms (with a standard deviation (SD) of 0.096%) than northbound ones (with a SD of 0.054%). In comparison, the volatility of relative equity returns is substantially

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[4] Individual firms' shareholdings under the Stock Connect programmes have been publicly available since 17 March 2017.

[5] Actively traded firms refer to those with non-zero equity flows in over 70% of trading days of the sample period under the programmes.

[6] In the specification, we also introduce a dummy variable to control for the effect of a permanent shift in equity flows to northbound firms after 1 June 2018 when A-shares were officially included in the MSCI EME index.

[7] A market survey by Standard Chartered (2018) shows that, when investing in China, investors' priorities are shifting from the design of investment mechanisms to more practical considerations, such as access to funding and stock account opening.

larger, with a SD of around 2.3% for both northbound and southbound firms, while that of the CNH movement remains less notable (0.29%).

3.   METHODOLOGY

We uncover the relationships between the equity flows and the selected determinants including the CNH movement in three steps. First, we estimate a total of 632 ML models from the RF, SVM and ANN classes. Second, we select the best 20 models based on their out-of-sample prediction accuracy, and use each of the best 20 models to predict the potential changes in equity flows on certain shocks to the CNH or other factors.[8] In evaluating the prediction accuracy, we split our data sample into estimation data for models' estimations and leave the rest as out-of-sample validation data for measuring the root mean squared errors of the estimated models.[9] Finally, we measure the potential changes in equity flows to each firm by taking the average predicted changes from these best 20 models.

We also identify the major characteristics of firms whose net flows are more affected by the CNH movement. To achieve this, we use the k-means clustering, which is a method of vector quantization that is popular for cluster analysis in data mining.[10] Apart from changes in net flows due to the CNH movement, several other firm-specific characteristics are selected for clustering purposes. They cover four aspects of a firm including (i) stock performance (proxied by equity return and stock price volatility), (ii) financial fundamentals (proxied by overall profitability, size, and leverage), (iii) shareholding structure (proxied by the percentage of shareholdings under the Stock Connect programmes and institutions' shareholdings); and (iv) the direct impact of CNH movements on a firm's profitability (proxied by the share of overseas revenue, the correlation between income losses due to exchange rate fluctuations, and the CNH movement).[11,12] To increase comparability across industries, all firms' variables are

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[8] The best 20 models are selected instead of only the best model to alleviate the over-fitting problem (Mullainathan and Spiess, 2017).

[9] The evaluation based on the validation data, instead of the estimation data, is important since machine learning models (or other conventional econometric models) can perform very well with the in-sample data, but lack performance in predicting some unknown data. This is also known as the "over-fitting" problem. To further reduce this problem during the model selection process, we also adopted a procedure called nested cross-validation. Specifically, we partitioned the sample data into smaller parts before putting them into different variants of estimation and out-of-sample validation data. We did this to ensure the time series structure of the original sample data was not broken. The prediction accuracy is then evaluated based on the average prediction accuracy across these different variants of data samples.

[10] The method primarily partitions firms into clusters in which each firm in the cluster has similar features defined by a bunch of selected firm-specific variables.

[11] The last aspect is only included in the analysis for northbound trades.

standardised in terms of their differences to the sector's average (in numbers of SD).[13]

4. EMPIRICAL FINDINGS

<u>The flow response of northbound firms to CNH movements</u>

In sum, our empirical results show that net flows to firms under the Stock Connect programmes will not be affected by the CNH movement, regardless of whether the total effect of all firms, or the effect by sector, are considered. Despite the insignificant impact on firms' equity flows, our results recognise that firms experiencing a decrease in net flows during the CNH depreciation will have weaker fundamentals and more volatile stock prices.

The left panel of Chart 3 depicts the total effect on the net flows to northbound firms (expressed as a percentage of their average daily net flows) at different levels of the CNH depreciation. The estimated effects range from -1% (i.e. decrease in net flows by 1%) to 2% (i.e. increase in net flows by 2%) across different levels of CNH depreciation considered. However, the 90% confidence intervals of these estimates fully cover the x-axis (i.e., a level of zero net flows), suggesting that the CNH depreciation does not have a significant effect on the net flows to northbound firms at a 10% significance level.

