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Measuring the Importance of Renminbi in the Exchange Rate Spillover Networks: New Indices of RMB Internationalisation

By Yinggang Zhou, Xin Cheng and Yiming Wang[1]

Abstract

Using an innovative network approach, this study constructs new indices of Renminbi (RMB) internationalisation and presents strong evidence of RMB's growing influence globally and regionally. We identify networks of exchange rate spillovers and examine time-varying spillover intensities among RMB and world major currencies of G20 members as well as currencies related to the Belt and Road Initiative (BRI). Shocks from RMB generate intensifying spillovers across currency networks. The role of RMB in the networks has increased steadily over time. Our findings highlight that RMB has become increasingly important since China has initiated the marketisation reform of its currency and proposed to build the modern Belt and Road.

Key words: RMB; spillover; financial network; the Belt and Road Initiative

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Introduction

The international status of a currency is dependent on the country's economic status and influence in the world (Chinn and Frankel 2007; Meissner and Oomes 2008). China is now the world's second largest economy with its GDP accounting for more than 15% of the global GDP. Moreover, China has become the largest country in terms of trade with its imports and exports accounting for 11% of the global trade. In the recent years, the People's Bank of China has endeavoured to improve the cross-border use of Renminbi (RMB) and open the financial market such as the interbank bond market. Following the milestone inclusion of RMB into the Special Drawing Right (SDR) basket in October 2016, a question naturally raised is whether RMB plays a growing role in the global and regional economy and financial system.

According to COFFER data of the International Monetary Fund (IMF), the Chinese yuan's share of currency reserves increased to 1.89% in the fourth quarter of 2018, ranking the fifth among all allocated reserves.[2] RMB is also the fifth most active currency for domestic and international payments by value with a share of 1.89% and the eighth most active currency for cross-border payments with a share of 1.22% in March 2019, according to the Society for Worldwide Interbank Financial Telecommunications (SWIFT).[3] In contrast, a survey by the Bank of International Settlements (BIS) shows that RMB accounted only 4.0% of the turnover of foreign exchange and OTC derivatives trading while the US dollar remained the dominant trading currency constituting 88% of all trades

[2] The IMF has released reserves held in RMB since the fourth quarter of 2016.

[3] The SWIFT has released the RMB Internationalisation Tracker monthly since 2011, reporting the RMB share as international payments currency.

in April 2016. [4] Meanwhile, some Chinese institutes have released RMB internationalisation reports based on the international use of RMB. The annual RMB Internationalisation Report by the China Construction Bank covers statistics overseas, including the growth of RMB assets and RMB offshore deposits, RMB offshore bond issuance, and so forth. The International Monetary Institute (IMI) of Renmin University of China compiles a quarterly RMB Internationalisation Index (RII) based on several international use of RMB. In this paper, we construct new indices of RMB internationalisation by measuring the importance of RMB in the exchange rate spillover networks. Our study extends the growing literature to show the increasing importance of RMB using exchange rate data (e.g. Shu, He and Cheng 2015) and makes several contributions.

Firstly, we measure the mutual impacts between major currencies using a network approach since the global major currencies anchor mutually with each other (Fratzscher and Mehl 2013). A network approach enriches our understanding of financial systems (Allen and Babus 2009).[5] Diebold and Yilmaz (2014) propose intuitive spillover measures based on forecast error variance decompositions of VAR models and define weighted, directed networks accordingly. Yang and Zhou (2017) extend this approach by studying volatility spillovers across countries and asset classes. With this novel empirical method, we use daily exchange rate changes to identify the time-varying network structure of spillovers that link RMB, including its mid-price, the on-shore and off-shore prices, with major global currencies as well as major currencies along the Belt and Road Initiative

[4] The BIS has conducted a triennial survey of foreign exchange and OTC derivatives trading on major currencies since 1995 and on RMB since 2007. The most recent survey was conducted in 2016.

[5] A network describes a collection of nodes and links between them. In the international monetary system, the nodes of the network represent exchange rate markets, and the links represent direct or indirect relationship between two currencies.

(BRI). With intensifying mutual spillover effects, the world is embracing a more multipolar monetary system. More importantly, RMB has played an important role in the multipolar monetary system since RMB has exerted intensifying spillover effects on currencies across the globe and regions, such as the BRI.

Secondly, we further compile a series of RMB impact indices based on the spillover networks estimated recursively using the VAR models following Diebold and Yilmaz (2014). These indices show whether spillover from RMB to other currencies has intensified steadily over years. In other words, these indices show RMB's relative importance as an anchor currency among all the currencies in the network. Moreover, the centrality of RMB in the network has grown steadily over the years, suggesting increased systemic importance of RMB. Compared with other RMB internalisation reports or indices which are released at most at the monthly frequency, our indices track RMB's relative importance as an anchor currency on daily frequency.

More importantly, we show that the growing impacts of RMB are related to the developments in RMB's marketisation reform in recent years and the progress of building the modern Belt and Road. In particular, the RMB's impact indices experienced a sharp jump when China launched the marketisation reform of its currency on 21 July 2005, driving other currencies to move in the same direction ever since. Meanwhile, the onshore RMB has taken the central position of the network among the Belt and Road related currencies since the BRI was proposed in 2013. Our findings highlight that RMB has become increasingly important since China initiated the marketisation reform of its currency and proposed to build the BRI.

The rest of this paper is organised as follows. First, it describes the data. The following section discusses the empirical methodology. Then, it presents the index of RMB empirical findings. The final section concludes.

Data

We use two sets of data to estimate the global and regional impacts of RMB. One is the currency data of the G20 countries to proxy for the global exchange rate market. The other is the currency data of major countries along the BRI and countries participating in building the modern Belt and Road.

Data of G20 currencies

The G20 is the premier forum for international cooperation on the most important aspects of the international economic and financial agenda. It brings together the world's major advanced and emerging economies which jointly account for around 90% of global GDP, 80% of global trade, and two thirds of the world's population. The G20 comprises Argentina, Australia, Brazil, Canada, China, the European Union (EU), France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the UK and the US.

To construct exchange rate spillover network for currencies of G20 members, we collect daily exchange rates of all 18 related currencies from Datastream. First, three RMB exchange rates are the onshore Chinese yuan (CNY), CNY central parity (CNYM), and offshore RMB in the Hong Kong SAR (CNH) per US dollar. Second, seven major developed market currencies are the US Dollar Index (DXY), the Euro (EUR), the Pound sterling (GBP), the Australian dollar (AUD), the Canadian dollar (CAD), the Japanese yen

(JPY) and the Korean won (KRW). Third, nine currencies for emerging markets include the Argentine peso (ARS), the Brazilian real (BRL), the India rupee (INR), the Indonesian rupiah (IDR), the Mexican peso (MXN), the Russian ruble (RUB), the Saudi Arabia riyal (SAR), the South Africa rand (ZAR), and the Turkish lira (TRY). Except for the DXY, all other exchange rates of the currencies are their prices in terms of the US dollar.

Our sample starts on 1 January 1999 when the Euro became legal tender for members of the European Monetary Union and ends at the end of 2018. Our subsamples start on 24 June 2005 when the China Foreign Exchange Trading System started to announce the CNY central parity (CNYM) and on 2 March 2011 when the CNH exchange rate was available. Following Forbes and Rigobon (2002), we compute two-day rolling-average of log differences of exchange rates to control for the fact that currency markets of different countries do not operate during the same trading hours.[6]

Summary statistics on two-day rolling-average exchange rate changes are reported in Panel A of Table 1. With 5,215 daily observations, the CNY and the CNYM are negative on average, suggesting the general trend of appreciation against the US dollar for the full sample. For the subsample, all three RMB exchange rate changes are positive on average, suggesting the general trend of deprecation against the US dollar since March 2011. All the standard deviations of all three RMB exchange rate changes are smaller than other currency counterparts, except for the SAR. Among three RMB exchange rate changes, the mid-price is the least volatile while the CNH is the most volatile, suggesting that the offshore market is less regulated and thus may provide additional and distinct information.

[6] Similarly, Yang and Zhou (2013) use two-day changes of CDS spreads to study credit risk spillover. Although two-day averaging obscures some lead/lag effects, most lead/lag relations are still captured by lags in the VAR analysis. Compared with using weekly exchange rate changes to address nonsynchronous trading issue, the benefit of two-day averaging is to keep as many observations as possible for the VAR analysis and particularly for recursive variance decompositions.

In contrast, the skewnesses and kurtosises of RMB exchange rate changes are generally higher than other currency counterparts of developed economies, suggesting more extreme events in the Chinese currency. This is probably due to China's exchange rate policy changes in recent years. Jarque-Bera tests indicate that all daily changes of exchange rate are not normally distributed. Also, ADF tests show that all exchange rates are stationary in the first differences.

Data of the currencies related to the BRI

Announced in 2013, the BRI has strengthened China's connectivity with 66 countries scattering along the ancient Silk Road. Meanwhile, the BRI is an open platform for all parties that are willing to contribute to global connectivity. So far, a total of 126 countries, including countries in America and Oceania, have signed cooperation documents with China on the BRI. We refer these 126 countries as participating countries. By the end of 2018, China's direct investment in the countries involved in B&R surpassed 90 billion dollars, realising a turnover of 400 billion US dollars in foreign contracted projects in these countries. Besides, 11 Chinese-funded banks have set up 76 first-grade institutions in 28 countries involved in B&R, and 50 banks from 22 countries involved in B&R have opened seven corporate banks, 19 branches, and 34 representative offices in China. All these efforts have potentially contributed to the promotion of RMB as an international or regional currency. This is why we further construct the indices of RMB impact on the currencies of the countries along the Belt and Road and participating in the BRI.

To construct exchange rate spillover network among the currencies of the countries along the Belt and Road, we dismiss the countries which had implemented a fixed exchange rate system since July 2005, according to the regime classification of Ilzetzki, Reinhart, and Rogoff (2017) and the IMF's annual report on the exchange rate arrangement and exchange restrictions[7]. We also dismiss the countries without legal tender at all, with a falling exchange rate, and/or with too much missing data in their exchange rates. Finally, we collect daily currencies exchange rates data for 26 countries from Datastream.

Besides the onshore the Chinese yuan (CNY), we collect 25 currencies, including the Mongolian tugrik (MNT), the Singapore dollar (SGD), the Malaysian ringgit (MYR), the Indonesian shield (IDR), the Thai baht (THB), the Vietnamese shield (VND), the Philippine peso (PHP), the Kazakhstan tenge (KZT), the Uzbekistan som (UZS), the Kyrgyzstan som (KGS), the Indian rupee (INR), the Pakistan rupee (PKR), the Sri Lanka rupee (LKR), the Russian ruble (RUB), the Moldova leu (MDL), the Polish zloty (PLN), the Czech krone (CZK), the Hungarian forint (HUF), the Iranian rial (IRR), the Turkish pound (TRY), the Syrian pound (SYP), the Israeli new shekel (ILS), the Yemen rial (YER), the Georgia larry (GEL), and the Egyptian pound (EGP). These 26 currencies cover countries which jointly account for 88.47% of population and 81.26% of GDP for the 66 countries along the Belt and Road. Similarly, we compute two-day rolling-average of log differences of exchange rates to address nonsynchronous trading issue.

Panel B of Table 1 reports summary statistics of two-day rolling-average exchange rate changes of major currencies along the Belt and Road. Except for CNY, SGD, THB, PHP, CZK, and ILS, exchange rate changes for most currencies are positive on average, suggesting a general trend of depreciation against USD. Among all the sample currencies, CNY is the least volatile. Moreover, the skewnesses and kurtosises of VND, KZT, UZS,

[7] Ilzetzki, Reinhart and Rogoff (2017) provide a comprehensive history of monthly exchange rate regime classification for 194 countries and territories over 1946-2016. They classify 194 countries into 6 major group according to the flexibility of their currencies, including the countries with a fixed exchange rate system, crawling peg regime, managed floating regime, freely floating regime, freely falling regime, and/or too many missing data.

