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Spillover effects of RMB exchange rate among B&R countries: Before and during COVID-19 event

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ABSTRACTS

The proposal of "The Belt and Road" (The B&R) Initiative has promoted regional economic cooperation and financial integration. It is crucial to measure the volatility spillover effects among "The B&R" currency market. Results from the time-varying spillover model show that "The B&R" system spillover index reflects some sudden regional crises. Likewise, the spillover of RMB exchange rate is affected by internal financial reforms as well as external economic shocks. Further, the recent outbreak of the COVID-19 has disrupted this system and the influence of RMB.

1. Introduction

In 2013, China launched the regional cooperation initiative "the Silk Road Economic Belt and the 21st-Century Maritime Silk Road" (i.e., "The Belt and Road" or "The B&R" Initiative), intending to promote the orderly and free flow of economic factors. "The B&R" Initiative is the greatest economic community in scale, covering 64% of the world's total population (Huang, 2016), one-third of global GDP, 75% of the total energy reserves, and a quarter of global cross-border trade in goods and services. "The B&R" Initiative has facilitated policy coordination, unobstructed trade, financial integration, and people-to-people contacts. On the one hand, "The B&R" Initiative has enhanced regional economic development (Wong, 2017), and accelerated partnership establishment in the process of RMB internationalization (Zhang et al., 2017). On the other hand, the dominant position of dollar in trade settlement seems to stuck the process of renminbi internationalization in "The B&R" Initiative (Liang, 2020). And the possibility of systemic risk derived from the participant countries' heterogeneous economic development status-had brought concern to merchants, investors, and policymakers.

The exchange rate, as determined by money supply, price level, national income, interest rate, output, and other relative economic variables (Stcokman, 1980; Frankel, 1992; Bacchetta and Van, 2006), fluctuated when changes happen in the country's economic openness, the flexibility of the exchange-rate regime, new information disturbance, etc. (Stanèík, 2007). Specifically in the system that we are exploring in the article-"The B&R" Initiative, research shows that exchange rates of participant countries fluctuated more widely and frequently in recent years (Lai and Guo, 2017). As globalization goes deeper, the spillover effect not only exists in domestic financial assets but also occurs across markets and countries. There are three main paths for the spillover of exchange rate fluctuations. The first is associated with trade integration—countries in one geographical region tend to form regional currency bloc

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(Subramanian and Kessler, 2013). The second correlates to the active global financial markets where geographically decentralized countries link to each other (Shu et al., 2015). The third is among countries that have pegged exchange regime correlation. To better investigate the risk involved in the cross-border trading activities, some studies focused more specifically on spillover effects between currency markets, adopting the approach of constructing spillover index (e.g. McMillan and Speight, 2010; Bubák et al., 2011) and analyzing the dynamic spillover structure (i.e., risk transmission path) of the exchange rate fluctuation (Liao et al., 2019).

To fill the gap of the former research, this paper constructed the spillover index in a nascent currency market system ("The B&R") and analyzed the time-varying dynamic effects of RMB and other participant currencies since "The B&R" Initiative was launched. More specifically, we portrayed the overall intensity of currency interdependency and individual currency stability under the strike of the COVID-19 pandemic.

This paper is organized as follows: Section 1 introduces the research background. Section 2 presents the research methodology and data. Section 3 shows empirical results and discussions both in long-term view and in the COVID-19 period. Section 4 draws the conclusions.

2. Methodology and data

2.1. Methodology

The measurement of exchange rate spillover effects is based on generalized vector autoregressive (GVAR) models and forecast error variances decomposition (FEVD) developed by Diebold and Yilmaz (2009; 2012). The spillover effects among different variables can be derived from the generalized forecast error variance decomposition of the moving average representation of the VAR model.

Consider the generalized VAR and the H-step-ahead variance decomposition to generate a matrix $\theta^H = [\theta_{ij}^H]$ given in Eq. (1), whose entries are the share of H-step-ahead error variance in forecasting x_i due to shocks to x_j.

$$\theta_{ij}{}^H = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e'_i A_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e'_i A_h \sum A'_h e_j)}, \tag{1}$$

and

$$\tilde{\theta}_{ij}^H = \frac{\theta_{ij}^H}{\sum_{j=1}^N \theta_{ij}^H}, \tag{2}$$

where Σ is the variance matrix for the error vectorε, $\sigma_{jj}$is the standard deviation of the error term for the jth equation, and$e_i$is the selection vector, with one as the ith element and zeros otherwise. $\sum_{j=1}^N \tilde{\theta}_{ij}^H = 1$ and $\sum_{i,j=1}^N \tilde{\theta}_{ij}^H = N$.

