China's Evolving Managed Float:
An Exploration of the Roles of the Fix and
Broad Dollar Movements in Explaining Daily
Exchange Rate Changes

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Abstract

We investigate the drivers of daily changes in the exchange value of the Chinese currency (CNY) since early 2016, when a new regime was introduced for setting the fix—the midpoint of the CNY's daily trading range against the U.S. dollar. Daily changes in the fix, which is announced just prior to the onset of onshore trading, are shown to be highly predictable and very responsive to the change in the CNY/USD rate during the previous day's onshore trading session and to changes in dollar cross rates. While highly predictable, the fix is shown to have uneven predictive power for the subsequent evolution of the currency's exchange value. Daily changes in the closing value of the exchange rate have centered on the changes implied by the fix to a much greater extent in months with higher intervention intensity, but less over the course of 2017, as intervention has waned. We document ways in which the short-run behavior of the CNY/USD exchange rate has evolved to more closely resemble behavior generally observed in freely floating currencies, even as the CNY continues to exhibit unusually low daily volatility. On days of broad dollar strengthening, the CNY is found to depreciate against the dollar but appreciate against the CFETS index, the authorities' main reference basket; the CNY now typically appreciates less than half as much as previously, when the currency was being managed primarily against the dollar.

Key words: Chinese currency, Chinese yuan, CNY, exchange rate regime, currency policy, flexible exchange rate, intervention, financial development

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I.   Introduction and overview

Market concerns about Chinese currency policy have declined substantially since roiling global markets in August 2015 and early 2016, notwithstanding further notable depreciation of the Chinese yuan (CNY) over the course of 2016. Many market participants have traced the reduced unease in part to the authorities' shift to a more predictable framework for setting the daily fixing rate; the fixing rate serves as the mid-point of the currency's daily trading range and is announced just prior to the start of the onshore trading session. But suggestions that the fix has played a key stabilizing role appear incomplete, given that they presume that the fix itself dampens volatility and guides where the CNY trades subsequently.

Surprisingly, the recent trading day behavior of the CNY has been little studied, notwithstanding clear signs both of active management by the authorities, and an important role for market forces. We help fill this gap by investigating the performance of the CNY since February 2016, focusing on the role of the daily fix, dollar cross-rates, overnight trading in the offshore market, and intervention in influencing the evolution of the bilateral and multilateral exchange value of the currency.

Regarding the fix, we show that about 95 percent of its daily variation can be predicted from a simple empirical model using changes in an index of dollar cross rates (e.g. EUR/USD, JPY/USD, etc, with weights taken from the authorities' main reference index), and changes in the CNY/USD exchange rate during the previous official trading day. We also document several shifts over the past year in the degree of passthrough of prior-day CNY/USD changes, including since mid-May 2017, when a so-called "countercyclical" element was introduced, and the passthrough declined notably. Our estimated parameters suggest that, by design, the fix plays at best a modest role in stabilizing the CNY's value against the dollar and the authorities' reference currency basket. This is because the fix passes through most, if not all, of the changes in the bilateral CNY/USD exchange rate during the prior trading day, and introduces only partial offsets for the impact of changes in dollar cross rates on the currency's multilateral value.

We then turn to investigating the degree to which daily changes in the fix appear to guide changes in the value of the CNY during the ensuing trading day. We propose a specific measure of "centering" and find that daily changes in the CNY closing price do not fully center on the changes implied by the fix, though they do take directional cues. In contrast, we find that the daily change in the CNY close does fully center on the change between the previous day's closing price and the onshore market's open. We also

1

find that the daily changes in the CNY center more closely around the fix during months with high intervention. Our results suggest that waning intervention over the course of 2017 may help explain why the fix has had much less predictive power in the latter part of our sample period.

To shed light on the CNY's incomplete centering on the fix, we explore the sensitivity of daily changes in the closing prices of CNY/USD exchange rate to the variables that predict changes in the fix, as well as to contemporaneous changes in dollar cross rates during official trading hours and overnight developments in the offshore CNH market. We find that daily changes in the CNY/USD closing price are generally much less sensitive than the fix to the variables that explain changes in the fix, with the notable exception of overnight changes in dollar cross rates. Of note, we find little evidence that the May 2017 introduction of a "countercyclical element" to the daily fix, apparently calibrated to lean against or partially reverse prior day CNY changes, has translated into similar changes in the behavior of the exchange rate. We also find that surprise deviations of the fix from our empirical model have limited predictive power for changes in the CNY during the ensuing trading day. This latter result appears inconsistent with the view often expressed by market commentators that surprises in the fix provide important signals that influence subsequent exchange rate changes.

We find that the CNY now responds systematically to short-term broad dollar movements, an important goal of the new fixing regime. Our estimated coefficients suggest that, on days when the dollar broadly strengthens, the currency now typically weakens against the dollar, but appreciates vis-à-vis the authorities' main reference basket (the CFETS index), though by less than half as much as when the currency was being managed bilaterally against the dollar.

Our results also document several ways in which daily changes in the CNY have evolved to more closely resemble the near random walk behavior typically seen in floating rate currencies. More recently, daily CNY changes do not appear to be correlated with lagged changes in dollar cross rates or the CNY/USD rate; daily changes in the CNY persist over time; and official intervention diminished substantially over the course of 2017. But the CNY's daily volatility against the dollar remains unusually low, compared to the currencies of most advanced economies and other large emerging market economies.

We interpret our results as pointing more to the authorities' active dampening of volatility in the exchange rate during the trading day, rather than the fix, as the key factor in calming markets since early 2016. By avoiding sudden moves that could upset markets, the authorities found space to allow more

substantial market-driven and/or policy-driven adjustment over longer horizons, both against the dollar and the authorities' reference basket.

II.   Recent evolution of China's currency regime

Over the past two years, China's approach to exchange rate management has evolved significantly, moving from a de facto crawling peg against the dollar with gradually widening bands, to a managed float referencing a currency basket. Key steps in the recent evolution have not always been well explained. As a result, some developments triggered surges in global market volatility in mid-2015 and early-2016, reflecting concerns about China's outlook, and its potentially significant impact on global trade and output. However, communication has improved since February 2016, and market participants have often cited the predictability of the post-February fix regime as a contributor to the reduction in volatility in Chinese and global markets since early 2016.

For context, between mid-2005 and mid-2015, the Chinese authorities alternated between periods of gradual, but not entirely steady appreciation of the daily fixing rate against the US dollar, and periods of holding the fixing rate relatively stable (Chart 1). Under this approach, the currency could at times persistently trade near the strong or weak side of a gradually widening trading band, requiring the central bank to engage in large scale intervention to maintain the currency within the target range.

