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Dancing with Dragon: the RMB and Developing Economies' Currencies*

By **He Qing, Liu Junyi and Yu Jishuang***

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Abstract

In this paper we analyse Chinese RMB co-movements with the currencies of other developing economies using daily data from January 1, 2006 to December 31, 2020. We find that the RMB plays an important role in East Asia & Pacific. Bilateral trade significantly increases the probability of RMB co-movements with other currencies while inflation differential decreases it. Additionally, the currencies of the economies that are more inclined to adopt a pegging system are less likely to co-move with the RMB. We further divide the sample into three sub-periods based on two major China's currency reforms and the results are consistent with our main finding. We also investigate the nonlinear determinants of RMB co-movements in high and low volatility regimes, respectively, and show the different patterns. Last but not least, we find that RMB currency swap and the Belt and Road Initiative amplify RMB co-movements in larger and more developed economies.

Keywords: the RMB, Co-movement, Belt and Road Initiative

JEL Classification: E58, F31, F33, F41

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1. Introduction

With the enhancement of China's economy and the gradual opening of China's financial market, the renminbi (RMB) has gradually become an important currency for international trade settlement and financial transactions, especially for countries that have close trade with China. According to the data from the Society for Worldwide Interbank Financial Telecommunication (SWIFT), the payments share of the RMB in the global market has increased to 1.88 percent, making it the fifth-most-used payment currency after the US dollar, the euro, the pound, and the yen as of December 2020. Most of those payments have involved developing economies. For instance, the payments denominated in RMB that flow between China and Thailand, Indonesia, and India increased over 2014-2018 by 35 percent, 58 percent and 106 percent, respectively (SWIFT, 2020). The internationalization of the RMB is also reflected by its growing weight in a basket of reference currency of other economies (Kawai and Pontines, 2016; Ito, 2017). However, the status of the RMB does not match that of China in the international economy (He et al., 2016). A natural question follows: what is the current international status of the RMB and what determines it?

To gauge the internationalization of the RMB, a number of studies have investigated the extent of RMB co-movement[1] with other currencies, mainly located in Asia. While most of the studies find significant co-movements between the RMB and Asian currencies (Ho et al., 2005; Balasubramaniam et al., 2011; Henning, 2013; Subramanian and Kessler, 2013; Kawai and Pontines, 2016; Ito, 2017), no consensus was reached on the status of the RMB in Asia. Henning (2013) and Subramanian and Kessler (2013) obtain the results that co-movements between the RMB and Asian currencies are larger compared to the US dollar and conclude that there has been a RMB bloc in Asia. On the contrary, Kawai and Pontines (2016) claim that the US dollar is still the dominant anchor currency but the RMB's influence is rising in the currency baskets of economies in East Asia in recent years.

What is missing from above literature is determining factors of the weight of the RMB within these regions. In addition, it remains unknown the effects of RMB outside Asian countries. We investigate the determinants of the strength of RMB's co-movement with all developing economies given data availability, paying particular attention to the Chinese policy impacts. Our research proceeds in three steps. First, we estimate the co-movements between the RMB and developing economies currencies. Second, we study the determinants of the co-movements, and find that bilateral trade significantly increases the probability of the co-movement, while inflation differential and the choice of adopting a fixed exchange rate regime reduce it.

Lastly, we investigate how two policies of China, RMB currency swap and the Belt and Road initiative (BRI), may affect our main results. The currency swap started in China in 2009 amid the great financial crisis aiming for liquidity, stability, and bilateral trade and investment. Bahaj and Reis (2020) find that RMB currency swap enhances the role of the RMB in bilateral trade, which is the most important determinant of currency co-movement. BRI, another policy factor, was initiated in 2013 serving the purpose of integrating China's economy with the developing economies along the "belt and road", and strengthening China's economic influence in the region (Wang, 2016). We hence include both policies in the model and find that the likelihood of RMB co-movement in larger and more developed economies

[1] Due to the China's increasing share and influence in the global economy, it is more pronounced that the co-movements emerged from the reason that the values of other currencies are driven by the RMB (McCauley and Shu, 2019).

increases after the two policies are in place.[2] In other words, currency swap and BRI amplify RMB co-movement.

This study contributes to the existing literature in two ways. First, while several studies focus on the RMB co-movements in Asia (Chen and Peng, 2010; Balasubramanian et al., 2011; Henning, 2013; Subramanian and Kessler, 2013; Shu et al., 2015; Kawai and Pontines, 2016; Keddad, 2019; McCauley and Shu, 2019), none has thoroughly investigated the RMB co-movements in developing economies and their determinants. This academic study is, to the best of our knowledge, the first that attempts to fill that gap by presenting the degree of the RMB co-movements in developing economies, and the finding that the RMB co-movements are driven mainly by trade and restrained by inflation concern as well as exchange rate regime choice.[3] Secondly, we enrich the literature of RMB currency swap's impact on bilateral trade and settlement (Zhang et al., 2017; McDowell, 2019; Song and Xia, 2020; Bahaj and Reis, 2020), and that of BRI's influence on cross-border trade and finance (Du and Zhang, 2018; Bastos, 2020; Foo et al., 2020; Liu et al., 2020), by pointing out the amplifying role of the two policies on RMB co-movement.

The remainder of the paper is structured as follows. Section 2 reviews the related literature. Section 3 introduces research design and the data. Section 4 reports and discusses the empirical results. Results of robustness and extension are reported in section 5. Section 6 concludes the paper.

2. Literature review

Frankel and Wei (1994) find no statistically significant evidence to support a yen bloc in East Asia in the mid-1980s, showing that nine of the ten East Asian countries they studied assigned heavy weights to the US dollar; and Singapore assigned weights to both the yen and the US dollar. The dominant US dollar gained a dynamic junior partner in the euro from 1999 onward. Their status as the reigning international currencies went unchallenged till the 2007–8 global financial crisis, which caused emerging economies to question the current dollar-euro monetary system and take steps to form a multi-polar one (Dobson and Masson, 2009; Cheung et al., 2010; Kenen, 2011).

Most of the widely discussed options for a third polar currency are Asian, which can be attributed to the emergence of Asia as the world's new economic powerhouse (Eichengreen, 2010; Angeloni and Sapir, 2011). Fratzscher and Mehl (2014) contend that the RMB has been the locomotive of the movements of major currencies in Asia since the mid-2000s, especially after the global financial crisis in 2007-8. Subramanian and Kessler (2013) note that the RMB overshadows the US dollar in East Asia, pointing to seven currencies out of ten in the region that co-move more closely with the RMB than with the US dollar. Ito (2017) confirms the increasing weight of the RMB in Asian countries' currency basket, but further investigates the growing influence of the RMB in both private and public sector of Asia. Evaluating the ways the RMB fulfills the two basic roles of a currency, Ito writes that "non-fully-convertible" RMB has served more

[2] Please note, the data of Belt and Road policy have to be hand-collected due to its limited data availability.

[3] Subramanian and Kessler (2013) explore the determinants of the co-movement between the RMB and other currencies using the cross-section data of 50 economies and focusing on trade factor. Our study covers not only trade factor but also all relevant factors investigated in the following literature, Alesina and Barro (2002), Meissner and Oomes (2009), Plümper and Neumayerm (2011), Ghosh (2014) and Fischer (2016), as well as other determinants derived from optimal currency area theory, time inconsistent theory, and Mundell–Fleming–Dornbusch model. In addition, our panel data is superior to cross-sectional data for the added variance in time within economy.

as a "store of value" than it has as "a medium of exchange," crediting this phenomenon to the heavier hand of Chinese monetary policy and its lesser subjugation to market forces.

Chow (2014), on the contrary, argues that the US dollar still retains a dominant influence in the region, but concedes how the role of the RMB in East Asian currencies' determination has increased after the 2007-8 financial crisis. Kawai and Pontines (2016) echo Chow's finding by showing that the US dollar continues to be the dominant anchor currency, further undermining the hypothesis of an RMB bloc in East Asia. They heartily maintain the thesis of US-dollar dominance, even while noting that the RMB has increased its influence in the implicit currency baskets of several East Asian economies at the expense of the yen.