The right panel of Chart 3 is a tree map that compares the changes in net flows to northbound firms associated with the CNH depreciation by sectors.[14] Among all these sectors, the financial sector has the largest average asset size, as represented by the largest rectangle size. Given a one-SD depreciation of the CNH, the estimated increase in the net flows is RMB40 million, or 3.5% of average daily net flows of all northbound firms, as indicated in the rectangle.[15] This suggests that the impact of the CNH depreciation on the overall market is insignificant. The impact on the non-financial sectors is even smaller in comparison, with the most responsive being the consumer product sector, where an outflow of 0.5% of all

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[12] Specifically, a more positive (negative) correlation means the firms suffer more losses when the CNH depreciates.

[13] Appendix 3 summarises the definition of each characteristic.

[14] Each sector is given a rectangle whose size is proportional to the share of sectoral market capitalisation to all the northbound firms' total market capitalisation. A rectangle is coloured (deeper) green to represent a (larger) increase in the net flows to the sector, and coloured (deeper) red to represent a (larger) decrease in the net flows to the sector.

[15] The estimated effect in renminbi terms is calculated using the average daily net flows of RMB1,147 million for the overall northbound trades of Stock Connect programmes during 20 March 2017 to 30 April 2019 (i.e. RMB1,147 million x 3.5% = RMB40 million).

northbound firms' average daily net flows is observed.

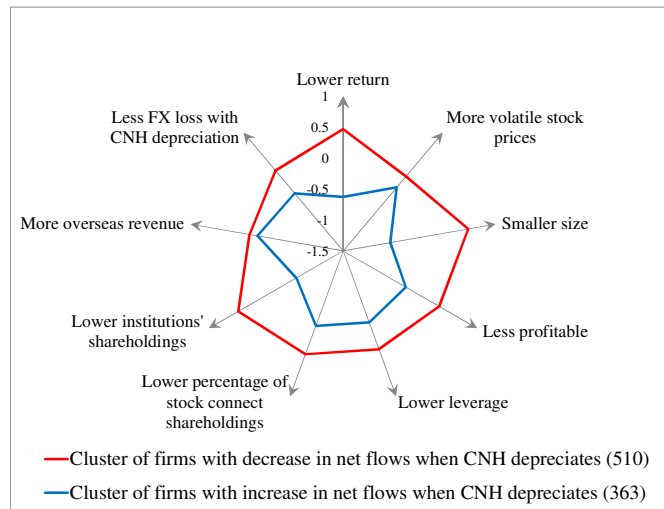| Chart 3: Effects of CNH depreciation on the net flows to northbound firms	
Overall effect (at different levels of CNH depreciation)	Sectoral effect (at 1 SD depreciation of the CNH)
Notes: (1) The total effect refers to the sum of effects to individual firms, expressed as percentage of average daily net flows. (2) Shaded areas denote 90% confidence interval. Source: HKMA staff estimates.	Note: Figure in bracket refers to the total effect of one standard deviation depreciation of the CNH (total in past 5 trading days) on the net flows to each sector (expressed as percentage of all northbound firms' average daily net flows). Source: HKMA staff estimates.

Despite this inconsequential effect on firms' equity flows, the cluster analysis [16] in Chart 4 identifies several characteristics of firms that would experience more outflows during CNH depreciation periods. These characteristics include smaller asset size, lower profitability, and more volatile stock prices, albeit with lower financial leverage and more overseas revenues.[17] In addition, they would have a lower Stock Connect shareholding, reflecting a lower interest in these stocks by Stock Connect investors.

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[16] A total of 873 northbound firms (around 79% of total northbound firms in the sample) are covered in this cluster analysis. The remaining firms are not covered in the cluster analysis due to incomplete data or existence of extreme outliers.

