# The CNH and CNY: A (rolling) fractional cointegration approach
*Very preliminary draft*

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**Abstract**

China seeks to internationalize its currency, especially by promoting an offshore market dedicated to international transactions with the rest of the world, while maintaining close control over its onshore currency, primarily dedicated to domestic transactions. The offshore exchange rate with the USD is supposed to be driven by market forces, while the onshore exchange rate continue to be managed by Chinese monetary authorities. Consequently, the two currencies are subject to frequent deviations reflecting these distinct market structures and investor behaviors.

In this paper, we aim to investigate whether these deviations are persistent and, if so, to what extent. Our methods rely on a fractional cointegration approach that allows us to assess whether the two exchange rates are co-persistent in nature and whether the deviations from their long-run equilibrium are weakly persistent, strongly persistent, or stationary. We also explore whether the persistence of these deviations varies over time and are driven by China's monetary and exchange rate policy uncertainty.

Our main results indicate a declining in the persistence of deviations especially after 2016. We also find a significant relationship between theses deviations and exchange rate and monetary policy uncertainty, especially when the CNH is weaker than the CNY.

*Keywords:* China, fractional cointegration, CNH and CNY
*JEL:*

## 1. Introduction

The economic development of China has been a remarkable phenomenon over the past decades, shaping not only the regional economy but also global dynamics (Zhang , 2024; Clayton et al. , 2023; Barcelona et al. , 2022; Keddad and Sato , 2022; Autor et al. , 2021; Adams et al. , 2021; Shagil et al. , 2019; Fontaine et al. , 2018; Fratzscher and Mehl , 2014). China's rapid economic growth has propelled it to the status

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of a global economic power, strengthening its integration within the international financial system and its ties with the rest of the world. To support this transition towards a more open economy, China has undertaken significant reforms in its exchange rate policy (see e.g., Jermann et al. , 2022). These reforms aimed to increase the convertibility of the renminbi (RMB) and further liberalize its financial market, thereby boosting demand for its currency and consolidating its position as the leading exporting country.

This was also accompanied by the emergence of the offshore RMB, the CNH, which plays a crucial role in the RMB internationalization process. The CNH functions as an offshore counterpart to the onshore CNY, granting foreign investors and companies direct access to the Chinese market, but also supporting mainland Chinese firms to promote their businesses outside mainland China.[1]

This parallel monetary system allowed China to promote the use of the RMB in international trade and financial transactions while maintaining control of its capital account to protect China from external financial exposure. As China continues to deepen its financial reforms and promote greater market opening, the CNH is expected to play an increasing role in strengthening the RMB's position as a global currency and promoting a Chinese economy more integrated into the international financial system.

Using a parallel currency can pose several challenges, the most important of which is maintaining a stable parity between CNH and CNY to ensure that the two currencies remain interchangeable (see Bahaj and Reis , 2024).[2] This objective is particularly difficult for monetary authorities to achieve, especially because of the existence of strict capital controls between the conversion of the CNH and the CNY, which limits the arbitrage forces to restore parity in financial markets.[3]

The literature has stressed out micro and macro factors explaining the spread between the two currencies, such as differences in the liquidity of the two market, policy reforms but also international trade tensions and geopolitical events (see e.g., Xu et al. , 2023; Tian et al. , 2023; Liu et al. , 2022; Chen and Xu , 2021; Li et al. , 2021; Jia et al. , 2021). However little is know about the deviation persistence between the two markets and economic factors that can explain its dynamic. In this paper, we aim to investigate whether these deviations are persistent and, if so, to what extent. Our methods rely on a fractional cointegration approach that allows us to assess whether the two exchange rates are co-persistent in nature

[1] The onshore CNY is supplied by banks operating within Mainland China, whereas the CNH is issued by both foreign banks and Chinese banks with branches or subsidiaries outside of China, notably in global financial centers such as Hong Kong, and to a lesser extent in the United Kingdom, Singapore, and the United States. The CNH can be freely converted into foreign currencies without restriction, unlike the CNY, which is subject to stringent exchange controls for both Chinese economic agents and foreign entities. For instance, the Renminbi Qualified Foreign Institutional Investor (RQFII) program allows foreign investors to invest directly in Mainland China's bond and equity markets, albeit under a fixed quota. Overall, the CNY is utilized domestically within Mainland China by Chinese nationals for internal transactions, while the CNH is predominantly employed by firms engaged in international trade with China, Chinese entities operating offshore, offshore Chinese banks (including clearing banks in other economies), and foreign financial institutions as part of their investment strategies or liquidity management.

[2] Bahaj and Reis (2024) insist on the fact that too large and persistent deviations would lead to one currency stop being used because of its declining value and the loose of confidence form Chinese economic agents.

[3] Despite the fact that the official conversion between the CHN and the CNY is one to one, the two exchange rates against other international currencies can deviate since the CNH is freely determined by market forces. This may lead to arbitrage opportunities for Chinese agents holding CNH, albeit limited due to restrictions on the conversion of the CNH and the CNY, leading then to persistent gap between the international price of the two currencies.

and whether the deviations from their long-run equilibrium are weakly persistent, strongly persistent, or stationary. The literature has widely relied on fractional cointegration framework for detecting long-run relationship between fractionally integrated processes (see e.g., Dettoni et al. , 2024; Xu et al. , 2023; Caporale and Gil-Alana , 2019).

In our case, this is motivated by two evidences. The first one is the evolution of exchange rate management in China since 2005. The most important milestone on RMB reforms is the adoption of a managed floating exchange rate regime against the US dollar and more recently against a basket of currencies. However, despite a more flexible approach through the gradual widening of the daily trading band, the RMB is still actively managed by the People's bank of China (PbOC). In this context, the traditional $I(0)/I(1)$ paradigm is non-relevant given the changing nature of the statistical properties of the RMB. Second, the spread between the two currencies has experienced significant divergences since the introduction of the CNH. The persistence of the deviations cannot be addressed in the traditional cointegration framework which is too restrictive as they can be weakly persistent, strongly persistent, or stationary. The assumption here is that the persistence of the CNH-CNY spread is a fractionally integrated $I(d)$ process, which offer a more powerful framework that the classical dichotomy between $I(0)$ and $I(1)$ process. This is one major contribution of our paper over previous studies which employed the classical $I(0)/I(1)$ cointegration framework.