The matrix $\tilde{\theta}^H$ shows the spillover effects among the N variables. Using the spillovers derived from GVAR and FEVD, the total *Spillover Index* is defined as Eq. (3), which measures the spillover effect of the whole model system:

$$S = \frac{\sum_{i,j=1,i\neq j}^N \tilde{\theta}_{ij}^H}{\sum_{i,j=1}^N \tilde{\theta}_{ij}^H} \times 100, \tag{3}$$

The *Spillover Index* of the system presents the average contribution of spillovers from shocks to the forecast error variance.internal spillover interaction among the exchange market system. Regarding the spillover effects of a certain currency, the aggregated spillover value of one currency to others (*To Index*) can be represented as Eq. (4).

$$x_{i_{To}} = \sum_{j=1,j\neq i}^N \tilde{\theta}_{ji}{}^H \tag{4}$$

While the aggregated spillover value of one currency from others (*From Index*) shown in

$$x_{i_{From}} = \sum_{j=1,j\neq i}^N \tilde{\theta}_{ij}^H \tag{5}$$

Moreover, the *Net* spillover value of the currencies given by Eq. (6) shows the direction of spillover risks. A positive *Net* suggests that the currency is a net risk transmitter, while a negative *Net* suggests that the currency is a net risk receiver.

$$x_{i_{Net}} = \sum_{j=1,j\neq i}^N \tilde{\theta}_{ji}^H - \sum_{j=1,j\neq i}^N \tilde{\theta}_{ij}^H \tag{6}$$

The above spillover indexes are static and simple, to further present the dynamic spillovers, a time-varying series of spillover index is necessary. The full-sample time window is divided into w-day rolling windows, and scrolls forward by s-day each time. That is, for the ith rolling window starting from day t to day $t + w$, the $(i + 1)$th rolling window is started in day $t + s$. In each rolling window, the spillover indexes mentioned hereinabove is given. This paper uses a 100-day rolling window with an 8-step forecast horizon scrolling by 1-day.

Table 1
Statistical analysis of the 21 currencies.

Category	Country/Region	Currency	Abbreviation	Mean	Std.dev.	Max	Min	Coefficient of Variation
International Currency	Australia	Australian Dollar	AUD	0.7963	0.0996	1.0583	0.6121	0.1251
	United Kingdom	U.K. Pound	GBP	6.5016	0.3204	7.1773	6.0950	0.0493
	Canada	Canadian Dollar	CAD	1.2371	0.1161	1.4589	0.9839	0.0939
	Europe	Euro	EUR	1.1856	0.0994	1.3953	1.0364	0.0838
"The B&R" Initiative Participating currency	Vietnam	Vietnamese Dong	VND	32.8033	1.7798	36.3590	28.6600	0.0543
	Angola	Angolan Kwanza	AOA	12.7177	1.9023	16.8447	8.5674	0.1496
	Republic of Belarus	Belarusian Ruble	BYN	8.1609	1.0422	9.8999	6.2940	0.1277
	Russia	Russian Ruble	RUB	1.3382	0.0567	1.4499	1.2242	0.0424
	Brazil	Brazilian Real	BRL	0.9630	0.0360	1.0313	0.8549	0.0373
	South Africa	Rand	ZAR	54.8710	13.5493	83.5913	29.9251	0.2469
	Sweden	Swedish Krona	SEK	1.4274	0.1451	1.7161	1.2031	0.1017
	Chile	Chilean Peso	CLP	47.7614	3.7251	54.2690	40.5690	0.0780
	Malaysia	Ringgit	MYR	3.1735	0.6883	5.0489	1.9528	0.2169
	Hungary	Hungarian Forint	HUF	3.8473	0.4468	4.4845	2.9715	0.1161
	Philippe	Philippine Peso	PHP	630.3049	77.4422	852.0600	466.5000	0.1229
	Thai	Thai Baht	THB	1120.7331	48.2964	1240.9000	1008.9000	0.0431
	China	Chinese yuan	CNY	0.2972	0.0086	0.3089	0.2806	0.0290
	Korea	Korean Won	KRW	185.5168	104.8175	506.2000	95.6600	0.5650
	Singapore	Singapore Dollar	SGD	265.1013	26.3730	315.2300	211.6900	0.0995
	Switzerland	Swiss Franc	CHF	1.6532	0.4767	2.3939	0.8536	0.2884
	Kuwait	Kuwaiti Dinar	KWD	344.0394	226.2828	768.0000	1.0000	0.6577

Note: Coefficient of Variation was calculated by dividing the standard deviation by the mean. It is a statistical measure of the dispersion of data points around the mean, which is commonly used to compare the data dispersion between distinct series of data.

2.2. Data description and analysis

To capture system risk contagion structure in "The B&R" Initiative system, the top 14 "The B&R" Initiative countries' currencies were firstly selected according to the scale of total import and export trade with China, such as Indian Rupee, Korean Won, Chilean Peso. Further, to analyze the impact of global mainstream currencies, the top 20 countries' currencies in the world for foreign direct investment (FDI) and the top 20 countries' currencies in the Chinn-Ito Index (KAOPEN Index) (Chinn, and Ito, 2008), including Kuwaiti Dinar, Australian dollar, Canadian dollar, and so on, were added. After excluding the currencies pegged to the U.S dollar or the Euro with a fixed exchange rate as well as those with a large number of missing exchange rate data such as UAE Dirham, 21 currencies were finally used as shown in Table 1. The exchange rate data was from the IMF database. The data set contains 1802 observations from January 1, 2013, to March 20, 2020, which is exhaustive and can present the development path of "The B&R" Initiative since it was proposed in 2013.