KGS, IRR, SYP, YER, GEL, EGP exchange rate changes are much higher than that of CNY, suggesting that the exchange rate of CNY is relatively stable among currencies for countries along the Belt and Road. Besides, Jarque-Bera tests indicate that all daily changes of exchange rate are not normally distributed. Also, ADF tests show that all exchange rates are stationary in the first differences.

Table 1. Summary statistics of daily exchange rate changes.

Panel A: Exchange rate changes of G20 currencies

	Mean (‰)	Std. (‰)	Min (‰)	Max (‰)	Skew	Kurt	JB test	ADF (none)	ADF (drift)	ADF (trend)	Nobs
CNY	-0.04	0.86	-10.14	14.05	0.31	36.28	241^{***}	-49.71^{*}	-49.79^{*}	-49.84^{*}	5215
CNYM	-0.04	0.84	-10.14	17.22	1.97	67.43	906^{***}	-48.37^{*}	-48.45^{*}	-48.50^{*}	5215
CNH	0.02	1.61	-13.20	22.25	1.35	29.32	60^{***}	-35.20^{*}	-35.20^{*}	-35.28^{*}	2044
DXY	0.01	3.50	-22.11	16.06	-0.07	4.76	1^{***}	-51.28^{*}	-51.27^{*}	-51.27^{*}	5215
EUR	0.01	4.31	-28.14	20.17	-0.02	4.78	1^{***}	-51.67^{*}	-51.67^{*}	-51.66^{*}	5215
GBP	0.05	4.20	-25.88	58.20	0.88	14.23	28^{***}	-52.96^{*}	-52.96^{*}	-52.97^{*}	5215
AUD	-0.03	5.52	-47.33	48.51	0.57	10.44	12^{***}	-52.94^{*}	-52.93^{*}	-52.94^{*}	5215
CAD	-0.02	3.98	-28.97	29.14	0.05	7.46	4^{***}	-51.60^{*}	-51.60^{*}	-51.63^{*}	5215
JPY	0.00	4.47	-29.78	23.41	-0.13	5.35	1^{***}	-52.47^{*}	-52.47^{*}	-52.46^{*}	5215
KRW	-0.01	4.55	-78.27	65.54	-0.54	44.27	370^{***}	-52.68^{*}	-52.67^{*}	-52.67^{*}	5215
ARS	0.70	7.89	-64.54	186.35	10.86	217.32	10083^{***}	-52.90^{*}	-53.31^{*}	-53.37^{*}	5215
BRL	0.22	7.63	-88.30	76.47	0.41	17.18	44^{***}	-52.01^{*}	-52.05^{*}	-52.05^{*}	5215
INR	0.10	2.68	-19.34	27.67	0.42	11.44	16^{***}	-51.32^{*}	-51.38^{*}	-51.39^{*}	5215
IDR	0.11	5.23	-59.65	60.05	-0.32	25.29	108^{***}	-53.06^{*}	-53.08^{*}	-53.08^{*}	5215
MXN	0.13	4.82	-28.16	54.73	1.03	13.68	26^{***}	-51.85^{*}	-51.89^{*}	-51.89^{*}	5215
RUB	0.22	5.78	-86.62	116.62	1.90	56.46	624^{***}	-53.54^{*}	-53.60^{*}	-53.62^{*}	5215
SAR	0.00	0.15	-3.26	4.03	2.47	237.64	11969^{***}	-59.33^{*}	-59.33^{*}	-59.32^{*}	5215
ZAR	0.17	7.42	-59.19	73.77	0.43	8.40	6^{***}	-52.75^{*}	-52.78^{*}	-52.77^{*}	5215
TRY	0.54	8.42	-99.37	265.18	9.25	272.61	15869^{***}	-56.65^{*}	-56.90^{*}	-56.91^{*}	5215

Panel B: Exchange rate changes for major currencies along the Belt and Road

	Mean (‰)	Std. (‰)	Min (‰)	Max (‰)	Skew	Kurt	JB test	ADF (none)	ADF (drift)	ADF (trend)	Nobs
CNY	-0.05	1.03	-10.14	14.05	0.57	23.24	60^{***}	-40.44^{*}	-40.53^{*}	-40.91^{*}	3507
MNT	0.23	3.09	-34.38	29.26	-0.13	21.09	48^{***}	-36.49^{*}	-36.66^{*}	-36.71^{*}	3507
SGD	-0.06	2.44	-15.06	18.07	0.08	6.25	2^{***}	-43.45^{*}	-43.47^{*}	-43.53^{*}	3507
MYR	0.02	2.94	-18.53	13.97	-0.15	6.01	1^{***}	-41.02^{*}	-41.01^{*}	-41.06^{*}	3507
IDR	0.11	3.38	-38.74	41.94	0.30	29.40	102^{***}	-39.50^{*}	-39.54^{*}	-39.57^{*}	3507
THB	-0.07	2.55	-24.48	46.05	2.77	68.65	634^{***}	-43.54^{*}	-43.57^{*}	-43.63^{*}	3507
VND	0.11	1.30	-6.20	34.64	13.34	294.19	12494^{***}	-41.81^{*}	-42.09^{*}	-42.10^{*}	3507
PHP	-0.02	2.38	-11.83	11.38	0.14	4.35	0^{***}	-39.45^{*}	-39.45^{*}	-39.60^{*}	3507
KZT	0.29	5.37	-52.51	153.59	14.10	322.52	15035^{***}	-43.28^{*}	-43.41^{*}	-43.49^{*}	3507
UZS	0.57	7.97	-7.75	379.75	42.34	1861.51	505775^{***}	-40.96^{*}	-41.16^{*}	-41.24^{*}	3507
KGS	0.15	3.11	-27.56	54.68	6.19	113.64	1811^{***}	-39.68^{*}	-39.77^{*}	-39.78^{*}	3507
INR	0.14	3.17	-19.34	27.67	0.35	8.58	5^{***}	-42.27^{*}	-42.34^{*}	-42.34^{*}	3507
PKR	0.24	2.19	-21.94	37.00	3.43	63.58	543^{***}	-41.82^{*}	-42.32^{*}	-42.33^{*}	3507
LKR	0.17	1.66	-11.82	22.18	2.38	41.25	217^{***}	-37.73^{*}	-38.08^{*}	-38.17^{*}	3507
RUB	0.25	6.58	-86.62	116.62	1.64	45.96	271^{***}	-42.01^{*}	-42.06^{*}	-42.09^{*}	3507
MDL	0.09	3.07	-18.04	25.82	0.82	11.77	12^{***}	-37.37^{*}	-37.39^{*}	-37.40^{*}	3507
PLN	0.03	6.41	-54.12	41.05	0.34	8.00	4^{***}	-41.35^{*}	-41.35^{*}	-41.35^{*}	3507
CZK	-0.03	5.38	-37.98	28.46	0.27	6.57	2^{***}	-42.10^{*}	-42.10^{*}	-42.12^{*}	3507
HUF	0.09	6.59	-43.46	40.40	0.23	6.14	1^{***}	-42.33^{*}	-42.33^{*}	-42.33^{*}	3507
IRR	0.44	8.97	-24.92	411.42	37.39	1574.44	361662^{***}	-41.18^{*}	-41.27^{*}	-41.29^{*}	3507
TRY	0.39	6.80	-66.81	113.36	1.95	43.76	245^{***}	-44.13^{*}	-44.28^{*}	-44.35^{*}	3507
SYP	0.65	11.43	-52.35	537.57	37.86	1633.63	389378^{***}	-40.21^{*}	-40.34^{*}	-40.40^{*}	3507
ILS	-0.06	3.62	-17.74	25.06	0.19	6.20	2^{***}	-41.91^{*}	-41.92^{*}	-41.93^{*}	3507
YER	0.08	2.00	-27.81	77.67	28.92	1136.78	188326^{***}	-38.16^{*}	-38.21^{*}	-38.20^{*}	3507
GEL	0.11	3.55	-33.98	69.17	4.07	86.17	1020^{***}	-38.79^{*}	-38.82^{*}	-38.88^{*}	3507
EGP	0.32	7.01	-37.81	261.80	27.80	957.29	133522^{***}	-34.07^{*}	-34.12^{*}	-34.17^{*}	3507

Notes: Panel A reports the summary statistics of two-day rolling average exchange rate changes for currencies of G20 members from 5 January 1999 to the end of 2018. Panel B reports the summary statistics of two-day rolling average exchange rate changes for currencies of countries along the Belt and Road from 22 July 2005 to the end of 2018. The Jarque-Bera tests and the Augmented Dickey Fuller (ADF) values are also reported. *, ** and *** denote rejection of the null hypothesis at the 10%, 5% and 1% level, respectively. The null hypothesis for JB tests, and the ADF tests is that the series is normally distributed, and that the series has a unit root. Nobs denotes the number of observations.

We also construct exchange rate spillover network among the currencies of the countries participating the BRI. Following the same criteria above, we select 45 currencies among the currencies of the 126 participating countries, which account for 81.77% of the population and 77.09% of GDP for the 126 countries participating the BRI, including the Chinese yuan (CNY), the Mongolian tugrik (MNT), the Korean won (KRW), the Singapore dollar (SGD), the Malaysian ringgit (MYR), the Indonesian shield (IDR), the Thai baht (THB), the Vietnamese shield (VND), the Philippine peso (PHP), the Kazakhstan tenge (KZT), the Uzbekistan som (UZS), the Kyrgyzstan som (KGS), the Indian rupee (INR), the Pakistan rupee (PKR), the Sri Lanka rupee (LKR), the Papua New Guinea kina (PGK), the New Zealand dollar (NZD), the Russian ruble (RUB), the Moldova leu (MDL), the Polish zloty (PLN), the Czech krone (CZK), the Hungarian forint (HUF), the Dominican peso (DOP), the Chile peso (CLP), the Costa Rica colon (CRC), the Uruguay new peso (UYU), the Iranian rial (IRR), the Turkish pound (TRY), the Syrian pound (SYP), the Israeli new shekel (ILS), the Yemen rial (YER), the Georgia larry (GEL), the Tanzania shilling (TZS), the Kenya shilling (KES), the Seychelles rupee (SCR), the Egyptian pound (EGP), the Algerian dinar (DZD), the Tunisian dinar (TND), the Libya dinar (LYD), the Mozambique meticala (MZN), the Zambian kwacha (ZMK), the Madagascar franc (MGA), the South African rand (ZAR), the Nigeria nile (NGN), and the Fiji yuan (FJD). We omit the summary statistics for this sample to save space.

Econometric methodology

We employ a two-pass procedure to describe spillovers across various currencies and their network structure and time variation.

VAR-based network

Our starting point is the vector autoregressive model of Sims (1980):

$$\Delta R_t^c = \mu + \sum_{i=1}^{I} B_i \Delta R_{t-i}^c + C\Delta X_t + e_t \ , \qquad (1)$$

where ΔR_t is a vector of two-day rolling-average exchange rate changes and ΔX_t is a vector of exogenous variables. Under certain assumptions (Pesaran and Shin 1998), a vector autoregressive model can be rewritten as the infinite moving average representation as shown in Equation (2).

$$\Delta R_t^c = \mu + \sum_{h=1}^{\infty} A_h \varepsilon_{t-h} + \sum_{h=1}^{\infty} G_h \Delta X_{t-h} + e_t. \qquad (2)$$

Correspondingly, the generalised impulse response and the generalised forecast error variance decompositions of the effect of a shock in the *j*-th currency at time *t* on *i*-th currency is given by Equation (3) and (4) respectively,

$$GIR_j^h = \sigma_{jj}^{-\frac{1}{2}} A_h \Sigma e_j, for\ h = 0,1,2,\cdots,$$

(3)

$$GVD_{i\leftarrow j}^h = \frac{\sigma_{jj}^{-1} \sum_{l=0}^{h} (e_i' A_l \Sigma e_j)^2}{\sum_{l=0}^{h} e_i' A_l \Sigma A_l' e_i}, for\ h = 0,1,2,\cdots,$$

(4)

where $\Sigma = \{\sigma_{ij}, \mathrm{i}, \mathrm{j} = 1,2,\cdots,\mathrm{n}\}$ is the variance–covariance matrix of the error term in Equation (1), A_h is the coefficient matrix in Equation (2), and e_i is an $\mathrm{n} \times 1$ selection vector with unity as its i-th element and zeros elsewhere.