To this end, we apply a rigorous estimation procedure. First, we test for the equality of integration order of the two exchange rates against the US dollar, which is a preliminary conditions for the existence of fractional cointegration. To do so, we apply the test of Hualde (2013). Second, we estimates a fractional triangular system with the semi-parametric estimator of Shimotsu (2012). To the best of our knowledge, there are only two papers relying on fractional integration framework (i.e. Xu et al. , 2023 and Chen and Xu , 2021). However, the estimator of Shimotsu (2012) offers a more parsimonious approach to the fully VECM parametric model employed in these studies because our method depends on three parameters only: the long-run correlation parameter between the CNH and the CNY, the persistence parameter of the long-run residuals, and the persistence parameter of the exogenous variable. This is especially relevant in our case as we focus on a bivariate system (i.e., the CNH and the CNY). Third, we test for the existence of fractional cointegration by applying the test of **?**. Following Okimoto and Shimotsu (2010), the next stage of our empirical strategy is to apply a rolling window estimation of the persistence parameters to obtain information about the underlying dynamics of the persistence of the CNH-CNY deviations. Our hypothesis is that the persistence of these deviations should decline over time if the two currency markets becomes more integrated.

In the final step, we extract the corresponding time-varying parameter to investigate the relationship between the persistence of these deviations and Chinese policy-specific uncertainty (EPU) indices (especially trade, monetary and exchange rate policies). In a context where the CNY is managed against a currency basket with a 2% daily trading band, the increasing pressures on the CNY can be reporter to the CNH, leading to important deviations between the two currencies. The is especially true in a context of greater economic uncertainty.

Our main results indicate a declining in the persistence of deviations especially after 2016. We also find a significant relationship between theses deviations and economic policy uncertainty, especially when the CNH is weaker than the CNY.

The outline of this paper is as follows. In Section 2, we present the literature review. 3 describes the data and the estimation strategy. 4 presents our results and 5 concludes.

## 2. Literature Review

The Chinese RMB has increasingly become a focal point in the recent academic literature, as the onshore CNY and offshore CNH markets are now playing pivotal roles in global financial markets. Cheung et al. (2021) examines the evolution of CNH trading patterns between 2016 and 2019 and assesses the determinants of changes across offshore financial centers. In addition to proxies of global FX market conditions, they consider the impact of changing geopolitical disputes (including China-US dispute but also Japan and Korea), trade relationships, China's policies to promote an offshore RMB center, and offshore financial center characteristics on offshore RMB trading (i.e., equity market capitalization, size of the international bond market and stage of financial development). They observe that engagement in political disputes negatively impacted offshore RMB share between 2016 and 2019. However, this impact was mitigated by bilateral trade volume, suggesting that existing economic linkages modified the implications of geopolitical factors. China's RQFII quotas and the host country's levels of equity market capitalization and financial development positively influence the geographical offshore RMB trading pattern, especially between 2016 and 2019.

A comprehensive conceptual framework of the China's parallel currency system is provided by Bahaj and Reis (2024). The authors offer two important contributions that are directly related to our study. First, they show that Chinese CNH monetary policy has succeeded in keeping deviations from the peg small and transitory through careful liquidity management and the supply of CNH money to accommodate shocks to the demand for CNH. Second, they propose a micro-founded model to support their empirical results, emphasizing the role liquidity policies (reserve requirements, helicopter drops of money or bills, control on the flow of deposits, etc.) in managing the foreign exchange rate. They provide evidence that the use of a parallel currency, i.e., the CNH, has allowed attenuation and smoothing of fluctuations in the domestic currency, i.e., the CNY, when it depreciated against the USD in 2015-16 and 2023.

Due to the necessity of maintaining parity between the two currencies, existing empirical literature has examined various aspects of RMB market dynamics, relying on diverse econometric methodologies and addressing key topics such as price discovery, exchange rate spreads, market integration, and the impact of policy reforms. For instance, Xu et al. (2023) investigate the time-varying price discovery dynamics between the onshore and offshore RMB markets, adopting a fractionally cointegrated vector autoregressive (FCVAR)? They find that the offshore market contributes 62% and the onshore market contributes 38% to price discovery, suggesting that the offshore market is more informative than the onshore market. The authors also assess the influence of equity market and economic policy uncertainty on price discovery and the arbitrage opportunities. They pay particular attention on the role of the CBOE China ETF Volatility Index, China economic policy uncertainty index, and China trade policy index. Their main findings indicate that higher market uncertainty exacerbates arbitrage opportunities and strengthens the role of the offshore market in price discovery.

Previous studies also explored the importance of major policy events, such as Chen and Xu (2021) who investigate the impact of adding the RMB to the IMF's Special Drawing Rights (SDR) basket on the relative and absolute price discovery of RMB in onshore and offshore markets. The authors utilize various price discovery measurements and employ methodologies such as pricing error measurement, variance ratio analysis, vector autoregression (VAR) models, and FCVAR models. They find that the inclusion of RMB in the SDR improved the price efficiency of both RMB markets, but offshore USD/CNH rates contribute more to price discovery than onshore USD/CNY rates. However, the inclusion of RMB in the SDR did not change the dominance of USD/CNH rates in price discovery. Their results suggest that onshore and offshore markets became better integrated after SDR implementation, with a decrease in price differences that reduced arbitrage opportunities. Owyong et al. (2015) examines the impact of widening the trading band for the RMB exchange rate, after April 14, 2012 and March 15, 2014 on the dynamics between onshore and offshore RMB markets. They use cointegration techniques, including granger linear and nonlinear causality tests. The authors find that with greater exchange-rate flexibility introduced with the first and band widening, ties between the two markets has weakened even if they remain linked by a long-term equilibrium relationship. They also find a stronger causal effect running from onshore to offshore spot exchange rates, while the causality direction is more balanced in the forward market. Li et al. (2021) also investigate the price discovery mechanism and interactions between the onshore and offshore RMB markets in the context of the significant exchange rate reform announced by the PBoC on August 11, 2015. The study utilizes offshore RMB non-deliverable forward (NDF) rates to investigate the price discovery mechanism of forward exchange rate markets. The findings suggest that there was a notable change in both return and volatility spillovers between the onshore and offshore markets after the reform. Before the reform, spillovers existed from the offshore forward markets to the onshore spot market, but after the reform, there was a reversal in direction and an increase in the strength of these spillovers. The authors argue that the reform might not have been an abrupt game changer but rather, it reflects long-term underlying drivers, such as the relative market size and the increased sway of China's regulations and policies, which have heightened the significance of the onshore market.[4] Jia et al. (2021) investigate the impact of market expectations in the offshore non-deliverable forward (NDF) market on the CNY spot rates, considering the context of China's gradual exchange rate liberalization (2005-2018). The study employs several econometric techniques such as GARCH, TAR or ARDL models, and provides evidence that the market-oriented reforms of exchange rates have strengthened the role of offshore market expectations in driving the onshore rates. If they observe any impact before 2010, it becomes significant from 2010 to 2018.