Apparently, as shown in Table 1, VND, AOA have relatively high coefficients of variation, suggesting that these currencies' exchange rates fluctuated violently during the period because of the impacts of some political or economic events.

Fig.1 shows how exchange rate fluctuates similarly when countries are geographically close (left part) or have cohesive trading relationships (right part). Fig.2 shows the appreciation or depreciation level of currencies in two stages during COVID-19. The results illustrate that the exchange fluctuation ranges of most currencies in the second stage are much greater than those in the first stage, and the emerging economics (such as Brazil and Russia) are a lot more sensitive in this fluctuation, which suggests that the pandemic brought serious uncertainty to currencies on different levels.

3. Results and discussion

In this section, we characterize spillover effects in “The B&R” currency markets throughout the relatively long term and during the short term of COVID-19. As defined above, *To Index* and *From Index* indicates risk transmission direction between specific currency pairs. Further, to have a holistic insight, we use the *Spillover Index* to characterize the intensity of interdependence between currency in an internal system. Here, an upward trend of *Spillover Index* together with currency depreciation should cause concern from independent investors and contravention from the central bank. (Liu et al., 2019) Because in this case, individual currency volatility could lead to a broader currency co-movement and cause wider risk (e.g. settlement risk) in trading activities.

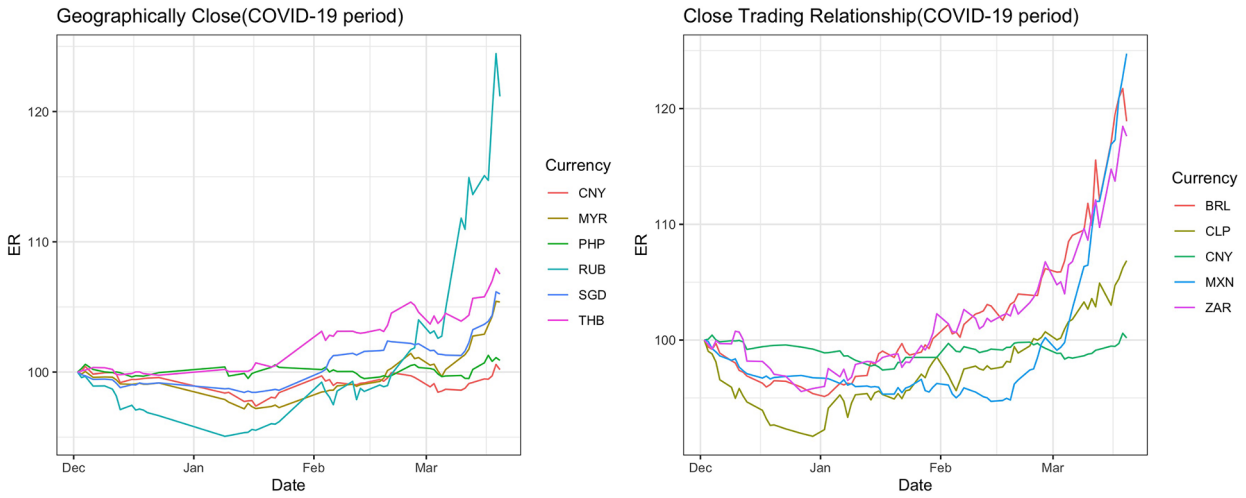

Fig. 1. Standardized exchange rate fluctuation.

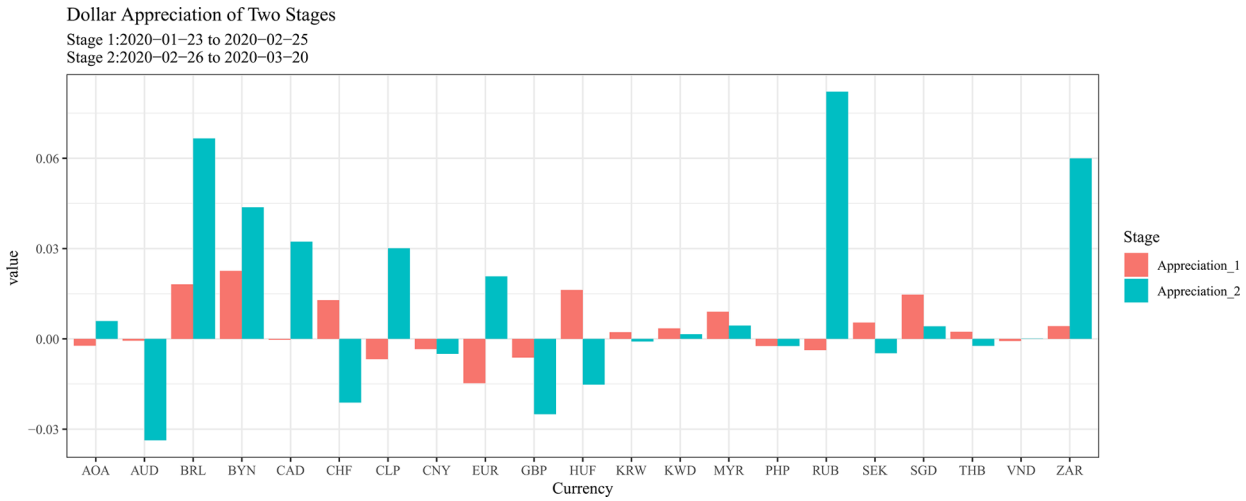

Fig. 2. Dollar appreciation level in the different economic area (Two stages comparison)
Note: Fig. 2 shows currency performance in two stages. The first stage was mainly during the outbreak period in China. The second stage showed currency performance after WHO announced that the COVID-19 had become a global pandemic.

