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What Drives Growing Currency Co-movements with the Renminbi?

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China's increasing trade volume and continuous integration with global financial markets have strengthened the influences of the renminbi on the exchange rates of different currencies. Previous studies find closer co-movements between the renminbi and other currencies. This paper is novel to investigate the underlying determinants of the co-movement further, using panel data of over thirty-four countries. Our results show that stronger bilateral trade and financial linkages with China have a positive association with the currency co-movement. Moreover, countries with greater flexibility in exchange rate regimes show stronger co-movements. These findings imply that growing co-movements are the consequence of autonomous decisions at the market rather than that of management by governments or central banks.

Keywords: Currency Co-movements, Renminbi, Trade Linkage, Financial Linkage, Exchange Rate Regime
JEL Classification: F31, F33, F36

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I. INTRODUCTION

China has increased its influence on the global economy in the real sector, such as production and trade. Recently, many studies report that the renminbi (RMB), the currency of China, also exerts strong influences on the value of other currencies, particularly in Asia. These influences are confirmed by growing exchange rate co-movements between the RMB and other currencies, shortly currency co-movements with the RMB. Discussions on the growing influence of the RMB lead to debates on the possibility of a regional RMB bloc and, further, of becoming an international vehicle currency in the future. These discussions are much akin to those on the formation of the yen bloc in Asia examined in Frankel and Wei (1994).

However, it should be noted that the degrees of currency co-movements with the RMB vary across countries. Within Asia, for instance, Kawai and Pontines (2016, Table 1) show that the co-movements with the RMB in the Philippines is much weaker than in Korea. Moreover, the co-movements witness significant variations in their degree over time. In particular, after the global financial crisis of 2008, the degree has grown in many countries.[1] This study goes further by examining what factors affect the magnitude of the currency co-movements with the RMB.

The theory of optimum currency areas (OCA) suggested by Mundell (1961) can be the starting point for this study. A common currency area is a currency bloc where member countries share a single currency or where the value of the currency in all member countries is pegged to an anchor currency to make perfect co-movements each other. Mundell (1961)'s model and its extended versions suggest several criteria for an optimum currency area (currency pegging or perfect currency co-movement) such as labor mobility, capital mobility, and trade.

Under these theoretical frameworks, we conduct empirical analyses to examine the underlying factors of currency co-movements using country panel data. The results provide the implications on the possibility for the RMB to form a currency bloc and more to be an international currency. Our findings are as follows. First, in many economies, their currencies witnessed significantly stronger co-movements with the RMB after the 2008 Global financial crisis (GFC). Second, bilateral trade linkage with China has a positive association with the currency co-movement with

[1] Please refer to Kawai and Pontines (2016, Figure 1) and our own results: Table 1 and Figure 1.

the RMB, which is in line with the previous studies. Third, bilateral financial linkage proxied by portfolio investment in and out of China turns out to relate to the currency co-movement despite still tight controls over the investment. Previous literature discussed little in the roles of financial linkage with China due to a lack of data. Thus, our findings are noble and critically contribute to the literature. Fourth, economies with greater flexibility in exchange rate regimes show stronger currency co-movements with the RMB. This finding implies that growing co-movements are the consequence of autonomous decisions at the market rather than that of management by governments or central banks, which is also distinct from the conventional wisdom. Last, currency co-movement is not restricted to China's neighboring countries or the Asian region. This global co-movement suggests that the RMB is more likely to become an international currency than to form a regional currency bloc in the future.

Section 2 calculates the degree of currency co-movement with the RMB and shows the growing influences of the RMB on the value of other currencies. Section 3 discusses the theoretical framework and the possible underlying factors of the currency co-movement. Section 4 explains the empirical model and the data for analyses. Section 5 presents the empirical results and interprets the main findings. Finally, section 6 concludes the paper.

II. GROWING CURRENCY CO-MOVEMENTS WITH THE RMB

Frankel and Wei (1994) develop a model to estimate the weights of international reference (or anchor) currencies in implicit or explicit currency baskets. In their model, a movement of a country's exchange rate depends on international currencies' movements, and the estimated coefficients are widely interpreted as the magnitude of influence (or currency co-movements) of each currency. Subramanian and Kessler (2013) and Kawai and Pontines (2016) estimate the influence of the RMB on other currencies by including the RMB movements in the right-hand side of Frankel and Wei (1994) model. In equation (1), similar to their methodology, we estimate currency co-movements with the RMB.

$$\Delta em_t^i = \alpha^i + \beta_R^i \Delta RMB_t + \beta_E^i \Delta EUR_t + \beta_J^i \Delta JPY_t + \beta_U^i \Delta USD_t + \beta_V^i \Delta VIX_t + \varepsilon_t^i \quad (1)$$

where Δem_t^i is the exchange rate returns of a country's currency i at time t. The equation (1) is estimated at each currency i. The model includes exchange rate returns of four international reference currencies on the right-hand side: Yuan (RMB), Euro (EUR), Japanese Yen (JPY), and US dollar (USD). The exchange rates are measured against a common numeraire. We adopt the Swiss franc (CHF) as the numeraire to control for the influence of the USD. We also control for the effects of global financial uncertainty by including the changes of VIX (the Chicago board options exchange volatility index). The daily returns of exchange rates and VIX (Δem_t^i, ΔRMB_t, ΔEUR_t, ΔJPY_t, ΔUSD_t, and ΔVIX_t) are the log differences of them. The coefficients of major currencies measure the degree of co-movement between each reference currency and a counterpart currency. Therefore, β_R^i is the RMB co-movement coefficient of currency i. In our analysis, thirty-four currencies' co-movements with the RMB are calculated using the equation (1).[2]

Kawai and Pontines (2016) point out that the equation (1) embeds the problem of multicollinearity due to a strong correlation between the movements in the US dollar and the RMB when the RMB was pegged to the US dollar. Thus, when estimating the coefficients, we choose only periods when the RMB was not pegged to the US dollar. In July 2005, China changed to the managed exchange rate regime from the fixed peg. However, during the GFC, the RMB was temporarily re-pegged to the USD. The un-pegged periods are from July 2005 to June 2008 for the pre-GFC and July 2010 to December 2018 for the post-GFC.