Any consensus that an RMB bloc in Asia exists is difficult to reach because of the various methods employed in past studies. Subramanian and Kessler (2013), for example, look at the two periods, July 2005-August 2008 and July 2010-July 2013, during which the RMB fluctuated relative to the US dollar, showing that the average weight of the RMB in East Asia is 60 percent higher than the US dollar. Henning (2013) selects two different intervals, July 22, 2005-July 2, 2009 and June 18, 2010-December 30, 2011, asserting that the RMB has become an anchor currency in East Asian countries. The caveat of this type of method is that during the period when the RMB is assumed to fluctuate vis-à-vis the US dollar, the RMB is de facto pegged to a basket of currencies largely dominated by the US dollar, which undermines his assertion.

There have been various attempts to partially control for the US dollar's influence on the RMB movement through econometric setups. Balasubramanian et al. (2011), for instance, adopt a two-step regression method, regressing the RMB on the US dollar and using the residual obtained as a proxy variable for the RMB. Their finding is that although the RMB has acquired certain anchorages, the US dollar remains dominant in East Asia. Kawai and Pontines (2016) point out that existing techniques fail to address the problem of severe multi-collinearity in estimations of Frankel–Wei regression model, in that the movements of the US dollar and the RMB are both included on the right-hand side of the equation. To provide stable and robust results, Kawai and Pontines (2016) propose a simple modification of Frankel–Wei regression model to estimate the RMB's weight in an economy's implicit currency basket and show that this new method yields results that are superior to those obtained by existing techniques.

A simpler way to filter out the influence of the US dollar on the RMB's movement is to use the US dollar as the denomination currency. Ho et al. (2005) present exchange rates of the currencies as per US dollar, then place the RMB-to-US dollar rate on the right side of standard Frankel-Wei model, finding that the RMB was assigned a significant weight in the currency baskets of the won, the New Taiwan dollar, the Singapore dollar and the Thai baht even before the exchange rate reform of China in 2005. Similarly, Shu et al. (2015) studies the impact of exchange rate of the RMB on other East Asian currencies, all denominated in the US dollar, upon the onshore and offshore RMB markets, and find that the two markets perform significantly differently.

We base our empirical model on Frankel and Wei's approach to investigate co-movements between developing economies' currency and the RMB. Recognizing the multi-collinearity issue raised in Subramanian and Kessler (2013) and Shu et al. (2015), we also use the US dollar as the denomination currency and choose the period when the RMB fluctuated relative to the US dollar. Further, we investigate the determinants of RMB co-movements and analyze the impact of China's international policy.

One strand of literature on determinants of the co-movements between the RMB and other currencies is focused on the weight of the RMB in currency baskets (McCauley and Shu, 2019). Others consider anchor currency theory, which can be another important factor of co-movements (Alesina and Barro, 2002; Meissner and Oomes, 2009; Plümper and Neumayerm, 2011; Ghosh, 2014; Fischer, 2016).

Optimal Currency Area (OCA) theory (Mundell, 1961) has been widely applied to the optimal exchange rate regime and anchor currency analysis. Alesina and Barro (2002) point out that the key determinant of adopting another economy's currency is the trade-off between trade expansion and independent monetary policy. Trade share is empirically found to be an imperative factor of anchor currency choice and hence currency co-movements (Galati, 2001; Subramanian and Kessler, 2013; Fischer, 2016). Output asymmetry and inflation differential are close to monetary policy independence. The larger the output asymmetry and inflation differential, the higher cost is incurred for pegging to the anchor currency.

Besides, Ghosh (2014) finds that economy size and development level exert significant influence on the choice of exchange rate system. Frieden (1991) argues that central banks peg their currencies to the anchor currency to rein in high inflation. Plümper and Neumayer (2011) find that the economies with a history of high inflation are more likely to peg their currency to the US dollar than to the Swiss franc or the Deutsche mark even facing low and less volatile inflation. Based on the Mundell–Fleming–Dornbusch model (MFD), real shocks and nominal shocks are also important. For the economies where real shocks dominate nominal shocks, they prefer float exchange rate regimes. And the rest lean toward fixed exchange rate regimes (Meissner and Oomes, 2009). Ghosh (2014) also documents that geographic size makes a significant impact on the choice of exchange rate regimes.

3. Research design and data

3.1 Co-movement estimation

To measure the degree of currency relatedness, researchers often look at co-movements of currencies (Frankel and Wei, 1994; Frankel and Xie, 2010), especially since most monetary authorities do not divulge information about national currency baskets to the public. Following Frankel and Wei (1994) and McCauley and Shu (2019), we use the logarithmic daily return of a developing economy currency denominated in the US dollar as the dependent variable, and the logarithmic return (also denominated in the US dollar) of the RMB, the Japanese yen, the euro, and the pound as the independent variables to eliminate the multi-collinearity between the RMB and the US dollar. Other control variables include global risk appetite and fluctuations in energy price which are generally considered as important factors of exchange rate movements (Fratzscher and Mehl, 2014; Keddad, 2019). Global risk appetite correlates with international capital flow and hence influences exchange rates. For energy importers and exporters, fluctuations in energy price are likely to affect exchange rates and possibly co-movements since most international energy commodities are mainly invoiced and settled in the US dollar. The baseline model is as follows

$$e_i = \delta_i + \beta_{i,1} e_{RMB} + \beta_{i,2} e_{EUR} + \beta_{i,3} e_{GBP} + \beta_{i,4} e_{JPY} + \beta_{i,5} e_{oil} + \beta_{i,6} vix + \varepsilon_i \quad (1)$$

where e_i, e_{RMB}, e_{EUR}, e_{GBP}, and e_{JPY} denote logarithmic daily returns of developing currency i, the RMB, the euro, the pound, and the Japanese yen per US

dollar, respectively[4]. ε is the error term. Global risk appetite and fluctuations in energy price are proxied by the Chicago Board Options Exchange Market Volatility Index (vix) and logarithmic daily return of Brent crude oil price (e_{oil}), respectively. The coefficient, $\beta_{i,1}$, measures the co-movements between the RMB and currency *i*.

3.2 Determinants of the co-movements

To analyze the determinants of RMB co-movements, we regress equation (1) in each calendar year and obtain annual estimate of $\beta_{i,1}$. Since co-movements usually refer to the positive linkage, we only retain $\beta_{i,1}$ that is significantly positive at the 5% level, and replace others with 0. The new variable is $Comove_{i,t}$. We then create a dummy variable, $I(Comove_{i,t} > 0)$, which equals 1 when currency *i* co-moves with the RMB,

Following the literature reviewed in section 2, we add such determinants as *Trade dependence*, *Output asymmetry*, *Inflation differential*, *Size*, *Development*, *High inflation*, *Real shock*, *Nominal shock*, and *Land*.

Trade dependence is measured by the ratio of total trade with China over total trade with the world. *Output asymmetry is* measured by the standard deviation of the difference in the growth rate of real output between other economies and China during the previous 10 years. *Inflation differential* is measured by the absolute value of the difference in inflation between other economies and China.

We include the logarithm of real PPP GDP as *Size* and the logarithm of per capita PPP GDP as *Development*. *High inflation* equals 1 when the economy has experienced high inflation above 50 percent between the current year and 1980 and current inflation is below 20 percent. *Real shock* is the standard deviation of the ratio of government expenditure over nominal GDP during 5 years and *Nominal shock* is the standard deviation of the growth rate of the broad money supply over 5 years. *Land* is measured by the natural logarithm of land area (square kilometres).

The regression is constructed as followed:

$$I(Comove_{i,t} > 0) = \alpha_0 + \alpha_t + \rho x_{i,t} + u_{i,t} \quad (2)$$

where $x_{i,t}$ is a vector of the determinants discussed above and α_t is the year fixed effects.

3.3 Data and summary statistics

The reform of China's exchange rate system in 2005 is a milestone of the marketization of the RMB. From 1994 to 2005, the exchange rate of the US dollar vis-à-vis the RMB had been fixed to 8.24 yuan per dollar. But on July 21, 2005, the People's Bank of China (PBOC), the central bank of China, announced an end to the RMB/USD peg and adopted a managed floating exchange rate regime that made use of a "reference basket" of currencies. The de jure depegging of the RMB from the US dollar on 21 July 2005 has encouraged some countries to include the RMB in their currency basket, especially for developing economies (He et al., 2021c), which also

[4] We use the CNY (onshore) rates in the baseline model. Note that onshore and offshore RMB rates indeed are not determined in the same exchange rate system, in that offshore RMB rate, as part of international exchange market, reflects international market status of the RMB, while onshore RMB rate is mainly managed and largely determined by the PBOC (He and McCauley, 2013). Onshore and offshore RMB rates in general show similar pattern but differ in short periods due to regulatory and geographical differences (Shu et al., 2015). We hence use CNH in the robustness check.

makes it possible and necessary to study co-movements between the RMB and other currencies (Kawai and Pontines, 2016; Ito，2017; Keddad, 2019). Due to limited availability of data, we sample 83 economies: 14 in East Asia & Pacific, 20 in Europe & Central Asia, 14 in Latin America & Caribbean, 12 in Middle East & North Africa, 5 in South Asia, and 18 in Sub-Saharan Africa[5].