[17] These firms are less likely to suffer losses from foreign exchange fluctuations when the CNH depreciates compared to the others. While this could be a positive factor for their stock prices, it could also make them less attractive to investors due to higher valuation.

Chart 4: Radar chart on average characteristics of clustered northbound firms

Lower return

More volatile stock prices

Smaller size

Less profitable

Lower leverage

Lower percentage of stock connect shareholdings

Lower institutions' shareholdings

More overseas revenue

Less FX loss with CNH depreciation

— Cluster of firms with decrease in net flows when CNH depreciates (510)
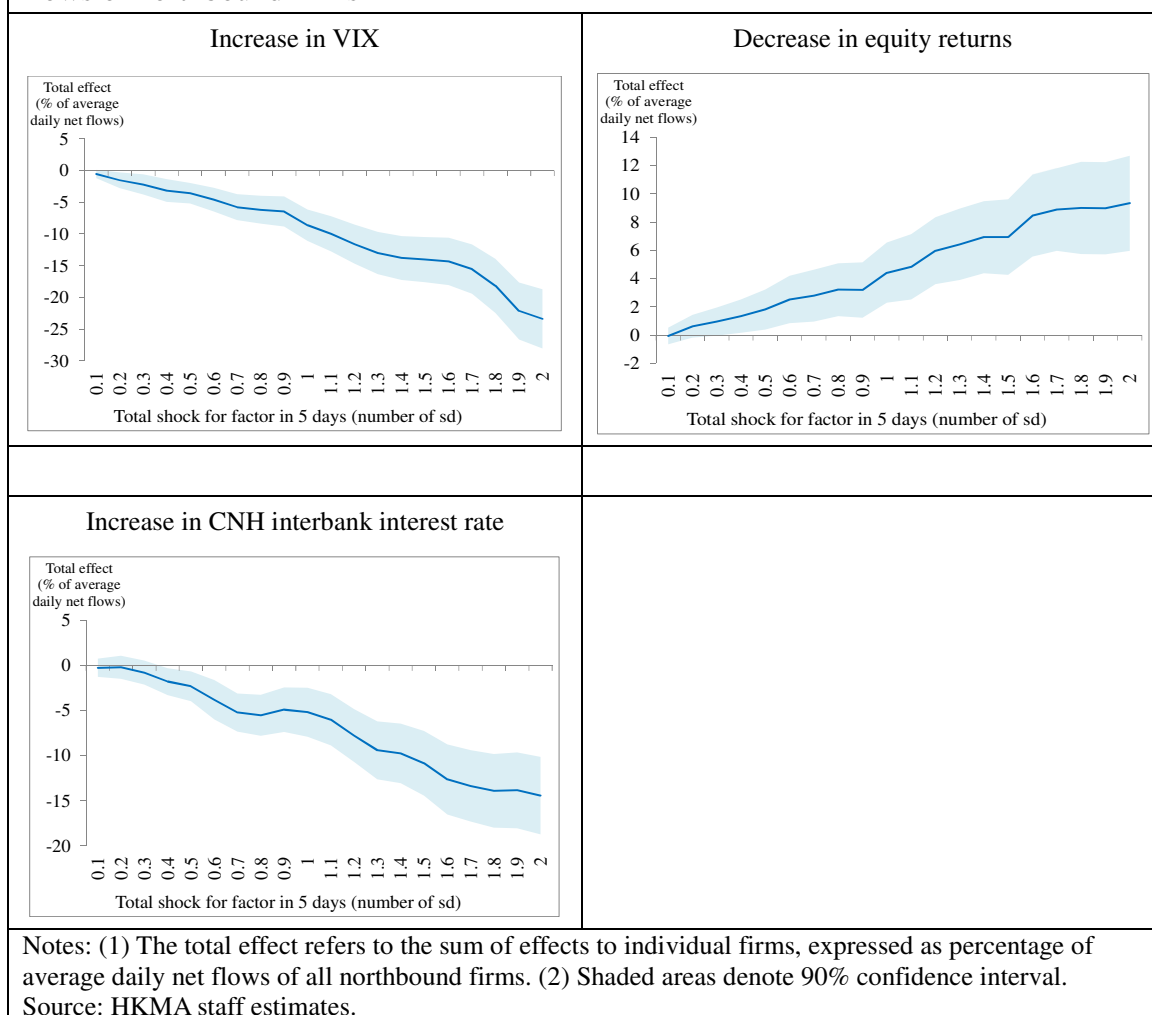— Cluster of firms with increase in net flows when CNH depreciates (363)