First, we determine whether there is a significant change in co-movements before and after the GFC for our sample currencies. Table 1 columns (1)-(2) show β_R^i before and after GFC of all currencies in the sample and the last column presents the difference of β_R^i between them. The majority of the currencies show stronger co-movements with the RMB after the GFC. Twenty-eight currencies show the statistical significance in positive co-movement, and eighteen currencies

[2] We obtain daily exchange rates from the BIS (the Bank for International Settlements) website. Initially, the BIS data covers 60 countries excluding Eurozone. Among them, we exclude 15 currencies that are pegged to other currency. Pegged currencies have only one currency, anchor, say the US dollar, in their currency basket, which has 100% weight. Thus, the RMB's weight in those currencies is zero. Moreover, six currencies with few observations are dropped. After taking out the five international currencies (RMB, EUR, JPY, USD, CHF) in the regressions, 34 currencies' co-movements with the RMB are estimated.

increase the value of coefficients, maintaining the significance. Polish zloty and Israeli new shekel lessen the co-movements with the RMB significantly. Besides, we calculate co-movement coefficients ($\beta_R^{i,qtr}$) in each quarter to present the dynamics of the co-movement with the RMB. Later, we construct the thirty-four country (currency) panel data using the time-varying co-movement coefficients and other variables. Figure 1 displays the trend of the quarterly co-movement coefficients for eight selected currencies in different regions. They all show steadily positive values after the GFC. However, as we discussed in the previous section, the dynamics of the co-movement with the RMB vary across economies.

Table 1. Currency Co-Movements with the RMB: The Pre/Post-GFC Periods

	Economy	Currency	2005Q3~2008Q2 $\beta_R^{i,preGFC}$ (a)	2010Q3~2018Q4 $\beta_R^{i,postGFC}$ (b)	(b)-(a)
1	South Korea	Korean won	0.172 [1.20]	0.740[11.41]***	0.568
2	Russia	Russian rouble	0.052 [1.09]	0.524 [3.76]***	0.472
3	Chinese Taipei	New Taiwan dollar	0.054 [0.56]	0.452 [12.99]***	0.398
4	United Kingdom	Pound sterling	0.042 [0.37]	0.421 [6.96]***	0.379
5	Malaysia	Malaysian ringgit	0.051 [0.57]	0.426 [7.22]***	0.376
6	South Africa	South African rand	0.580 [1.63]*	0.887 [7.53]***	0.308
7	Canada	Canadian dollar	0.129 [0.71]	0.369 [5.71]***	0.241
8	India	Indian rupee	0.140 [1.10]	0.364 [5.98]***	0.225
9	Australia	Australian dollar	0.367 [2.26]**	0.579 [7.35]***	0.213
10	New Zealand	New Zealand dollar	0.243 [0.93]	0.415 [4.90]***	0.173
11	Mexico	Mexican peso	0.282 [1.35]*	0.442 [4.55]***	0.161
12	Peru	Peruvian sol	0.030 [0.33]	0.189 [4.99]***	0.159
13	Brunei	Brunei dollar	0.245 [2.73]***	0.399 [8.18]***	0.154
14	Indonesia	Indonesia rupiah	0.315 [1.43]*	0.462 [7.50]***	0.148
15	Norway	Norwegian krone	0.127 [0.85]	0.253 [3.78]***	0.126
16	Philippines	Philippine peso	0.150 [1.15]	0.253 [6.10]***	0.104
17	Turkey	Turkish lira	0.413 [1.30]*	0.474 [4.09]***	0.061
18	Brazil	Brazilian real	0.450 [1.05]	0.502 [4.07]***	0.053
19	Chile	Chilean peso	0.135 [0.71]	0.133 [1.55]*	-0.003
20	Hungary	Hungarian forint	0.140 [0.67]	0.136 [2.22]**	-0.004
21	Thailand	Thai baht	0.364 [1.66]**	0.349 [9.83]***	-0.016

Table 1. Continued

	Economy	Currency	2005Q3~2008Q2 $\beta_R^{i,preGFC}$ (a)	2010Q3~2018Q4 $\beta_R^{i,postGFC}$ (b)	(b)-(a)
22	Singapore	Singapore dollar	0.425 [5.79]***	0.387[11.13]***	-0.038
23	Poland	Polish zloty	0.302 [1.52]*	0.179 [3.37]***	-0.124
24	Israel	Israeli new shekel	0.323 [1.70]**	0.149 [2.93]***	-0.174
25	Iceland	Iceland krona	0.413 [1.05]	0.206 [3.10]***	-0.207
26	Serbia	Serbian dinar	0.502 [2.06]**	0.250 [3.68]***	-0.253
27	Sweden	Swedish krona	-0.153 [1.29]	0.229 [4.10]***	0.382
28	Kazakhstan	Kazakhstan tenge	-0.123 [0.42]	0.193 [1.39]*	0.316
29	Argentina	Argentine peso	-0.036 [0.26]	0.136 [0.89]	0.171
30	Sri Lanka	Sri Lanka rupee	0.009 [0.09]	0.037 [1.01]	0.029
31	Czech Republic	Czech koruna	-0.019 [0.17]	0.008 [0.22]	0.027
32	Pakistan	Pakistan rupee	0.007 [0.05]	0.017 [0.29]	0.011
33	Colombia	Colombian peso	0.243 [1.28]	0.085 [0.83]	-0.159
34	Nepal	Nepalese rupee	0.510 [1.56]*	-0.039 [0.48]	-0.549

Note: The regression for each country follows the equation (1) for each sample period. The first section presents currencies based on (b)-(a) ranking, and both (a) and (b) are positive. This table reports only β_R^i to save spaces. [ ] shows t-values of β_R^i. *, **, and *** indicates 10%, 5%, and 1% significance level. Source: Authors' calculation