3.1. Bidirectional spillover effects in "The B&R" system

After deleting the missing value, data are pre-processed with the methods of logarithm and first-order difference to eliminate the possible seasonality and heteroscedasticity of the time series data. The results of unit root tests ensured that all the series are stationary.

Fig.3 shows the thermodynamic diagram of the static full-sample spillover table. In the whole currency system, the *Spillover Index* within the 21-currency system reaches 20.34%, which indicates a significant level of internal interaction in the world's currency market. When it comes to CNY's influence in the world, results show that CNY ranks 6th in CNY_{To}, 3rd from last in CNY_{From} and 5th in CNY_{Net} with a positive value respectively. CNY, therefore, as a net risk transmitter, has a strong international influence in the world, and it is less likely to be affected by international exchange rate fluctuations.

Fig.4 illustrates the time-varying *Spillover Index* in "The B&R" exchange market system. Starting with 67.6%, the *Spillover Index* increases considerably after China issued "The B&R" Initiative. The *Spillover Index* in "The B&R" Initiative system is larger than 60%, indicating that there is a substantial internal spillover effect in "The B&R" exchange market. There were also some enormous increases in *Spillover Index* when crisis events happened in some participant countries of "The B&R" Initiative. Moreover, the exchange rate spillovers during crisis periods probably convert to risk contagion, further increasing the instability within the system.

Fig.5 shows the time-varying CNY_{From} in global and "The B&R" systems. The results illustrate that the spillover effects of CNY among the global foreign exchange market and among "The B&R" Initiative foreign exchange market fluctuated consistently. Furthermore, some reforms in the CNY exchange rate system or changes in China-US relationships both contributed to the large