The exchange rate data are the daily nominal exchange rates in the Bloomberg database from January 1, 2006 to December 31, 2020. Since the RMB was de facto pegged to the US dollar from July 2008 to June 2010 and as such no statistically meaningful results can be obtained during that period, we trimmed the sample accordingly.

The distribution of currencies that significantly co-move with the RMB by year and region is reported in Table 1. Figure 1 shows the time-varying regional averages of co-movements between currencies and the RMB.

Table 1 The distribution of currencies co-moving with the RMB by year and region

This table displays the distribution of currencies co-moving with the RMB by year and region. The first column reports the number of the currencies in each region and the next five columns report the number of currencies that show co-move with RMB significantly at the 5% significance level.

	# of currencies	2006	2007	2008	2009	2010
East Asia & Pacific	14	7	1	4	--	5
Europe & Central Asia	20	4	4	1	--	4
Latin America & Caribbean	14	1	1	0	--	0
Middle East & North Africa	12	3	0	1	--	1
South Asia	5	2	0	1	--	2
Sub-Saharan Africa	18	1	2	2	--	5
Total	83	18	8	9	--	17

	# of currencies	2011	2012	2013	2014	2015
East Asia & Pacific	14	4	5	1	1	5
Europe & Central Asia	20	4	2	0	1	0
Latin America & Caribbean	14	2	0	0	0	1
Middle East & North Africa	12	2	0	0	1	1
South Asia	5	3	0	0	0	1
Sub-Saharan Africa	18	2	0	1	1	0
Total	83	17	7	2	4	8

	# of currencies	2016	2017	2018	2019	2020
East Asia & Pacific	14	7	4	8	9	7
Europe & Central Asia	20	6	3	4	6	6
Latin America & Caribbean	14	3	2	3	6	4
Middle East & North Africa	12	0	0	0	2	1
South Asia	5	1	1	2	2	1
Sub-Saharan Africa	18	3	3	6	4	3
Total	83	20	13	23	29	22

[5] The detailed regional distribution is reported in Appendix II.

Figure 1 Regional co-movements between currencies and the RMB

This figure presents the time-varying regional averages of co-movements between currencies and the RMB.

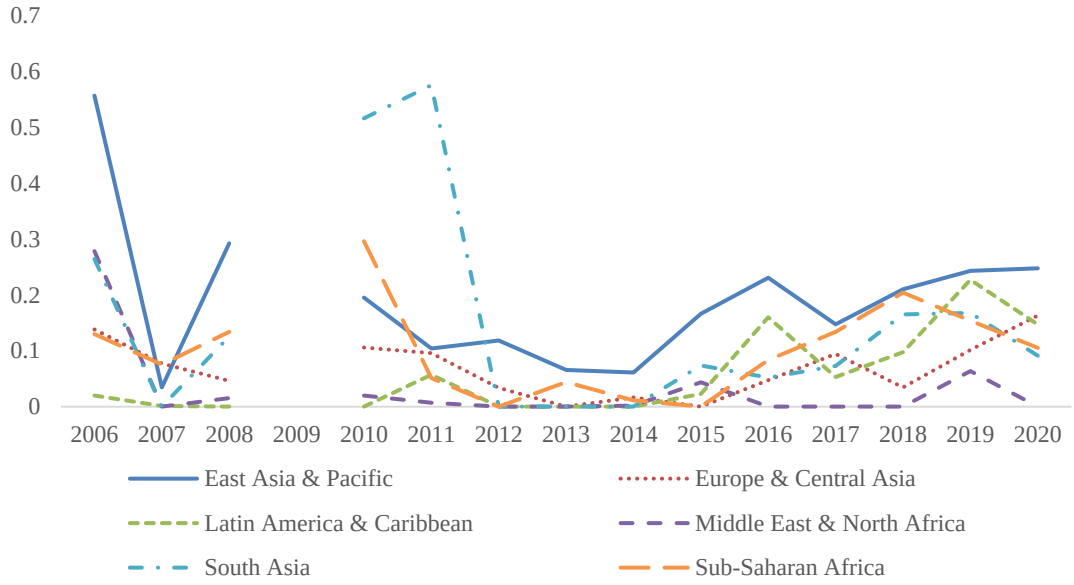

Table 2 provides summary statistics of the co-movements between currencies and the RMB and the determinant variables. In around 17 percent of all currency-year observations, currencies of developing economies significantly co-move with the RMB and the average co-movement is 0.094. Both percentage and degree of RMB co-movement suggest that the RMB had yet been influential on developing economies in the sample period.

Table 2 Summary statistics

This table provides summary statistics of co-movements between currencies and the RMB and the determinant variables. Variable definitions are presented in Appendix I.

	N	Mean	Std. Dev.	p25	p50	p75
Comove	1162	0.0937	0.2740	0	0	0
1(Comove>0)	1162	0.1695	0.3754	0	0	0
Trade dependence	1162	0.1266	0.1131	0.0490	0.0952	0.1692
Output asymmetry	1162	0.0348	0.0477	0.0206	0.0272	0.0378
Inflation differential	1162	0.0491	0.0642	0.0137	0.0291	0.0604
Size	1162	25.5478	1.8996	24.3306	25.5462	26.9797
Development	1162	9.2568	1.0222	8.5637	9.3759	9.9455
High inflation	1162	0.4363	0.4961	0	0	1
Real shock	1162	0.0228	0.0369	0.0099	0.0155	0.0254
Nominal shock	1162	0.0694	0.0604	0.0298	0.0519	0.0907
Land	83	12.0665	2.0776	10.8437	12.2058	13.5875

4. Empirical results

4.1 Co-movements

Table 3 presents the estimation results of the co-movements between four major international currencies and developing economy currencies from January 1, 2006 to December 31, 2020.

In the case of East Asia & Pacific, some currencies, such as Cambodian riel (KHR), Solomon Islands dollar (SBD), and Vietnamese Dong (VND), co-move with no currency as their corresponding R-square of regressions are close to 0, which may reflect the fact that these currencies were de facto pegged to the US dollar during the sample time. For the rest, estimation coefficients of the euro, the pound, and the yen are relatively small in value, regardless of significance level, and coefficients of the RMB are significantly positive and relatively large in value, owing to these economies' deeper trade and financial integration with China.

The euro is found to be the predominant currency in Europe & Central Asia, and its co-movements with other currencies in the region can be explained by a higher degree of economic and geopolitical integration in the region. The RMB, however, exerted significant influence on some economies such as Belarus and Bulgaria.

In Latin America & Caribbean, South Asia, and Sub-Saharan Africa, the RMB has also demonstrated as influential as the euro, but stronger than the pound and the Japanese yen. Similar to East Asia & Pacific, some currencies in this area were estimated with zero R-square in our model indicating they were also de facto pegged to the US dollar.

Finally, Algeria dinar (DZD) is the only currency in Middle East & North Africa that slightly co-moves with the RMB while most of the other economies in the area are oil exporters and hence chose to peg their currencies to the US dollar so as to facilitate oil-related transactions and stabilize their economy. This finding is consistent with that of Ilzetzki et al. (2019).

Table 3 Exchange rate co-movements throughout the entire period

This table presents the estimation results of the co-movements between four major international currencies and developing economy currencies from January 1, 2006 to December 31, 2020. Significance level: *** p<0.01, ** p<0.05, * p<0.1.