Figure 1. Trend of Currency Co-Movements with the RMB in Selected Economies

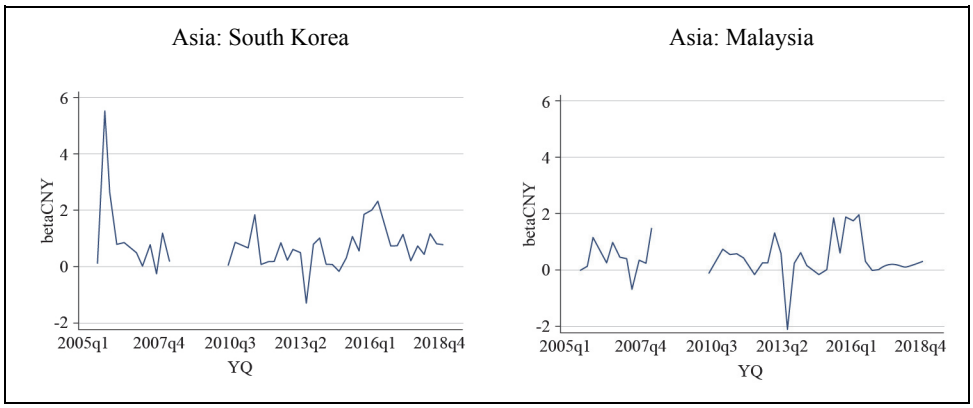
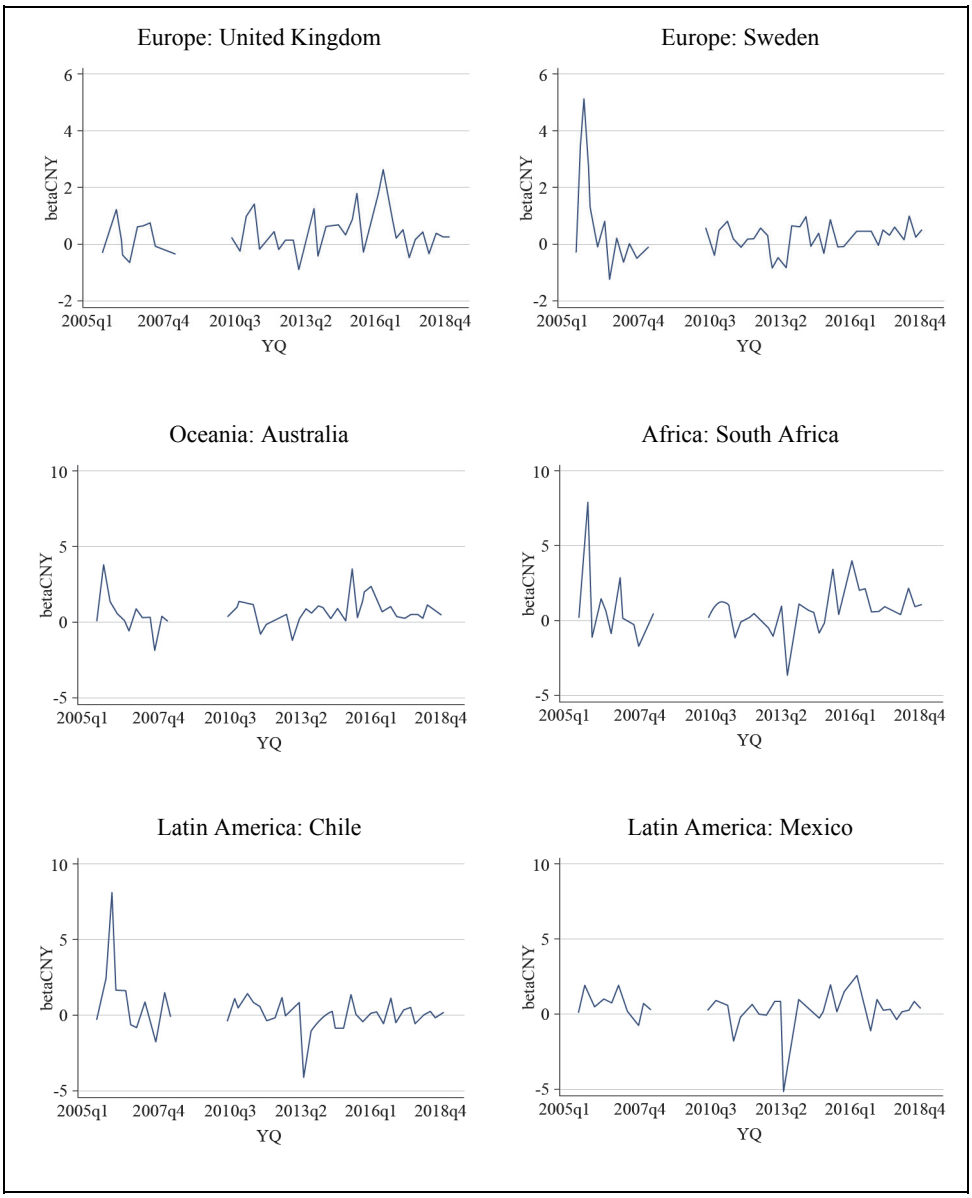


Figure 1. Continued



Source: Authors' calculation

III. THEORETICAL FRAMEWORK

As found in section 2, previous studies also observe growing co-movements with, or stronger influences of the RMB on many other currencies in the recent years (Ito, 2010; Pontines and Siregar, 2012; Shu et al., 2015; McCauley and Shu, 2019; Keddad, 2019). Some conclude that beyond merely stronger co-movements, an RMB bloc has been emerging in Asia. This RMB block discussion means that the RMB became the dominant currency, by its weight exceeding the weight of the US dollar in implicit or explicit currency baskets of some Asian economies (Ho et al., 2005; Henning, 2012; Fratzscher and Mehl, 2014). On the contrary, others present evidence that the RMB is still less influential than the US dollar in most Asian economies, although it is more influential than before. That is, a renminbi bloc is too early to tell (Kawai and Pontines, 2016; Kim et al., 2018).

All the studies present the evidence of growing co-movements with the RMB, albeit to a different degree, but few studies explain what causes growing currency co-movements. Neither examines why currencies show different magnitudes in the currency co-movement. Just some studies conjecture that China's growing trade share over time and different geographical distance to China among countries could determine the magnitudes. This study aims to fill this gap through a rigorous empirical analysis.

The majority of previous studies tend to explain the currency co-movement with trade linkage between countries. Frankel and Wei (1994) first examined if a yen bloc was created by calculating the weight assigned to the Japanese yen in the currency baskets of the Asian economies. They assumed that Japan's increased trade shares would lead to the increased weight of the yen, producing stronger currency co-movements. This assumption is based on the idea that massive trade partners of Japan want to stabilize exchange rates by linking their currencies to the yen. Although they did not find the trade linkage effects for the yen, the idea to relate the currency co-movement to bilateral trade linkage remains steady. Some attempt to explain higher weights of the RMB in the currency baskets of Asian countries with China's increased trade shares in the region (Eichengreen and Lombardi, 2017; Kim et al., 2018; Keddad, 2019). Their rationales are also based on the same idea in Frankel and Wei (1994), i.e., the stabilization of the value of the currency against the primary trade partner. However, they present supposition without empirical evidence. Fratzschner and Mehl (2014) is the only study that

attempts to find underlying causes of the growing influence of the RMB through data analysis. Their results from a cross-country analysis show an inconsistent relationship between trade or finance linkages and China's currency influence, measured as the responsiveness to China's exchange rate policies.

The scarcity of empirical studies on the underlying causes of the currency co-movement relates to the absence of an established theory on that issue. Before theories are developed, it is appropriate to start from discussions of the OCA theory. According to the OCA theory, an important determinant of whether a country participates in a common currency area is the potential reduction in transaction costs. In a currency bloc, a relaxed version of the common currency area, an anchor currency is chosen, and then, the values of other currencies perfectly co-move with that of the anchor currency. Although this anchor currency example is an extreme case of the currency co-movement, the determinants of the choice of an anchor currency are likely similar to underlying causes of the currency co-movement. Following the OCA theory, the studies on the currency bloc assume that currency to minimize the transaction costs is determined as an anchor. The transaction costs include the cost due to the uncertainty of exchange rates. Therefore, it is optimal for a member country to choose the currency of its largest trading partner. Such a choice can also alleviate the difficulties from the limited autonomy of the monetary policy due to currency pegging because strong bilateral trade linkage produces synchronized business cycles between two countries.