On August 11, 2015, the Chinese authorities took a notable step toward making the currency regime more flexible: they announced that going forward the daily fixing rate would be set with reference to

Chart 1. USD/CNY Closing Exchange Rate and Daily Trading Bands
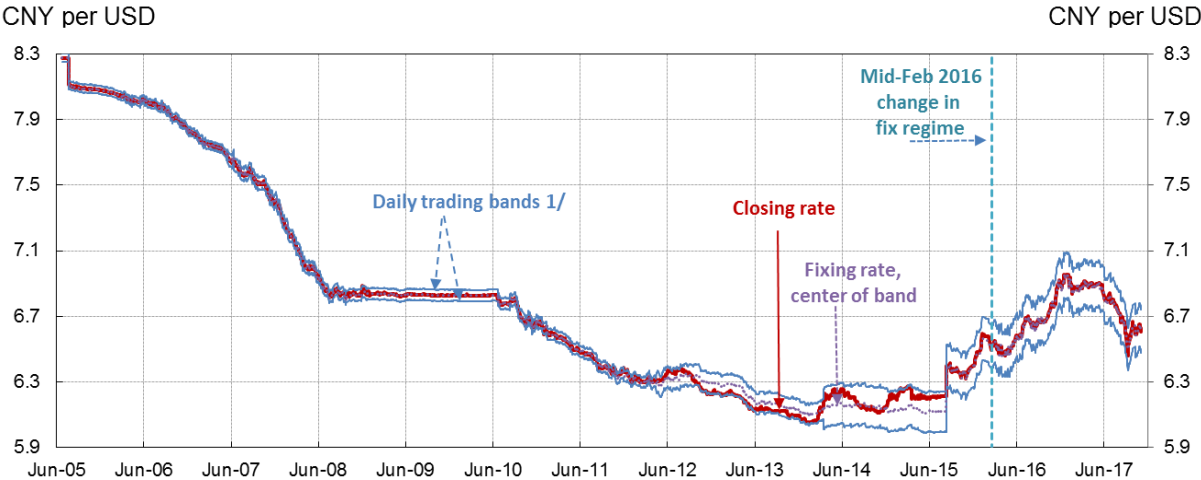
1/ Bands were widened May 18, 2007 (from ± 0.3 percent to ± 0.5 percent), Apr 16, 2012 (to ± 1 percent), and Mar 15, 2014 (to ± 2 percent).
Sources: PBOC, Bloomberg.

the previous day's closing level. In principle, the new rules implied that the CNY could depreciate as much as 10 percent against the dollar in a week. But in practice, the authorities intervened heavily in response to an upsurge in volatility and accelerating capital outflows following the August policy change announcement. As a result, after an initial adjustment, the exchange value of the CNY against the dollar traded in relatively narrow range from mid-August into October.

Another important step was taken in December 2015, when the authorities announced and began to regularly publish a new official effective exchange rate index (the CFETS Index), which they said "should help bring about a shift" in how market participants viewed the exchange rate. The announcement was generally interpreted by market participants as signaling the authorities' intention to manage the exchange rate more actively against this new index going forward.[1] But the operational implications were not explained nor understood at the time. When the CNY subsequently began to depreciate at an accelerating pace in December 2015 and early 2016, against a backdrop of broad dollar strength, Chinese and global market volatility spiked. Market participants feared that the Chinese authorities were countenancing or perhaps even pursuing a substantial weakening of the currency.
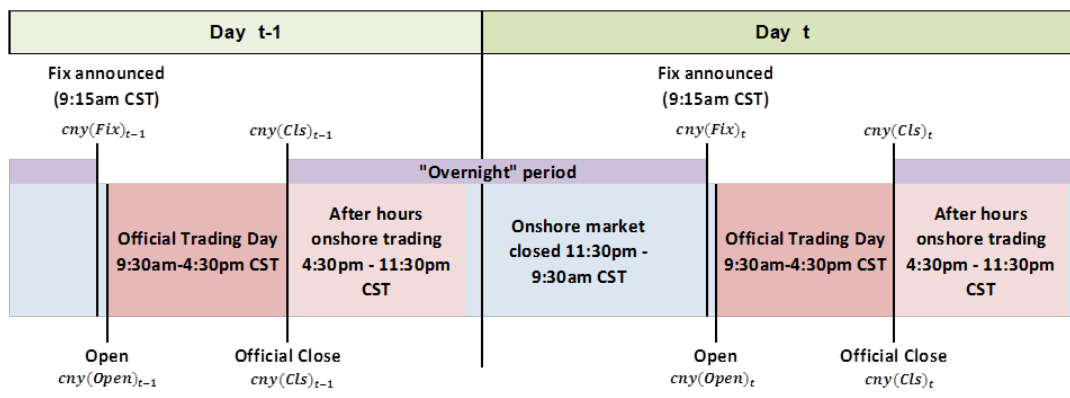
In an effort to calm markets, the Chinese authorities again resorted to heavy intervention in January and early February 2016 to stabilize the dollar-yuan exchange rate. In addition, they took steps, most notably in mid-February 2016, to explain more fully how they expected the new exchange rate regime to function, and to reassure local and foreign investors that they were neither targeting, nor expecting further substantial depreciation. Subsequently, the authorities provided detailed guidance to market participants regarding how the fixing rate should evolve in relation to developments in the CNY/USD exchange rate and dollar cross-rates during the prior trading day and overnight, enhancing the predictability of the process. As it became clear that the new approach to setting the fix was being implemented in line with the authorities' guidance, market participants began to cite the predictable approach as an important stabilizing factor in Chinese and global markets.

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[1] It had already been announced, on August 11, 2015, when the new fixing regime was introduced, that the fixing rates would also "take into account" exchange rate movements among the major currencies. However, before December 2015, it was not clear that any material adjustments for cross rate developments were in fact being made. Of note, over the previous decade, the authorities had characterized the de facto crawling peg regime as a "managed floating exchange rate based on market supply and demand with reference to a basket of currencies," though the basket was never specified and there was no significant relationship between short-term cross-rate movements and changes in the dollar exchange rate.

III.   The mechanics and role of the daily USD/CNY fix

Under current practices, China's official foreign currency trading day begins at 9:30 am CST (China Standard Time), and ends at 4:30 pm CST (see Chart 2). Just prior to the launch of trading, at 9:15 CST, the PBOC announces the fixing rate for the USD/CNY exchange rate, based on submissions from local dealing banks. The authorities also announce fixing rates against the CNY for other currencies included in the CFETS index, based on the USD/CNY fix and the prevailing dollar crosses. The USD/CNY fixing rate is based on a trimmed weighted average of submissions by market participants.