Some other studies investigated the role of macroeconomic variables in the dynamic of pricing deviations between CNH and CNY. For instance, Tian et al. (2023) aim to understand the dynamics of the CNY-CNH relationship, particularly focusing on the information spillover between the two markets, the impact of major macroeconomic events, and the role of the CNH market in determining RMB rates. The paper employs the wavelet method, chosen for its ability to analyze both time and frequency domains. The study reveals that the information spillover between the CNY and CNH markets is bi-directional and asymmetric and time varying, with a relationship that is strengthened during major macroeconomic events (i.e., China's exchange rate reform, US-China trade tensions, COVID-19 pandemic, rise in global economic uncertainty since 2022 global). The CNH market plays a significant role in determining RMB rates, with its activities influenced by macroeconomic events and having a closer connection to the exchange rate differential than the CNY market. Li et al. (2020) examines the dynamics of the CNY-CNH spread, focusing on the influence of economic policy uncertainty (EPU) shocks constructed as a composite EPU index based on EPU indices of China and the G7 countries by using principal component analysis (PCA). They employ the nonlinear ARDL (NARDL) model to examine the potentially asymmetric transmission of EPU to the CNY-CNH spread and find that positive shocks to the composite EPU induce widening spreads. Funke et al. (2015) investigate how RMB-related policies as well as macroeconomic and market fundamentals influence the pricing and volatility differential between the CNH and CNY. The researchers employ extended GARCH models and compile a series of policy variables to capture changes in the degree of market segmentation between onshore and offshore markets, including relaxation of barriers to renminbi trade settlement and cross-border fund flows, as well as changes in trading bands and conversion quotas. They demonstrate that liquidity in the offshore market plays a significant role in explaining the level of the CNH–CNY differential. Indeed, measures focused on increasing liquidity in offshore markets, such as permitting cross-border RMB fund flows, have notably reduced the volatility of the offshore–onshore spread. However, rise in global risk aversion has the opposite effect.

Finally, a final part of the literature explored the dynamics of deviations and the predictive power of each currency in forecasting the CNH-CNY spread or the central RMB parity rate. For instance, Liu et al.

[4]See also Ho et al. (2018) regarding price discovery and NDF.

(2022) investigate the drivers of the CNY-CNH spread analyze its predictability. They focus on time-series measures of spread skewness as a predictive indicator for forecasting the CNY-CNH spread. The authors demonstrates that it offers better predictive power compared to benchmark models, although predictability tends to decline at longer forecast horizons. However, they observe a significant negative impact of skewness on market liquidity, especially the CNH market, then affecting CNH-CNY spread. The study also considers the impact of asymmetric skewness but find any improvements of the predictability. Han et al. (2018) explore the persistent pricing deviations between CNY and CNH by focusing on the role of investor attention, especially around CNY-CNH differential peaks relationship. Using a wide array of attention indices constructed through partial least squares (PLS) approach, the study demonstrates the statistically and economically significant predictability of CNH-CNY pricing gap and carry trade. They also find that investor attention provides more useful information than macroeconomic variables (i.e., industrial production, 1-month interest rate, M1 and M3, and consumer price index). Cheung and Rime (2014) explore the dynamic of the offshore market and its implications for the onshore market, especially its predictive power for the RMB central parity rate. The authors combine a microstructure approach with a VECM specification, emphasizing the role of order flow and limit-order book data, in determining exchange rates. They find that these microstructure variables affect especially the variations in the CNH exchange rate, which confirm that the CNY is mainly driven by policy intervention of monetary authorities. They also study the long run and short run relationships between CNH and CNY and find that CNH, rather the CNY, adjust to deviations from their long-run equilibrium. In the short run, CNH is an important determinant of the CNY dynamics, especially after April 2012, while the reverse is true in earlier periods. Xu et al. (2017) investigate the time-varying lead-lag relationship between the CNY and CNH exchange rates. The study relies on the thermal optimal path (TOP) method to capture the dynamic lead-lag structure between the CNY and CNH exchange rates. The analysis is conducted at both daily and minute-scale frequencies to provide insights into short-term and long-term interactions between the two exchange rates. The study finds that the lead-lag relationship between CNY and CNH exchange rates varies over time, indicating dynamic interactions between the the two RMB markets. The authors also observe distinct dynamics in short-term and long-term interactions. For instance, at the daily level, their lead-lag structure is highly intricated. However, the minute-scale interaction depends on whether the market is upward (RMB depreciation) or downward (RMB appreciation), with in the former case the offshore exchange rate leading the onshore exchange rate because investors may trade preferentially with the CNH under these market conditions.

# 3. Methodology

## 3.1. Data

Exchange rates data of CNY and CNH against the US dollar (USD) are collected from Refintiv Eikon. We use weekly data from 6th August, 2010 to 7th of June, 2024. For China's economic policy uncertainty (*EPU*), we select Huang and Luk (2020)'s index that uses information from ten Mainland China newspapers (We also select several Chinese policy-specific uncertainty indices from the Huang and Luk (2020) dataset, such as monetary (MPU), trade (TPU) and capital account policies and the exchange rate (XPU). The China and policy-specific EPU data stop in 17th of June, 2022 because of data availability.[5]

Figure 1 illustrates the exchange rate trends of the CNH, the CNY against the USD. The exchange rates of the CNH and CNY generally exhibit similar dynamics, confirming, unsurprisingly, that the two series are closely related. However, offshore currency exhibits greater volatility due to its greater sensitivity to market speculation. The CNY experienced a persistent and continuous appreciation from the introduction of the CNH in February 2010 until early 2014. This period was followed by a gradual trend of depreciation. A stability in the exchange rate was noted preceding the reform of exchange rate policy by Chinese authorities in August 2015.[6] The trend reversed in 2017, leading to a consistent appreciation during the following year. Following the declaration of COVID-19 in 2020, the CNY gradually appreciated against the dollar until 2022. Despite the crisis period, the CNY managed to retain the confidence of currency holders, indicating China's growing role in the international monetary system. This confidence is further justified by the long period of stability between 2017 and 2020 (with minimal variations around the fixed parity).

Figure **??** displays the log-deviation from parity between the two currencies (a positive observation means that CNH has appreciated further than the CNY and *vice-versa*). The first episodes of persistent deviations between the two Chinese currencies were noted in the second half of 2010. The CNH appreciated against the CNY due to liquidity constraints caused by high demand for CNH from investors (Xu et al. , 2017). During the last two quarters of 2012, the CNH significantly depreciated against the CNY. This gap was sustained by the consequences of the European debt crisis, which drove investors toward more reliable currencies like the US dollar. In August 2015, the new exchange rate reform implemented by Chinese authorities resulted in the devaluation of the CNY. This led to a new episode of divergence

[5]We extrapolate policy-specific EPU data from monthly to weekly frequency with the Denton method and use the China EPU as a weekly frequency indicator for guiding the extrapolation.