Consequently, the currency of the largest trade partner will be the anchor for other currencies in a peg system or a currency bloc and be the currency with which other currencies highly co-move in floating exchange rate regimes. This trade linkage effect creates network externalities or positive feedback effects to incentivize the third country to participate in the currency bloc (Yehoue, 2004). This approach is in the same line with Frankel and Wei (1994). This transaction cost approach can be extended to financial linkage effects, suggesting that the currency of a country with more financial transactions is more likely chosen as an anchor.

Following this theoretical framework, some empirically study on the determinants of anchor currency choice and participation in a currency bloc. Meissner and Oomes (2009) and Fischer (2016) examine the dollar and former European currencies such as the Mark and the Franc as anchor currencies and find consistent and expected results on trade linkage. For financial linkage, however, Meissner and Oomes (2009) only find ambiguous results.

Given a limited number of previous empirical works, this study contributes to the literature by examining which underlying factors affect the co-movement with a currency in question, i.e., the RMB. We mainly focus on trade and financial linkages, following the theoretical framework of transaction costs.[3] A country that has stronger trade or financial linkage with China is expected to reveal greater co-movements with the RMB. In the analysis, we control for inflation rates and interest rates because they also affect exchange rates in non-fixed exchange rate regimes. If a country's monetary policy is highly synchronized with China's to produce similar variations in inflation rates and interest rates, two countries will show strong currency co-movements, *ceteris paribus*. Therefore, we examine the effects of trade and financial linkages controlling for the similarity in monetary policies.

IV. EMPIRICAL METHODOLOGY

1. Model

In this section, we mainly focus on the roles of trade and finance linkages with China in the currency co-movements with the RMB, as discussed in section 3. The empirical analysis employs a country-panel data model that can measure two aspects of panel data relationship: time-varying and time-invariant factors. First, main regressors such as trade and finance linkages with China have dramatically increased since the GFC. Moreover, Table 1 confirms the time-variant changes of currency co-movements with the RMB. The panel data represents those time-varying effects. Second, unobserved time-invariant factors (such as culture, history, etc.) can influence the roles of trade and finance linkages with China. We consider those relationships in empirical models by applying the country-panel data.

In the analysis, we employ the Driscoll and Kraay (1998)'s nonparametric covariance matrix estimator. The Driscoll and Kraay (1998) estimator produce heteroscedasticity consistent standard errors when there is cross-sectional and temporal dependence, which is the characteristics of our country panel data. Driscoll

[3] The variable of business cycle correlations, a determinant of the OCA formation, is deliberately not included in our estimations, considering very high correlations between trade links and business cycle synchronization (Frankel and Rose, 1998, etc.)

and Kraay's standard errors are adjusted for country-pair-level heteroskedasticity and autocorrelation. The base empirical model for estimation is:

$$C_{i,t} = a + \mathrm{b}T_{i,t} + cF_{i,t} + \sum_{k=1} d_k Z_{i,t}^k + \mu_{i,t} \quad (2)$$

In equation (2), $C_{i,t}$ is the RMB weight at time t of country i currency's basket among reference international currencies or country i currency's co-movement with the RMB in time t. We calculate $C_{i,t}$ (which is also $\beta_R^{i,t}$ in section 2) using the daily BIS nominal exchange rates dataset. We choose the quarterly frequency 1) because higher frequency such as monthly or daily requires overlapping window between time intervals in equation (1) regressions, and 2) the available high frequency of economic variables is quarterly. $T_{i,t}$ and $F_{i,t}$ are trade and financial linkages. $Z_{i,t}^k$ is a vector of control variables which will be discussed later in this section. The quarterly country panel data with C_{it} and other variables covers thirty-four counties. The list of countries is in Table 1. The analysis period is from 2010 Q3 to 2018 Q4 when the RMB is relatively flexible. Once the RMB was pegged to the US dollar, the co-movement with the RMB indicated the co-movement with the US dollar. Thus, we exclude the period when the RMB exchange rate regime is pegged to the US dollar. After the GFC, China went back to the managed floating exchange regime system and steadily expanded the range of RMB per US dollar movement. Moreover, in August 2015, China officially announced the adoption of a multiple currency basket system. Thus, it is reasonable to proceed with empirical analysis using the sample period after the GFC.

2. Trade and Financial Linkages

The absence of studies on determinants of currency co-movement contrasts with abundant studies on business cycle co-movement (Ductor and Leiva-Leon, 2016, etc.). Given few studies on the former, this paper applies the discussions on business cycle co-movement to the currency co-movement. As major determinants or channels of business cycle co-movement, trade and financial linkages have been examined carefully (Frankel and Rose, 1998; Kose et al., 2003; Imbs, 2004; Shin and Sohn, 2006; Pyun and An, 2016).

$T_{i,t}$ is the bilateral trade linkage between a country i and China which is measured as the sum of exports and imports of the country i with China to its total

trade.[4] The subscript, China, is omitted for simplicity of expression. We obtain the bilateral trade data from monthly IMF (International Monetary Fund), DOT (Direction of Trade) and aggregate the data to quarterly.

$$T_{i,t} = T_{i,China,t} = \frac{Exports_{i,China,t}+Imports_{i,China,t}}{Exports_{i,t}+Imports_{i,t}} \quad (3)$$

We can expect that an economy with a more profound trade linkage to China will show stronger currency co-movement because it is much affected by the Chinese economy. Many studies find that bilateral trade linkage causes the business cycle synchronization with an increased intra-industry trade (Shin and Sohn, 2006; Inklaar et al., 2008; Duval et al., 2016). The synchronization of the business cycle, a fundamental factor of exchange rates, may lead to the currency co-movement.