	Currency	EUR		GBP		JPY		RMB		R-squared	Observations
East Asia & Pacific	BND	0.230***	(0.011)	0.111***	(0.011)	0.054***	(0.009)	0.343***	(0.026)	0.40	3142
	FJD	0.201***	(0.022)	0.042*	(0.022)	0.019	(0.018)	0.179***	(0.054)	0.07	3107
	IDR	0.094***	(0.021)	0.128***	(0.021)	-0.074***	(0.017)	0.480***	(0.051)	0.11	3142
	KHR	0.008	(0.012)	0.002	(0.011)	-0.007	(0.009)	0.010	(0.028)	0.00	3068
	KRW	0.218***	(0.020)	0.156***	(0.019)	-0.037**	(0.016)	0.658***	(0.047)	0.22	3142
	MNT	0.002	(0.012)	-0.009	(0.012)	0.003	(0.010)	0.005	(0.029)	0.00	3112
	MYR	0.130***	(0.017)	0.112***	(0.017)	-0.049***	(0.013)	0.355***	(0.040)	0.16	3126
	PHP	0.127***	(0.014)	0.065***	(0.014)	-0.054***	(0.011)	0.336***	(0.033)	0.12	3142
	SGD	0.255***	(0.010)	0.122***	(0.010)	0.057***	(0.008)	0.315***	(0.024)	0.47	3142
	SBD	-0.042	(0.033)	0.051	(0.032)	-0.024	(0.026)	-0.125	(0.078)	0.00	3020
	THB	0.121***	(0.012)	0.051***	(0.011)	0.039***	(0.009)	0.350***	(0.027)	0.19	3142
	VND	-0.002	(0.006)	-0.000	(0.006)	0.001	(0.005)	0.020	(0.014)	0.00	3108
	VUV	-0.018	(0.033)	-0.005	(0.032)	-0.017	(0.026)	0.155**	(0.079)	0.00	3119
	WST	-0.014	(0.061)	0.025	(0.059)	-0.039	(0.048)	0.253*	(0.144)	0.00	3124
Europe & Central Asia	ALL	0.845	(0.012)	-0.025**	(0.012)	0.004	(0.010)	0.063**	(0.030)	0.71	3142

Currency	EUR		GBP		JPY		RMB		R-squared	Observations
AZN	0.003	(0.016)	-0.001	(0.016)	0.035***	(0.013)	-0.016	(0.038)	0.00	3134
BGN	0.969***	(0.006)	-0.004	(0.005)	0.009**	(0.004)	0.037***	(0.013)	0.94	3142
BAM	0.888***	(0.013)	-0.011	(0.012)	0.007	(0.010)	-0.017	(0.030)	0.73	3140
BYN	0.068***	(0.017)	-0.002	(0.017)	-0.032**	(0.013)	0.323***	(0.041)	0.06	3119
CZK	1.064***	(0.013)	0.050***	(0.013)	-0.018*	(0.010)	0.091***	(0.031)	0.79	3142
GEL	0.013	(0.019)	-0.004	(0.019)	0.003	(0.015)	0.092**	(0.046)	0.00	3129
HRK	0.999***	(0.006)	0.003	(0.006)	0.009*	(0.005)	0.003	(0.015)	0.93	3142
HUF	1.183***	(0.021)	0.098***	(0.020)	-0.149***	(0.016)	0.070	(0.049)	0.65	3142
KZT	0.026	(0.017)	-0.006	(0.017)	0.007	(0.014)	0.169***	(0.041)	0.03	3140
KGS	0.015	(0.016)	-0.022	(0.016)	0.011	(0.013)	0.073*	(0.039)	0.01	3081
MDL	0.048**	(0.020)	0.010	(0.020)	0.008	(0.016)	0.022	(0.048)	0.01	3133
MKD	0.517***	(0.019)	-0.004	(0.019)	-0.017	(0.015)	0.382***	(0.046)	0.30	3141
PLN	1.138***	(0.018)	0.109***	(0.018)	-0.124***	(0.014)	0.095**	(0.043)	0.70	3142
RON	1.042***	(0.012)	0.025**	(0.012)	-0.063***	(0.009)	0.032	(0.029)	0.80	3142
RUB	0.327***	(0.033)	0.129***	(0.032)	-0.136***	(0.026)	0.378***	(0.078)	0.21	3142
RSD	0.856	(0.019)	-0.019	(0.019)	-0.015	(0.015)	-0.071	(0.046)	0.51	3127

	Currency	EUR		GBP		JPY		RMB		R-squared	Observations
	TJS	-0.008***	(0.009)	0.006	(0.008)	0.000	(0.007)	-0.000	(0.020)	0.00	3003
	TRY	0.454***	(0.035)	0.156***	(0.034)	-0.254***	(0.028)	0.368***	(0.084)	0.13	3142
	UAH	0.060*	(0.034)	-0.008	(0.033)	0.025	(0.026)	0.117	(0.080)	0.00	3136
Latin America & Caribbean	ARS	0.066***	(0.025)	0.004	(0.024)	-0.044**	(0.019)	0.225***	(0.059)	0.01	2962
	BRL	0.384***	(0.040)	0.141***	(0.039)	-0.112***	(0.031)	0.289***	(0.094)	0.10	3093
	CLP	0.260***	(0.025)	0.120***	(0.024)	-0.106***	(0.020)	0.464***	(0.059)	0.16	3140
	COP	0.143***	(0.030)	0.178***	(0.029)	-0.138***	(0.023)	0.548***	(0.070)	0.17	3140
	CRC	0.022*	(0.012)	-0.040***	(0.012)	0.005	(0.009)	-0.042	(0.029)	0.01	3142
	DOP	-0.018	(0.016)	0.018	(0.016)	0.021*	(0.013)	0.004	(0.038)	0.00	3140
	GTQ	0.003	(0.007)	0.004	(0.007)	-0.002	(0.005)	-0.021	(0.016)	0.00	3140
	HNL	0.003	(0.006)	-0.003	(0.006)	0.003	(0.004)	0.009	(0.014)	0.00	3140
	MXN	0.317***	(0.028)	0.230***	(0.028)	-0.194***	(0.022)	0.249***	(0.068)	0.18	3142
	NIO	0.001	(0.012)	-0.008	(0.012)	0.001	(0.009)	-0.024	(0.028)	0.00	3142
	PEN	0.050***	(0.012)	0.045***	(0.012)	-0.044***	(0.010)	0.205***	(0.029)	0.07	3138
	PYG	0.012	(0.019)	0.018	(0.018)	0.009	(0.015)	-0.002	(0.045)	0.00	3132
	TTD	0.000	(0.013)	-0.004	(0.013)	0.009	(0.010)	-0.045	(0.031)	0.00	3128
	UYU	0.066***	(0.022)	0.007	(0.022)	-0.028	(0.018)	0.232***	(0.053)	0.02	3142

	Currency	EUR		GBP		JPY		RMB		R-squared	Observations
Middle East & North Africa	AED	0.000	(0.000)	-0.000*	(0.000)	0.000*	(0.000)	-0.000	(0.001)	0.00	3142
	DZD	0.268***	(0.025)	-0.005	(0.024)	-0.002	(0.020)	0.102*	(0.059)	0.06	3142
	EGP	-0.006	(0.010)	0.018*	(0.010)	0.007	(0.008)	-0.017	(0.025)	0.00	3142
	JOD	0.001	(0.006)	-0.001	(0.006)	-0.001	(0.005)	0.015	(0.014)	0.00	3142
	KWD	0.095***	(0.003)	0.014***	(0.003)	0.025***	(0.003)	0.010	(0.008)	0.38	3142
	LBP	0.009*	(0.005)	-0.002	(0.005)	0.003	(0.004)	-0.014	(0.013)	0.00	3113
	LYD	0.055**	(0.026)	0.010	(0.025)	0.000	(0.020)	-0.024	(0.061)	0.00	3140
	MAD	0.735***	(0.006)	-0.006	(0.006)	-0.003	(0.005)	-0.067***	(0.014)	0.89	3142
	OMR	0.001	(0.001)	-0.001	(0.001)	0.000	(0.001)	-0.001	(0.003)	0.00	3142
	QAR	0.001	(0.005)	-0.005	(0.005)	-0.004	(0.004)	-0.001	(0.012)	0.00	3142
	SAR	-0.001	(0.001)	-0.000	(0.001)	0.001	(0.001)	0.000	(0.002)	0.00	3142
	TND	0.610***	(0.020)	0.023	(0.020)	0.016	(0.016)	0.062	(0.049)	0.34	3136
South Asia	BDT	0.024*	(0.013)	-0.015	(0.013)	0.003	(0.010)	0.052*	(0.030)	0.00	2942
	INR	0.132***	(0.018)	0.099***	(0.018)	-0.080***	(0.014)	0.362***	(0.043)	0.11	3013
	LKR	-0.002	(0.009)	0.006	(0.009)	0.003	(0.007)	0.025	(0.022)	0.00	3109
	NPR	0.069***	(0.019)	0.028	(0.018)	-0.060***	(0.015)	0.254***	(0.044)	0.03	3132
	PKR	0.010	(0.013)	0.007	(0.013)	-0.008	(0.010)	-0.034	(0.031)	0.00	3142
Sub-Saharan Africa	AOA	0.019	(0.020)	-0.030	(0.019)	0.009	(0.015)	-0.001	(0.047)	0.00	3142
	BIF	0.012	(0.021)	-0.014	(0.020)	0.007	(0.016)	0.077	(0.049)	0.00	3140