Chart 2. China: The Onshore FX Trading Day

Day t-1		Day t	
Fix announced (9:15am CST) $cny(Fix)_{t-1}$	Official Close $cny(Cls)_{t-1}$	Fix announced (9:15am CST) $cny(Fix)_t$	$cny(Cls)_t$

"Overnight" period

| | Official Trading Day 9:30am-4:30pm CST | After hours onshore trading 4:30pm - 11:30pm CST | Onshore market closed 11:30pm - 9:30am CST | | Official Trading Day 9:30am-4:30pm CST | After hours onshore trading 4:30pm - 11:30pm CST |

| Open $cny(Open)_{t-1}$ | Official Close $cny(Cls)_{t-1}$ | | | Open $cny(Open)_t$ | Official Close $cny(Cls)_t$ |

Note: 9:30 am CST is equivalent to 9:30 pm EDT and 10:30 pm EST, and 2:30 am LDT and 3:30 am LST.

The fixing rate, officially referred to as the "central parity rate", serves as the midpoint point for the intraday trading range (± 2 percent) for the currency, but is not a mandated transaction rate for entities buying or selling FX. In this respect, the CNY fix differs from the transaction-based fixes observed in some other markets, most notably the WM/Reuters benchmark rates set each day in London at 4pm. In fact, when onshore CNY trading opens at 9:30 CST, trading often begins at prices that differ from the fixing rate. Indeed, over the past year, the standard deviation of the log difference between the fix and the open price has been nearly half as large as the standard deviation for changes in the dollar value of the CNY over the full day (i.e. from close to close).

PBOC officials have provided guidance to fixing participants (dealing banks in the onshore FX market) regarding how to formulate their submissions. Initially, in early 2016, they counselled participants that their submissions should take account of both (a) market forces during the prior trading day, as reflected in the official 4:30 pm CST closing price vis-à-vis the dollar, which are expected to be passed through in full, and (b) the amount of currency change against the dollar needed to dampen the change in the value of the CFETS index due to cross-rate development during the previous trading day and overnight (i.e. after the official close) (PBOC 2016). The guidance also suggested that participants

consider changes in other reference indices (such as the SDR basket and the BIS' effective exchange rate index), but didn't suggest specific weights.

Of note, while the onshore market officially closes at 4:30 pm CST, the onshore trading system remains open until 11:30 pm CST. However, onshore liquidity declines markedly after the official close and the authorities have instructed market participants to only take into account onshore developments up to the official close of the prior day in setting their submissions for a given day's fix.

The authorities announced a modification to their guidance about one year later, over the weekend of February 18-19, 2017, counseling fix participants to only seek to offset cross-rate developments (i.e. between the dollar and other currencies, excluding the CNY), that take place overnight, between the official close of the previous trading day and 7:30 am CST. Most recently, on May 26, the authorities indicated publicly that they were "considering" changing the fixing mechanism yet again, to include an undefined "countercyclical mechanism". The addition of a countercyclical mechanism was confirmed in the PBOC's Q2 2017 Monetary Policy Report (PBOC 2017). Many market participants perceive that the introduction of countercyclical adjustments may have slightly preceded the May 26 announcement, based on the behavior of the fix earlier in the month (Peng and Wang, 2017). While the countercyclical mechanism has not been explicitly explained, the general view among market commentators has been that it has entailed both increased discretion and a systematic effort to lean against changes in the CNY/USD exchange rate during the prior trading day.

IV.   The CFETS Index and the "CFETS-weighted Dollar-Cross Index"

The authorities' main reference index, the CFETS index, was first announced in December 2015. It is a geometrically weighted index of the foreign currency cost of the CNY. Initially, 13 currencies were included in the index, comprised of all the currencies included in the CFETS automated system at that time; the basket was expanded to 24 currencies at the end of 2016, incorporating additional currencies that had been added to the CFETS system over the course of 2016.

As shown algebraically in Annex 1, the CFETS index equivalently can be calculated as the product of the USD cost of the CNY (CNY/USD), relative to the base period, and a weighted dollar-cross index (*DolCross*) of the cost of the dollar in the other currencies in the CFETS basket (using the CFETS index weights). Representing the CFETS as the product of the bilateral CNY/USD rate and CFETS-weighted dollar-cross index is useful for examining the contribution of these two factors to changes in the nominal

effective exchange rate, as measured by the CFETS index. Putting things in terms of log changes we have that over any window:

$$\Delta \ln(CFETS) = \Delta \ln(DolCross) + \Delta \ln(CNYUSD)$$

This equation implies that to keep the CFETS index unchanged over any window, the CNY would need to *depreciate* against the dollar by the same magnitude that the dollar *appreciates* against the weighted dollar-cross index, and vice versa.[2]

V.   An empirical model of the CNY fix

The Chinese authorities' published guidance on how the daily fix is set makes reference to incorporating changes in CNY/USD rate during the preceding trading day, and setting the fix to offset changes in the dollar cross rates that would change the level of the CFETS index. Accordingly, in our empirical model, we regress the daily log change in the fix (from fix-to-fix) on the daily log change in the CFETS-weighted dollar-cross index (from fix-to-fix), and the daily log change in the CNY/USD exchange rate (from close-to-close). In both cases we distinguish between the "overnight" period, changes from one day's official close to the next day's fix, and the "onshore trading day" period, from the fix to that day's close:

$$\ln\left(\frac{cny(Fix)_t}{cny(Fix)_{t-1}}\right) = C + \beta_1 \cdot \ln\left(\frac{DolCross(Fix)_t}{DolCross(Cls)_{t-1}}\right) + \beta_2 \cdot \ln\left(\frac{DolCross(Cls)_{t-1}}{DolCross(Fix)_{t-1}}\right)$$

$$+ \beta_3 \cdot \ln\left(\frac{cny(Cls)_{t-1}}{cny(Fix)_{t-1}}\right) + \beta_4 \cdot \ln\left(\frac{cny(Fix)_{t-1}}{cny(Cls)_{t-2}}\right) + \varepsilon_t \qquad (1)$$

where $cny(Fix)_t$ is the fixing price of the Chinese yuan (CNY) in US dollars on trading day t, $cny(Cls)_t$ is the 4:30 closing price of the CNY in US dollars on trading day t, and $DolCross(Fix)_t$ and $DolCross(Cls)_t$ are the values of the CFETS-weighted dollar-cross indexes measured using dollar crosses at the fix (9:15 am CST) and close (4:30 pm CST) respectively, on trading day t.[3] For

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[2] The weights in the CFETS-weighted dollar-cross index do not sum to one. This reflects the fact that CFETS weights sum to one, but the dollar is not included in the dollar-cross index. An implication is that the CFETS-weighted dollar cross index, by construction, will have less volatility than an index where the weights for the included series are scaled up to sum to one. For example, if all the dollar crosses were to rise by an equivalent *x* percent, the CFETS-weighted dollar-cross index would rise by the product of the aggregate weights (i.e. one minus the dollar's weight in the CFETS basket) and *x* percent.