Notes: 1. Figures represent the average difference to sector's average (in numbers of SD) for firms in each cluster. 2. Figures in bracket denote number of firms in each cluster.
Source: HKMA staff estimates.

The flow response of northbound firms to other variables

In contrast, the net flows are considerably more responsive to changes in other variables. Chart 5 depicts the potential response of the net flows of the northbound firms to changes in the VIX, equity returns, and the CNH interbank interest rate. Among these variables, the VIX has the largest impact on the net flows. The total net flows are estimated to decline by 9% of the daily average net flows when the VIX increases by one SD, while the decline in net flows more than doubles to 23% of the daily average net flows when the VIX increases by two SDs.

For responses to equity returns, the correlation between net flows and equity returns is negative. This means the more the equity returns decrease, the larger the net flows increase. In the extreme, when the equity returns decrease by two SDs, the net flows to northbound firms increase by 9% of the daily net flows of all northbound firms. In comparison, the CNH interbank interest rate has a similar effect on the net flows. When the interest rate increases by two SDs, the net flows decrease by almost 14% daily on average.

Chart 5: Effects of VIX, equity returns, and CNH interbank interest rate on the net flows of northbound firms

Increase in VIX	Decrease in equity returns
Total effect (% of average daily net flows)	Total effect (% of average daily net flows)
Total shock for factor in 5 days (number of sd)	Total shock for factor in 5 days (number of sd)

Increase in CNH interbank interest rate	
Total effect (% of average daily net flows)	
Total shock for factor in 5 days (number of sd)	

Notes: (1) The total effect refers to the sum of effects to individual firms, expressed as percentage of average daily net flows of all northbound firms. (2) Shaded areas denote 90% confidence interval.
Source: HKMA staff estimates.

The flow response of southbound firms

For southbound firms, we consistently find that the CNH movement does not significantly affect their net flows (the left panel of Chart 6). Indeed, in absolute terms the largest impact was not more than 2% of the average daily net flows of southbound firms (the right panel of Chart 6). Based on the cluster analysis,[18] we also find that firms showing a decrease in net flows during a CNH depreciation will have weaker fundamentals, such as smaller size and less profitable, and have more volatile stock prices (Chart 7), compared with firms with an increase in net flows.

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[18] The same set of firms' variables in northbound firms is used, except for shares of overseas revenue and correlation between exchange rate losses and CNH movements. A total of 382 southbound firms are covered in the cluster analysis, with the remaining 30 firms not being covered due to incomplete data or existence of extreme outliers.