Currency	EUR		GBP		JPY		RMB		R-squared	Observations
BWP	0.320***	(0.028)	0.128***	(0.028)	-0.033	(0.022)	0.516***	(0.067)	0.14	3125
XAF	0.953***	(0.017)	0.004	(0.017)	-0.008	(0.013)	0.131***	(0.041)	0.63	3133
CDF	-0.003	(0.023)	0.025	(0.023)	-0.002	(0.018)	-0.006	(0.057)	0.00	2961
CVE	0.739***	(0.019)	-0.038**	(0.019)	-0.008	(0.015)	0.139***	(0.046)	0.44	3071
GHS	-0.051	(0.032)	-0.016	(0.031)	0.004	(0.025)	0.129*	(0.076)	0.00	3140
KES	0.022	(0.017)	0.018	(0.017)	-0.002	(0.014)	0.031	(0.041)	0.00	3139
MGA	0.098**	(0.044)	-0.017	(0.044)	-0.001	(0.035)	0.196*	(0.106)	0.00	2952
MUR	0.087***	(0.025)	-0.051**	(0.024)	-0.019	(0.019)	0.111*	(0.059)	0.01	3133
NAD	0.560***	(0.039)	0.297***	(0.038)	-0.222***	(0.030)	0.665***	(0.092)	0.22	3140
NGN	-0.012	(0.023)	0.019	(0.022)	0.010	(0.018)	0.073	(0.054)	0.00	3142
RWF	0.035	(0.027)	-0.032	(0.026)	0.003	(0.021)	0.034	(0.063)	0.00	3128
SCR	0.061	(0.065)	-0.032	(0.064)	0.043	(0.051)	0.295*	(0.156)	0.00	3091
TZS	-0.004	(0.021)	0.007	(0.021)	-0.016	(0.017)	-0.033	(0.051)	0.00	3135
UGX	0.014	(0.019)	0.031*	(0.018)	-0.037**	(0.015)	0.082*	(0.045)	0.01	3140
ZAR	0.560***	(0.039)	0.297***	(0.038)	-0.222***	(0.030)	0.665***	(0.092)	0.22	3140
ZMW	0.120***	(0.043)	0.008	(0.042)	-0.013	(0.034)	0.018	(0.102)	0.01	3136

4.2 Determinants of exchange rate co-movements

We report in Table 4 the regression results of the determinants of RMB co-movement. *Year* are year-level dummies controlled for in column (5) - (7). Results of three methods, OLS, logit and probit, are presented in column (1)-(5), (6) and (7), respectively. In column (6) and (7) we show the average marginal effects of independent variables in the logit model and probit model. As shown in Table 4, our results are consistent in various specifications. We hence focus on the results of OLS in this section.

Trade dependence increases the probability of RMB co-movement while *Inflation differential* deceases it, which is consistent with OCA argument. The more trade with China, the more beneficial it is for developing economies to place the RMB in their currency baskets. Higher inflation differential reflects larger cost of maintaining the consistency of the two countries' monetary policies, and hence less chances of RMB co-movement. *Output asymmetry* has not statistically significant effects suggests that central banks may focus more directly on inflation than on economic growth in determining exchange rate policy. *Size* and *Development* are found to increase the chances of RMB co-movement. And it is consistent with the view that larger economic size and higher economic development level increase the probability of adopting an intermediate regime, where the RMB can be placed into a currency basket, relative to a fixed regime with the US dollar as the anchor currency (Meissner and Oomes, 2009). For example, Cambodia and Vietnam both peg their currencies to the US dollar. In Cambodia, the US dollar has dominated all aspects of currency circulation. On the contrary, Singapore, a high-income economy, adopts an exchange rate system where the Singapore dollar is managed against a basket of currencies of its major trading partners.

High inflation is negatively correlated with RMB co-movements, because developing economies tend to peg their currencies to the US dollar fearing for another hyperinflation (Plümper and Neumayer, 2011). Similarly, *Nominal shock* increases the possibility of an economy adopting a fixed exchange rate system, thus reducing the possibility of co-movements between the economy's currency and the RMB.

Table 4 The determinants of co-movements between currencies and the RMB

This table reports the determinants of whether other currencies co-move with the RMB. Year represents year-level dummies, controlled for in the column (5) – (7). The results of three methods, OLS, logit and probit, are presented in column (1) - (5), (6) and (7), respectively. Results in column (6) and (7) reports average margin effects of independent variables in the logit model and probit model. Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Variable definitions are presented in Appendix I.

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) Logit	(7) Probit
Trade dependence	0.181**	0.194**	0.219**	0.253***	0.233**	0.254***	0.234**
	(0.088)	(0.087)	(0.086)	(0.092)	(0.093)	(0.095)	(0.095)
Output asymmetry	-0.109	-0.131	-0.321	-0.266	0.127	0.350	0.283
	(0.216)	(0.216)	(0.313)	(0.315)	(0.305)	(0.434)	(0.416)
Inflation differential	-0.564***	-0.642***	-0.442***	-0.425***	-0.491***	-0.676***	-0.632***
	(0.123)	(0.128)	(0.136)	(0.134)	(0.144)	(0.244)	(0.222)
Size	0.014**	0.018**	0.015**	0.027**	0.025**	0.015	0.014
	(0.007)	(0.007)	(0.007)	(0.012)	(0.011)	(0.011)	(0.010)
Development	0.048***	0.045***	0.042***	0.031**	0.031**	0.042***	0.042***

	(0.013)	(0.012)	(0.012)	(0.015)	(0.014)	(0.015)	(0.014)
High inflation		-0.077***	-0.057**	-0.055**	-0.058**	-0.043*	-0.045**
		(0.022)	(0.023)	(0.023)	(0.022)	(0.022)	(0.022)
Real shock			0.403	0.436	-0.088	-0.251	-0.221
			(0.413)	(0.415)	(0.390)	(0.569)	(0.540)
Nominal shock			-0.646***	-0.605***	-0.555***	-1.059***	-0.958***
			(0.155)	(0.156)	(0.167)	(0.370)	(0.343)
Land				-0.013	-0.011	-0.004	-0.005
				(0.009)	(0.009)	(0.008)	(0.008)
Constant	-0.632***	-0.673***	-0.550***	-0.587***	-0.481***		
	(0.161)	(0.161)	(0.166)	(0.172)	(0.171)		
Year	No	No	No	No	Yes	Yes	Yes
Adj./Pseudo R^2	0.033	0.042	0.049	0.050	0.096	0.142	0.140
Observations	1,162	1,162	1,162	1,162	1,162	1,162	1,162

4.3 Sub-period

On 21 July 2005, the People Bank of China (PBOC) decided to adopt a managed floating exchange rate regime with reference to a basket of currencies, indicating an end to the era when the RMB was fixed to the US dollar. On June 19, 2010 and on August 11, 2015, the PBOC announced that it would "further the reform of exchange rate regime and enhance the flexibility of RMB exchange rate[6]". On the latter date, the PBOC made an announcement claiming that it would "improve quotation of the central parity of RMB against US dollar" and "the quotes of central parity that market makers report to the China Foreign Exchange Trade System (CFETS) daily before market opens should refer to the closing rate of the inter-bank foreign exchange market on the previous day"[7]. The two reforms divided the entire sample into 3 periods and the RMB's flexibility in each period is different. Thus, we regress equation (2) in 3 periods to explore the impact of the reforms on determinants of RMB co-movements. Results are shown in Table 5.

In 2006-2008, *Nominal shock* reduces the co-movement as expected while *Trade dependence* is irrelevant, which can be due to the small room of the RMB's flexibility at that time weakening the effect of trade sector on the RMB. Further evidence is shown in both 2010-2015 and 2016-2020 when RMB's flexibility jumped up by market-oriented reforms: *Trade dependence* increases the co-movement statistically and economically significant in both later periods.