[3] Note that we get almost identical results if instead we place the fix-vs-prior close differential on the left hand side. Subtracting $ln\left(\frac{cny(Cls)_{t-1}}{cny(Fix)_{t-1}}\right)$ from both sides of equation (1), and rearranging we get:

$DolCross(Fix)_t$, we use the cross rates implied by the official fixing rates of the CNY against the various currencies. We use the Chinese trading calendar, and measure changes in dollar crosses across any Chinese market holidays.

Our estimates use data for the period from February 17, 2016 through September 28, 2017. This window begins when a new approach to setting the fix apparently began to be implemented, coming out of the Chinese New Year Holiday of 2016; we eliminate the first two trading days after that holiday because of a large initial currency adjustment following the extended holiday. Details about our data can be found in Annex 2.

We identify three apparent adjustments to the fixing rule over the course of our sample window. Our estimated coefficients appear to shift in the period following the November 8, 2016 US election, when the US dollar appreciated rapidly, and the Chinese authorities stepped up the pace of intervention and tightened controls on capital outflows in an effort to lean against a weakening of the CNY. A second shift appears to have taken place starting February 20, 2017, following the issuance of new guidance to fix participants over the weekend of February 18-19; Chinese banks were instructed from that point forward to only adjust for overnight changes in dollar crosses, and no longer include adjustments for changes in the dollar crosses during the prior trading day. And we identify a third breakpoint in mid-May 2017, when the authorities publicly floated the possibility of adding an undefined countercyclical element to the daily fix; we chose May 15 as our break date after investigating windows between end-April and end-May for a possible regime break. Chow F-tests for structural breaks at each of these three dates were able to reject the null hypothesis of no breaks at the 1 percent level.

The evolution of the CNY/USD rate, the CFETS index, and the CFETS-weighted dollar cross index since end-2015 is summarized in Chart 3. Chart 3 also contains vertical lines showing the beginning and end of our sample and the three break points which we identify; we label the implied time periods I through IV. As can be seen, in the latter two periods, III and IV, the dollar-cross index trended downward over

$$\ln\left(\frac{cny(Fix)_t}{cny(Cls)_{t-1}}\right) = C + \beta_1 \cdot \ln\left(\frac{DolCross(Fix)_t}{DolCross(Cls)_{t-1}}\right) + \beta_2 \cdot \ln\left(\frac{DolCross(Cls)_{t-1}}{DolCross(Fix)_{t-1}}\right)$$

$$+ (\beta_3 - 1) \cdot \ln\left(\frac{cny(Cls)_{t-1}}{cny(Fix)_{t-1}}\right) + \beta_4 \cdot \ln\left(\frac{cny(Fix)_{t-1}}{cny(Cls)_{t-2}}\right) + \varepsilon_t \qquad (1a)$$

The estimated coefficients, standard errors, and residuals are identical to those in (1), except the coefficient on $\ln\left(\frac{cny(Cls)_{t-1}}{cny(Fix)_{t-1}}\right)$, which becomes $(\beta_3 - 1)$.

Chart 3. China: Exchange Rate Indices

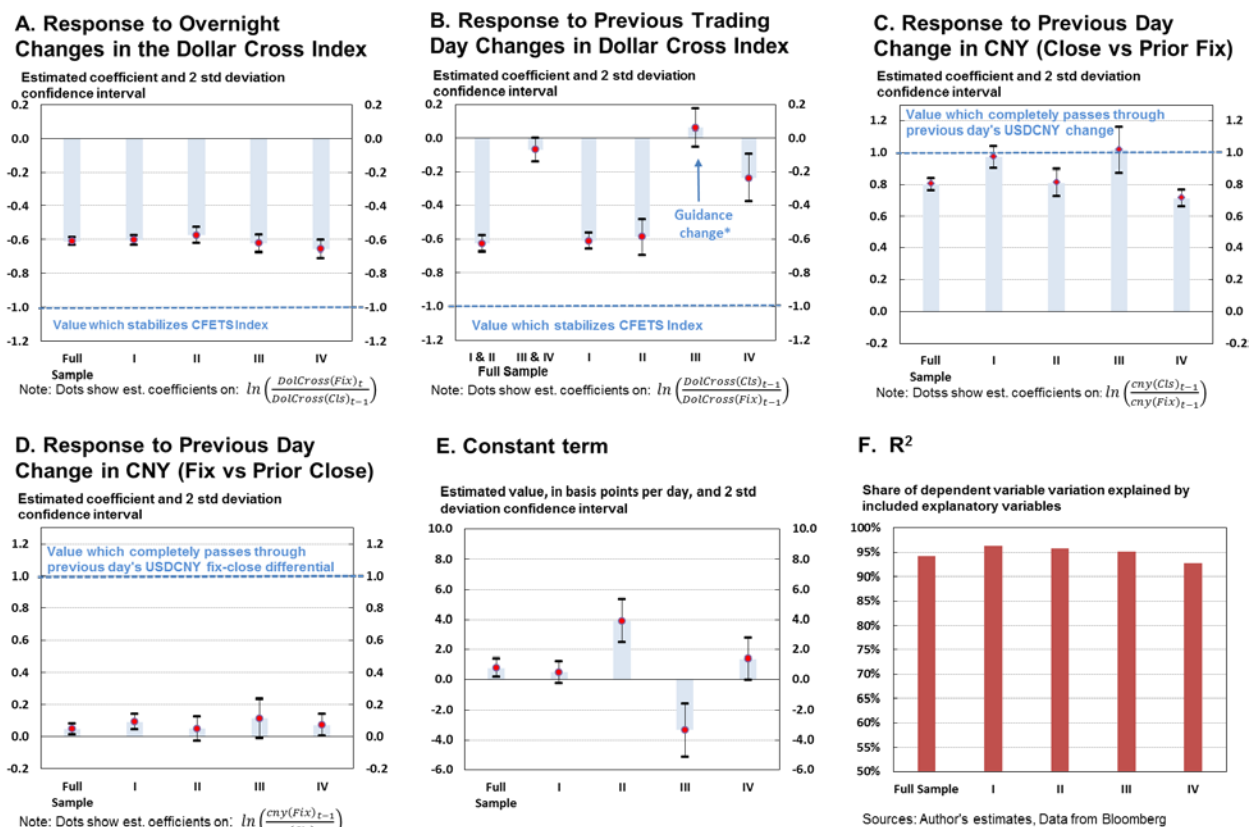Source: Bloomberg and author's calculations.
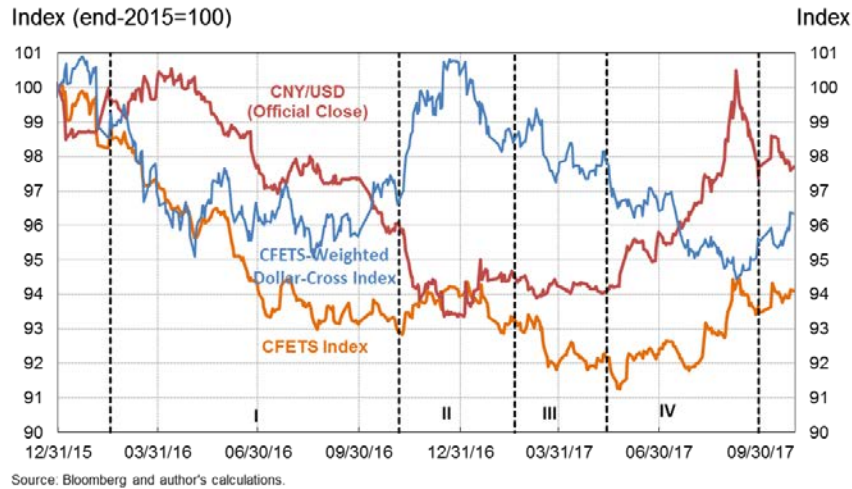
the course of 2017, and fully reversed the increase which took place during Q4 2016. Overall, the CNY depreciated by 6½ percent against the CFETS index between end-2015 and end-September 2017, with about 2 percentage points of the decline due to depreciation of the CNY against the dollar and 4½ percentage points due to depreciation of the US dollar against the CFETS-weighted dollar-cross index.