The generalised impulse response analysis as well as generalised variance decomposition was introduced by Pesaran and Shin (1998). The appeal of the generalised version of impulse response analysis and variance decomposition is order-invariant as opposed to the Cholesky-based impulse response analysis and variance decomposition which are sensitive to ordering.

Although both the generalised impulse response and forecast error variance decomposition can be used to define weighted, directed, and time-varying networks (Diebold and Yilmaz 2014; Alter and Beyer 2014; Yang and Zhou 2017), we identify networks of exchange rate spillovers using generalised impulse response instead of variance decomposition for two main reasons. Firstly, the elements of variance decomposition are not additive and comparable directly. The entries in the variance decomposition matrix are variance shares ranging from 0% to 100%. They are weights that measuring how much innovation of each currency contributes to the variance of the total n-step-ahead forecast error of another currency and thus are the intensity of each currency in explaining the variation of another currency. However, the weights are not additive and comparable directly because the variation of different currencies may be quite different. Secondly, we cannot infer the exact direction of change for each currency in response to the change of CNY from the variance decomposition because all its elements are positive. In contrast, using impulse response analysis, we can detect the direction and magnitude of each currency changes, namely appreciates or depreciates, in response to one unit change of RMB exchange rates.

Therefore, we identify weighted and directed networks of exchange rate spillovers by estimating the generalised impulse response for each currency using Equation (3). Firstly, the entries in the impulse response matrix are weights that measuring how much the change of each currency leads to the variation of another currency. Secondly, the impulse response matrix is generally asymmetric, thereby suggesting that spillover effects between currencies are directed. For example, if the *ij*-th element of the matrix (the *i*-th currency's variation derived by the *j*-th currency's innovation) is greater than that of the *ji*-th element, we can argue that there is a directional net spillover effect from the *j*-th currency to the *i*-th currency. Thirdly, the network dynamics can be traced by making impulse response analysis at different points of time. We discuss these in detail below.

Structure and Dynamics of Spillover Networks

Following Diebold and Yilmaz (2014) and Alter and Beyer (2014), we construct the spillover network of exchange rates based on impulse response analysis as follows:

	ΔR_1	ΔR_2	…	ΔR_N	*FROM*
ΔR_1	$S_{1\leftarrow 1}$	$S_{1\leftarrow 2}$	…	$S_{1\leftarrow N}$	$FR_1 = \frac{\sum_{j\neq 1} S_{1\leftarrow j}}{N-1}$
ΔR_2	$S_{2\leftarrow 1}$	$S_{2\leftarrow 2}$	…	$S_{2\leftarrow N}$	$FR_2 = \frac{\sum_{j\neq 2} S_{2\leftarrow j}}{N-1}$
…	…	…	…	…	…
ΔR_N	$S_{N\leftarrow 1}$	$S_{N\leftarrow 2}$	…	$S_{N\leftarrow N}$	$FR_N = \frac{\sum_{j\neq N} S_{N\leftarrow j}}{N-1}$
TO	$TO_1 = \frac{\sum_{i\neq 1} S_{i\leftarrow 1}}{N-1}$	$TO_2 = \frac{\sum_{i\neq 2} S^H_{i\leftarrow 2}}{N-1}$	…	$TO_N = \frac{\sum_{i\neq N} S^H_{i\leftarrow N}}{N-1}$	
NET	$NET_1 = TO_1 - FR_1$	$NET_2 = TO_2 - FR_2$	…	$NET_N = TO_N - FR_N$	

In the spillover matrix, column variables are the origin of spillovers while row variables are the spillover receivers. The element in row i and column j, which denoted as $S_{i\leftarrow j}$, is the quantitative measure of potential spillover effects of *j*-th currency on *i*-th currency. It is computed as the average cumulated response of *i*-th currency in the following week, as shown in Equation (6), where $GIR_{i\leftarrow j}^{h}$ being the *i*-th element of $GIR_{j}^{h=0}$. With Equation (6), $S_{i\leftarrow j}$ measures how much the *i*-th currencies change with one standard error shock to the *j*-th currencies. We can either compute $S_{i\leftarrow j}$ as the average cumulated response of *i*-th currency in the following week in percentage of the initial shock to *j*-th currency (Alter and Beyer 2014), as shown in Equation (7). With Equation (7), $S_{i\leftarrow j}$ measures how much the *i*-th currencies change with one-unit change of the *j*-th currencies. We estimate mutual spillover network using Equation (6) if the endogenous variables do not vary a lot in case of G20 currencies, otherwise we estimate mutual spillover network using Equation (7) in case of BRI related currencies.

$$S_{i\leftarrow j} = \frac{GIR_{i\leftarrow j}^{h=0} + \sum_{h=0}^{1} GIR_{i\leftarrow j}^{h} + \sum_{h=0}^{5} GIR_{i\leftarrow j}^{h}}{3} \quad , \quad for \quad i,j \in ALL$$[8]

(6)

$$S_{i\leftarrow j} = \frac{GIR_{i\leftarrow j}^{h=0} + \sum_{h=0}^{1} GIR_{i\leftarrow j}^{h} + \sum_{h=0}^{5} GIR_{i\leftarrow j}^{h}}{3 * GIR_{j\leftarrow j}^{h=0}} \quad , \quad for \quad i,j \in ALL$$

(7)

We further average up off-diagonal pairwise spillover intensity on each column and each row to represent the outward and inward spillover effect for each currency which is labelled 'TO' and 'FR' in the spillover matrix respectively. Specifically, the average outward spillover effect from *j*-th currency to others is shown in Equation (8),

$$TO_{j}^{\Omega} = \frac{\sum_{i\neq j} S_{i\leftarrow j}}{N}, for\ i \in \Omega, j \notin \Omega \tag{8}$$[9]

where N is the number of currencies in the set Ω.

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[8] *ALL* is a set which contain all endogenous variables in Equation (1).
[9] Ω is subset of the set *ALL* defined in Equation (1).

Similarly, the average inward spillover effects from others to i-th currency is shown in Equation (9),

$$FR_i^{\Omega} = \frac{\sum_{j \neq i} S_{i \leftarrow j}}{N}, for\ i\ \in \Omega, j \notin \Omega \tag{9}$$

where N is the number of currencies in the set Ω.

Finally, we define net spillover effect as the difference between 'TO' and 'FR' as shown in Equation (10) which is labelled 'NET' in the last row of the spillover matrix.

$$NET_i^{\Omega} = TO_i^{\Omega} - FR_i^{\Omega}, for \quad i \quad \in \text{ALL} \quad .$$

(10)

Following Yang and Zhou (2017), we estimate the above impulse response matrix recursively in each period with an expanding sample after the initial sample period. In contrast to rolling sample spillovers in Diebold and Yilmaz (2014), our recursive estimation of spillovers can better capture the stock effect[10] of RMB spillovers over the course of RMB internationalisation rather than flow effect on the days when the central bank of China reformed the RMB exchange rate regime. Moreover, the recursive estimates are not sensitive to the window length and the outcome of the recursive estimation is a sample of spillover estimates which are updated in a Bayesian matter.

The indices of RMB impact on the G20 currencies

We estimate the spillover networks of the exchange rate changes among the G20 currencies and construct the RMB global and regional impact indices.

Network results

[10] See D'Amico and King (2013) for the differences between stock and flow effects of QE.

Schwarz's Bayesian Criterion suggests an optimal lag of k=2 for all the model specifications under consideration. Thus, a 17-variable VAR model with lag of 2 are estimated to summarise dynamic interactions among two-day rolling average changes of the 17 exchange rates. We construct spillover network of the major currencies of G20 members using Equation (6) and present it in Table 2.

Table 2. Results of generalised impulse response matrix for G20 currencies.

	CNY	AUD	CAD	JPY	KRW	GBP	EUR	DXY	ARS	BRL	INR	IDR	MXN	RUB	SAR	ZAR	TRY	FROM
CNY	0	2	1	1	2	1	2	2	0	1	2	1	1	1	0	2	1	1
AUD	7	0	38	1	23	29	31	32	2	25	21	12	28	19	4	34	21	20
CAD	4	27	0	0	13	18	18	21	2	15	12	6	20	14	1	20	12	13
JPY	3	2	1	0	1	5	13	19	1	-2	-2	3	-6	-1	2	1	-3	2
KRW	6	22	18	2	0	14	14	15	1	15	19	10	18	11	1	20	12	12
GBP	5	21	20	4	10	0	28	30	2	10	10	4	11	10	1	17	10	12
EUR	5	23	19	11	9	27	0	43	1	9	10	4	10	11	1	18	11	13
DXY	4	19	18	13	8	23	35	0	1	8	8	4	9	9	1	15	8	12
ARS	3	4	4	0	2	4	3	3	0	8	4	0	6	4	0	3	5	3
BRL	4	32	27	-3	18	17	17	19	6	0	19	14	41	21	2	32	27	18
INR	4	11	9	-1	10	7	7	8	1	8	0	5	11	8	0	10	7	7
IDR	5	14	11	2	12	7	7	7	0	11	11	0	11	8	0	11	9	8
MXN	4	23	22	-6	15	13	11	12	3	24	17	7	0	17	3	25	17	13
RUB	6	19	20	0	10	13	15	15	3	16	15	6	21	0	2	20	13	12
SAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZAR	9	42	36	2	25	28	32	32	3	29	23	9	38	25	-1	0	30	23
TRY	5	28	23	-3	16	17	22	22	4	28	18	8	29	18	-1	35	0	17
TO	5	18	17	1	11	14	16	18	2	13	12	6	15	11	1	16	11	
NET	3	-2	4	-1	-2	2	3	6	-1	-6	5	-2	3	-1	1	-6	-5	

Notes: This table reports the results of generalised impulse response among exchange rate changes of major G20 currencies using Equation (6). The endogenous variables are two-day rolling average exchange rate changes from 5 January 1999 to the end of 2018.