[6]Before this reform, the central parity rate of the RMB was essentially set by the central bank, leading to discrepancies between the spot market rate and the central parity rate. The reform introduced a more market-oriented approach, where market makers offer quotation prices based on a basket of currencies and the previous day's closing rate, which are then used by the PBoC to determine the central parity rate. This reform, along with the widening of the daily fluctuation limit on the RMB exchange rate to 2% since March 2014, significantly loosened the PBoC's control over the RMB exchange rate, marking a crucial step toward greater flexibility. The reform had a substantial impact on the RMB spot market, with the bilateral spot rate of the RMB against the USD depreciating by over 3% in the three days following the reform.

between the two exchange rates. Indeed, the surprise devaluation, which caused market concern, led to a short-term depreciation of the CNH that was greater than that of the domestic currency.

Figure 3 represents the evolution of the policy-specific uncertainty indices over the period from 2000 to 2022. The figure reveals periods of significant volatility often correlated with major economic and political events. As a whole, the indices exhibit notable peaks around 2010 and 2015, and a marked increase towards the end of the period in 2020. For the TPU, the launch of the Belt and Road Initiative aimed at enhancing international trade links, generated both opportunities and uncertainties that could explain the peak observed in 2015. From 2018 to 2020, the US-China trade war led to a significant rise in trade policy uncertainty, culminating in high tariffs and unstable negotiations. The MPU index experiences similar fluctuations th at could be linked to the surprise devaluation of the CNY in August 2015 to make Chinese exports more competitive. From 2018 to 2020, adjustments in monetary policy to counteract the effects of the trade war with the United States and manage the economic impacts of the COVID-19 pandemic increased monetary policy uncertainty. Finally, the XPU index displays significant fluctuations that are frequently associated with key policy changes, such as the 2015 devaluation of the CNY and its inclusion in the IMF's Special Drawing Rights (SDR) basket in 2016.

### 3.2. Econometric strategy

As mentioned in the introduction, in the spirit of Owyong et al. (2015) and Xu et al. (2023), we rely on cointegration theory to investigate the extent to which the CNH and the CNY are tied in the long run. However, we adopt a different approach as we perform a semi-parametric estimation of a triangular fractional cointegration system, allowing us to robustly estimate the strength of the long-run relationship. Our estimation strategy operates in three steps to rigorously satisfy the cointegration theory requirements. First, we test for the equality of the integration orders of the CNH and CNY. Rather than relying on classical unit-root tests that necessarily fall within the restrictive $I(1)/I(0)$ paradigm, we apply the test of Hualde (2013) and make only mild assumptions about the parameter space of the persistence parameter. Second, we apply the frequency domain estimator of fractional cointegration developed by Shimotsu (2012), designed to handle triangular systems. This alternative to the so-called VECM representation makes sense here as we are interested in a bivariate system with some *a priori* knowledge regarding the weak exogeneity of the CNH. Finally, we test for the existence of a long-run equilibrium by implementing the test of Wang et al. (2015). It extends the test for equality of fractional orders to the case where one of the variables of interest is not directly observed and has to be estimated.

*Step 1: Testing the equality of fractional integration orders*

Define $y_t$ and $h_t$ as the CNY and CNH, respectively. Also define the vector $z_t = (y_t, h_t)'$, $t = 1, \ldots, n$. Under the null hypothesis $H_0 : \delta_y = \delta_h = \delta$ versus the alternative $H_1 : \delta_y \neq \delta_h$, Hualde (2013) suggests the following statistic:

$$\widehat{t} = \frac{(2\pi n)^{-1/2} \widehat{a}' \sum_{t=1}^{n} z_t(\widehat{\delta}_h, \widehat{\delta}_y)}{(\widehat{a}' \widehat{f}_{z(.)}(0) \widehat{a})^{1/2}} \xrightarrow{d} \mathcal{N}(0,1)$$

where $z_t(\widehat{\delta}_y, \widehat{\delta}_h) = \left((1-L)^{\widehat{\delta}_y} y_t, (1-L)^{\widehat{\delta}_h} h_t\right)'$, $\widehat{f}_{z(.)}(0)$ is the spectral density matrix of $z_t(\widehat{\delta}_y, \widehat{\delta}_h)$, and $\widehat{a} = \left(\mathbb{1}\left(n^{\kappa}(\widehat{\delta}_y - \widehat{\delta}_x) > h_n\right), \mathbb{1}\left(n^{\kappa}(\widehat{\delta}_y - \widehat{\delta}_x) \leq h_n\right)\right)'$. We estimate the spectral density nonparametrically using $m$ frequencies around the origin. The statistic hence depends on tuning parameters $\kappa$, $m$, and $\ell_n$, set to $\kappa = 1/2$, $m = n^{\kappa}$, and $\ell_n = \log n^{\kappa}$ in the sequel. The long memory estimates are obtained by applying the exact local Whittle estimator of Shimotsu (2010) over $m$ frequencies. This estimator operates under mild assumptions regarding the parameter space and remains asymptotically Gaussian if $\delta \in (-1/2, 2)$.

*Step 2: Estimating the fractional triangular system*

If one fails to reject $H_0$, cointegration can be investigated. Compared to the fully parametric VECM approach used in Xu et al. (2023), we adopt a triangular system representation by assuming that $h_t$ is weakly exogenous:

$$\begin{aligned} y_t &= \beta h_t + (1-L)^{-\gamma} \varepsilon_t, \\ h_t &= (1-L)^{-\delta} v_t, \end{aligned}$$

where $\gamma$ denotes the long memory parameter of the long-run residuals. This representation is more parsimonious as it depends on three parameters. Also, as we are not interested in the short-run dynamics, we can implement the semi-parametric estimator of Shimotsu (2012). It is also based on the frequency domain and focuses on $m$ frequencies in the vicinity of the spectral density origin. Like the estimator of Shimotsu (2010), it also offers simple asymptotic properties:

$$\sqrt{m}\,\mathrm{diag}(I_2, \lambda_m^{\gamma-\delta})(\widehat{\vartheta} - \vartheta) \xrightarrow{d} \mathcal{N}(0, \Xi^{-1})$$

with $\lambda_m$ being the $m^{th}$ Fourier frequency and $\Xi^{-1}$ the asymptotic covariance matrix of $\widehat{\vartheta} = (\beta, \delta, \gamma)'$.