Table 5 Sub period

This table reports the determinants of whether other currencies co-move with CNY in three subperiods. Year represents year-level dummies, controlled in all three periods. Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Variable definitions are presented in Appendix I.

	(1) 2006-2008	(2) 2010-2015	(3) 2016-2020
Trade dependence	0.064	0.224*	0.343**
	(0.170)	(0.123)	(0.173)
Output asymmetry	3.261*	-0.260	0.426
	(1.706)	(0.286)	(0.725)
Inflation differential	-0.563	-0.050	-1.086***

[6] Available at http://www.pbc.gov.cn/en/3688110/3688175/3707924/index.html.

[7] Available at http://www.pbc.gov.cn/en/3688110/3688181/a13b2cb0/index89.html.

	(0.391)	(0.182)	(0.255)
Size	0.008	0.018	0.039*
	(0.023)	(0.015)	(0.022)
Development	-0.014	0.007	0.086***
	(0.027)	(0.019)	(0.030)
High inflation	-0.019	-0.029	-0.107**
	(0.047)	(0.028)	(0.045)
Real shock	-0.453	0.375	-0.315
	(1.294)	(0.404)	(0.912)
Nominal shock	-1.079***	-0.410*	-1.157**
	(0.271)	(0.219)	(0.550)
Land	-0.023	-0.024**	0.020
	(0.016)	(0.012)	(0.019)
Constant	0.440	0.018	-1.684***
	(0.365)	(0.228)	(0.304)
Year	Yes	Yes	Yes
Adj. R^2	0.065	0.058	0.151
Observations	249	498	415

5. Robustness and extension

5.1 Alternative specifications

In the benchmark model, we construct *Comove* through retaining the estimates of $\beta_{i,1}$ that are significantly positive at the 5% significance level, and replacing other values with 0. In order to avoid processing arbitrariness, we change the significance criterion to 10%. The corresponding results that are consistent with the main finding are presented in column (1) of Table 6.

Central banks and investors may pay special attention to the offshore RMB market due to its spatial separation, less regulation, and incomplete capital account information. (He and McCauley, 2013). The offshore RMB market has indeed scaled up rapidly since its inception in 2010. However, the offshore RMB exchange rate has also been inconsistent with the onshore one, and more importantly the impact of the two RMB rates on East Asian currencies are found to be both statistically and economically different (Shu et al., 2015). We hence replace the CNY (onshore) rates in equations (1) with the CNH (offshore), and construct *Comove* the same way as in the baseline model. The coefficients of the determinants of RMB co-movement using CNH are shown in column (2) of Table 6. Results of column (2) are consistent with our main findings.

Column (3) of Table 6 reports the results of the determinants of *Comove*. All coefficients show same statistically significant signs except for those of *Trade dependence*, *Size* and *Development*, which are still positive but insignificant. In general we argue that this may be because the choice of placing and the way of weighing the RMB in the currency basket are two different decision-making processes.

Specifically, larger and more developed economy tend to adopt an intermediate exchange rate regime (discussed above), under which an economy normally includes multiple currencies in the basket so the weight of the RMB is more likely to be affected by the economic relationship between home economy and other non-China economies than by *Size* and *Development*. The statistically insignificant correlation between *Trade dependence* and *Comove* suggests that although trade can increase the probability of RMB co-movement, it has no influence on the degree of the co-movement. Similar story can be found in the early internationalization of the US dollar. United States was

the world's largest exporter in 1912, while the US dollar did not become an international currency until 1944 (Bahaj and Ries, 2020).

We also add two additional control variables, *Reserve* and *Financial development*, to the model and present the result in Column (4) of Table 6. *Reserve* is a ratio of actual foreign reserve over M2, and *Financial development* is another ratio of M2 over nominal GDP. The economic rationale for those two additional variables are: 1. Once foreign reserve is depleted pegging exchange rate is expected to die out as pointed out by Krugman (1979); 2. Countries with more advanced financial system is normally more attractive to international capital and hence more inclined to maintain independent monetary policy, which leaves no room for pegging exchange rate system. The results are as expected. The coefficient of *Reserve* is negative though statistically insignificant, and that of *Financial development* is statistically positive, showing that the degree of financial development is positively correlated with RMB co-movement.

Besides, we re-estimate the variable of *Comove* using the method in Kawai and Pontines (2016). Specifically, we use the Swiss franc (CHF) as the unit currency, logarithmic returns of the RMB exchange rate as the dependent variable, and logarithmic returns of the US dollar, the euro, the pound, and the Yen as independent variables, so as to "purify" the variance of the RMB in the following way:

$$e_{CNY} = \eta + \gamma_1 e_{USD} + \gamma_2 e_{EUR} + \gamma_3 e_{GBP} + \gamma_4 e_{JPY} + \mu \tag{3}$$

Then the estimated error term, $\hat{\mu}$, will be the proxy of the RMB replacing e_{CNY} as in (4):

$$e_i = \alpha_i + \beta_{1,i} e_{USD} + \beta_{i,2} e_{EUR} + \beta_{i,3} e_{GBP} + \beta_{i,4} e_{JPY} + \beta_{i,5} \hat{\mu} + \beta_{i,6} e_{oil} + \beta_{i,7} vix + \varepsilon_i \tag{4}$$

Kawai and Pontines（2016）take further steps to stabilize the RMB coefficient as follows, $\beta_{i,1} + \beta_{i,2} + \beta_{i,3} + \beta_{i,4} + \beta_{i,5} = 1$. We accordingly transform (4) into (5):

$$e^i - \hat{\mu} = \alpha_i + \beta_{1,j}(e_{USD} - \hat{\mu}) + \beta_{2,j}(e_{EUR} - \hat{\mu}) + \beta_{3,j}(e_{GBP} - \hat{\mu}) + \beta_{4,j}(e_{JPY} - \hat{\mu}) + \beta_{i,6} e_{oil} + \beta_{i,7} vix + \varepsilon_i \tag{5}$$

The final estimated RMB coefficient is $\beta_{i,5} = 1 - (\beta_{i,1} + \beta_{i,2} + \beta_{i,3} + \beta_{i,4})$. After we repeat the same steps in our baseline regression, replacing *Comove* with $\beta_{i,5}$, the result reaffirms the robustness.

Based on Ilzetzki et al. (2019), we category our sample by exchange rate regime as follows: 25 countries in our sample peg their currency to another international currency, 36 adopt crawling peg, 20 are managed floating, 1 is freely floating, and 1 country has dual market in which parallel market data is missing. To control for exchange regime effect, we added regime dummies in the regression, corresponding to the above 5 exchange rate regimes. The result presented in column (6) of Table 6 reaffirms the main conclusion.

Table 6 Robustness checks

This table reports robustness checks of changing the significance criteria in define *Comove*, using CHN rates instead of CNY rates, using *Comove* as the independent variable, adding more control variables, using the CHF as the denomination currency, and adding exchange rate regime dummies, including de facto peg, crawling peg, managed floating, freely floating, and dual market in which parallel market data is

missing. Year represents year-level dummies, controlled for in all columns. Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Variable definitions are presented in Appendix I.