	AUD	CNY	CAD	EUR	THB	ZAR	SEK	SGD	CHF	RUB	GBP	PHP	BRL	MYR	CLP	KRW	KWD	AOA	HUF	BYN	VND	From Others
AUD	29.10	0.09	5.44	0.01	0.07	0.42	0.01	0.52	0.28	0.01	0.13	0.23	0.05	0.05	0.08	0.34	0.08	0.17	2.93	0.13	0.03	11.08
CNY	2.88	72.67	0.70	0.02	0.14	0.01	0.10	0.08	0.09	0.02	0.17	0.23	0.14	1.14	0.12	0.12	0.15	0.10	2.12	0.00	0.01	8.37
CAD	4.94	0.98	49.91	0.00	0.00	0.03	0.35	0.05	0.94	0.17	0.07	0.01	0.07	0.15	0.16	0.01	0.70	0.48	0.21	0.48	0.12	9.92
EUR	2.35	2.05	3.54	41.49	0.16	0.36	0.09	0.09	0.11	0.04	0.01	0.05	0.43	0.11	0.53	0.03	0.02	0.02	9.17	0.61	0.00	19.77
THB	6.35	1.65	2.28	0.55	78.42	0.12	0.18	0.43	0.09	0.11	0.01	0.01	0.07	0.11	0.01	0.02	0.41	0.03	3.32	0.02	0.24	16.02
ZAR	5.63	1.72	3.31	0.77	1.30	82.30	0.03	0.08	0.01	0.32	0.16	0.07	0.30	0.04	0.02	0.01	0.04	0.61	1.83	0.06	0.00	16.33
SEK	4.23	2.82	2.44	11.88	0.86	0.10	86.92	0.60	0.03	0.05	0.02	0.22	0.21	0.04	0.72	0.03	0.04	0.19	5.51	0.57	0.03	30.60
SGD	12.00	4.17	4.67	1.70	6.40	0.63	0.48	60.13	0.23	0.01	0.14	0.13	0.01	0.03	0.20	0.12	0.10	0.19	5.37	0.07	0.01	36.64
CHF	1.41	0.80	1.45	11.34	0.20	0.16	0.82	0.86	94.09	0.00	0.06	0.02	0.15	0.11	0.29	0.10	0.16	0.01	3.99	0.96	0.00	22.89
RUB	2.52	0.29	2.64	0.22	1.05	2.21	1.76	0.16	0.12	86.62	0.03	0.18	0.34	0.19	0.04	0.09	0.14	0.22	0.41	0.04	0.04	12.71
GBP	3.48	2.54	3.93	6.09	0.41	0.72	2.78	0.74	0.12	0.06	66.70	0.00	0.02	0.64	0.57	0.37	0.07	0.01	1.88	0.20	0.05	24.70
PHP	2.95	0.86	0.58	0.09	1.56	0.53	0.60	1.15	0.04	0.35	0.02	82.59	0.03	0.42	1.21	1.64	0.13	0.06	0.26	0.28	0.05	12.79
BRL	1.58	0.02	1.89	0.29	1.25	3.11	0.72	0.35	0.01	1.13	0.21	1.71	92.83	0.09	0.11	0.39	0.09	0.06	0.43	0.00	0.06	13.52
MYR	6.69	1.96	2.69	0.03	4.98	1.82	0.28	22.47	0.18	3.61	0.27	1.60	0.93	92.04	0.31	0.05	0.02	0.14	1.63	0.01	0.23	49.93
CLP	3.09	1.78	3.24	0.03	0.72	4.52	0.59	0.47	1.23	1.45	0.47	2.81	2.53	0.68	91.58	0.42	0.07	0.60	1.13	0.01	0.03	25.84
KRW	5.04	2.73	1.61	0.07	1.65	0.64	0.10	5.16	0.15	0.03	0.37	9.62	0.78	0.54	3.18	95.30	0.03	0.21	0.88	0.01	0.24	33.06
KWD	2.84	1.23	2.17	12.56	0.40	0.36	2.02	5.66	1.83	0.29	0.53	0.23	0.27	0.82	0.20	0.07	94.23	0.02	3.58	0.43	0.00	35.54
AOA	0.12	0.20	0.07	0.19	0.05	0.03	1.20	0.18	0.08	0.16	0.15	0.02	0.22	0.26	0.03	0.65	0.16	96.62	0.04	0.01	0.00	3.83
HUF	2.29	1.22	6.28	12.35	0.04	1.14	0.43	0.30	0.21	0.03	0.01	0.09	0.23	0.25	0.45	0.06	0.28	0.07	54.44	0.39	0.05	26.16
BYN	0.37	0.15	0.97	0.27	0.01	0.59	0.40	0.33	0.11	5.53	0.09	0.03	0.22	0.63	0.09	0.04	2.75	0.17	0.64	95.69	0.01	13.41
VND	0.12	0.06	0.19	0.04	0.32	0.19	0.15	0.18	0.04	0.01	0.02	0.14	0.13	1.66	0.10	0.14	0.34	0.02	0.23	0.00	98.80	4.06
To Other	70.90	27.33	50.09	58.51	21.58	17.70	13.08	39.87	5.91	13.38	2.95	17.41	7.17	7.96	8.42	4.70	5.77	3.38	45.56	4.31	1.20	427.17
Net	59.82	18.96	40.17	38.74	5.55	1.38	-17.52	3.24	-16.98	0.67	-21.75	4.62	-6.35	-41.98	-17.42	-28.36	-29.77	-0.44	19.39	-9.10	-2.86	**20.34%**

Fig. 3. Static spillover table (2013.1.1–2020.3.20).

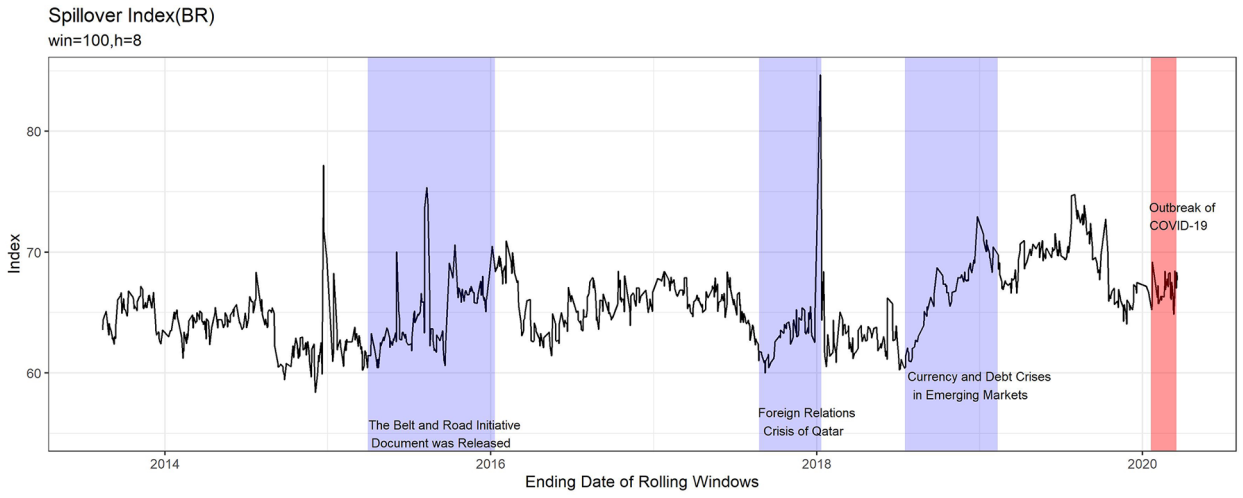

Fig. 4. The dynamics of *Spillover Index* in "The B&R" Initiative (Starting point 2013.8.14).