Chart 4 summarizes our estimation results for our empirical model of the daily fix. In each panel we show our estimated response coefficient for a given explanatory variable, and a 2 standard deviation confidence interval around the coefficient estimate. The first dot in each panel shows the estimated response coefficient for the full sample period, while subsequent dots show our estimated coefficients for each of the four subsamples, labeled I through IV.

Looking first to panel A, it can be seen that the estimated response coefficient to overnight changes in the CFETS-weighted dollar crosses (i.e. from the prior close to the fix) is fairly stable across our four sub-samples, at around -0.6.[4] This coefficient implies that when the dollar-cross index rises (i.e. the dollar strengthens) by 10 basis points overnight, the fix will be set 6 basis points weaker (the CNY depreciates vis-à-vis the dollar), and vice versa when the dollar index declines. While the coefficient on the dollar crosses is sizeable, it is also significantly different from -1, which is the value that would imply full offset of the impact of dollar cross changes on level of the CFETS index. In other words, the fixing rule would only partially stabilize the value of the CNY against the CFETS index in the face of cumulative overnight changes in the dollar cross indices.

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[4] Jermann, Wei, and Yue (2017) find a response coefficient to dollar cross movements of around -0.5. They hypothesize that this value reflects an equal weighting on two perceived objectives of the Chinese authorities: to adjust the fix to reflect supply and demand conditions and to stabilize the currency against the reference basket.

Chart 4. Estimated Determinants of the Change in the CNY/USD Fix from the Previous Day's Fix

A. Response to Overnight Changes in the Dollar Cross Index

Estimated coefficient and 2 std deviation confidence interval

Value which stabilizes CFETS Index

Full Sample, I, II, III, IV

Note: Dots show est. coefficients on: $ln\left(\frac{DolCross(Fix)_t}{DolCross(Cls)_{t-1}}\right)$

B. Response to Previous Trading Day Changes in Dollar Cross Index

Estimated coefficient and 2 std deviation confidence interval

Guidance change*

Value which stabilizes CFETS Index

I & II, III & IV, Full Sample, I, II, III, IV

Note: Dots show est. coefficients on: $ln\left(\frac{DolCross(Cls)_{t-1}}{DolCross(Fix)_{t-1}}\right)$

C. Response to Previous Day Change in CNY (Close vs Prior Fix)

Estimated coefficient and 2 std deviation confidence interval

Value which completely passes through previous day's USDCNY change

Full Sample, I, II, III, IV

Note: Dotss show est. coefficients on: $ln\left(\frac{cny(Cls)_{t-1}}{cny(Fix)_{t-1}}\right)$

D. Response to Previous Day Change in CNY (Fix vs Prior Close)

Estimated coefficient and 2 std deviation confidence interval

Value which completely passes through previous day's USDCNY fix-close differential

Full Sample, I, II, III, IV

Note: Dots show est. oefficients on: $ln\left(\frac{cny(Fix)_{t-1}}{cny(Cls)_{t-2}}\right)$

E. Constant term

Estimated value, in basis points per day, and 2 std deviation confidence interval

Full Sample, I, II, III, IV

F. R^2

Share of dependent variable variation explained by included explanatory variables

Full Sample, I, II, III, IV

Sources: Author's estimates, Data from Bloomberg

Panel B shows our estimated response coefficients to changes in the dollar-cross index during the previous trading day (from the prior fix to the prior close). These coefficients evolve in a manner broadly consistent with changing PBOC public guidance: from February 2016 through February 2017 (sub-periods I and II), we find estimated response coefficients that are essentially that same as those on the overnight dollar crosses, -0.6. But after February 18, 2017, when the PBOC instructed banks to only consider overnight changes in cross rates, the estimated coefficient becomes statistically indistinguishable from zero in period III. In the most recent period, from mid-May into September, when unspecified countercyclical adjustments were introduced to banks' fix submissions, we find evidence of a renewed offset adjustment for dollar cross-rate movements in the prior trading day, but of smaller magnitude than in periods I and II.