	(1) *p*=0.1	(2) CNH	(3) *Comove*	(4) Control	(5) CHF	（6） Regime
Trade dependence	0.244**	0.305***	0.063	0.207**	0.327***	0.195**
	(0.100)	(0.110)	(0.062)	(0.100)	(0.115)	(0.094)
Output asymmetry	0.160	-0.261	0.030	0.106	0.516	-0.071
	(0.328)	(0.360)	(0.198)	(0.345)	(0.323)	(0.283)
Inflation differential	-0.510***	-0.733***	-0.295***	-0.310	-0.826***	-0.383**
	(0.162)	(0.203)	(0.096)	(0.194)	(0.162)	(0.174)
Size	0.026**	0.049***	0.002	0.015	0.041***	0.020*
	(0.012)	(0.015)	(0.009)	(0.013)	(0.012)	(0.012)
Development	0.036**	0.085***	0.011	0.036**	0.005	0.026*
	(0.015)	(0.019)	(0.009)	(0.016)	(0.016)	(0.015)
High inflation	-0.058**	-0.131***	-0.040**	-0.048*	-0.084***	-0.047**
	(0.024)	(0.028)	(0.016)	(0.025)	(0.024)	(0.023)
Real shock	-0.246	-0.169	-0.166	-0.578	-0.307	0.014
	(0.422)	(0.451)	(0.263)	(0.486)	(0.418)	(0.368)
Nominal shock	-0.523***	-0.675***	-0.446***	-0.426**	-0.011	-0.459***
	(0.192)	(0.238)	(0.127)	(0.196)	(0.218)	(0.170)
Land	-0.016	0.014	0.003	-0.007	-0.020**	-0.014
	(0.010)	(0.013)	(0.007)	(0.011)	(0.009)	(0.010)
Reserve				-0.033		
				(0.028)		
Financial development				0.090**		
				(0.044)		
Constant	-0.458**	-1.776***	0.096	-0.341*	-0.656***	-0.303*
	(0.184)	(0.218)	(0.186)	(0.192)	(0.215)	(0.178)
Year	Yes	Yes	Yes	Yes	Yes	Yes
Exchange rate regime	No	No	No	No	No	Yes
Adj. R^2	0.087	0.169	0.052	0.092	0.107	0.095
Observations	1,162	830	1,162	1,123	728	1070

5.2 Nonlinear determinants

Evidently, the unusual exchange rate volatility may weaken the role of the RMB as a vehicle for cross-border transactions (He et al., 2021c). To make the issue more complicated, foreign currencies may respond asymmetrically to high and low volatility of home currency value, transnational trade competition level and domestic inflation pressure. Therefore, currency co-movement can be subject to nonlinear factors. In this section, we focus on the nonlinear determinants of RMB co-movement using threshold estimation (Hansen, 2000). We use *Volatility*, measured by the annual standard deviation of exchange rate returns, as the threshold variable. The exchange rate is defined as units of each currency per CNY.

Table 7 reports the results of nonlinear determinants of RMB co-movement. The threshold value is 0.594 and the LM-test statistic for no threshold is 43.316, rejecting the null hypothesis of no threshold at the 10 percent level (Hansen, 2000). In the low volatility regime, the results are similar to those in the benchmark model: *Trade dependence* and *Size* stimulates the co-movement while *Inflation differential*, *High inflation* and *Nominal shock* restrain it. High volatility regime, however, presents a different pattern of the nonlinear determinants. Specifically, *Trade dependence* and *Size* decrease the probability of RMB co-movement even though the statistical significance level declines. High volatility of exchange rate usually reflects high volume of capital flow (Hutson and Laing, 2014; Forbes and Warnock, 2021), so the positive effect of bilateral trade on RMB co-movement may be diluted, which can even turn to a negative impact for high volatility of the capital market. Facing high exchange rate volatility, most currency co-movements are under market pressure (Clark et al., 2004), hence large economies that have resourceful ways of intervening in exchange rate market may end up with low RMB co-movement.

Table 7 Nonlinear determinants of co-movements between currencies and the RMB

This table reports nonlinear determinants of the RMB co-movement using threshold estimation. Volatility, measured by the annual standard deviation of exchange rate returns, is used as the threshold variable. The exchange rate is defined as units of the target currency per unit of CNY (Hansen, 2000). Year represents year-level dummies, controlled for in both columns. Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Variable definitions are presented in Appendix I.

Panel A Testing result for threshold effects

Threshold value	0.594*
LM-test for no threshold:	43.316
Bootstrap P-value	0.053

Panel B Threshold regression

	(1) Low volatility	(2) High volatility
Trade dependence	0.350***	-0.295*
	(0.113)	(0.167)
Output asymmetry	0.352	-0.699
	(0.385)	(0.646)
Inflation differential	-0.440**	-0.574**
	(0.190)	(0.252)
Size	0.038**	-0.033*
	(0.015)	(0.018)
Development	0.023	0.057**
	(0.017)	(0.024)
High inflation	-0.056**	-0.008
	(0.027)	(0.044)

Real shock	-0.167	0.360
	(0.744)	(0.657)
Nominal shock	-0.658***	-0.592*
	(0.203)	(0.326)
Land	-0.026**	0.046***
	(0.011)	(0.015)
Constant	-0.547**	-0.022
	(0.245)	(0.279)
Year	Yes	Yes
Adj. R^2	0.097	0.143
Observations	834	328

5.3 Bilateral local currency swap agreements

Currency swap stimulates currency co-movements through strengthening bilateral trade as long as home currency is used in trade invoicing (Bahaj and Reis, 2020; Gopinath and Stein, 2021), and through tightening financial links (Zhang et al., 2017). Starting from 2009, the PBOC has initiated a series of currency swap agreements to promote trade and investment and to strengthen financial relationship with other countries.

McDowell (2019) points out that RMB currency swap agreements function as a short-term liquidity backstop outside of the Bretton Woods institutions for China's partner countries in need. Song and Xia (2020) also show that RMB swap increases the number, value and proportion of the RMB settlement in cross-border trade.

As of the end of 2020, China had signed currency swap agreements with 39 monetary authorities and the amount exceeds 3.8 trillion RMB[8]. Based on the signing dates, we construct the dummy variable *Swap*, which equals 1 for the time posterior to the swap agreement, and 0 otherwise.

Column (1) in Panel A of Table 8 reports the impact of currency swap agreements on RMB co-movements. The possibility of RMB co-movements increases by 0.1 for the agreement. The amplifying effect need to be decomposed into various factors in distinct economies. Argentina, for example, exchanged its RMB reserves that came from currency swap agreement for the US dollar in 2015. Therefore, we dig deeper into the issue by including some economic characteristics: *Size*, *Development* and *High inflation*. Column (2)-(4) in Table 8 report those results. We find that *Swap* increases the probability of RMB co-movement with the currencies of larger and more developed economies. This is because larger and more developed economies tend to have more sophisticated financial systems that are able to fully utilize currency swap agreements to stabilize their exchange rate market.

Table 8 The impact of signing swap agreements

This table reports the impact of signing swap agreements on RMB co-movements. *Swap* is a dummy variable that equals 1 in the years after the economy signed a swap agreement with China and 0 otherwise. *Swap amount* equals the natural logarithm of the swap agreement amount plus: 1 for the years posterior to the agreement and 0 otherwise. Control represents the determinants in the baseline model. Year is year-level dummies, controlled in all columns. Robust standard errors in parentheses.

[8] We collect the data of currency swap from the official website of the PBOC.

Significance level: *** p<0.01, ** p<0.05, * p<0.1. Variable definitions are presented in Appendix I.

Panel A

	(1)	(2)	(3)	(4)
Swap	0.110***	-1.871***	-1.024***	0.159***
	(0.036)	(0.592)	(0.346)	(0.051)
*Swap * Size*		0.074***		
		(0.022)		
*Swap * Development*			0.116***	
			(0.036)	
*Swap * High inflation*				-0.100
				(0.066)
Size	0.018	0.012	0.015	0.015
	(0.011)	(0.012)	(0.011)	(0.012)
Development	0.025*	0.029**	0.017	0.027*
	(0.014)	(0.014)	(0.014)	(0.014)
High inflation	-0.054**	-0.045**	-0.049**	-0.037
	(0.022)	(0.023)	(0.022)	(0.024)
Control	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Adj. R^2	0.104	0.113	0.112	0.106
Observations	1,162	1,162	1,162	1,162

Panel B

	(1)	(2)	(3)	(4)
Swap amount	0.027***	-0.266**	-0.130*	0.034***
	(0.007)	(0.131)	(0.067)	(0.008)
*Swap amount * Size*		0.011**		
		(0.005)		
*Swap amount * Development*			0.016**	
			(0.007)	
*Swap amount * High inflation*				-0.015
				(0.012)
Size	0.013	0.010	0.010	0.010
	(0.012)	(0.012)	(0.011)	(0.012)
Development	0.023	0.026*	0.019	0.025*
	(0.014)	(0.014)	(0.014)	(0.014)
High inflation	-0.048**	-0.046**	-0.044**	-0.034
	(0.022)	(0.023)	(0.022)	(0.024)
Control	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Adj. R^2	0.113	0.117	0.117	0.114
Observations	1,162	1,162	1,162	1,162

In Panel B, we replace *Swap* with *Swap amount*, which equals the natural logarithm of the currency amount plus 1 for the time posterior to the agreement, and 0 otherwise. The results are consistent with those in Panel A.