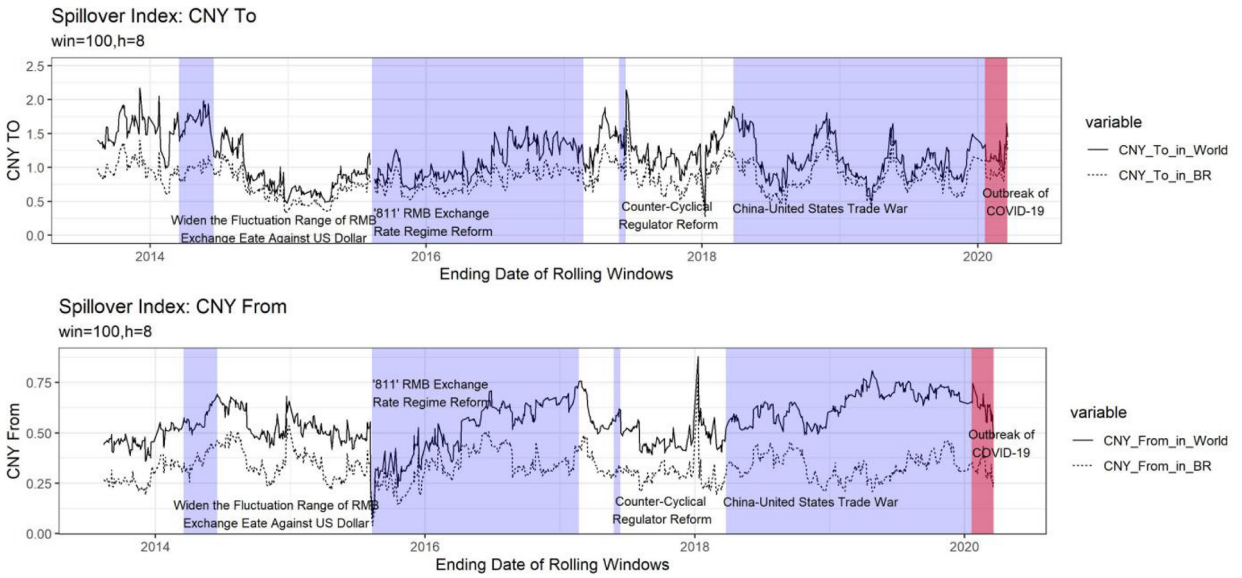

Fig. 5. The dynamics of spillover effects of CNY (Starting point 2013.8.14).

fluctuations of CNY_{To} and CNY_{From}. First, on March 15, 2014, the People's Bank of China (PBC) widened the floating range of the market price of CNY against the U.S. dollar in the interbank spot foreign exchange market from 1 to 2%. Next, later on August 11, 2015, PBC reformed the RMB exchange rate central parity rate quotation mechanism. What's more, on December 11, 2015, PBC released the RMB exchange rate index and introduced a basket of currencies and countercyclical factors to enable RMB's stability and marketization. During the periods after these events, the spillover effects of CNY fluctuated considerably. All these events caused policy shocks on CNY's spillover fluctuation pattern.

3.2. Spillover effects during COVID-19 period

Fig.6 shows the dynamic *Spillover Index* of the two systems during the COVID-19 outbreak. After the outbreak of the pandemic, the *Spillover Index* in both the two systems started to fluctuate frequently, which suggests that the shocks of the COVID-19 pandemic destabilized the global and "The B&R" Initiative exchange market. Yet compared to the range of bursts in other period (eg. Foreign Relations Crisis of Qatar in 2018 in Fig.4), our empirical results show the spillover severity inside the system is limited.

As shown in Fig.7, on January 19, 2020, CNY_{To} significantly decreased, while the CNY_{From} increased mildly, which could be due to the unexpected shocks of COVID-19 on the foreign exchange market's confidence in CNY. From January 19, 2020, to February 27, 2020, CNY_{To} has remained at a relatively low level because COVID-19 led to the economic downturn and shrinking demand in China. In late February, CNY_{To} tended to bounce back, but the curve presented a downward trend again because of the slump in global