Panel C plots the estimated response of the fix to the log difference between the prior day's closing price of the CNY/USD rate and the fix that preceded it. The PBOC's public guidance implies that this coefficient should be 1, implying full pass-through of the previous trading day's change vis-à-vis that day's fix. For our full sample period, we find a response coefficient close to, but below 1, equal to about

seven-eighths. This coefficient implies that almost all of a given trading day's change in the level of the CNY/USD rate vis-à-vis the previous day's fix is carried through to the next day's fix.

Of note, the estimated pass-through coefficient is statistically indistinguishable from 1 in the first and third subsample periods. However, in the second and fourth subsamples, the pass-through declines to about 0.8 and 0.7, respectively. The lower pass-through from November to February may have reflected an effort to dampen currency volatility in the window following the US election, when the dollar was strengthening broadly, and the CNY tending to depreciate. And the more recent lowering of the pass-through, since May 15, 2017, likely reflects the impact of the discretionary "countercyclical element" that was added to the fixing rule around that time.

Panel D plots the response of the fix to the prior day's deviation of the fix from the previous close. This element does not feature in the official guidance, but for the sample period as a whole, and several of the sub-periods, we find a statistically significant response coefficient of around 0.1. This indicates that in practice there is some small positive serial correlation between changes between the close and the subsequent fixes on successive days.

Regarding the goodness of fit, as shown in panel F, we find very high R^2s for our first three sub-periods: our simple model accounts for about 95 percent of the daily variation in the fix in each of these periods. In the last sub-period, since mid-May 2017, the explanatory power of our model of the fix declines to a still high 92 percent, suggesting a greater role for discretion and/or that we have not fully captured the contours of the rumored "counter-cyclical element" in the current fixing rule. It is notable however that we do not find evidence of parameter instability within the window May 15 to September 28, 2017. For the sample as a whole, when we allow the coefficient on the previous day's dollar crosses to differ before and after February 18, 2017, in accordance with the published guidance, our R^2 exceeds 94 percent.

It is important to recognize that while we have shown that the fix became very predictable (given information about the prior trading session and overnight cross rates), our estimated coefficients imply that this post-February 2016 approach to setting the fix would by itself do little to dampen volatility in the currency. This is because the fixing rule is calibrated to pass through most to all of the previous day's changes in the CNY's dollar value. Hence, large trading day changes lead immediately to large changes in the subsequent fix. And as we have shown, while the fix did introduce some offsets for dollar cross changes, these were only partial (60 percent for overnight changes), and therefore sufficient to

11

only dampen, but not prevent multilateral appreciation if the dollar strengthened broadly and on a sustained basis. Indeed, the CNY depreciated significantly against both the dollar and the CFETS index over the course of 2016, as shown in Chart 3. Moreover, there is also the question of the extent to which the fix actually guides behavior of the exchange rate, a question we turn to next.

VI.   Do daily changes in the CNY center around the fix?

As noted earlier in Section III, the CNY need not, and in fact does not always open at the same level as the fix. Moreover, the CNY can trade as much as 2 percent stronger or weaker than the fix in the ensuing trading session. So this naturally begs the question of whether the fix provides much of a guide to the exchange rate's behavior during the subsequent trading session. This is especially important for the multi-day trajectory of the exchange rate, because, as shown above, the fix largely passes through movements in the CNY/USD exchange rate during the trading day to the next day's fix.

Whether changes in the CNY during the ensuing trading day center on the fix depends on:
(a) the degree to which the fix approximates an equilibrium starting point for the day's trading, and/or
(b) the degree to which the fix signals an actual or perceived target around which the authorities guide the exchange rate through intervention or other means. On the latter point, China's authorities have engaged in sizeable intervention in 2016 and early 2017 to guide and dampen movements in the exchange rate, for example, by selling some $440 billion in reserves in 2016.[5] Indeed, as shown in Chart 5, the CNY has been much less volatile than the more freely floating currencies included in its reference basket.

For our purposes, we say that the daily change in the CNY/USD exchange rate "centers" on the CNY/USD fix (or some other benchmark, such as the opening price) if, when we regress the change in the value of the CNY between 4:30 pm closes on the differential between the previous close and the 9:15 am fix (or the alternative benchmark), we find an estimated coefficient (β) that is close to 1, such that we cannot reject the hypothesis that it is equal to 1.[6]

$$\ln\left(\frac{cny(Cls)_t}{cny(Cls)_{t-1}}\right) = C + \beta \cdot \ln\left(\frac{cny(Fix)_t}{cny(Cls)_{t-1}}\right) + \varepsilon_t \qquad (2)$$

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[5] Based on the reported annual change in reserves in the official balance of payments statistics.

[6] For a variable which follows a random walk, it can be shown that its change over any interval is centered on its change from the start of the interval to any point in time within the interval.

Chart 5. Standard Deviations of Daily Exchange Rate Changes vs the US Dollar

From Mid-Feb 2016 to End-Sep 2017
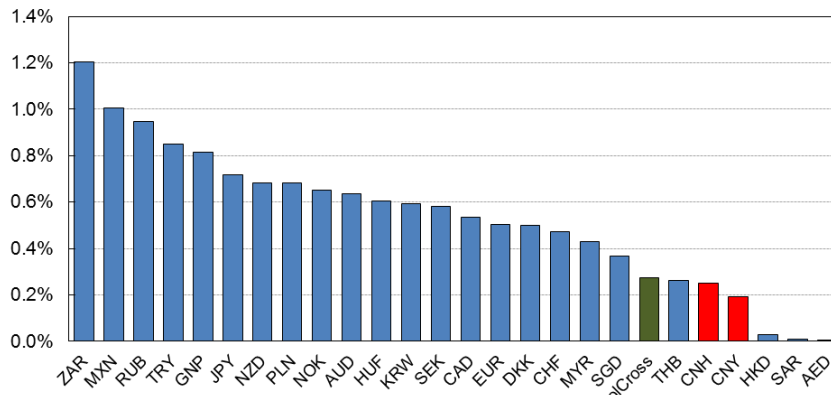
*DolCross is the weighted dollar cross, using the CFETS index weights for the currencies shown in the chart.
Sources: Bloomberg and staff calculations. Data as of Sep-2017.
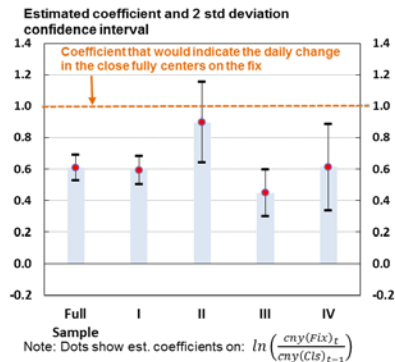
On the other hand, if the fix (or some other benchmark) is not informative about the change in the CNY, we would expect to find a coefficient close to 0. In the intermediate case, if the fix provides some signal about the direction and magnitude of change of the CNY, we might expect to find a value for β that lies between 0 and 1. In this latter, intermediate case, the closeness of the estimated coefficient to 1 or 0 could reflect the degree of signal vs. noise in the fix. But it also could reflect an issue of scaling; for example, if the fix is directionally quite informative, but scaled to over-predict changes in the CNY, we might find a high R squared value for our centering regression, notwithstanding an estimated β significantly lower than 1.