$F_{i,t}$ is the bilateral financial linkage between a country i and China. The bilateral financial linkage is measured using cross-country asset positions. IMF (International Monetary Fund) reports direct investment asset positions from CDIS (Coordinated Direct Investment Survey) and portfolio investment asset positions from CPIS (Coordinated Portfolio Investment Survey). We employ two variables as a proxy for bilateral financial linkage: bilateral foreign direct investment holdings ($FDI_{i,t}$) and portfolio investment holdings ($PORT_{i,t}$) with China. $FDI_{i,t}$ is the sum of outward and inward direct investment positions of country i with China over the total direct investment of the country i. $PORT_{i,t}$ is the sum of assets and liabilities holdings of country i with China over total portfolio investment of the country i following Pyun and An (2016).

$$FDI_{i,t} = FDI_{i,China,t} = \frac{Outwards_{i,China,t}+Inwards_{i,China,t}}{Outwards_{i,t}+Inwards_{i,t}} \quad (4)$$

$$PORT_{i,t} = PORT_{i,China,t} = \frac{Assets_{i,China,t}+Liabilities_{i,China,t}}{Assets_{i,t}+Liabilities_{i,t}} \quad (5)$$

[4] One might suggest to use GDP instead of total trade in normalizing the bilateral trade linkage. In our robustness tests, we calculate the bilateral trade over GDP and find similar results. However, when using the bilateral trade over GDP, we find that trade and economic variables over GDP are highly correlated. To avoid the multicollinearity issues, we mainly report results using the bilateral trade as a percentage of total trade.

A deep financial linkage or more capital holdings will affect the degree of currency co-movement, similar to the trade linkage effect.

3. Control Variables

We consider other potential determinants such as the similarity of monetary policy, the flexibility of the exchange rate system in China and counterpart economies, and financial risk in China. The subscripts, i and t, are omitted for simplicity of expression.

The similarity of monetary policy: Because exchange rates are affected by interest rate and inflation rate, it is fair to assume that their co-movement also positively correlates to the similarity in monetary policy among economies. As a proxy of the policy co-movement, we use the similarity of interest rates and inflation rates between China and country i. The similarity of interest rate (*INT*) is the absolute value of interest rate change differences between China and country i, using 90 days interest rates from IMF IFS (International Financial Statistics) database and several central banks' websites. The similarity of inflation rate (*INF*) is the correlation coefficients with a twelve-month rolling window, using inflation rates based on the Consumer Price Index from IMF IFS and central banks websites.

The flexibility of the exchange rate system: Flexibility of exchange rate possibility affects the co-movement, but it is hard to predict the direction in theory. It could affect the co-movement negatively if the currencies co-move due to the engagement by the government in the exchange markets. On the other way around, a more flexible exchange rate system could make two currencies closer due to the investors' activities in the exchange markets. Ilzetzki et al. (2019) provide exchange rate regime classifications (1~13) from no separate legal tender or currency union to freely floating using de factor exchange rate arrangements. We adopt their regime classification of country i (*REG*) in the analysis. Please see Appendix Table A1 for detailed classification.

Financial risk in China: The level of financial uncertainty or risk in China may affect the co-movement. For instance, we can expect that over-credit in China increases financial risk, leading counterpart economies to respond to the RMB fluctuations more sensitively. We measure the risk as a non-public credit to GDP ratio gap from BIS (*CRISK*).

Trade openness: The extent to which a counterpart country is exposed or opened to the global market possibly affects the co-movement. A trade-opened economy will be more sensitive to external factors, among which are the global and Chinese export market conditions. However, it is uncertain in which direction the global integration in an economy affects its currency co-movement with the RMB. We measure the trade openness level as total trade to GDP ratio (*TOPEN*).

Financial openness: Like trade openness, a financially open economy is more exposed to external factors including the RMB exchange rate but, simultaneously, has better abilities to hedge external shocks, as suggested by Kalemli-Ozcam et al. (2001). Thus, it is also uncertain whether the global financial integration strengthens or weakens the currency co-movement. We measure the financial openness level as a total portfolio investment to GDP ratio (*FOPEN*).

Unobserved country heterogeneity: There may be unobserved country-specific linkages with China, such as geographical distance. To take them into account, we examine country-fixed effects as control variables.

Table 2 presents the summary statistics of the variables described above. The number of observations with non-missing *C*, *T*, and *FDI* values is 1,081. *PORT* has some missing observations. China's cross-border portfolio investment holdings data is indirectly collected from 2010Q3 to 2014Q4. In 2010, 37 countries voluntarily reported their assets and liabilities with China, and in 2014, the number of countries increased to 67. We obtain their voluntary reporting data from 2010 to 2014. Since 2015, China has reported its cross-border holdings to the IMF. Few countries do not provide monthly CPI or interest rates. Thus, *INT* and *INF* also show fewer observations. The ranges of *C* or *Cus* are approximately between -1.6 and 0.6. The correlation coefficients in Panel B suggest that *C* and *Cus* are highly correlated at 0.81 coefficient. The trade linkage (*T*) is slightly correlated with financial linkage measures (*FDI* and *PORT*).

Table 2. Summary Statistics and Correlation Coefficients

Panel A. Summary Statistics

	Variables	Unit	N	Mean	SD	P5	P25	P50	P75	P95
1)	*C*	-	1,081	0.27	0.55	-1.55	-0.58	-0.05	0.21	0.57
2)	*Cus*	-	1,081	0.27	0.45	-1.18	-0.42	0.01	0.21	0.52
3)	*T*	%	1,081	12.06	6.67	3.68	6.15	11.66	16.32	24.06
4)	*FDI*	%	1,081	6.94	13.38	0.04	0.28	1.33	5.55	33.45
5)	*PORT*	%	845	1.58	2.79	0.00	0.04	0.23	1.54	8.45
6)	*INT*	%	851	0.67	0.61	0.02	0.20	0.53	0.99	1.74
7)	*INF*	-	991	0.10	0.50	-0.72	-0.32	0.13	0.53	0.85
8)	*TOPEN*	%	1,081	16.82	11.67	6.34	9.77	12.68	19.77	39.53
9)	*FOPEN*	%	903	55.43	73.95	0.14	3.89	31.72	77.94	245.58
10)	*REG*	-	1,081	14.62	6.40	3.60	9.50	16.00	20.80	23.00
11)	*CRISK*	%	1,041	10.40	2.05	7.00	8.00	11.00	12.00	13.00

Panel B. Correlation Coefficients

	Variables	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)
1)	*C*	1									
2)	*Cus*	0.81	1								
3)	*T*	0.16	0.18	1							
4)	*FDI*	0.13	0.16	0.52	1						
5)	*PORT*	0.12	0.15	0.32	0.42	1					
6)	*INT*	0.09	0.06	0.03	-0.05	-0.06	1				
7)	*INF*	0.09	0.01	-0.01	0.10	0.02	-0.12	1			
8)	*TOPEN*	-0.08	-0.09	-0.20	0.20	0.03	-0.07	0.01	1		
9)	*FOPEN*	0.00	-0.02	-0.32	-0.02	-0.02	-0.11	0.18	0.20	1	
10)	*REG*	0.13	0.15	0.26	0.03	-0.17	0.02	0.10	-0.33	0.33	1
11)	*CRISK*	0.09	0.04	-0.06	-0.03	0.08	0.01	-0.04	-0.05	0.00	-0.04

Note: This table reports descriptive statistics of variables. The sample is country-quarter observations from 2010Q3 to 2018Q4 of 34 countries. *C* and *Cus* are the currency co-movements with the RMB of the exchange rate per Swiss franc and US dollar, respectively. The definitions of other variables are explained in the main text. Panel A shows the distribution of these variables. SD is the standard deviation, and P5 is the data point at 5% distribution. Panel B shows the correlation coefficients.