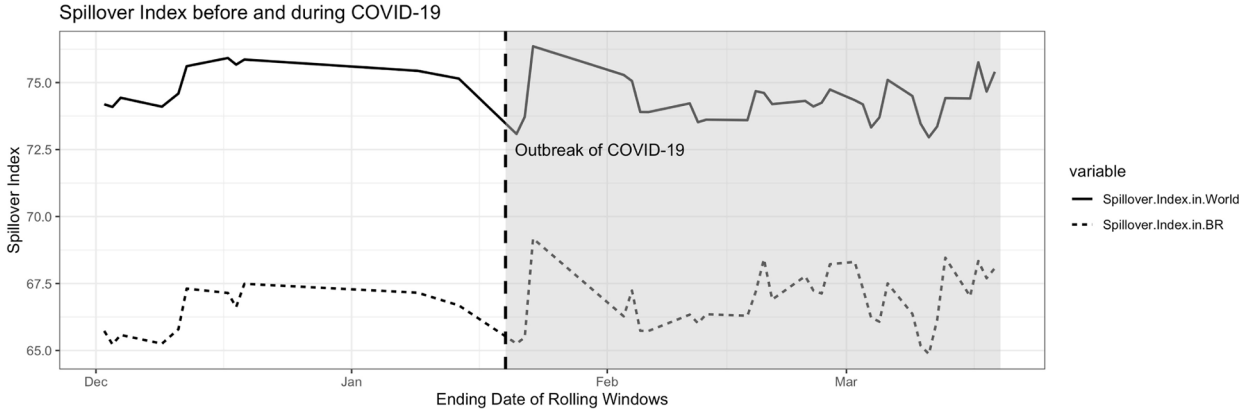

Fig. 6. *Spillover Index* during COVID-19 (starting point 2019.12.3)
Note: January 19, 2020 was set as the beginning of COVID-19 outbreak, when Chinese officials announced that the coronavirus could be infected from person to person. The information about significant points during COVID-19 comes from the web page of World Health Organization: Timeline: WHO's COVID-19 response (https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#!).

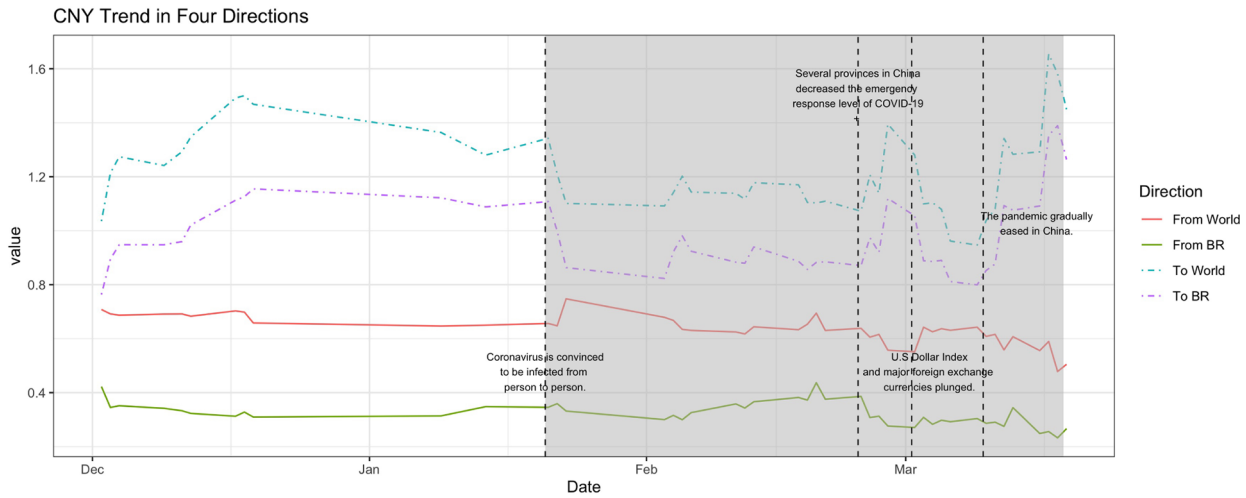

Fig. 7. Spillover effects of CNY during COVID-19 (starting point 2019.12.3).

exchange markets.

This situation started to change since March 8, 2020, with the global spread of the COVID-19, U.S. stocks triggered circuit breakers which halted trading for four times in 10 days, the same triggering of circuit breakers also appeared in many countries in the world. Meanwhile, Chinese policymakers stepped in early to safeguard financial stability, taking actions like backstopping interbank markets, providing financial support to firms under pressure, and letting the RMB adjust to external pressures. As the pandemic eased and the economy started to recover in China, the influence of CNY measured by CNY_{To} started to pick up. Meanwhile, CNY_{From}, which implies the risk of CNY to be affected by other currencies, has decreased slightly.

As shown in Fig.8, the coronavirus also led to significant changes in the spillover indexes of other currencies.

In late February and early March, COVID-19 began to spread worldwide, and Europe was becoming the center of the pandemic: the confirmed cases in Italy, Spain, France, and other European countries continued to increase. After March 3, there appeared a sharp decrease in EUR_{To}.

In "The B&R" Initiative system, the epidemic situation is synchronized with the degree of geographical dispersion. In Southeast Asia, due to their geographical proximity to China, the pandemic had begun to spread by the end of February. Singapore, for example, has long depended on international trade as its major economic growth impetus. SGD, as a special offshore financial center's currency and the net risk receiver, is highly susceptible to fluctuations in exchange rates of other currencies. SGD_{To} has been decreasing since late February.

3.3. Robustness assessment

To test the robustness of our results, we compared different hyperparameters: rolling window width (i.e., $w = 90/100/110$ days) and forecast horizons (i.e., $H = 6/8/10$ days). Results presented in Fig.9 verify that CNY_{T0} follows a similar fluctuation pattern for each value of w and H. This means that our results are robust and consistent.