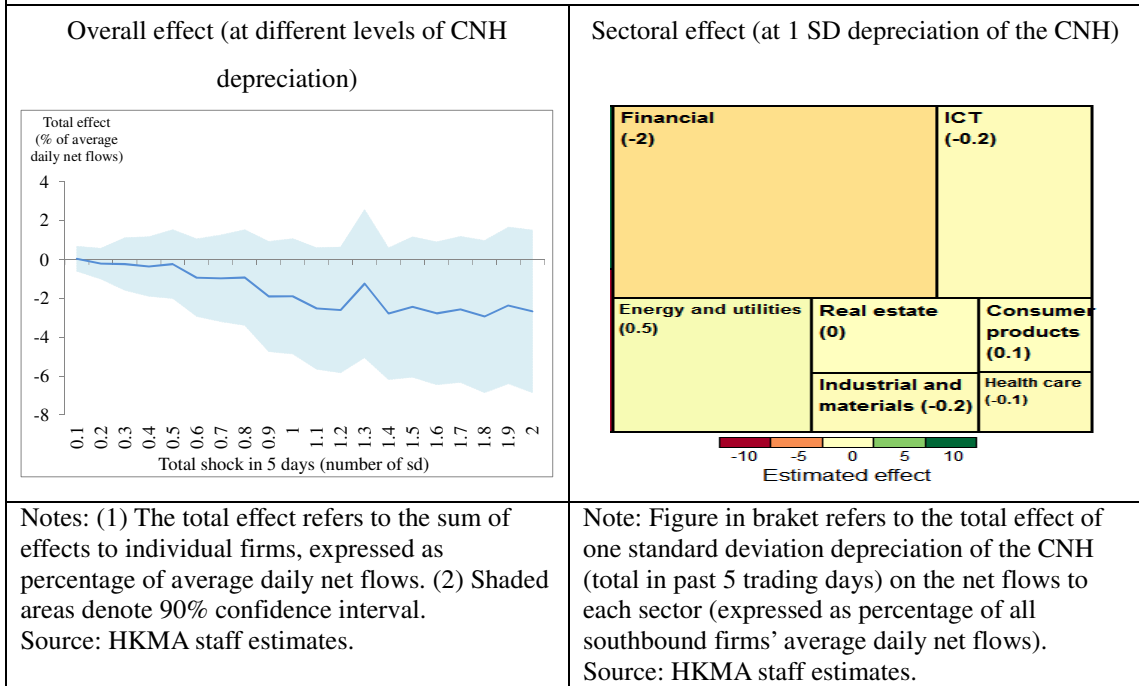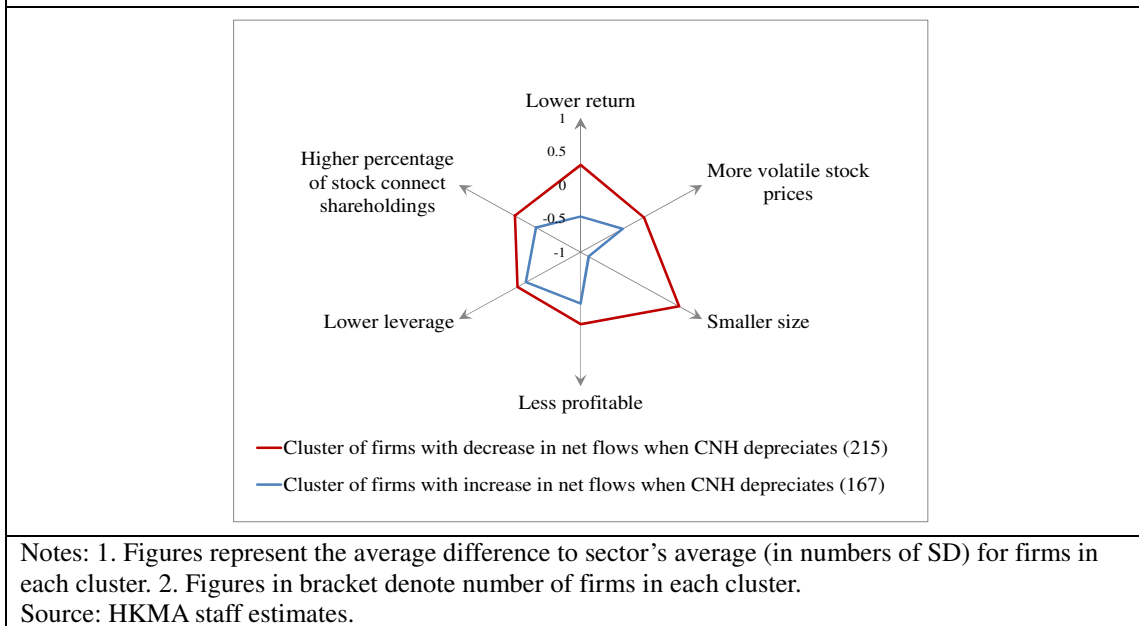| Chart 6: Effects of CNH depreciation on the net flows to southbound firms	
Overall effect (at different levels of CNH depreciation)	Sectoral effect (at 1 SD depreciation of the CNH)