Chart 6 summarizes the results of such an exercise for two benchmarks, the differential between the fix and the prior close (shown in Panels A to C) and the change from the prior close to the open of onshore trading (Panels D to F). In both sets of panels, we show results for the sample as a whole, and for the four subperiods identified earlier, in our modeling of the fix.
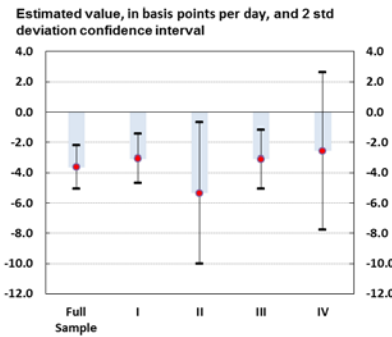
Looking first to our estimates for the fix (Panels A to C), we find that for the sample as a whole and most subintervals, our estimated response coefficients on the prior close-to-fix differential are positive, and significantly different from 0. But in most subperiods, the estimated betas also are well short of 1. So while the change from the previous close to the fix provides significant directional information about the expected change in the CNY, these results suggest the fix generally provides a somewhat noisy signal, and the close generally does not fully "center" on the fix.

13

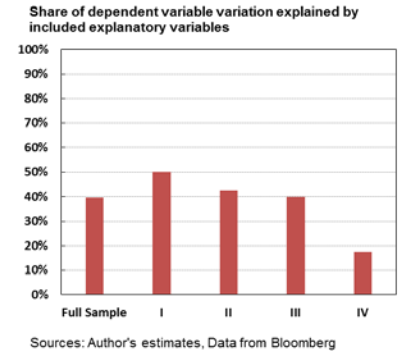## Chart 6. Does the Daily Change in the CNY Center on the Fix or the Open?

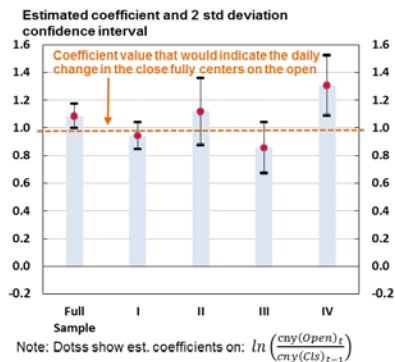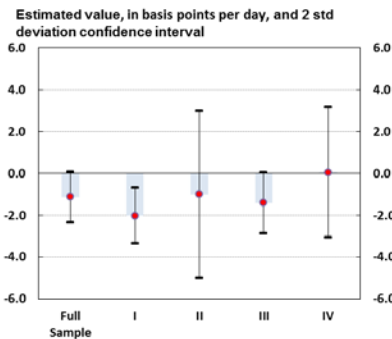**A. Response of CNY (Cls-Cls) to Fix vs Prior Close Differential**

Estimated coefficient and 2 std deviation confidence interval

Coefficient that would indicate the daily change in the close fully centers on the fix

Note: Dots show est. coefficients on: $ln\left(\frac{cny(Fix)_t}{cny(Cls)_{t-1}}\right)$

B. Constant term

Estimated value, in basis points per day, and 2 std deviation confidence interval

C. R^2

Share of dependent variable variation explained by included explanatory variables

Sources: Author's estimates, Data from Bloomberg

D. Response of CNY (Cls-Cls) to Open vs Prior Close Differential

Estimated coefficient and 2 std deviation confidence interval

Coefficient value that would indicate the daily change in the close fully centers on the open

Note: Dotss show est. coefficients on: $ln\left(\frac{cny(Open)_t}{cny(Cls)_{t-1}}\right)$

E. Constant term

Estimated value, in basis points per day, and 2 std deviation confidence interval

F. R^2

Share of dependent variable variation explained by included explanatory variables

Sources: Author's estimates, Data from Bloomberg

In contrast, as shown in panels D to F, we find that the daily close has more consistently centered on the open, or more precisely that the one day change in the close centers on the change from the previous close to the open for that day. For the sample period as a whole, and for all but fourth subperiod, the estimated coefficients on the prior close-to-open change lies within a two standard deviation confidence interval that includes the value of 1; hence, expect in subperiod IV, we are unable to reject the hypothesis that our estimated betas are equal to 1. Moreover, comparing panels C and F, the proportion of the daily variation in the CNY explained by the open vs prior close differential (i.e. the R squared from these regressions) is notably higher, by some 20 percentage points for the full sample, than the proportion explained by the differential between the fix and prior close and the fix.

VII.   Does intervention intensity explain the degree of CNY centering around the fix?
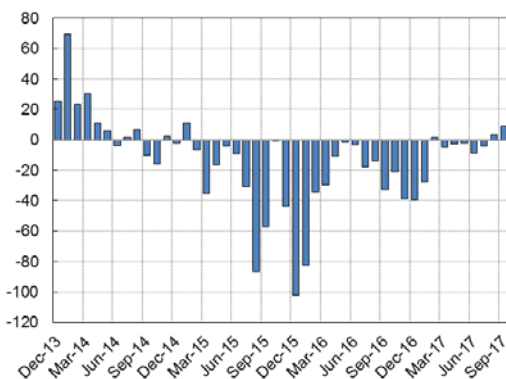
Turning back to Panels A to C in Chart 6, it is notable that in the second subperiod, from early November through the first half of February, we find a greater degree of centering on the fix, with a point estimate for β close to, but slightly below 1. Also, as we noted, the explanatory value of the fix (R^2) declines markedly in the fourth subperiod, the period from May 12 to September 28, 2017.