V. EMPIRICAL RESULTS AND DISCUSSIONS

1. Results from FDI Stocks as Financial Linkage

Table 3 shows the results from pooled OLS models where the shares of China in total trade and FDI (foreign direct investment) are used as the indicators of trade and financial linkages, respectively. Model (1) ~ (3) show positive and significant coefficients for trade linkage, meaning that a country that trades with China more as a percentage of total trade shows stronger currency co-movements with the RMB. This outcome is consistent with the theories of OCA and the anchor currency choice. However, it is notable that bilateral FDI stocks turn out to be not significant in explaining the currency co-movement. To check the sensitivity of the results, model (4) ~ (6) incorporate control variables. The control variables for the similarity of monetary policies, i.e., differences of changes in interest rates (*INT*) and inflation rates correlation coefficients (*INF),* do not change the sign and significance of *T*. The coefficient of *INF* shows significantly positive coefficients, which means expectedly stronger currency co-movements in a country whose monetary policies are more homogeneous with China's.

As well, we note that the degree of currency co-movement can also be affected by the flexibility of exchange rate regimes in China and counterpart countries. Model (5) and (6) control for this effect. We use *de facto* exchange rate arrangements of Ilzetzki et al. (2019) to measure the flexibility of exchange rates in counterpart countries. Ilzetzki et al. (2019) classify the regimes into 13 groups, which are expressed as a categorical variable, *REG*. A higher value of *REG* represents greater flexibility of exchange rate regimes.[5]

[5] Appendix Table A1 explains the classification in detail.

Table 3. Trade and FDI: Pooled OLS

Models	(1)	(2)	(3)	(4)	(5)	(6)
Variables		*Base*		*Monetary policies*	*Exchange rate regimes*	*China's basket regime*
T	0.084***		0.083***	0.159***	0.098***	0.066**
	(0.022)		(0.021)	(0.042)	(0.035)	(0.032)
FDI		0.011	0.005	-0.052**	-0.018	-0.013
		(0.007)	(0.007)	(0.019)	(0.023)	(0.024)
INT				0.824	0.903	1.136
				(0.728)	(0.716)	(0.761)
INF				1.157**	0.952*	1.291**
				(0.504)	(0.500)	(0.485)
REG					0.412*	0.424*
					(0.204)	(0.210)
CREG						1.826**
						(0.861)
CRISK	0.083	0.082	0.083	0.073	0.082	0.093*
	(0.064)	(0.065)	(0.064)	(0.061)	(0.063)	(0.053)
Constant	0.456	1.399*	0.439	-0.492	-4.420*	-5.273**
	(0.806)	(0.773)	(0.814)	(1.135)	(2.353)	(2.572)
Obs.	1,081	1,081	1,081	792	752	752
Adj. R^2	0.019	0.01	0.019	0.045	0.058	0.081

Note: Driscoll-Kraay (1998) standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1

With regard to the flexibility of the RMB exchange rates, China returned to the managed floating system after the GFC and widened the daily fluctuation band from ±0.5% to ±2.0% step by step. The most notable shift appeared in August 2015 when the People's Bank of China (PBC) announced a transition to the *de facto* currency basket system for greater flexibility of exchange rates and departure from the dollar only linked system. Thus, we compare currency co-movements before and after this transition using a dummy variable, *CREG*.

REG has significantly positive coefficients to demonstrate that a country with greater exchange rate flexibility has stronger currency co-movements with the RMB. Next, *CREG* also shows a significantly positive coefficient, which means more synchronized movements between the RMB and other currencies after the transition to the basket system in China. In sum, the trade effect mostly remains significant even after controlling for other factors, whereas *FDI* is not associated with the currency co-movement. The positive trade effect is consistent with the

previous studies on the choice of anchor currencies and the formation of currency blocs.

Table 4. Trade and FDI: Fixed Effects

Models	(1)	(2)	(3)	(4)
Estimation	*Time FE*	*Time FE*	*CTY FE*	*CTY FE*
Variables	*Monetary policies*	*Exchange rate regimes*	*Monetary policies*	*China's basket regime*
T	0.143***	0.075**	0.141	-0.135
	(0.044)	(0.032)	(0.119)	(0.127)
FDI	-0.036*	0.002	-0.040	-0.042
	(0.021)	(0.022)	(0.049)	(0.051)
INT	0.723	0.834	1.032	1.256*
	(0.527)	(0.521)	(0.690)	(0.702)
INF	0.750**	0.582*	0.985	1.189**
	(0.330)	(0.319)	(0.641)	(0.563)
REG		0.448**		
		(0.210)		
CREG				2.382**
				(1.010)
CRISK	0.255***	0.086	0.070	0.095
	(0.007)	(0.088)	(0.065)	(0.056)
Constant	0.048	-4.023	-0.436	1.164
	(0.579)	(0.000)	(1.686)	(1.405)
Obs.	792	752	792	792
Adj. R^2	0.223	0.240	0.027	0.06

Note: Driscoll-Kraay (1998) standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1

Table 4 displays the results from fixed-effect models that control for time-specific or country-specific heterogeneity. Model (1) and (2) apply time-fixed effects assuming that there are common factors all the countries encounter in each quarter. This assumption is relevant because China frequently introduced slight changes in its exchange rate policies or big devaluations to which all other currencies were commonly exposed. Therefore, it is reasonable to consider these unobserved time-specific factors. In model (1), *T* has a significant and positive coefficient, but *FDI*

does not, which is the same results from the pooled OLS.[6] In the country-fixed effects model (3) and (4), *T* loses the significance and has a negative sign with the basket dummy added. The country-fixed effects may proxy for time-invariant country factors such as physical distance with China, sharing similar cultures, language barriers, and so on. These factors are well-known determinants of bilateral trade. Thus, the country-fixed effects models might not be appropriate to be used for the trade linkage variable. From the next results, we will focus more on the time-fixed effects models.