Total effect
(% of average
daily net flows)

Total shock in 5 days (number of sd)

Financial (-2) | ICT (-0.2)
Energy and utilities (0.5) | Real estate (0) | Consumer products (0.1)
Industrial and materials (-0.2) | Health care (-0.1)

Estimated effect: -10 -5 0 5 10

Notes: (1) The total effect refers to the sum of effects to individual firms, expressed as percentage of average daily net flows. (2) Shaded areas denote 90% confidence interval.
Source: HKMA staff estimates.

Note: Figure in braket refers to the total effect of one standard deviation depreciation of the CNH (total in past 5 trading days) on the net flows to each sector (expressed as percentage of all southbound firms' average daily net flows).
Source: HKMA staff estimates.

Chart 7: Radar chart on average characteristics of clustered southbound firms

Lower return
More volatile stock prices
Smaller size
Less profitable
Lower leverage
Higher percentage of stock connect shareholdings

— Cluster of firms with decrease in net flows when CNH depreciates (215)
— Cluster of firms with increase in net flows when CNH depreciates (167)

Notes: 1. Figures represent the average difference to sector's average (in numbers of SD) for firms in each cluster. 2. Figures in bracket denote number of firms in each cluster.
Source: HKMA staff estimates.

Among the other three selected factors, we find that the net flows to southbound firms are responsive only to global stock market volatility. Chart 8 depicts the net flow responses to these factors. As shown in the chart, the net flows are significantly correlated with the VIX. When the VIX increases by two SDs, the net flows to the southbound firms are estimated to decline by around 12% of their daily average. For the other two factors, the net flows are estimated to fluctuate by only 3% and 1% of daily average respectively, when equity return and interest rate

change drastically by two SDs.[19]

Chart 8: Effects of VIX, equity returns, and Shanghai interbank offered rate on the net flows of southbound firms
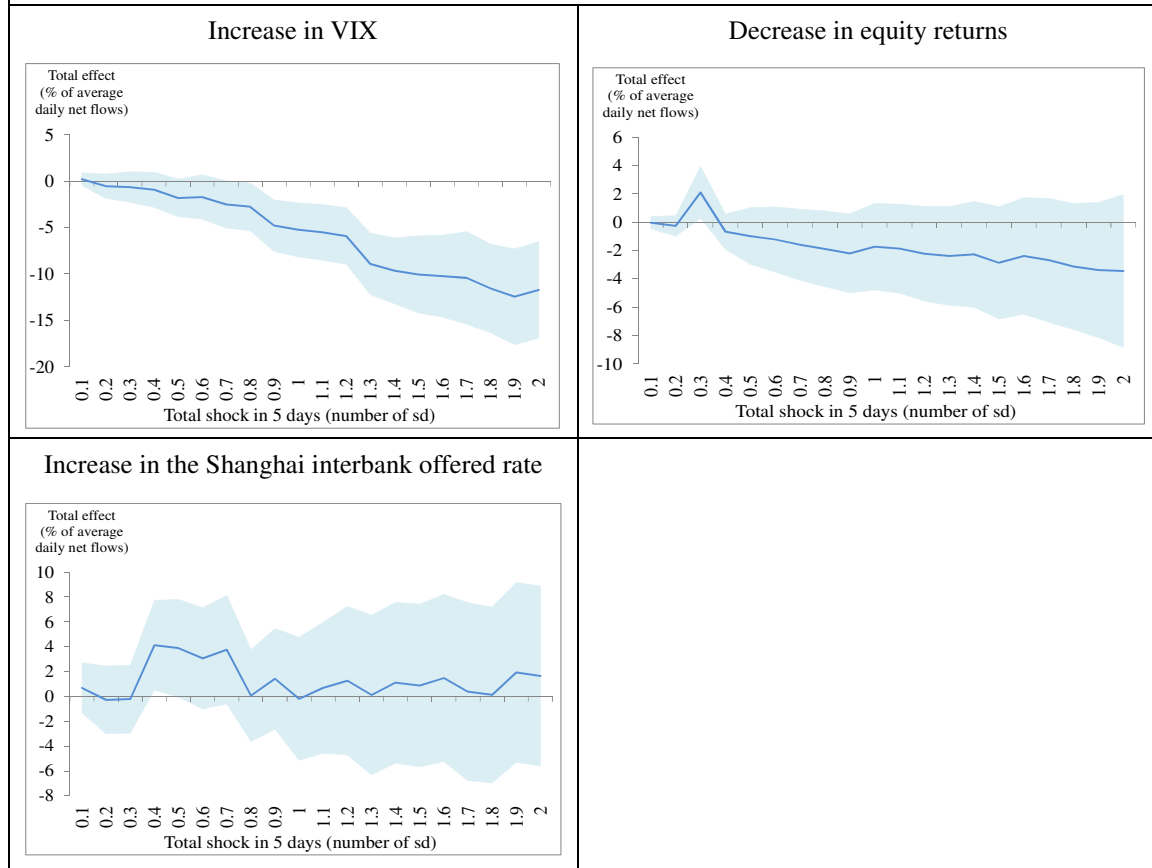
Increase in VIX