The strength of the cointegration relationship depends on the relative magnitude of the $\delta$ and $\gamma$ coefficients. There are three cases: The strong fractional cointegration for which $\nu = \delta - \gamma > 0.5$ with $1 > \delta > 0.5$; the weak fractional cointegration where $\nu = \delta - \gamma \leq 0.5$ with $1 > \delta \geq 0.5$; and the stationary fractional cointegration where $\nu = \delta - \gamma < 0.5$ with $0.5 > \delta > 0$.[7] *Step 3: Testing for fractional cointegration*

[7] the $I(1)/I(0)$ paradigm belongs to the first category.

To investigate the existence of a long-run equilibrium, we must test for $H_0 : \gamma = \delta$ versus $H_1 : \gamma < \delta$.[8] However, the test of Hualde (2013) cannot be used as the long-run errors are unobserved and must be estimated from the previous step. To address this particular case, Wang et al. (2015) suggest the following residual-based test statistic under $H_0$:

$$\widehat{F} = \frac{n^{-1/2} \sum_{t=1}^{n} \Delta^{\widehat{\gamma}} h_t}{(2\pi \widehat{f}_v(0))^{1/2}} \xrightarrow{d} \mathcal{N}(0,1)$$

where $\widehat{f}_v(\lambda)$ is the spectral density of $\widehat{v}_t = (1-L)^{\widehat{\delta}} h_t$ evaluated as $\lambda \to 0$.

# 4. Empirical results

*Full sample analysis*

Table 1 displays the results from the estimation procedure detailed in section 3.2. First, we observe that the two series are fractionally integrated, not stationary with a unit root (i.e., $\delta > 1$). However, the Hualde (2013) confirms that the two series have the same integration order, suggesting that they similarly persistent. This condition is necessary for the two variables being fractionally cointegrated. Consequently, we apply the Shimotsu (2012)'s estimator to estimate the persistence of the deviations between the two currencies and then, the strength of their long-run relationship. From Table 1b, we observe that the long-run correlation coefficient is close to unity (0.967). The estimate of $\gamma$ corresponds to the persistence of the cointegrating errors, and then the persistence of deviations from the long-run equilibrium. We observe that the $\gamma$ coefficient is lower than 0.5, suggesting that the deviations are stationary and weakly persistent.

As explained above, the strength of the cointegration relationship depends on $\delta$ and $\gamma$ coefficients. From the literature, we can classify this strength into three scenarios: The strong fractional cointegration for which $\nu = \delta - \gamma > 0.5$ with $1 > \delta > 0.5$; the weak fractional cointegration where $\nu = \delta - \gamma \leq 0.5$ with $1 > \delta \geq 0.5$; and the stationary fractional cointegration where $\nu = \delta - \gamma < 0.5$ with $0.5 > \delta > 0$.[9]

In this case, this gap (called $\nu$) is equal to 0.604. This indicates that the two variables are strongly and fractionally cointegrated since $\nu > 0.5$ with $\delta > 1$.

We also estimate the ECM equation in order to investigate if the mean-reverting process is stronger when the CNH is weaker than the CNY. To do so, we calculate a dummy variable equal to 1 when the CNH is weaker than the CNY and we estimate the following equation:

[8] Note that in this configuration, we test for the absence of cointegration under the null hypothesis.
[9] the $I(1)/I(0)$ paradigm belongs to the first category.

$$\Delta CNH_t \quad = \quad \delta + \gamma CNY_{t-1} + \alpha ECT_{t-1} * I_{t-1} + \varepsilon_t$$

The ECT corresponds to the long-run residuals estimated with Shimotsu (2012) (see Table 1), but fractionally differentiated to get an $I(0)$ process. The result presented in Table 2 show that the alpha coefficient is negative and the effect is stronger during periods where the CNH is weaker than the CNY. This indicates that the mean-reverting process is faster when the CNH has depreciated against the CNY one week before. One explanation is that monetary authorities appear less inclined to intervene when the offshore yuan (CNH) appreciates against the onshore yuan (CNY). For instance, Funke et al. (2015) find that stronger GDP growth and higher returns on Chinese shares, which are dual-listed in Hong Kong and mainland China, tend to lead to an appreciation of the CNH relative to the CNY. Since the CNH is freely convertible in offshore markets, it tends to appreciate more than the CNY when macroeconomic fundamentals are strong. In this context, monetary authorities in both Hong Kong and mainland China are less likely to intervene to adjust the CNH money supply, unlike situations where the CNH depreciates against the CNY due to speculative pressures on the latter.

*Rolling cointegration*

As documented in Okimoto and Shimotsu (2010), the degree of persistence is likely to vary over time. To capture the time-varying nature of the long memory parameters, these authors suggest a simple rolling procedure. In the sequel, we extend this methodology to the cointegration analysis and pay a particular attention to the cointregration strength. The length of each rolling window is 180 weeks and we iterate over 543 weeks. As the rolling window size is only moderately large, the frequency domain estimators are likely to converge with some difficulties and to provide, occasionally, erratic results. To overcome this issue we apply an insanity filter in the spirit of Swanson and White (1995). The same procedure is apply to compute the confidence intervals of the cointegration parameters and hence, no value is reported when the insanity filter operates.

Figure 4 display the rolling estimates of parameters $\beta$, $\gamma$ and $\delta$. First, the estimates of $\delta$ correspond to the persistence of the CNY. The coefficient is almost always higher than unity, suggesting than the CNY has a unit root even when looking at specific intervals. The result confirms the appreciating trend of the CNY over the period. This is particularly evident after 2014 as displayed by Figure 1 and the estimates of $\delta$ that is progressively increasing after 2014.

From the rolling estimates of $\gamma$, we conclude that the cointegrating errors are non-stationary but mean-reverting and highly persistent. An interesting observation is the gradual decrease of the persistence over the sample with a more pronounced break in 2016. Indeed, before 2016, the $\gamma$ coefficient is not confined in a specific parameters space (higher or lower than 0.5) and alternates between stationary and non-stationary episodes. However, after 2016, the persistence declines and remains lower than 0.5 until the end of the sample, and is even close to zero on several occasion. Regarding the $\beta$ coefficient, it is very close to unity over the full period but seems to be more stable after 2016.

The strength of the cointegration is given by the gap between the coefficients $\delta$ and $\gamma$ corresponding to the $\nu$ value plotted in Figure 5. We observe that the CNY-CNH relationship falls into the strong fractional cointegration over the full period with an exception around 2012. However, the strength of the cointegration gradually increase after 2016 with a $\nu$ value higher than 0.8 or even higher than 1. This indicates that the two currencies becomes more and more co-persistent and cointegrated through time.