2. Results from Portfolio Investment Stocks as Financial Linkage

In recent decades, China has rapidly increased FDI in overseas infrastructure and natural resource sectors, while in the opposite direction, foreign countries have carried out voluminous FDI in China to utilize its vast market and cheap labor. These FDI flows are part of long-term investment and deeply linked to real sectors, which possibly leads to a concern that *FDI* may not fully reflect bilateral financial linkage. Therefore, we introduce bilateral portfolio investment stocks as a proxy for financial links. Although China still controls over capital flows, particularly portfolio investment and international loans heavily, it has gradually liberalized portfolio investment for the last two decades. Thus, we suppose that portfolio investment (*PORT*) can be a better indicator of financial linkages than *FDI* because it is more volatile and closer to the nature of finance.

In Table 5, all the results are the same as the previous ones, except for portfolio investment stocks. Different from *FDI*, *PORT* shows consistently significant and positive coefficients. This finding means that more bilateral portfolio investment with China leads to stronger currency co-movements with the RMB. This result remains unchanged after controlling for other variables. The coefficients of *PORT* are larger than those of *T*. We can interpret that cross-border portfolio investments have a greater impact on co-movements than trade with a change of the same percentage. Table 6 shows the results from the fixed-effect model, and *PORT* remains significant.

[6] The exchange rate regime is time-varying variable in principle, but it is actually time-invariant because few countries changed their exchange rate regimes in the sample period. Thus, we don't include the variable in country-fixed effect models.

Table 5. Trade and Portfolio Investment: Pooled OLS

Models	(1)	(2)	(3)	(4)	(5)	(6)
Variables		*Base*		*Monetary policies*	*Exchange rate regimes*	*China's basket regime*
T	0.084***		0.096***	0.139***	0.097**	0.067**
	(0.022)		(0.028)	(0.046)	(0.039)	(0.033)
PORT		0.235***	0.197***	0.141**	0.209**	0.222**
		(0.063)	(0.063)	(0.069)	(0.085)	(0.091)
INT				0.970	0.973	1.302
				(0.842)	(0.841)	(0.890)
INF				1.168*	1.040*	1.509**
				(0.579)	(0.576)	(0.589)
REG					0.385**	0.375*
					(0.173)	(0.186)
CREG						2.403**
						(1.095)
CRISK	0.083	0.084	0.085	0.082	0.083	0.102
	(0.064)	(0.075)	(0.074)	(0.078)	(0.078)	(0.064)
Constant	0.456	1.273	0.160	-0.737	-4.512*	-5.571**
	(0.806)	(0.942)	(0.995)	(1.364)	(2.387)	(2.731)
Obs.	1,081	845	845	643	637	637
Adj. R^2	0.019	0.023	0.034	0.056	0.068	0.105

Note: Driscoll-Kraay (1998) standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1

It is a noble finding of our study that *PORT* is an underlying factor of the currency co-movement because the previous studies on the currency pegging or currency blocs considered only trade links. As expected, portfolio investment stocks appear to be a better indicator of financial linkage than FDI stocks. As well, stronger currency co-movements under greater exchange rate flexibility and in the post-basket period are also reconfirmed in the estimations using portfolio investments. Later this section, we discuss these findings in detail.

Table 6. Trade and Portfolio Investment: Fixed effects

Models	(1)	(2)	(3)	(4)
Estimation	*Time FE*	*Time FE*	*CTY FE*	*CTY FE*
Variables	*Monetary policies*	*Exchange rate regimes*	*Monetary policies*	*China's basket regime*
T	0.134**	0.094**	0.295	-0.227
	(0.052)	(0.042)	(0.243)	(0.216)
PORT	0.127**	0.195**	0.262*	0.245*
	(0.060)	(0.079)	(0.132)	(0.140)
INT	0.732	0.713	1.129	1.430
	(0.542)	(0.509)	(0.877)	(0.899)
INF	0.933***	0.789**	1.177	1.467**
	(0.328)	(0.317)	(0.756)	(0.697)
REG		0.372*		
		(0.186)		
CREG				3.088**
				(1.147)
CRISK	0.295***	0.158*	0.076	0.104
	(0.009)	(0.091)	(0.076)	(0.062)
Constant	0.365	-3.186	-2.596	1.092
	(0.751)	(0.000)	(3.404)	(2.845)
Obs.	643	637	643	643
Adj. R^2	0.305	0.317	0.038	0.083

Note: Driscoll-Kraay (1998) standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1

3. Robustness Tests

There is a concern that multicollinearity can arise between the weights of anchor currencies calculated following Frankel and Wei (1994) when the Swiss franc or the SDR is used as numeraire. In particular, the RMB may have multicollinearity with the US dollar because the RMB was pegged to the US dollar for a long time and, after allowed to fluctuate, carefully managed to be stable against the dollar. To include both the RMB and the US dollar on the right-hand side of the equation may produce multicollinearity, which leads to the overestimated weight of the RMB (Ho et al., 2005; Fratzscher and Mehl, 2014; Kawai and Pontines, 2016). Confining the sample to the period for the RMB to float cannot be enough. As

numeraire, therefore, we use the US dollar instead of the Swiss franc and re-calculate the weight of the RMB or the co-movement coefficients, following Ho et al. (2005).

Table 7 displays the results from the regressions using the recalculated weights of the RMB. The effects of trade linkages are the same as the earlier results, though they lose the significance in the country-fixed-effect models. Remarkably, portfolio investment stocks continue to have significant and positive effects on currency co-movement. We can conclude that the possible multicollinearity of the RBM with the US dollar does not change the primary findings of the study.

Table 7. Robustness Tests: Per Dollar

Models	(1)	(2)	(3)	(4)
Estimation	*Time FE*	*Time FE*	*CTY FE*	*CTY FE*
Variables	*Monetary policies*	*Exchange rate regimes*	*Monetary policies*	*China's basket regime*
Dep. Var.	*Cus*	*Cus*	*Cus*	*Cus*
T	0.119***	0.079**	0.069	-0.328*
	(0.041)	(0.032)	(0.198)	(0.191)
PORT	0.179***	0.247***	0.255**	0.242**
	(0.058)	(0.079)	(0.107)	(0.109)
INT	1.216	1.198*	0.567	0.795
	(0.768)	(0.704)	(0.862)	(0.856)
INF	0.207	0.049	0.165	0.385
	(0.338)	(0.300)	(0.493)	(0.423)
REG		0.375**		
		(0.184)		
CREG				2.343**
				(1.050)
CRISK	0.236***	0.089	0.023	0.044
	(0.008)	(0.092)	(0.059)	(0.052)
Constant	0.170	-3.397	0.944	3.742
	(0.707)	(0.000)	(2.748)	(2.402)
Obs.	643	637	643	643
Adj. R^2	0.288	0.304	0.015	0.056

Note: Driscoll-Kraay (1998) standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1