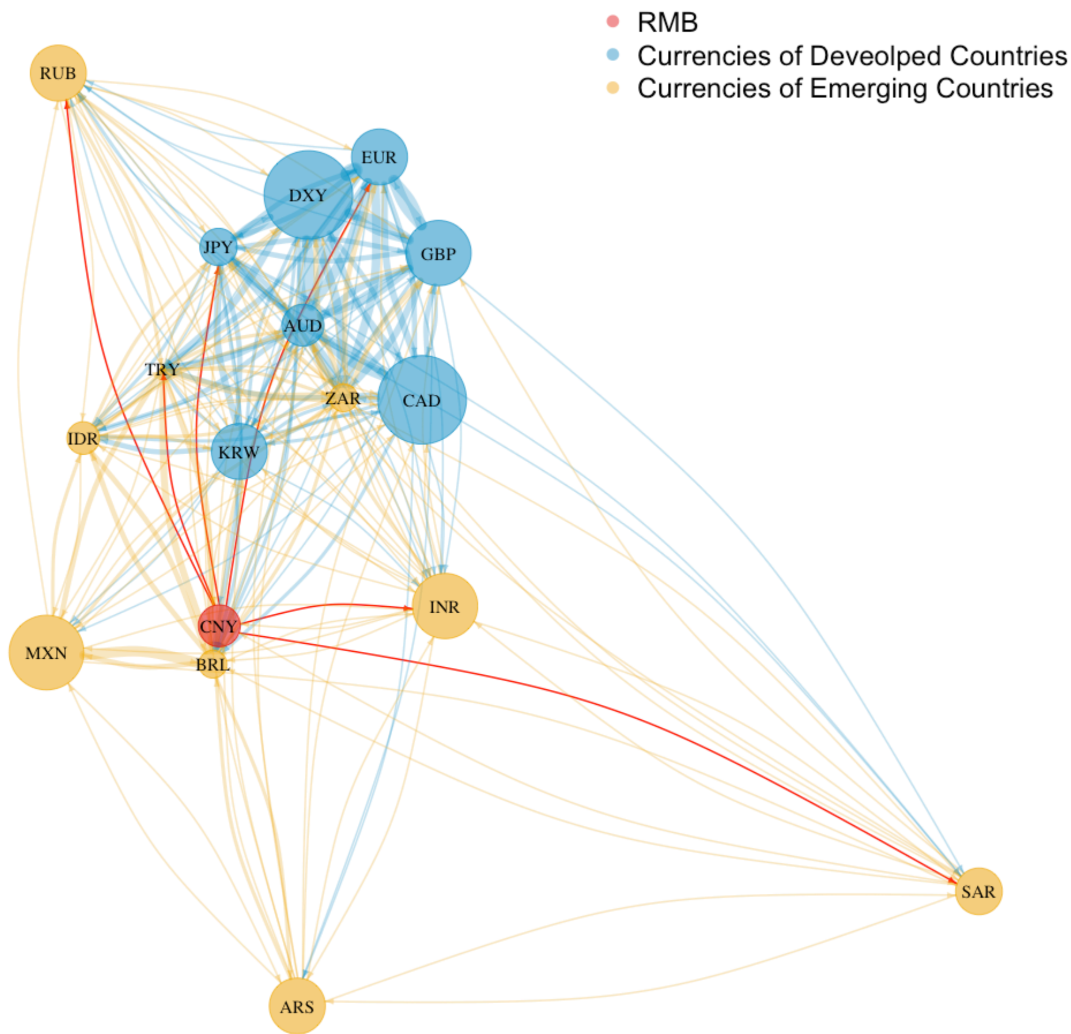
First, column currencies are the origin of spillovers while row currencies are the spillover receivers. For example, the first column displays the strength of CNY's influence on other currency. With one standard error shock of CNY change[11], ZAR, AUD, KRW, and RUB change by 9 bps, 7 bps, 6 bps, and 6 bps, respectively. On the other hand, one standard error shocks of ZAR, AUD, KRW, and RUB changes lead to CNY changes by 2 bps, 2 bps, 2 bps, and 1 bps, respectively.

To quantify how important a currency in the spillover network is relative to others, we follow Diebold and Yilmaz (2014) to calculate net spillover index as shown in the bottom row of Table 2. The net spillover effects on USD, CAD, EUR, CNY and GBP are 6 bps, 4 bps, 3 bps, 3 bps, and 2 bps, respectively.

We also estimate spillover networks for sub-samples and present the interactions between currencies using graphs as shown in Figure 1. The sizes of dots are calibrated according to their net spillover magnitudes. The edges of nodes point to the currencies which receive positive spillover effect. Besides, the width and length of edges are also weighted. The spillover effect is greater with a wider and shorter edge. Therefore, the location of a node for a currency implies its relative network importance.

[11] One standard error shock of CNY is historical volatility of CNY's exchange rate changes, which is about 0.86 ‰.

Panel A: Network before 21 July 2005



Panel B: Network after July 21 2005

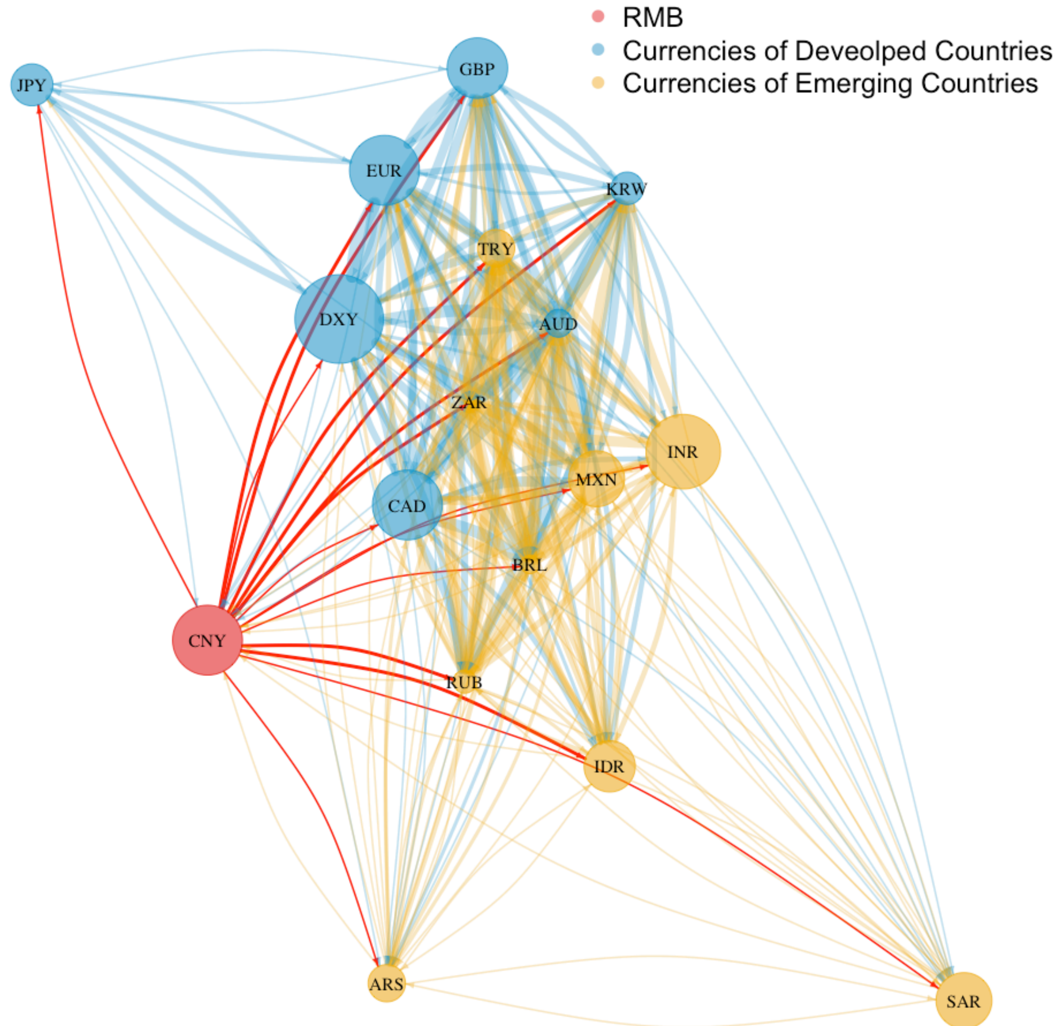


Figure 1. Spillover networks among the major G20 currencies.

Notes: This figure represents spillover networks of currencies for G20 members estimated using Equation (6). The sizes of dots are calibrated correspondingly to their net spillover index. The edges of nodes point to the currencies which receive positive spillover effect. Besides, the width and length of edges are also weighted. The spillover effect is greater with a wider and shorter edge. Therefore, the location of a node for a currency implies its relative network importance. Panel A shows a spillover network of G20 currencies which is estimated using data starts from 5 January 1999 and ends on 20 July 2005. Panel B shows a spillover network of G20 currencies which is estimated using data starts from 20 July 2005 and ends on 1 January 1999.

Panel A of Figure 1 shows a spillover network of G20 currencies which is estimated with data starting from 5 January 1999 and ending on 20 July 2005. The blue dots which represent currencies for developed markets gather together. It suggests that the mutual interactions among currencies for developed markets were more active and intense. The yellow dots which represent currencies for emerging markets are on the periphery of the network, indicating that emerging market currencies had relatively smaller impact on others. The red dot which has positive net spillovers effects on six currencies is CNY. During the sample period, the US dollar had a significant impact on other G20 currencies, as the US dollar has been the world's major currency and fulfilled its role as an 'anchor currencies' which reflects the financial-economic, political and military position of the US.

Panel B of Figure 1 shows a spillover network of G20 currencies which is estimated with data from 20 July 2005 to the end of 2018. During the sample period, the US dollar still played the largest net spillover effect on other currencies. But the situation has changed radically. The relative importance of the US dollar has declined substantially due to the rise of other currencies, especially the rise of RMB. It indicates that the world is indeed embracing the trend towards a multipolar international monetary system.

Results on RMB spillover dynamics

To further explore time-varying spillover intensity, we construct CNY impact index by estimating recursively with an expanding sample using Equations (1), (3) and (7)-(10).[12] We also construct RMB impact indices for CNH and CNY central parity.

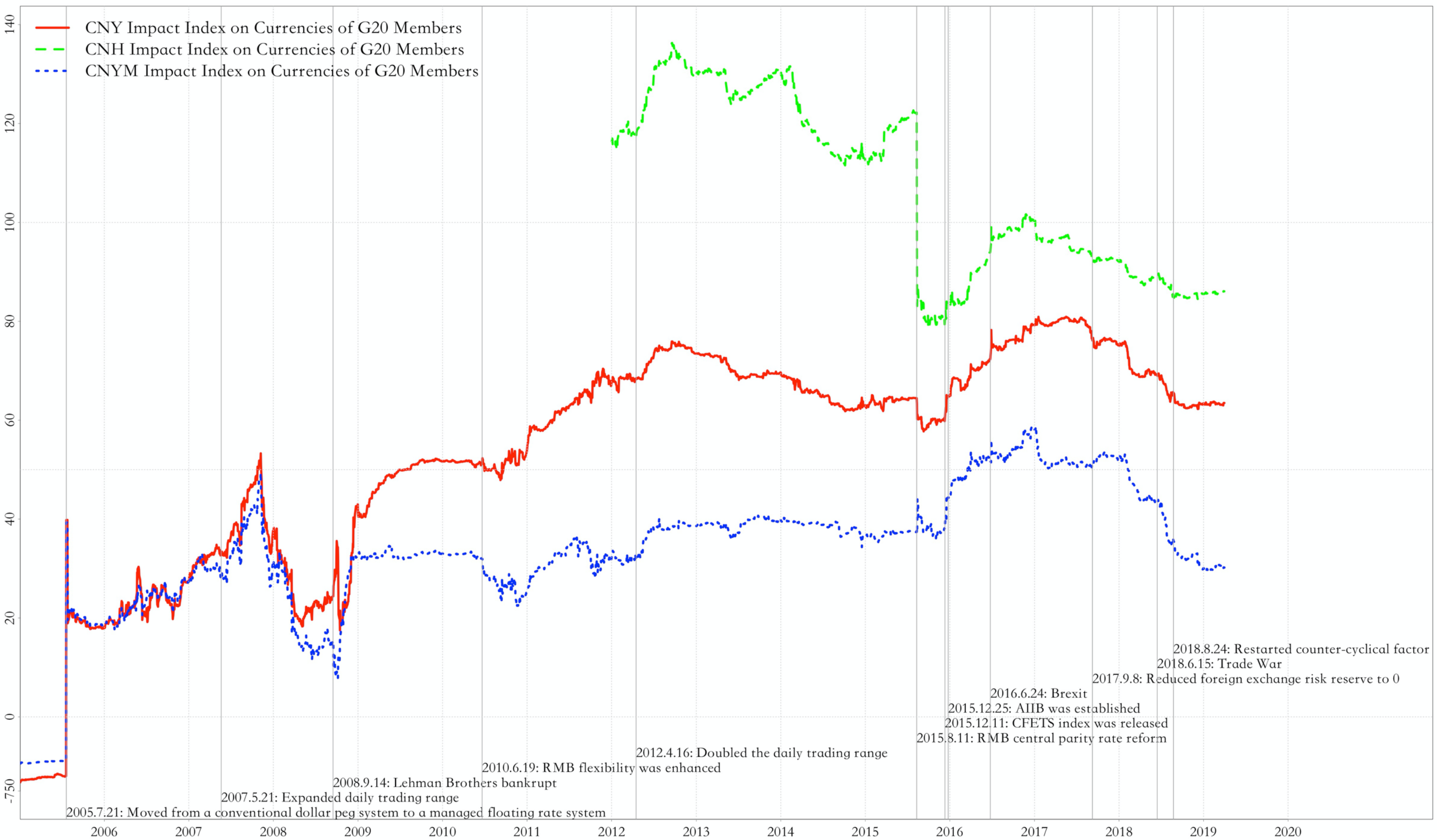
Panel A of Figure 2 shows the dynamics of CNY, CNH and CNY central parity's impact indices. At the very beginning, the impact index of CNY on G20 currencies is