The significant results reflect the central bank's ability to maintain the peg, especially after 2016 and the sharp depreciation of the CNY. Starting in 2017, the CNY's volatility was reduced and was no longer on the depreciation trend that began in 2014, which helped maintain the CNH-CNY parity due to less speculative pressure. In addition, in May 2017, the PBoC introduced a countercyclical adjustment factor into the peg calculation method designed to smooth out excessive fluctuations and avoid significant volatility in the yuan, especially during periods of high speculation or external pressures. The 2017 reform was mainly aimed at stabilizing the market after the turbulence of previous years. As a result, the CNY experienced less volatility compared with 2015-2016, reducing the persistence of gaps with the CNH.

Finally, the PBoC and the Hong Kong Monetary Authority (HKMA) have implemented a range of reforms and liquidity tools to enhance their management of the CNY by exerting greater control over the offshore money supply (Bahaj and Reis , 2024). Key measures include the issuance of CNH-denominated bills by the PBoC in Hong Kong, introduced in 2018, which helps manage CNH liquidity and stabilize the offshore market. Additionally, the HKMA has introduced reforms to strengthen liquidity regulation and improve the management of CNH liquidity for commercial banks in Hong Kong, notably through repo facilities and repurchase agreements. These efforts collectively aim to ensure better liquidity conditions and then reducing the deviation persistence between the CNH and the CNY.

*Policy uncertainty*

Table 3 displays the influence of the policy SPU indices on the deviations between the CNH and the CNY. We find that uncertainty is negatively related to the deviations. Indeed, all coefficients are negatively related with long-run residuals and the effect is the highest for XPU and MPU. However, this is mitigated when the CNH is depreciating against the CNY as the relationship turns positive in all cases. One explanation is related to depreciation pressures faced by the CNY like in 2015, when exchange rate uncertainty was particularly high (see Figure 3). In this context, as explained by Bahaj and Reis (2024), the

CNH serves as an escape valve to ease the depreciation pressure on the CNY against the USD, helping the PBoC maintain the CNY-USD trading band. This mechanism works because the CNH is freely determined by market forces of supply and demand. As a result, the CNH absorbs speculative pressure on the CNY, creating a gap between the two currencies. However, as previously discussed, the PBoC cannot allow these deviations to persist for long, as this would encourage arbitrage and undermine the effectiveness of capital controls between the CNH and the CNY. Therefore, in December 2015, the PBoC tightened liquidity controls to restore parity, leading to a reduction in CNH deposits and a spike in interbank rates.

## 5. Conclusion

In this paper, we aim to investigate whether CNH-CNY deviations are persistent and, if so, to what extent. Our methods rely on a fractional cointegration approach that allows us to assess whether the volatility of the two exchange rates is co-persistent in nature and whether the deviations from their long-run equilibrium are weakly persistent, strongly persistent, or stationary. We also explore whether the persistence of these deviations varies over time and is associated with specific financial turmoil or economic events.

Furthermore, we examine whether these deviations are linked to Chinese policy uncertainty. Our main results indicate a declining in the persistence of deviations especially after 2016. We also find a significant relationship between theses deviations and exchange rate and monetary policy uncertainty, especially when the CNH is weaker than the CNY.

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Table 1: Static estimation

| | | | |
|---|---|---|---|
| Part a - Equality of integration order | | | |
| Shimotsu (2010): | $d_1$ (CNH) | $d_2$ (CNY) | |
| | 1.265 | 1.288 | |
| | () | () | |
| Huald (2013): | Stat. | p-val | |
| | 1.079 | 0.255 | |
| Part b - Cointegration estimates | | | |
| Shimotsu (2012) | $\beta$ | $\delta$ | $\gamma$ |
| | 0.967 | 1.0561*** | 0.452*** |
| | NaN | (0.098) | (0.0981) |
| Part c - Cointegration test | | | |
| Wang et al. (2015): | Stat | p-val | |
| | 118 | 0 | |

*Notes*: *, **, and *** denote significance at 10%, 5% and 1%, respectively. Standard errors of parameters are reported in parentheses.

Table 2: ECM estimation

| | Model 1 | Model 2 |
|---|---|---|
| $\Delta CNY$ | 1,017*** | 1,021*** |
| | (0,022) | (0,022) |
| ECT(-1) | -0,078* | 0,029 |
| | (0,039) | (0,061) |
| I(-1)*ECT(-1) | | -0,175** |
| | | (0,074) |
| | | |
| R2 | 0,75 | 0,75 |
| LL | 1831,81 | 1834,527 |

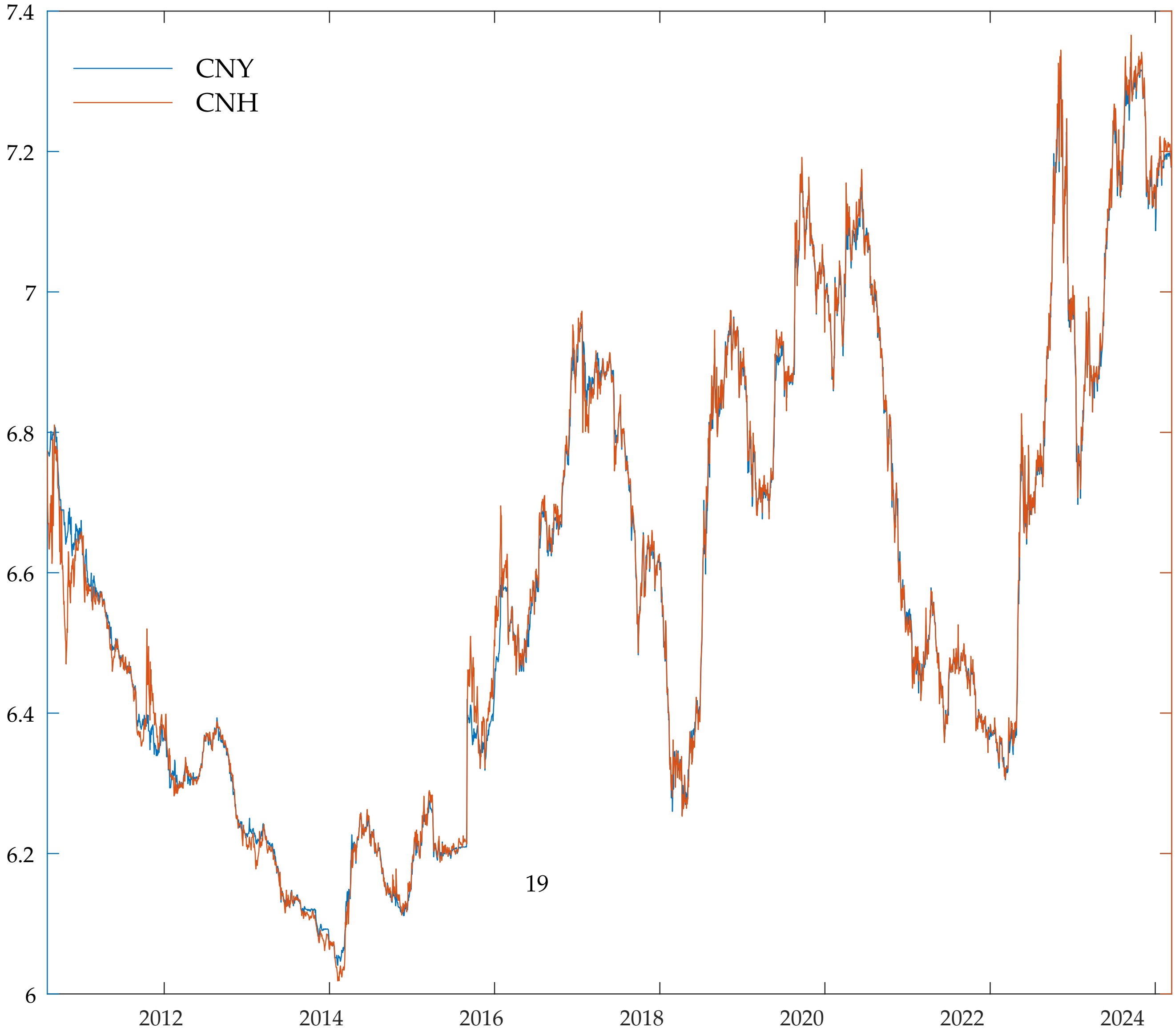
*Notes*: *, **, and *** denote significance at 10%, 5% and 1%, respectively. Standard errors of parameters are reported in parentheses.