Table 8. Robustness Tests: Trade and Financial Openness

Models	(1)	(2)	(3)	(4)
Estimation	*Time FE*	*Time FE*	*CTY FE*	*CTY FE*
Variables	*Monetary policies*	*Exchange rate regimes*	*Monetary policies*	*China's basket regime*
T	0.149**	0.091**	0.206	-0.243
	(0.055)	(0.043)	(0.241)	(0.221)
PORT	0.122*	0.197**	0.249*	0.238
	(0.061)	(0.074)	(0.139)	(0.143)
INT	0.789	0.716	1.170	1.440
	(0.528)	(0.507)	(0.871)	(0.896)
INF	0.768*	0.800**	1.198	1.478**
	(0.395)	(0.377)	(0.740)	(0.702)
TOPEN	-0.014	0.006	-0.132	-0.076
	(0.020)	(0.018)	(0.157)	(0.140)
FOPEN	0.005	-0.001	0.024*	0.000
	(0.004)	(0.004)	(0.013)	(0.013)
REG		0.394**		
		(0.157)		
CREG				3.059**
				(1.196)
CRISK	0.297***	0.146*	0.058	0.099
	(0.009)	(0.077)	(0.069)	(0.059)
Constant	0.118		-0.278	2.686
	(0.703)		(4.855)	(4.415)
Obs.	643	637	643	643
Adj. R^2	0.309	0.317	0.043	0.083

Note: Driscoll-Kraay (1998) standard errors in parenthesis, *** p<0.01, ** p<0.05, * p<0.1

Another test for robustness adds the overall openness of trade and capital flows to control variables. It is to allow for channels to co-movements with the RMB through indirect links to the Chinese economy. That is, the Chinese economy can affect the exchange rates of other currencies through its impacts on the global economy. This indirect effect, if any, is expected to be stronger in an economy more open to the global economy. The openness is measured as trade and portfolio investment stocks as percentages of GDP. As shown in Table 8, the results are similar to the earlier ones. *T* is significant only in time-fixed models, while *PORT* is in both time-fixed and country-fixed effect models. Besides, overall trade

openness is not significantly associated with the currency co-movement, whereas the openness of capital flows is mostly positive. In sum, we confirm that financial linkage measured with portfolio investment stocks affects more strongly than trade linkage.

4. Discussions

The primary findings of the study are that a country strongly tied with China in terms of trade and portfolio investment witnesses more synchronized currency movement with the RMB. Although the effect of trade linkages is expected from and consistent with the previous studies on related topics, it is a notable new finding that bilateral portfolio investment, part of financial linkages, turns out to have stronger effects than trade linkages. Now, we need to deliberate how bilateral trade and financial linkages lead to currency co-movements. Most of the literature on the common currency area or the anchor currency choice supposes that the connections between underlying factors or bilateral linkages and the currency co-movement are constructed through policy maker's decisions or management. It is because the participation in a particular currency bloc or the choice of anchor currency belongs to the realm of policy decision making. Most studies using the equation in Frankel and Wei (1994) implicitly assume that the weights of anchor currencies or currency co-movements are determined as a result of intervention or policies by central banks. This assumption is understandable when we consider that initially, Frankel and Wei (1994) develop the equation to estimate the weight of each currency in the basket system, one of managed floating regimes. These studies explain that central banks keep the value of currency stable with that of major trading partners to minimize the uncertainty of exchange rates, consequently creating currency co-movements.

However, our findings challenge this conventional wisdom because the flexibility of exchange rate regimes shows consistently significant and positive coefficients, that is, stronger co-movements with the RMB in a country with a more flexible exchange rate regime. This result suggests that currency co-movements are the outcome of market operations rather than the central bank's interventions. For instance, it is reasonable to interpret that strong co-movements of the Korean won or the Australian dollar with the RMB is generated through autonomous foreign exchange trading agents because Korea and Australia have virtually free-floating

exchange rate regimes. Such reactions at foreign exchange markets are likely driven by the expectation that two countries' economic fundamentals, such as growth rates, will change in a synchronized manner with China's due to tight economic ties. In conclusion, increased economic integration with China may lead to currency co-movements with the RMB naturally, not intentionally. The positive coefficients of portfolio investment imply that financial linkages not less than trade linkages contribute to bilateral economic integration to cause currency co-movements.

VI. CONCLUSION

Empirical results show increased influences of the RMB on the value of other currencies after the GFC and further acceleration of the trend since China's official transition to the currency basket system. Currency co-movements, an indicator of the influences, appear strongly in countries with tighter trade and financial linkages with China. Previous studies on the related topics such as the optimal currency area or the currency bloc little considered the effects of financial linkages, possibly because the theories were developed before capital account liberalization in emerging economies. In contrast, it is a contribution of this study to find that bilateral portfolio investment stocks work as an underlying factor of currency co-movements, at least for the RMB. Another remarkable finding is that currency co-movements are observed in countries with more flexible exchange rater regimes. This finding is not consistent with the previous literature to understand that currency co-movements are the result of central banks' alignment or management of exchange rates. In particular, it implies that the growing influences of the RMB are the result of foreign exchange markets' responses to increasing linkages to the Chinese economy. It is an interesting topic for future research whether those findings are also observed for other anchor currencies like the US dollar and the former German mark and French franc.

This study finds that trade linkage using gross trade data is a determinant of currency co-movement with RMB. The value-added trade data or the intra-industry trade structure may be another proxy variables for trade linkages. Future research should also consider whether they have an impact on currency co-movements.

The results of this study predict further growing influences of the RMB over the value of other currencies, given the expected progress toward a more flexible exchange rate regime and more liberalized capital flows in China, thus more

financial linkages to overseas. As well, the influences of the RMB will not stay just as a regional phenomenon because its growing trade and financial linkages will be confined to Asian or neighboring countries.[7]

[7] Though not reported in the paper, the geographical distance from China does not significantly affect the currency co-movement.

APPENDIX

Table A1. Definition of Exchange Rate Regimes

Regime	Definition
1	No separate legal tender or currency union
2	Pre announced peg or currency board arrangement
3	Pre announced horizontal band that is narrower than or equal to +/-2%
4	De facto peg
5	Pre announced crawling peg; de facto moving band narrower than or equal to +/-1%
6	Pre announced crawling band that is narrower than or equal to +/-2% or de facto horizontal band that is narrower than or equal to +/-2%
7	De facto crawling peg
8	De facto crawling band that is narrower than or equal to +/-2%
9	Pre announced crawling band that is wider than or equal to +/-2%
10	De facto crawling band that is narrower than or equal to +/-5%
11	Moving band that is narrower than or equal to +/-2%
12	De facto moving band +/-5% or Managed floating
13	Freely floating

Source: Ilzetzki et al. (2019).

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