[12] For recursive estimation, the initial sample period is 5 January 1999 to 1 January 2005 and the final sample period is 5 January 1999 to the end of 2018.

negative, suggesting that CNY has no capacity to drive other currencies to move in the same direction. However, CNY's index soared to the positive value on 21 July 2005, when the central bank of China launched the transition of RMB regime from a conventional dollar peg system to a managed floating rate system. The index became volatile during the financial crisis in 2008 and then went on an upward trend. The dynamic of CNY central parity's index is similar to that of CNY but without much gain in overall influence. The impact index of CNH on G20 currencies is much bigger than that of CNY and CNY central parity. Arguably, offshore markets for a currency provide an important dimension when measuring the regional and global influence of that currency (He and McCauley 2012). Interestingly, both the impact indices of CNY and CNH dropped sharply on 11 August 2015, when the central bank of China exerted an RMB central parity rate reform. In contrast, the index of CNY central parity increased a little bit in the following days.

We further calculate the impact indices of CNY on the currencies of developed and emerging markets and display them separately in Panel B of Figure 2. Although the pattern of dynamics for both indices are quite similar to that of the impact index on G20 currencies, we observe an apparent drop of CNY's impact on the currencies of developed markets while a slight increase of CNY's impact on emerging market currencies. The difference indicates that the influence of the CNY central parity reform is far more complicated than we thought.

Panel A: Dynamics of impact indices of CNY, CNH and mid-price on G20 currencies



Panel B: Dynamics of CNY's impact indices on G20 currencies

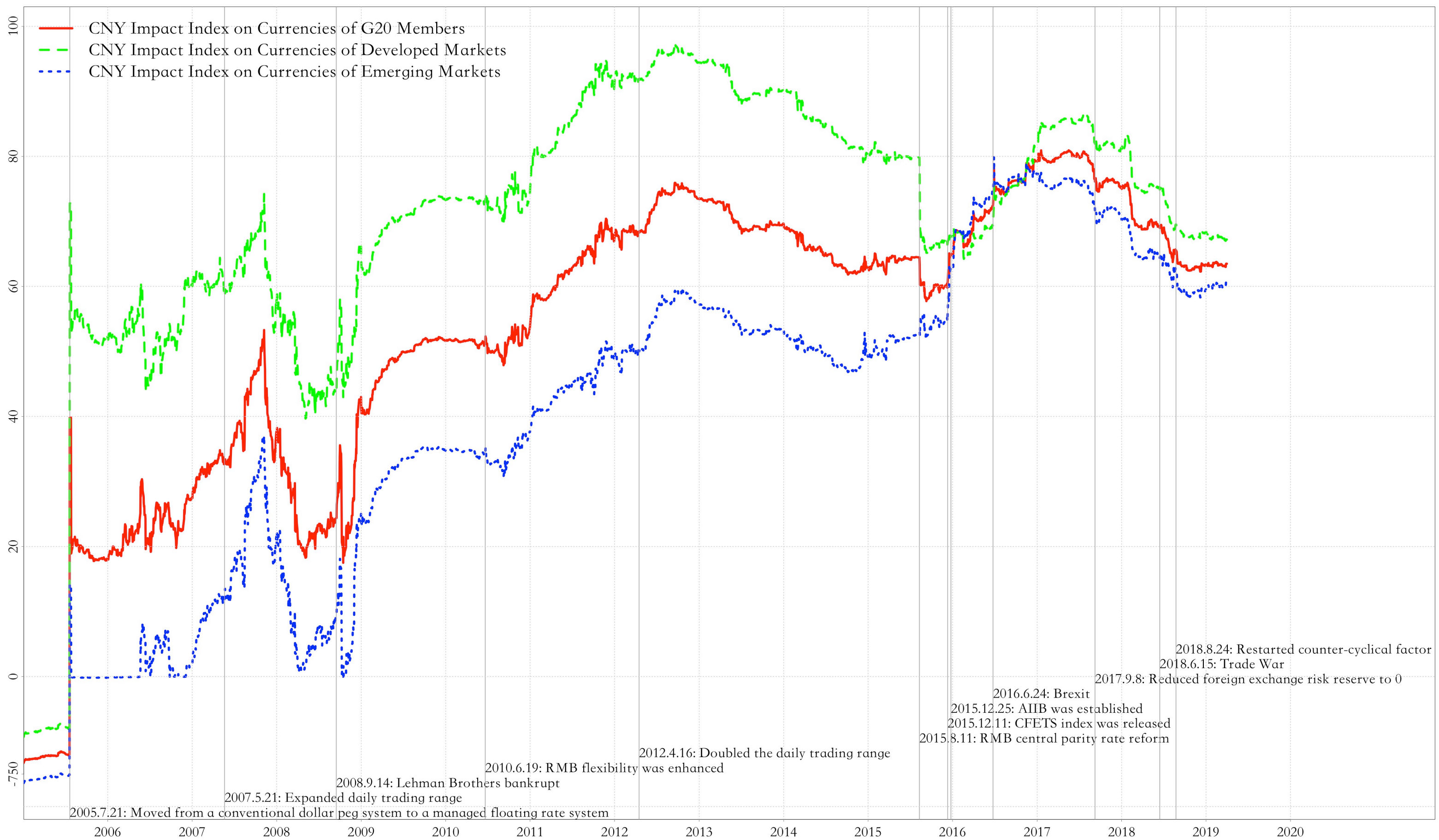


Figure 2. Dynamics of RMB impact indices on G20 currencies.

Notes: This figure displays dynamics of RMB impact indices for currencies of G20 members. Panel A shows the dynamics of CNY, CNH and CNY central parity's impact indices on currencies of all G20 members. Panel B shows the dynamics of CNY's impact indices on currencies of all G20 members, developed markets and emerging markets.

To take a closer look at the dynamics of RMB impact indices, we display the interactions between CNY and other currencies in Table 3 on six dates around several important events.

Firstly, we show the interactions between CNY and other currencies before and after seven trading days when the Chinese central bank initiated the reform to managed floating regime. CNY's impact index is significantly negative before 21 July 2005. But specifically, CNY had a positive but limited influence impacts on JPY, EUR, INR, RUB, SAR and TRY, which is in line with our intuition, as shown in the first column of Table 3. Besides, since RMB was under a fixed exchange rate regime, the currency exchange rates of other countries had no influence on CNY. As shown in the second column, the inward spillover effects on CNY are almost zeros. After seven days of the reform, earth-shaking changes have taken place. As shown in the fourth column of the table, CNY's outward impacts turn to be positive for most of the other currencies, especially for currencies of developed markets which results in a positive overall net spillover index.

Secondly, we show the interactions between CNY and other currencies before and after seven trading days when the Chinese central bank launched the reform of the RMB central parity price on 11 August 2015, in the seventh to 12th columns. When the People's Bank of China (the Chinese central bank) initiated a currency reform on 11 August 2015, RMB's midpoint immediately fell by 1.9%, the biggest single-day drop in the RMB's modern history,[13] the global currency market has braced for RMB weakness.[14] Before the reform, CNY's impact indices had become significantly positive with a net spillover effect on the developed market currencies of about 80% and a net spillover effect of about 53%. Seven trading days after the reform, CNY's net spillover effect on the currencies of developed markets decreased dramatically from 80% to 67%. In contrast, its net spillover effect on the currencies of emerging markets increased a little bit. On average, the CNY's impact indices decreased due to the reform.

Finally, we show the interactions between CNY and other currencies before and after seven trading days when the foreign exchange risk reserve requirement was reduced to 0 on 8 September 2017. As shown in the last six columns, CNY's net spillover index decreased a little bit.

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[13] See The battle of midpoint, *Economist*, 15 August 2015.
[14] See *Financial Times*, 21 September 2015.

Table 3. Results of the impacts of CNY on G20 currencies around some events.

Period	1999-01-05/2005-07-20			1999-01-05/2005-07-28			1999-01-05/2015-08-10			1999-01-05/2015-08-18			1999-01-05/2017-09-07			1999-01-05/2017-09-15		
Ω	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$
AUD	-327	0	-326	76	0	76	133	2	131	118	2	116	120	3	117	118	3	116
CAD	-363	0	-363	-9	0	-9	53	2	51	45	2	43	68	3	65	67	3	64
JPY	504	0	504	144	1	143	50	1	48	40	1	39	62	2	60	64	2	61
KRW	-869	0	-869	92	1	91	74	1	72	76	2	75	102	3	98	99	3	95
GBP	-1644	0	-1644	34	0	34	81	2	79	69	2	66	98	4	94	94	4	90
EUR	229	0	229	23	0	23	101	3	98	75	2	72	78	3	74	78	4	75
DXY	-302	0	-302	13	0	13	83	4	79	65	3	62	72	5	67	72	5	67
ARS	-200	0	-200	0	0	0	8	0	8	9	0	9	56	1	56	54	1	54
BRL	-3176	0	-3176	-127	0	-127	74	1	73	68	1	67	76	1	75	75	1	74
INR	50	0	50	32	6	27	73	4	69	80	5	75	66	6	60	65	6	58
IDR	-2935	0	-2935	1	0	1	65	1	64	71	1	70	72	2	70	71	2	69
MXN	-1120	0	-1119	6	0	6	52	1	51	54	1	53	72	2	70	70	2	67
RUB	369	0	369	7	0	6	98	1	96	104	2	102	115	2	113	110	2	108
SAR	5	3	2	0	27	-27	1	6	-6	1	7	-6	1	9	-8	1	10	-9
ZAR	-2106	0	-2106	63	0	63	71	1	70	71	1	70	139	2	137	132	2	130
TRY	2305	0	2305	-14	0	-14	48	1	47	52	1	52	79	1	78	76	1	75
ED	-396	0	-396	53	0	53	82	2	80	70	2	67	86	3	82	85	3	81
EM	-757	0	-757	-4	4	-7	54	2	53	57	2	54	75	3	72	73	3	70
ALL	-599	0	-599	21	2	19	66	2	64	62	2	60	80	3	77	78	3	75

Notes: This table reports the outward, inward and net spillover indices of CNY for sub-samples as shown in the first row of the table and the mutual spillover effect is estimated using Equation (6). $\mathrm{TO}_{CNY}^{\Omega}$ represents CNY's outward spillover effect on currencies in the set Ω as shown in Equation (8). $\mathrm{FR}_{CNY}^{\Omega}$ represents CNY's inward spillover effect from currencies in the set Ω as shown in Equation (9). $\mathrm{NET}_{CNY}^{\Omega}$ represents CNY's net spillover effect on currencies in the set Ω as shown in Equation (10). The first column displays currencies which belong to set Ω. *ED* is a set for currencies of developed markets. *ED = {DXY, EUR, GBP, AUD, CAD, JPY, KRW}*. *EM* is a set for currencies of emerging markets. *EM = {ARS, BRL, INR, IDR, MXN, RUB, SAR, ZAR, TRY}*. ALL is a set for currencies of member of G20. *ALL = {ED, EM}*.