Table 3: Influence of China policy-specific uncertainty indices

| | EPU | XPU | MPU | TPU |
|---|---|---|---|---|
| C | 0,084*** | 0,084*** | 0,085*** | 0,080*** |
| | (0,008) | (0,003) | (0,006) | (0,003) |
| X | -0,089** | -0,106*** | -0,096*** | -0,065*** |
| | (0,045) | (0,019) | (0,034) | (0,017) |
| X*I | 0,148*** | 0,159*** | 0,152*** | 0,140*** |
| | (0,008) | (0,008) | (0,008) | (0,008) |
| | | | | |
| R-squared | 0,331 | 0,350 | 0,337 | 0,314 |
| LL | 1535,958 | 1545,285 | 1538,925 | 1528,565 |

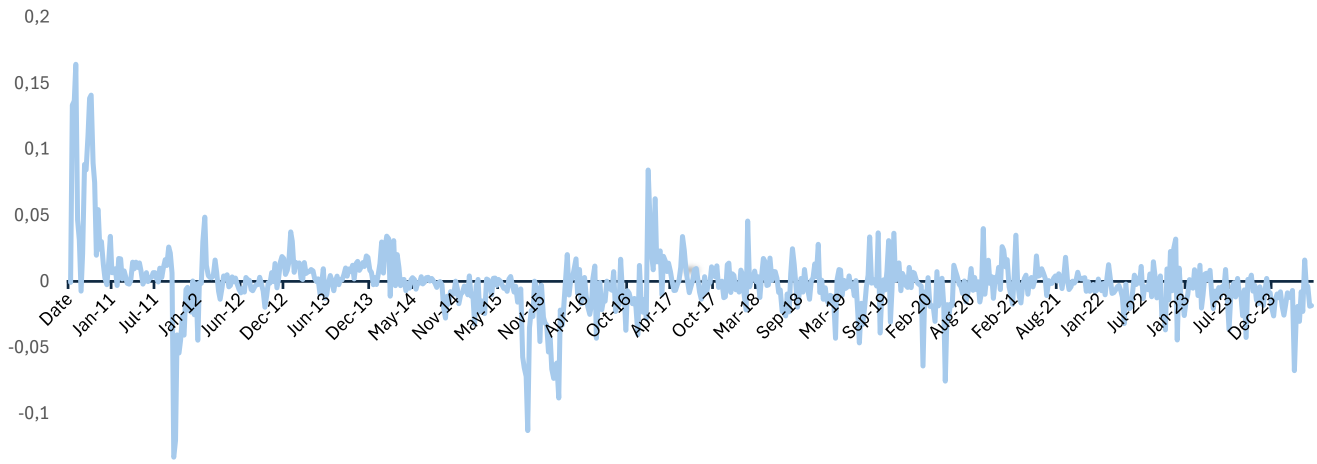
*Notes*: *, **, and *** denote significance at 10%, 5% and 1%, respectively. Standard errors of parameters are reported in parentheses.