Decrease in equity returns

Increase in the Shanghai interbank offered rate

Notes: (1) The total effect refers to the sum of effects to individual firms, expressed as percentage of average daily net flows of all southbound firms. (2) Shaded areas denote 90% confidence interval. Source: HKMA staff estimates.

5.   SUMMARY AND IMPLICATION

Our empirical findings suggest movements in the offshore renminbi exchange rate have an insignificant impact on equity flows to both Mainland and Hong Kong listed firms under the Stock Connect programmes.[20,21] Only in extreme

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[19] The insignificance of the two selected factors might be due to a wide range of complicated reasons that need further investigation. For example, regarding the factor of equity returns, we find some tentative evidence that when grouping firms by the extent of their AH share price disparity, firms' response to equity returns are heterogeneous at group level, but offset each other at the aggregate level. For the interest rate factor, its insignificance might be partly due to the fact that margin trading is not allowed for southbound trades, thus the interest rate is less relevant for Mainland investors when making their investment decisions on southbound trades.

[20] While our analysis only covers the sample period from March 2017 due to data availability, we conduct a robustness check using the data on net flows at the stock market level (which have been available since the inception of the Stock Connect programmes), where the insignificant effect of the CNH movement on net flows also holds with the aggregate data.

[21] In studying the dynamics between foreign equity inflows, equity returns and exchange rate movements

circumstances would investors sell the stocks of firms that are smaller in asset size and have weaker fundamentals when the renminbi is depreciating, but the selling pressure would not have a significant impact on overall equity flows. This may be attributable to the fact that the currency risk arising from renminbi fluctuations could be hedged effectively by a diversified suite of renminbi exchange rate instruments available in the markets.[22]

Among other selected factors, global stock volatility was found to have the strongest impact on equity flows for both northbound and southbound trades. This implies that with continued growth in these trades through the Stock Connect programmes, potential global market spillovers will become more noteworthy. As such, investors should be mindful of sudden cross-border equity flows triggered by escalating global market uncertainty.

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for six emerging Asian markets, Chai-Anant and Ho (2008) also found that movement in the exchange rate has only a marginal influence in the cross border equity flows into these stock markets.

[22] On the back of increasing market demand for renminbi risk management due to the expanding offshore RMB market, the HKEX offers a diversified suite of renminbi currency products contracts based on the exchange rates between renminbi and other currencies to provide greater capital efficiency and flexibility for managing exposure. For instance, the USD/CNH futures and USD/CNH options were launched in September 2012 and March 2017.