The indices of RMB impact on the currencies related to the BRI

Similarly, we estimate spillover networks of the exchange rate changes among the currencies of countries along the Belt and Road and participating countries in building the modern Belt and Road, and construct CNY's impact indices on the BRI's related currencies.

Network results

First, we estimate a VAR model with lag of 2 using two-day rolling average changes of the 26 exchange rates for the currencies of countries along the Belt and Road. The spillover network among the 26 currencies using Equations (7)-(10) is presented in Table 4. For the full sample which starts on 22 July 2005 and ends by the end of 2018, the net spillover index for CNY is 18% while that of SGD is 26%, which indicates that SGD plays a leading role in the region while CNY takes the second place.

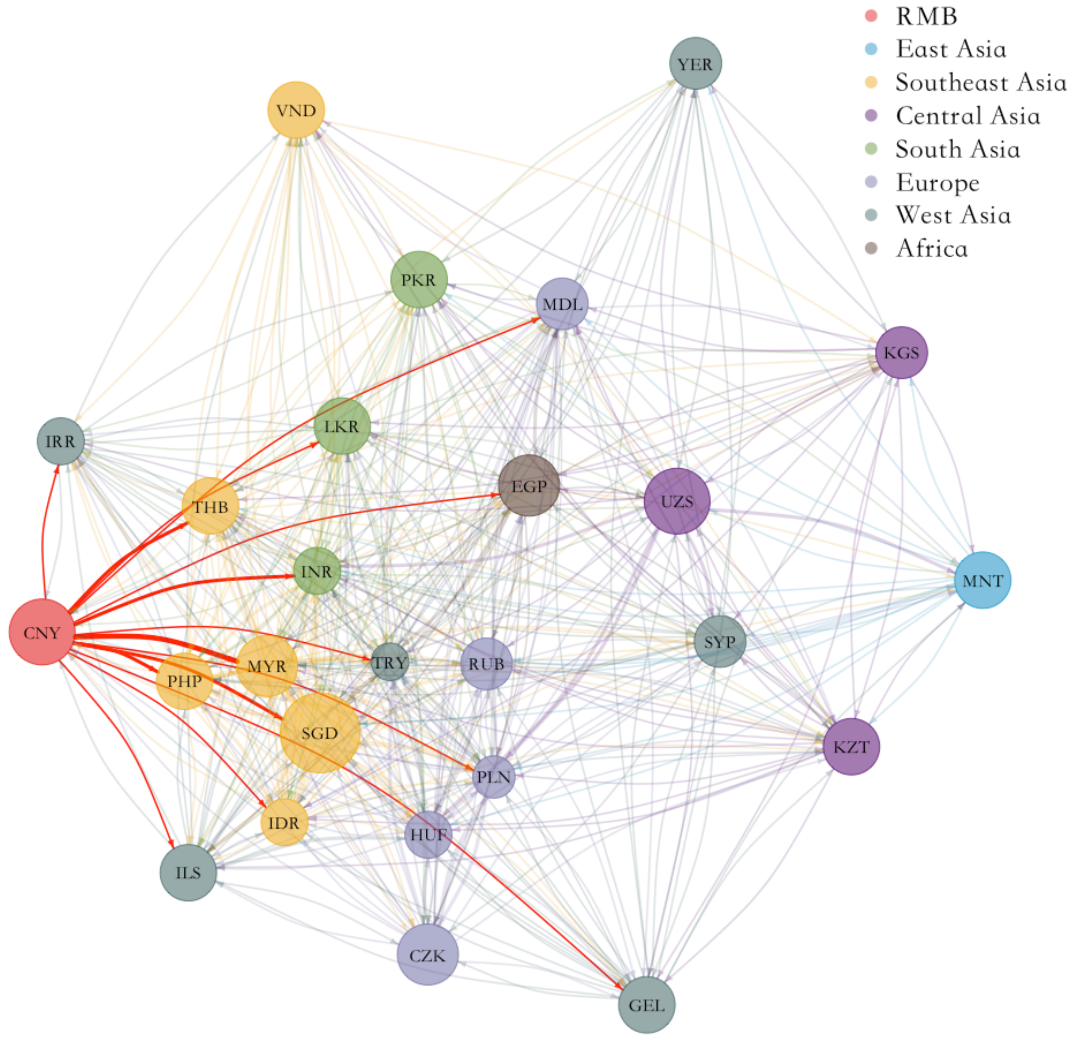
Table 4. Results of generalised impulse response matrix for the major currencies along the Belt and Road.

	CNY	MNT	SGD	MYR	IDR	THB	VND	PHP	KZT	UZS	KGS	INR	PKR	LKR	RUB	MDL	PLN	CZK	HUF	IRR	TRY	SYP	ILS	YER	GEL	EGP	FROM
CNY	0	0	16	12	6	9	2	7	1	0	0	5	0	2	2	1	2	0	1	0	2	0	3	1	2	0	3
MNT	2	0	-3	0	1	1	-1	-9	6	0	4	-2	1	-5	0	6	3	-2	1	-1	0	2	-3	-4	3	2	0
SGD	44	0	0	48	22	25	0	36	0	-1	-2	26	1	1	9	3	18	14	17	0	12	0	17	2	0	0	12
MYR	85	-2	118	0	45	46	9	75	5	-1	-2	46	4	9	16	6	19	11	19	1	15	0	26	1	1	1	22
IDR	57	-4	84	68	0	41	13	72	2	-1	4	44	3	18	13	5	21	11	16	0	18	0	20	0	5	1	21
THB	51	-1	55	41	25	0	6	33	2	0	-2	28	1	3	8	1	9	5	9	1	8	0	11	4	2	-1	12
VND	7	-1	3	4	2	3	0	4	1	0	0	3	1	2	1	2	0	0	0	0	2	0	1	-1	-1	0	1
PHP	33	-4	63	54	35	27	8	0	1	-1	-3	45	8	12	7	0	18	11	15	1	13	0	14	0	-1	0	14
KZT	41	12	12	25	13	13	20	9	0	1	26	4	-2	9	18	4	12	0	7	0	5	0	11	0	3	1	10
UZS	-32	1	-10	-6	-1	-2	8	-3	6	0	3	1	3	0	-4	-5	-2	4	0	1	-1	1	-8	4	25	1	-1
KGS	8	3	7	4	1	0	9	1	8	0	0	-3	0	7	2	2	3	-5	0	0	2	0	0	-3	3	0	2
INR	42	-3	73	55	35	35	8	68	2	0	-8	0	11	18	12	6	23	7	19	1	18	0	17	2	0	0	18
PKR	2	2	5	5	4	4	4	10	1	0	1	8	0	7	1	2	0	2	1	0	0	0	-1	1	-2	0	2
LKR	6	-3	6	6	6	2	2	8	1	0	2	10	2	0	1	0	4	4	2	1	1	0	2	-8	1	0	2
RUB	54	3	108	76	40	43	19	47	20	-1	-4	54	2	14	0	20	40	30	38	-1	28	0	24	-4	0	1	26
MDL	15	6	13	6	1	0	4	-1	3	0	1	6	4	5	5	0	3	1	4	0	2	0	2	6	5	-2	4
PLN	13	-1	76	30	18	16	2	42	4	0	-5	33	-1	20	15	5	0	79	73	0	27	0	26	-1	4	1	19
CZK	0	-1	25	6	2	0	-2	6	-1	1	-7	2	6	11	5	0	39	0	32	0	7	0	11	-3	1	0	6
HUF	4	4	78	30	9	17	-1	33	1	0	-7	30	0	8	15	4	69	63	0	-1	30	-1	34	-7	4	-2	17
IRR	-6	1	16	22	3	24	15	19	0	1	-3	24	4	5	4	3	3	2	3	0	1	1	7	-3	2	0	6
TRY	45	-1	121	55	39	39	22	69	1	0	-11	59	-2	9	26	6	59	37	70	0	0	1	47	-3	7	3	28
SYP	-3	32	17	9	8	2	-5	17	0	1	-4	2	-10	26	0	2	3	10	3	1	2	0	-3	-1	10	0	5
ILS	11	-5	46	25	12	10	-6	18	2	-2	-3	18	-1	3	6	2	15	13	19	0	12	0	0	2	0	-1	8
YER	-1	1	2	-1	0	3	-1	1	1	0	-2	0	1	-20	1	3	-1	-1	-2	0	-1	0	1	0	0	0	-1
GEL	20	-2	7	9	2	7	2	6	5	2	-4	0	-6	6	6	8	5	6	4	0	6	1	0	0	0	0	4
EGP	14	3	-6	1	3	-2	2	4	2	1	-1	5	2	14	2	-6	2	0	-5	0	2	0	-3	0	9	0	2
TO	21	2	37	23	13	15	6	23	3	0	-1	18	1	7	7	3	15	12	14	0	9	0	10	-1	3	0	
NET	18	2	26	1	-7	3	4	9	-7	1	-3	0	-1	5	-19	0	-4	6	-3	-6	-19	-5	2	0	0	-2	

Notes: This table reports the results of generalised impulse response for currencies of countries along the Belt and Road estimated using Equation (7). The endogenous variables are two-day rolling average exchange rate changes from 22 July 2005 to the end of 2018.

We also estimate spillover networks for sub-samples and plot the interactions among the sample currencies in Figure 3. Panel A of Figure 3 shows the spillover network which is estimated with data from 22 July 2005 to 7 September 2013, before the BRI was proposed. The red dot which represents the onshore RMB lies on the periphery of the network before the BRI. Panel B of Figure 3 shows the spillover network which is estimated with data from 8 September 2013 to the end of 2018. Since the BRI was proposed, the onshore RMB has taken the central position of the network, indicating a leading role in the BRI's related currencies. Moreover, we observe that the currencies in the same region cluster together, which is in line with our intuition.