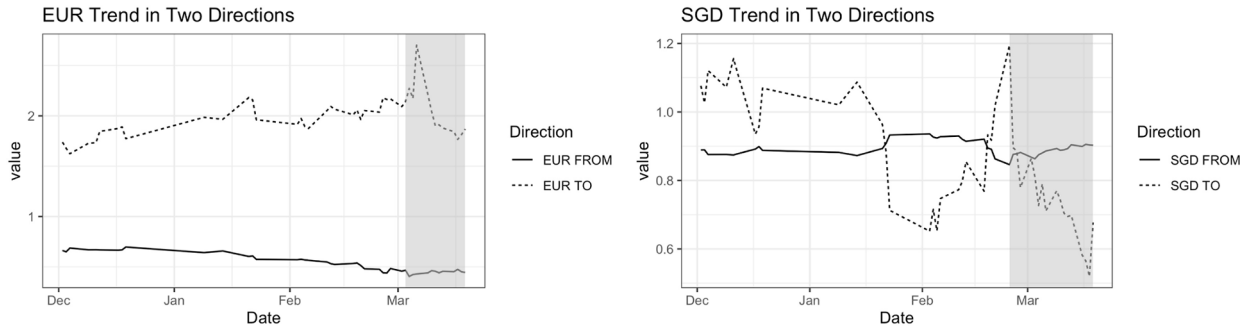

Fig. 8. Spillover effects of some “The B&R” countries during COVID-19 (starting point 2019.12.3).

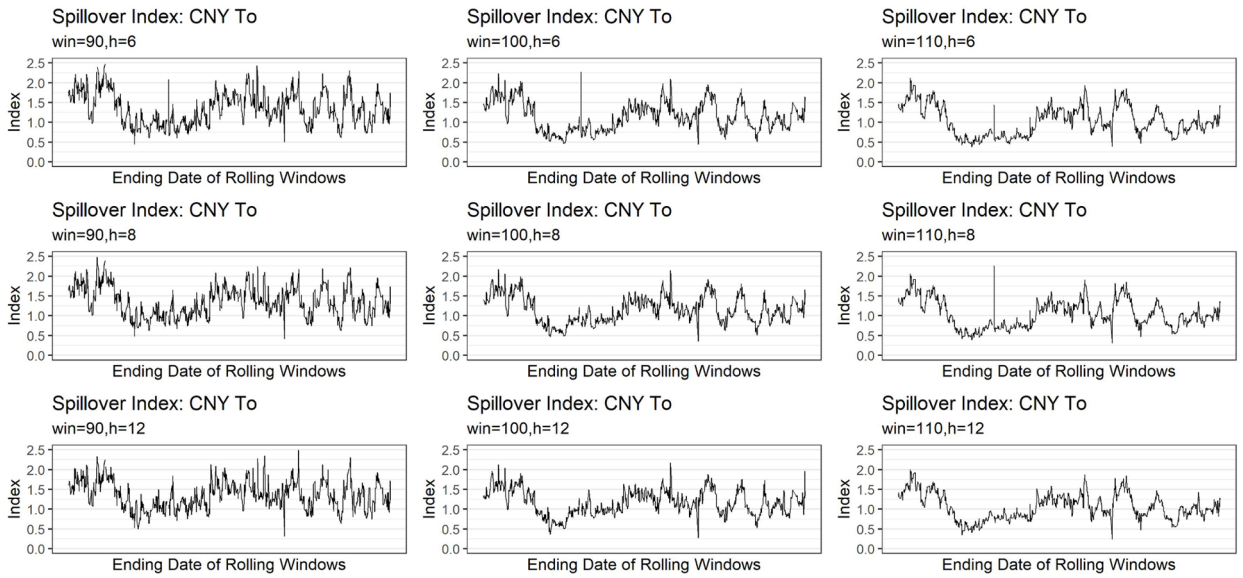

Fig. 9. Robustness of CNY_{To}.

4. Conclusions

This paper implemented the VAR-based spillover index approach to explore the spillover effects during the COVID-19 outbreak among the global exchange market and "The B&R" Initiative exchange market. Our main findings can be summarized as follow.

Firstly, the internal interaction is strong among the global foreign exchange markets and among "The B&R" Initiative participant countries. Second, spillovers of RMB are inevitably influenced by modifying exchange rate regimes and global economic and political events, which were reflected in the dynamic change of the spillover index of RMB, including CNY_{To} and CNY_{From}. Third, the results of the time-varying *Spillover Index* indicated that exchange rate risk contagion among the countries along "The B&R" Initiative is significantly related to their economic and trade relations as well as some sudden crises that happened in these countries.

Regarding the recent COVID-19 events, the outbreak in China and its global spread has driven the global and "The B&R" Initiative foreign exchange markets increasingly risky and unstable. Specifically, the pandemics has made great shocks in RMB, impacting its spillover effects on the global foreign exchange market, and also led to considerable changes in the spillovers of other currencies in "The B&R" Initiative system.

CRediT authorship contribution statement

Zhixi Wei: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Yu Luo:** Methodology, Software, Formal analysis, Writing - original draft. **Zili Huang:** Writing - review & editing. **Kun Guo:** Validation, Writing - review & editing, Supervision.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.frl.2020.101782.

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