5.4 The Belt and Road Initiative (BRI)

Since its inception in 2013 by the Chinese government, BRI has been nearly as controversial as it is consequential. It has influenced the landscape of trade across the world. Boosted by its central role in BRI and China's new phase of openness to foreign investment,[9] the RMB has been expected by the Chinese government to meet the transactional needs of the BRI countries and fulfil its geopolitical mission (He et al., 2021b, Xu et al., 2022).

Liu (2015) and Wang (2016) forecast that trade and financial exchanges between China and the BRI countries will rise, which will push China's deeper integration into the world economy and expand China's influence in the region and even globally. Qian et al. (2019) point out that BRI is a good opportunity to accelerate the internationalization of the RMB through issuing RMB-denominated "Silk Road Bonds" to fund the infrastructure projects along the BRI regions. The deepening trade and financial relations between China and the BRI economies motivate us to test the BRI's impact on RMB co-movement (He et al., 2021a).

Since the BRI economies did not join the initiative at the same time, and even multiple signing dates of the same economy could also be documented, in the estimation we choose the date when an economy signed the BRI documents for the first time[10]. Based on the data, we construct the dummy variable *BRI*, which equals 1 for the time posterior, and 0 otherwise.

Table 9 reports the results of adding *BRI* and its interactive term with some economic characteristics to the baseline model. BRI is expected to positively correlate with RMB co-movement as it increases credit-based cross-border investments and facilitates bilateral trades (Enderwick, 2018; Ramasamy and Yeung, 2019). The direct impact of BRI on RMB co-movement as reported in column (1) of Table 9, however, fail to support the view. This may be due to a considerable diversity of the BRI constituent countries in that they vary not only in income level but also in infrastructure potential as measured by land mass, population, road, and rail density.

We then extend the question to whether the impact of *BRI* on RMB co-movement relies on economic characteristics. The statistically positive interaction terms, *BRI * Size* and *BRI * Development*, suggest that BRI indeed catalysts RMB co-movement, but only through size and development level of the receiver economy. Specifically, BRI increases RMB co-movement in larger and more developed economies, which may be contributable to their advanced financial system; while the administrative obstacles to business and poor infrastructure potentials of smaller and less developed countries may hinder BRI's influence on the co-movement (Du and Zhang, 2018).

Table 9 The impact of the Belt and Road Initiative

This table reports the impact of Belt and Road Initiative on co-movements. *BRI* is a dummy variable that equals 1 for the years after the economy signed relevant cooperation documents in the Belt and Road framework with China and 0 otherwise. Control represents the determinants in the baseline model. Year is year-level dummies, controlled for in all columns. Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Variable definitions are presented in Appendix I.

	(1)	(2)	(3)	(4)

[9] "China Speeds Up Opening of Market to Investment Bank Giants" on the Bloomberg website: https://www.bloomberg.com/news/articles/2020-01-15/china-speeds-up-opening-of-market-to-investment-banking-giants. Accessed on April 9, 2020.

[10] We collect the data from the official website of BRI and cross-check them with other news reports and foreign official communications.

BRI	-0.022	-1.677***	-0.914***	-0.003
	(0.045)	(0.412)	(0.259)	(0.060)
*BRI * Size*		0.064***		
		(0.016)		
*BRI * Development*			0.093***	
			(0.027)	
*BRI * High inflation*				-0.035
				(0.062)
Size	0.025**	0.015	0.025**	0.024**
	(0.011)	(0.012)	(0.011)	(0.011)
Development	0.032**	0.031**	0.017	0.033**
	(0.014)	(0.014)	(0.014)	(0.014)
High inflation	-0.056**	-0.049**	-0.056**	-0.049**
	(0.023)	(0.023)	(0.022)	(0.024)
Control	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Adj. R^2	0.095	0.108	0.104	0.095
Observations	1,162	1,162	1,162	1,162

6. Conclusion

In this paper we explore the co-movements between the currencies of developing economies and the RMB. We find that while the RMB plays an important role in East Asia & Pacific, it had yet been influential on developing economies.

We also investigate the determinants of RMB co-movement, and find that bilateral trade significantly increases, while inflation differential decreases, the probability of the co-movement. Additionally, the currencies of the economies that are more inclined to adopt a pegging system are less likely to co-move with the RMB.

We further divide the sample into three sub-periods based on two major China's currency reforms and find the consistent results supporting our main conclusion. We also investigate nonlinear determinants of RMB co-movement by dividing the sample into high and low volatility regimes and show that high volatility regime presents a different pattern of determinants. Finally, we find that RMB currency swap and the Belt and Road Initiative catalyst the co-movement in larger and more developed economies.

Appendix I Variable definitions and data sources

This table presents the abbreviation, definition and source of variables we have used.

Variable	Definition	Data source
Co-movements between currencies and the RMB		
$\Delta log\ (x)$	Log daily return of USD/*x* (*x* = RMB, EUR, JPY, GBP, and other currencies) exchange rates	FX, VIX, Oil data from Bloomberg
VIX	The Chicago Board Options Exchange Market Volatility Index	
Oil	Log daily return of Brent crude oil prices	
Comove	Estimated co-movements between developing economy currencies and the RMB	
Determinant		

Trade dependence	Total trade with China divided by that with the world	DOTS, IMF
Output asymmetry	The standard deviation of the difference of growth rates of real output between other economies and China in the previous 10 years	WEO, IMF and WDI, World Bank
Inflation differential	The absolute value of the difference of the inflation between other economies and China	
High inflation	= 1 when an economy has experienced a high inflation above 50 % between the current year and 1980 and current inflation is below 20%	
Real shock	The standard deviation of the government expenditure to GDP ratio during the previous 5 years	
Nominal shock	The standard deviation of growth rates of broad money supply during the previous 5 years	
Size	The logarithm of real PPP GDP (2017 international dollar)	
Development	The logarithm of per capita PPP GDP (2017 international dollar)	
Land	The natural logarithm of land area (square kms)	
Reserve	Reserves divided by M2	
Financial development	M2 divided by GDP	
Exchange rate regime dummy	Including de facto peg, crawling peg, managed floating, freely floating, and dual market in which parallel market data is missing	Ilzetzki et al. (2019)

Appendix II Economy sample and regional distribution

This table lists the economy sample we used and their regional distribution.

Region	Economy (Currency)
East Asia & Pacific	Brunei (BND), Fiji (FJD), Indonesia (IDR), Cambodia (KHR), Korea, Rep. (KRW), Mongolia (MNT), Malaysia (MYR), Philippines (PHP), Singapore (SGD), Solomon Islands (SBD), Thailand (THB), Vietnam (VND), Vanuatu (VUV), Samoa (WST)
Europe & Central Asia	Albania (ALL), Azerbaijan (AZN), Bulgaria (BGN), Bosnia and Herzegovina (BAM), Belarus (BYN), Czech Republic (CZK), Georgia (GEL), Croatia (HRK), Hungary (HUF), Kazakhstan (KZT), Kyrgyz Republic (KGS), Moldova (MDL), North Macedonia (MKD), Poland (PLN), Romania (RON), Russian Federation (RUB), Serbia (RSD), Tajikistan (TJS), Turkey (TRY), Ukraine (UAH)
Latin America & Caribbean	Argentina (ARS), Brazil (BRL), Chile (CLP), Colombia (COP), Costa Rica (CRC), Dominican Republic (DOP), Guatemala (GTQ), Honduras (HNL), Mexico (MXN), Nicaragua (NIO), Peru (PEN), Paraguay (PYG), Trinidad and Tobago (TTD), Uruguay (UYU)

Middle East & North Africa	United Arab Emirates (AED), Algeria (DZD), Egypt (EGP), Jordan (JOD), Kuwait (KWD), Lebanon (LBP), Libya (LYD), Morocco (MAD), Oman (OMR), Qatar (QAR), Saudi Arabia (SAR), Tunisia (TND)
South Asia	Bangladesh (BDT), India (INR), Sri Lanka (LKR), Nepal (NPR), Pakistan (PKR)
Sub-Saharan Africa	Angola (AOA), Burundi (BIF), Botswana (BWP), Central African Republic (XAF), Congo, Dem. Rep. (CDF), Cape Verde (CVE), Ghana (GHS), Kenya (KES), Madagascar (MGA), Mauritius (MUR), Namibia (NAD), Nigeria (NGN), Rwanda (RWF), Seychelles (SCR), Tanzania (TZS), Uganda (UGX), South Africa (ZAR), Zambia (ZMW)

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