Panel A: Network before the BRI was proposed



Panel B: Network after BRI was proposed

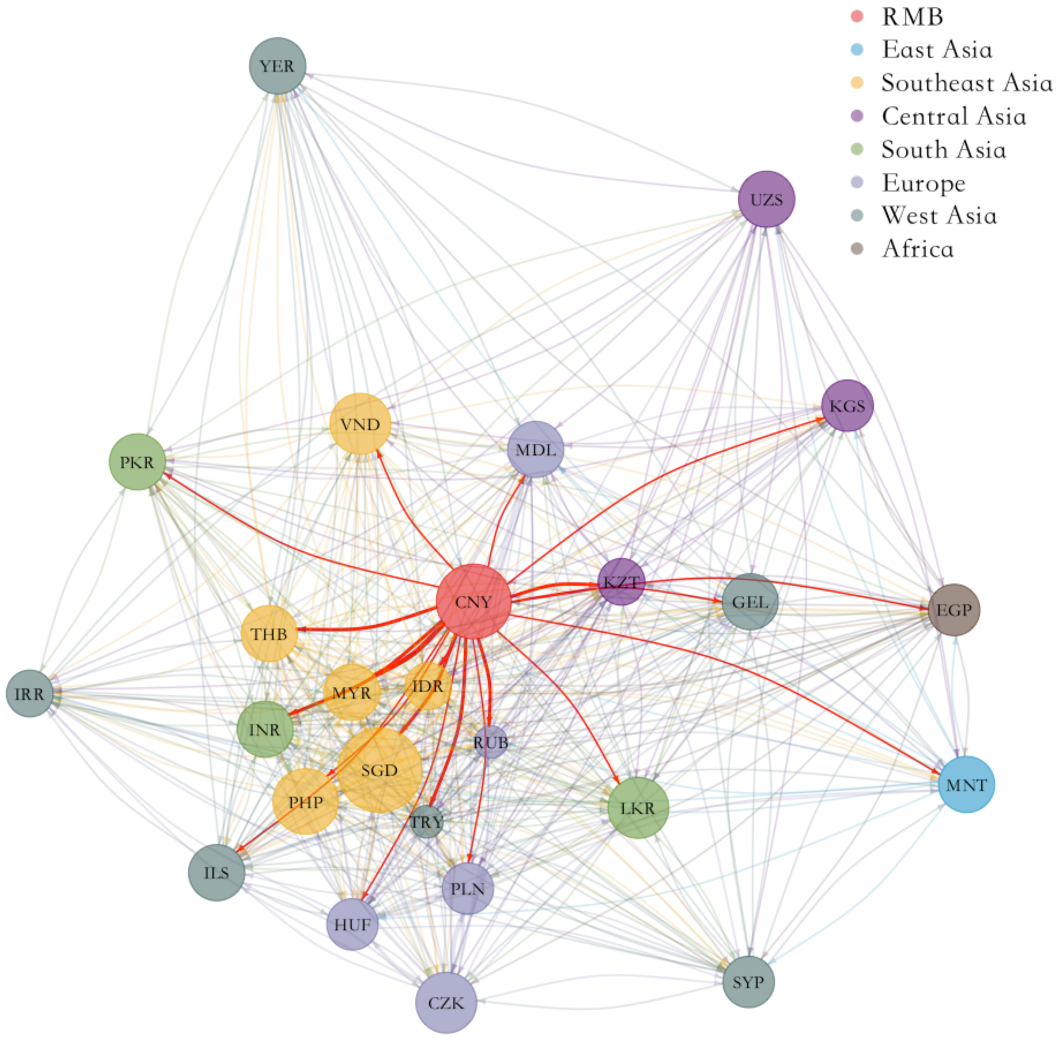
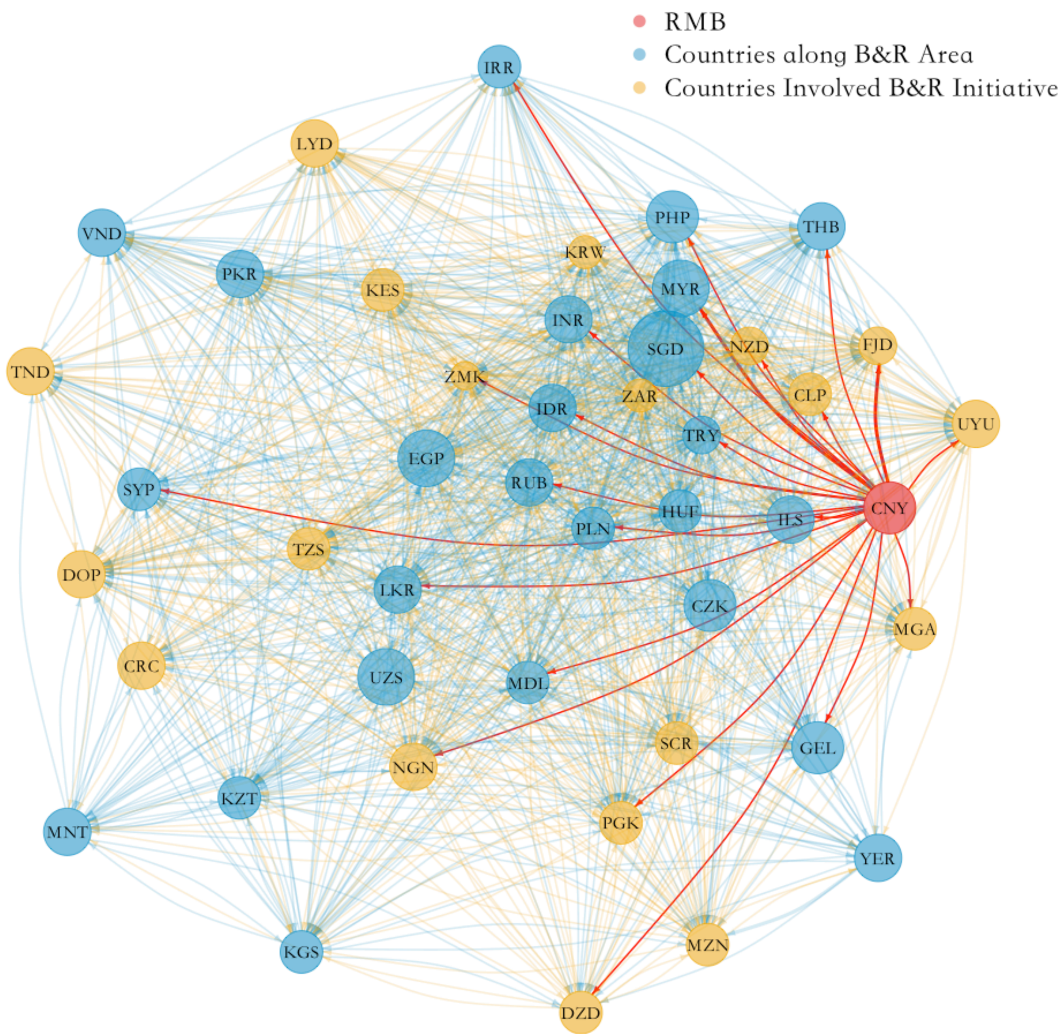


Figure 3. Spillover networks among currencies of countries along the Belt and Road.
Notes: This figure represents spillover networks for currencies of counties along the Belt and Road estimated using Equation (7). The sizes of dots are calibrated correspondingly to their net spillover index. The edges of nodes point to the currencies which receive positive spillover effect. Besides, the width and length of edges are also weighted. The spillover effect is greater with a wider and shorter edge. Therefore, the location of a node for a currency implies its relative network importance. Panel A shows a spillover network of the 26 currencies which is estimated using data starts from 22 July 2005 and ends on 7 September 2013. Panel B shows a spillover network of the 26 currencies which is estimated using data from 8 September 2013 to the end of 2018.

Figure 4 plots the spillover networks of the two sub-samples for 45 currencies of participating countries in building the modern Belt and Road. Similarly, CNY lies on the periphery of the network before the BRI was proposed as shown in Panel A. Thereafter, CNY moved to the centre of the network as shown in Panel B.

Panel A: Network before the BRI was proposed



Panel B: Network after the BRI was proposed

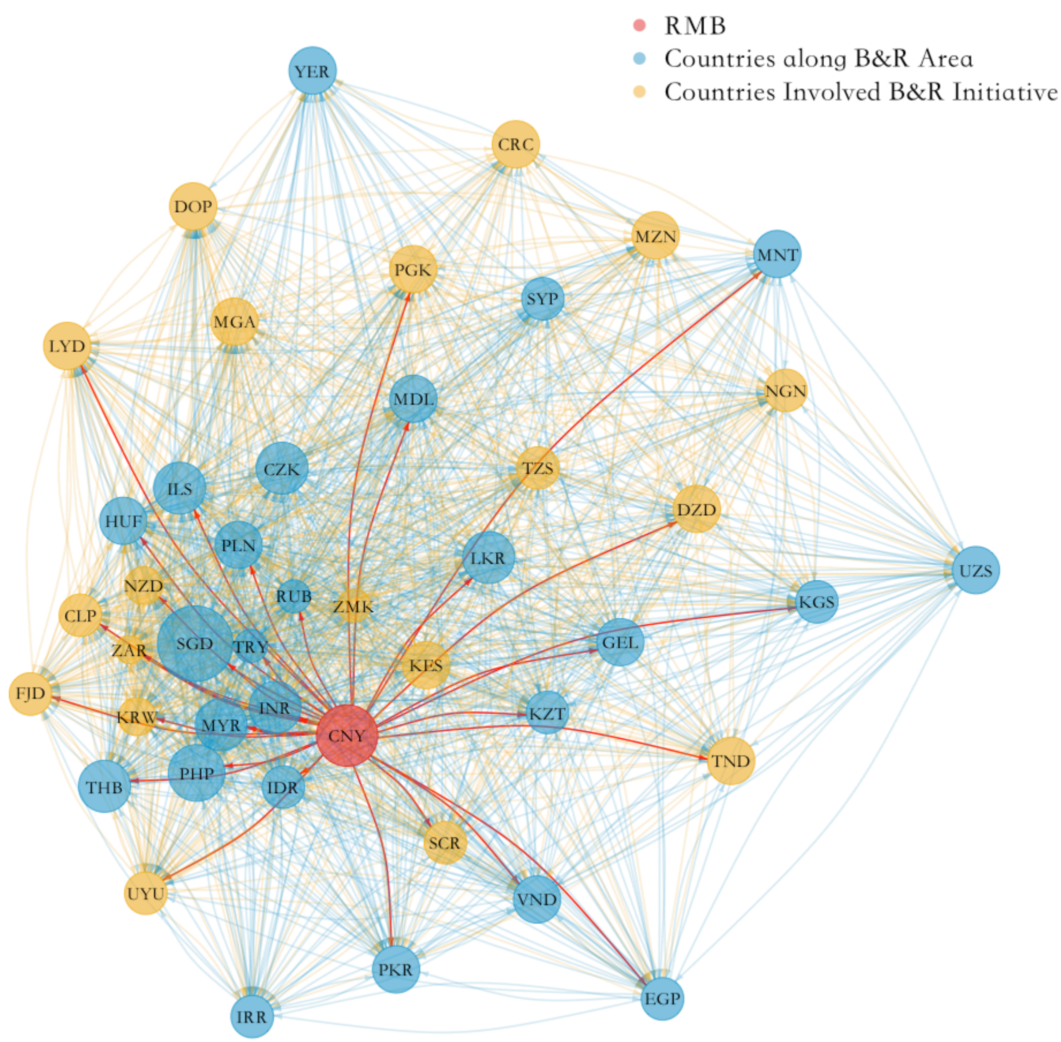


Figure 4. Spillover networks for currencies of participating countries the BRI.

Notes: This figure represents spillover networks for currencies of counties participating the BRI estimated using Equation (7). The sizes of dots are calibrated correspondingly to their net spillover index. The edges of nodes point to the currencies which receive positive spillover effect. Besides, the width and length of edges are also weighted. The spillover effect is greater with a wider and shorter edge. Therefore, the location of a node for a currency implies its relative network importance. Panel A shows a spillover network of the 45 currencies which is estimated using data starts from 22 July 2005 and ends on 7 September 2013. Panel B shows a spillover network of the 45 currencies which is estimated using data from 8 September 2013 to the end of 2018.

Results on RMB spillover dynamics

We further construct CNY's impact index on the currencies of 25 countries along the Belt and Road and 44 countries participating in the BRI by estimating recursively with an expanding sample using Equations (1), (3) and (7)-(10). To control the impact of major anchor currencies, we use the two days rolling of the DXY and exchange rate changes of EUR, JPY, and GBP as control variables in Equation (1). For recursive estimation, the initial sample period is 22 July 2005 to 1 January 2009 and the final sample period is from 22 July 2005 to the end of 2018.

Panel A of Figure 5 shows the dynamics of CNY's impact indices on the BRI's related currencies. The red and green lines represent the CNY's impact indices on the currencies of countries along the Belt and Road, and currencies of countries participating in the BRI respectively. While the blue line represents CNY's impact indices on the Euro and currencies of countries participating in the BRI. Except for some small ups and downs, the CNY's impact indices are generally on the rise, especially on days when China Foreign Exchange Trade System (CFETS) released RMB exchange rate index, when the Asian Infrastructure Investment Bank (AIIB) was established, and when the BRI was first written into the UN General Assembly resolution.