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Appendix 1: Brief descriptions of Random Forest (RF), Support Vector Machine (SVM), and Artificial Neural Network (ANN)

The three ML techniques are discussed more specifically:

- RF is based on a number of decision trees. Each decision tree has a branching structure that consecutively divides y into classes based on some features about x. The process continues until a criterion about information gain is reached. The branching structure of a tree can deal with complicated relationship among variables in an interpretable way. However, a single tree is susceptible to over-fitting, which often means poor performance in out-of-sample prediction. To tackle this problem, a number of roughly independent trees are estimated and their results are then aggregated. Such an algorithm is known as RF.

- SVM is a technique usually applied to classification problems. The central idea is to classify data points into non-overlapping classes by means of a line (2-variable case), a plane (3-variable case) or more generally a hyperplane (more than 3 variables). SVM defines the best hyperplane as the one having the maximum margin, i.e. vertical distance to its closest data points. Such closest data points are known as 'support vectors' and they are crucial for the characterization of the hyperplane.

- ANN mimics the way human brains solve problems. It has layers of interconnected units (known as "neurons"), with each neuron using different functions to identify the relationship between y and x based on observed data. The connections between neurons have weights that can be tuned to obtain an optimal result (e.g. minimizing a loss function). Because of the network structure, ANN is highly flexible and especially suited for situations with complex relations among the variables.

Appendix 2: Summary statistics of variables for individual firm analysis

Variable			Unit	Mean	SD	Max	Min
Firm-specific variables	Northbound firms (1,110)	Net flows (% of total market capitalisation)	%	0.003	0.054	5.31	-9,75
		Equity returns	%	-0.046	2.303	14.947	-68.81
	Southbound firms (412)	Net flows (% of total market capitalisation)	%	0.006	0.096	10	-12.916
		Equity returns	%	-0.046	2.233	69.9	-81
Market variables		Daily percentage change in renminbi exchange rate (CNH per HKD)	%	0.006	0.292	1.103	-1.29
		Daily changes in VIX index	N/A	-0.008	1.6	20.01	-7.34
		Daily changes in 3-month CNH interbank interest rate	%	-0.003	0.1	1.962	-1.181
		Daily changes in 3-month Shanghai interbank offered rate	%	-0.002	0.021	0.046	-0.11

Note: Positive figure for net flows denotes an inflow to the firms.

Appendix 3: Definitions of firm's characteristics in cluster analysis

Aspect	Characteristics	Definition (reference time)	Used in	Data source
Stock market performances	Average return	Firm's daily stock return (20 March 2017 – 30 April 2019)	Both	Bloomberg, Wind
	Return volatility	Standard deviation of firm' s daily stock return (20 March 2017 – 30 April 2019)	Both	Bloomberg, Wind
Financial fundamentals	Size	Market capitalisation (log scale, (2016 – 2018 average)	Both	Bloomberg, Wind
	Overall profitability	Return on equity (2016 – 2018 average)	Both	Bloomberg, Wind
	Leverage	Liability to asset ratio (2016 – 2018 average)	Both	Bloomberg, Wind
Shareholding structure	Percentage of shareholdings under Stock Connect programme	Percentage of shareholdings under Stock Connect programme (daily average during 20 March 2017 – 30 April 2019)	Both	Wind
	Institutions' shareholdings	Shareholding by institutions (2016 – 2018 average)	Northbound only	Wind
Direct impact of CNH depreciation on firm's profitability	Share of overseas revenue	Share of revenue from outside of firm's country of domicile (2018 or latest available)	Northbound only	Bloomberg
	Correlation between foreign exchange losses and CNH depreciation	Correlation coefficient between firm's annual income losses due to foreign exchange and annual depreciation rate of CNH against HKD (2014 – 2018)	Northbound only	Bloomberg