Figure 1: CNH and CNY exchanges rates



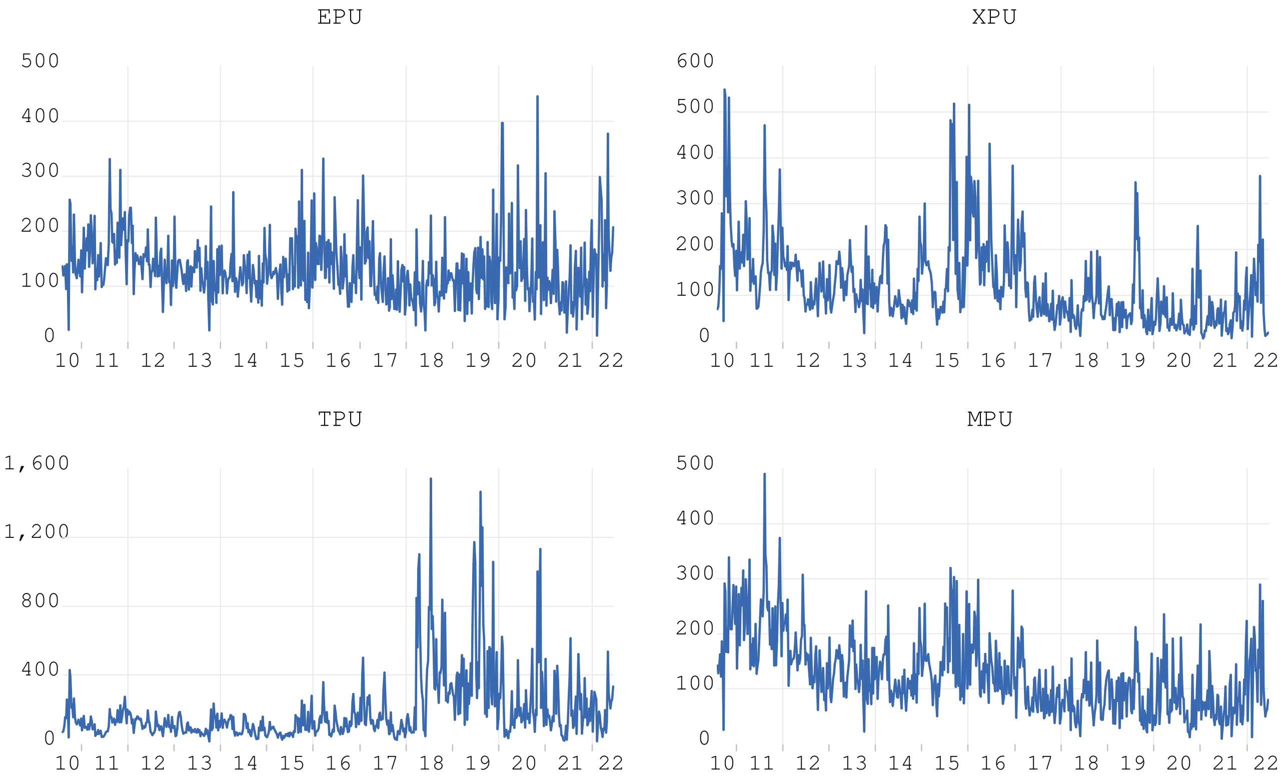

*Notes:*

Figure 2: CNH and CNY spread



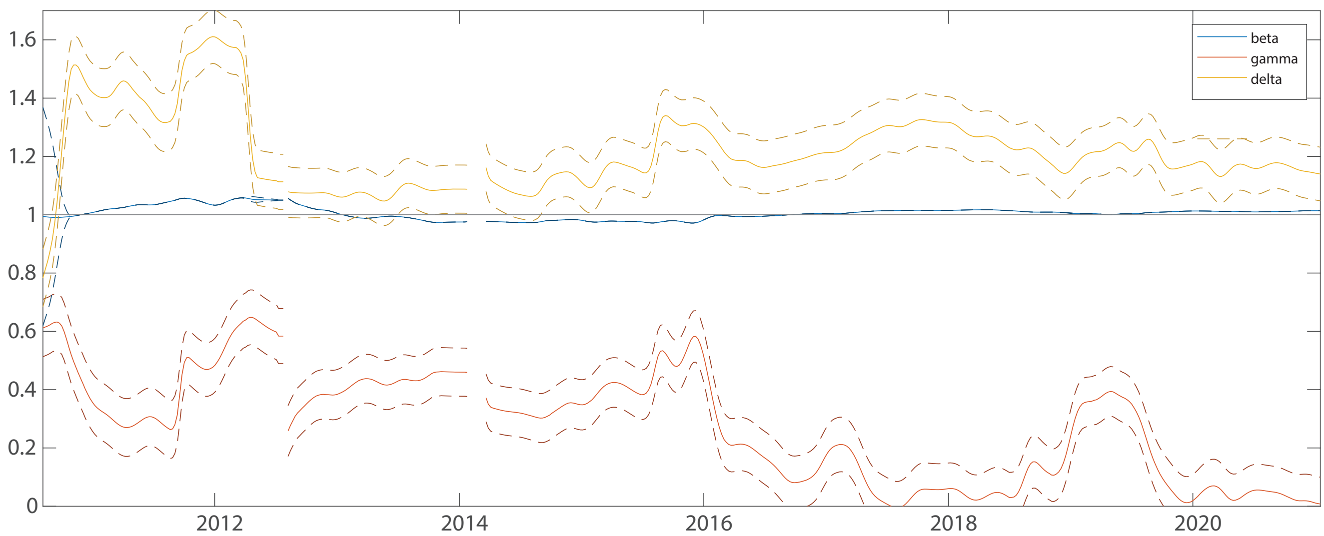

*Notes:*

Figure 3: China policy-specific uncertainty indices



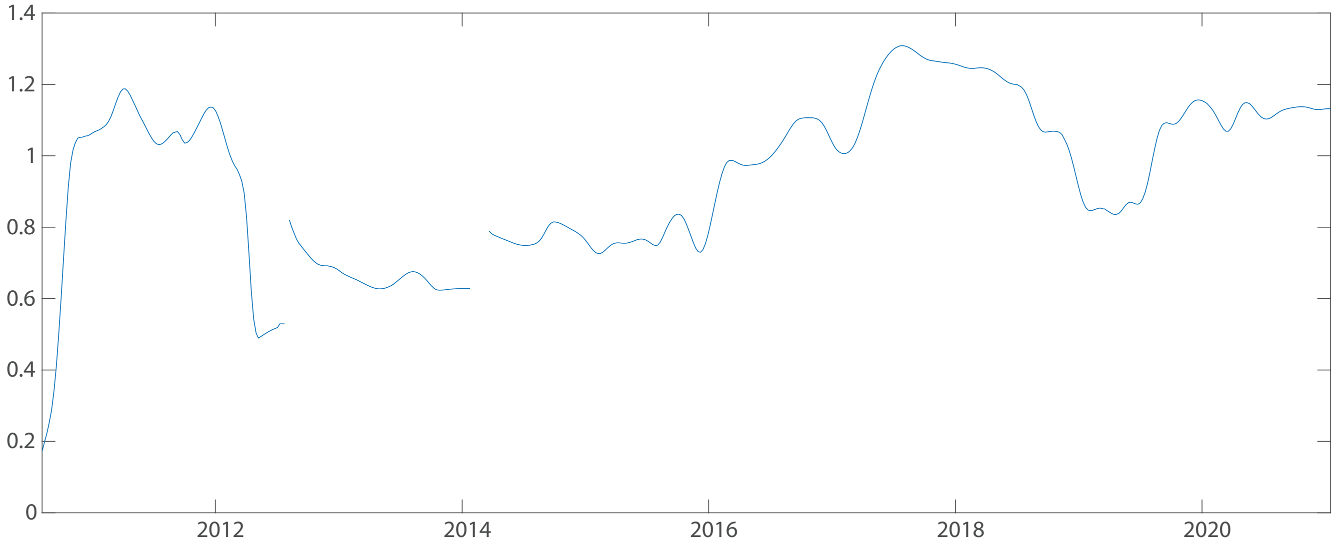

*Notes:*

Figure 4: Rolling cointegration estimates




*Notes:*

Figure 5: Deviations persitence between CNH and CNY (strenght of the cointegration relationship)




*Notes:*