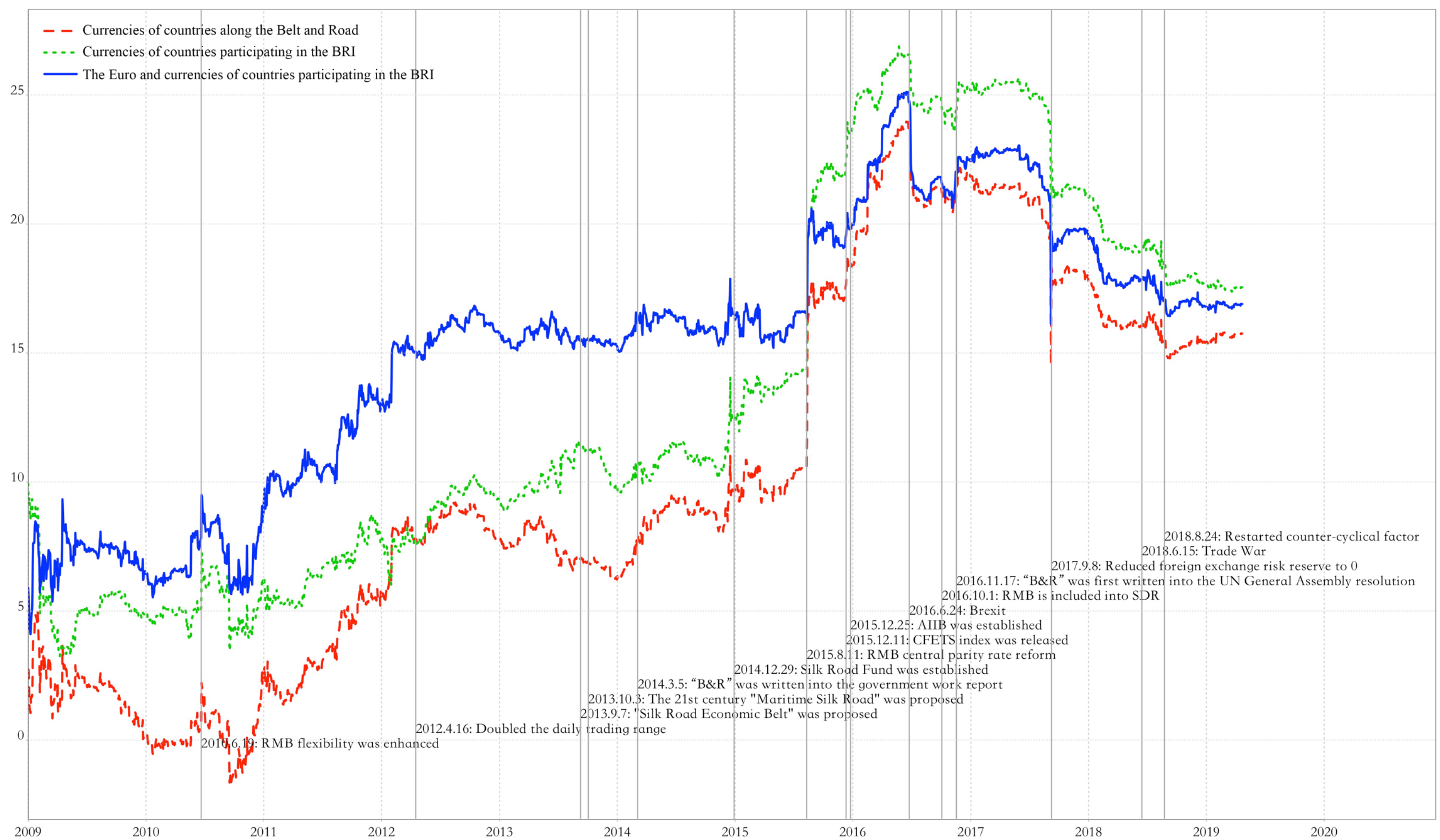


Figure 5. Dynamics of RMB impact indices on major currencies related to the BRI.

Notes: This figure displays the dynamics of RMB impact indices on currencies of countries related to the BRI. The red line represents CNY's index on currencies of countries along the Belt and Road, the green line represents CNY's index on currencies of countries participating in the BRI, the blue line represents CNY's index on the Euro and currencies of countries participating in the BRI.

Noticeably, in contrast to the sharp decrease of the impact indices of CNY on G20 currencies and especially currencies for developed markets, the impact indices of CNY on the currencies of countries along the Belt and Road increased sharply on 11 August 2015. In line with the decreased impact of CNY on G20 currencies, the impact of CNY on the currencies of countries along the Belt and Road decreased one day before 8 September 2017 when the foreign exchange rate reserve requirement was reduced to 0. Indeed, the impact of RMB marketisation reform is subtle. It is worthwhile to further explore the balance of maintaining RMB stability, increasing the marketisation of RMB, and improving the international influence of the RMB.

To take a closer look at the dynamics of RMB index on the 44 currencies for countries participating the BRI, we display the interactions between CNY and other currencies in Table 5 on six dates around three events. To save space, we put 44 currencies into nine groups according to their locations of countries since we have observed a spatial clustering effect of currencies and calculate CNY's outward, inward and net spillover indices on currencies of nine regions.[15]

Firstly, the impact index of CNY didn't change much the day before the BRI was proposed and seven trading days after, as shown in the first six columns. Secondly, CNY's net spillover index increased for all regions except for Oceania and Europe after seven trading days when the central bank of China exerted an RMB central parity rate reform on 11 August 2015, as shown in the following six columns. Thirdly, CNY's net spillover index

[15] Specifically, we classify CNY, MNT, and KRW as East Asia currencies, SGD, MYR, IDR, THB, VND, and PHP as Southeast Asia currencies, KZT, UZS, and KGS as Central Asia currencies, INR, PKR, and LKR as South Asia currencies, PGK, NZD, and FJD as Oceania currencies, RUB, MDL, PLN, CZK, and HUF as Europe currencies, DOP, CLP, CRC, and UYU as America currencies, IRR, TRY, SYP, ILS, YER, and GEL as West Asia currencies, TZS, KES, SCR, EGP, DZD, TND, LYD, MZN, ZMK, MGA, ZAR, and NGN as Africa currencies.

decreased sharply two days before the foreign exchange rate risk reserve requirement was reduced to 0, as shown in the last six columns, especially for currencies of Southeast Asia.

Table 5. Results of the impacts of CNY on the BRI related currencies around some events.

Period	2013-09-06			2013-09-16			2015-08-10			2015-08-18			2017-09-04			2017-09-07		
Ω	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$	$\mathrm{TO}_{CNY}^{\Omega}$	$\mathrm{FR}_{CNY}^{\Omega}$	$\mathrm{NET}_{CNY}^{\Omega}$
East Asia	-20	0	-19	-19	0	-19	-4	0	-4	11	0	11	32	1	31	31	1	30
Southeast Asia	41	3	37	41	3	37	45	3	42	58	5	53	55	7	48	57	7	50
Central Asia	-22	-9	-13	-22	-9	-13	-16	-4	-12	-11	-3	-8	12	-2	14	-8	0	-8
South Asia	19	1	19	19	1	19	15	0	15	21	1	20	17	1	16	15	1	14
Oceania	44	1	43	44	1	43	49	1	48	46	1	45	36	2	34	36	2	34
Europe	7	1	7	7	1	7	13	0	12	18	1	17	20	1	20	19	1	18
America	-4	0	-4	-4	0	-4	-4	0	-4	3	0	3	12	0	12	10	0	10
West Asia	7	0	8	7	0	7	9	0	9	13	0	13	17	1	15	9	1	8
Africa	-7	0	-7	-7	0	-7	-2	0	-3	6	0	6	7	0	7	4	0	4
ALL	7	0	7	7	0	7	11	0	11	18	1	17	21	1	20	18	1	16

Notes: This table reports the outward, inward and net spillover indices of CNY for sub-samples as shown in the first row of the table and the mutual spillover effect is estimated using Equation (7). $\mathrm{TO}_{CNY}^{\Omega}$ represents CNY's outward spillover effect on currencies in the set Ω as shown in Equation (8). $\mathrm{FR}_{CNY}^{\Omega}$ represents CNY's inward spillover effect from currencies in the set Ω as shown in Equation (9). $\mathrm{NET}_{CNY}^{\Omega}$ represents CNY's net spillover effect on currencies in the set Ω as shown in Equation (10). The first column displays currencies in a specific area which belong to the set Ω.

Robustness check

Capital control is our main concern when we evaluate the importance of RMB as a potential anchor currency because the capital account openness of China is far below the average according to Chinn and Ito (2006). Besides, being included in the SDR basket doesn't naturally lead to the free convertibility of RMB. Actually, RMB is the only IMF reserve currency that isn't fully convertible, and RMB is included into the SDR basket as a freely usable currency instead of a free convertible currency. It indeed seems to be a puzzle when RMB implements considerable influence globally under a rather tight capital control.

However, CNH is much less regulated and is de facto fully convertible for it is being freely traded outside the Chinese mainland, such as in the Hong Kong SAR and Singapore. In regard to CNH, we are able to check the influence of convertibility of RMB by comparing the performance of CNY and CNH among the currencies in the SDR basket. The sample period starts from 2 March 2011, when the data for CNH is available, and ends by the end of 2018.

Table A in Appendix shows the spillover network among onshore RMB (CNY), JPY, GBP, EUR, and the DXY estimated using Equation (6). Table B in Appendix shows the spillover network among offshore RMB (CNH) and other four currencies estimated using Equation (6). CNY's outward spillover effect is the least, which is 3.07 basis point, whereas the counterparts of the DXY, EUR, GBP, and JPY are 21.68, 16.99, 11.97, and 7.85 basis points, respectively. However, CNY is ranked the second among the five currencies in terms of the net spillover effect due to limited inward spillover effect on CNY. We believe that the modest outward spillover effect of RMB comes from its considerable use globally as RMB has become the fifth active currency as an international payment and a reserve currency. On the other side, the limited inward spillover effect on CNY may be due to the relatively tight capital control of the Chinese central bank. We observe a similar pattern in CNH. As regards convertibility, the net spillover effect of CNH is even larger, which is 5.37 basis point.

Conclusions

Using daily exchange rate data, we construct a mutually anchoring network among the G20 currencies and major currencies related to the BRI. Based on the generalised impulse response analysis, a series of RMB impact indices are constructed to measure RMB's relative importance as an anchor currency from the perspective of networks. We show that the impact of RMB has increased substantially since the central bank of China launched the transition of RMB regime from a conventional dollar peg system to a managed floating rate system in July 2005. Besides, CNY's impact on major currencies related to the BRI has increased steadily since it was proposed in 2013. Our findings highlight that RMB has become increasingly important since China initiated market reforms of its currency and proposed to build the modern Belt and Road.

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Appendix

Table A. Results of generalised impulse response matrix for five currencies in the SDR basket.

	CNY	JPY	GBP	EUR	DXY	FROM
CNY	0	1.55	2.94	2.64	3.11	2.56
JPY	3.75	0	3.36	12.2	18.61	9.48
GBP	7.77	4.33	0	23.01	26.62	15.43
EUR	5.61	11.8	21.9	0	38.4	19.43
DXY	5.37	13.71	19.69	30.12	0	17.22
OUT	5.63	7.85	11.97	16.99	21.68	
NET	3.07	-1.63	-3.46	-2.44	4.46	

Notes: This table reports the results of generalised impulse response among exchange rate changes of five currencies in the SDR basket estimated using Equation (6). The endogenous variables are two-day rolling average exchange rate changes from 2 March 2011 when CNH is available, to the end of 2018.

Table B.: Results of generalised impulse response matrix for CNH and other four currencies in the SDR basket

	CNH	JPY	GBP	EUR	DXY	FROM
CNH	0	2.45	4.98	5.06	5.6	4.52
JPY	5.73	0	3.36	12.15	18.52	9.94
GBP	11.94	4.31	0	22.91	26.47	16.41
EUR	11.69	11.78	21.86	0	38.24	20.89
DXY	10.24	13.69	19.65	30.03	0	18.4
OUT	9.9	8.06	12.46	17.54	22.21	
NET	5.37	-1.88	-3.95	-3.35	3.81	

Notes: This table reports the results of generalised impulse response among exchange rate changes of CNH and other four currencies in the SDR basket estimated using Equation (6). The endogenous variables are two-day rolling average exchange rate changes from 2 March 2011 when CNH is available, to the end of 2018.