It seems plausible that these differences across subperiods could reflect differences in intensity of intervention. As can be seen in Chart 7, Panel A, the months from November 2016 through January 2017 were a period of relatively monthly high drawdowns in the foreign assets of the Chinese central bank, apparently reflecting a greater intensity of exchange market intervention, while more recently, the intensity of intervention appears to have declined substantially.[7]

Chart 7. China: Intervention Indicators

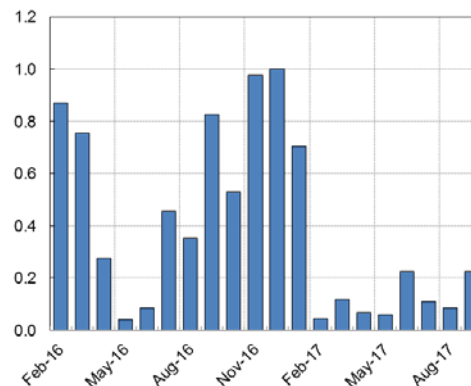A. China: Estimated Reserve Operations
Billions of dollars per month
Sources: IIF

B. China: Intervention Intensity Index
Index
Sources: Authors calculation, based on IIF estimates

To formally test whether intervention influences the degree to which the change in the CNY close centers on the fix, we constructed a monthly intervention intensity index. Our measure, plotted in panel B of Chart 7, varies between 0 and 1, where a value of 1 is assigned to the month in our sample period with the highest estimated intervention, December 2016; other months are scaled to the absolute values of the reserves changes in those months, relative to the peak month.
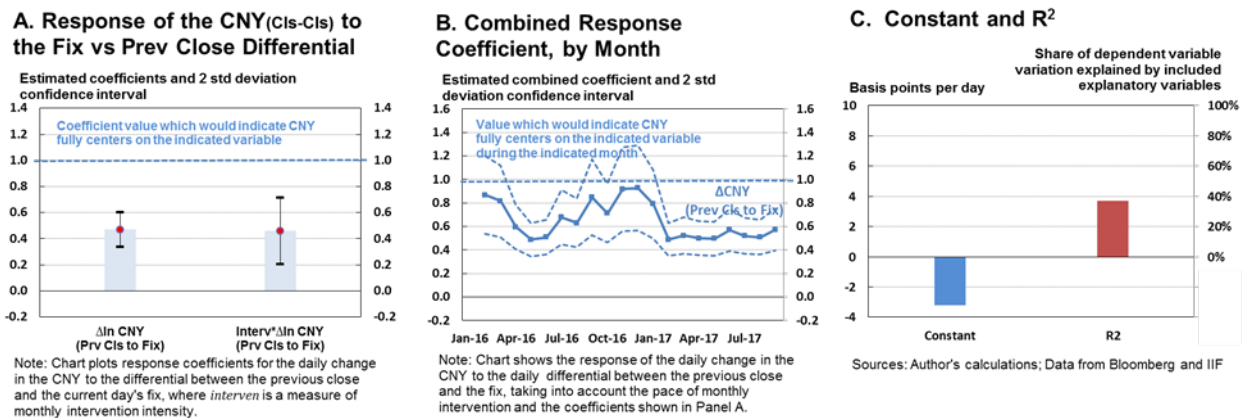
We then constructed an interactive variable—the product of our monthly intervention intensity index ($intervention_t$) and the close-fix differential—and added this term to our centering regression (equation 2), and tested whether the coefficient on this interactive term (the β_2 in equation 3, below) was economically and statistically significant:

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[7] Analysts use a number of published indicators to estimate monthly intervention, including: changes in the level of official reserves, reported in dollars; changes in the central bank's foreign assets, valued in local currency, and domestic banks' net transactions with customers in foreign exchange (for example, see Setser, 2016). These measures each have their relative advantages and disadvantages and are not perfectly correlated from month to month. In the analysis here, we use the IIF's estimates of monthly reserve operations which the IIF bases on a weighted average of these above mentioned monthly measures, with weights calibrated to best track with the reserve changes in the quarterly balance of payments. We obtain qualitatively similar results when we construct an intervention intensity measure using monthly changes in the reported local currency value of the PBOC's foreign assets, the single measure which best tracks with the reserves change reported in the balance of payments.

$$\ln\left(\frac{cny(Cls)_t}{cny(Cls)_{t-1}}\right) = C + \beta_1 \cdot \ln\left(\frac{cny(Fix)_t}{cny(Cls)_{t-1}}\right) + \beta_2 \cdot intervention_t \cdot \ln\left(\frac{cny(Fix)_t}{cny(Cls)_{t-1}}\right) + \varepsilon_t \qquad (3)$$

As can be seen in Chart 8, we indeed find an economically and statistically significant coefficient (β_2) on our interactive intervention term. In panel B, we plot the implied total response coefficient each month, reflecting the sum of our estimated β_1 and our intervention intensity measure multiplied by β_2. These results suggest that the CNY nearly centered on the fix in months with high intervention intensity, such as December 2016; but the fix did not fully center on the close in months with low intervention intensity, as has been the case for much of 2017.

Chart 8. Does Intervention Cause the CNY Center To a Greater Degree on the Fix?

A. Response of the CNY(Cls-Cls) to the Fix vs Prev Close Differential

Note: Chart plots response coefficients for the daily change in the CNY to the differential between the previous close and the current day's fix, where *interven* is a measure of monthly intervention intensity.

B. Combined Response Coefficient, by Month

Note: Chart shows the response of the daily change in the CNY to the daily differential between the previous close and the fix, taking into account the pace of monthly intervention and the coefficients shown in Panel A.

C. Constant and R²

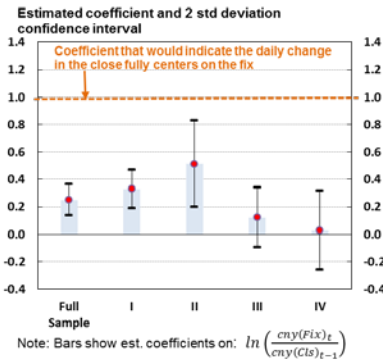Sources: Author's calculations; Data from Bloomberg and IIF

We also considered the possibility that daily changes in the CNY/USD rate (from close to close) might center on more on overnight changes in the offshore CNH market, rather than the fix vs prior close, especially during periods of relatively low intervention. Offshore trading in CNH continues throughout the day, in Hong Kong and other financial centers, even while the onshore CNY market is closed. While capital controls impede full arbitrage, the CNH/USD and CNY/USD exchange rates demonstrate considerable co-movement when both markets are open, and the differential between the CNY and CNH exchange rates has typically traded in a narrow range, reflecting opportunities to arbitrage over time any persistent differentials through permitted trade and capital account transactions. As a result, it seems reasonable to hypothesize that overnight trading in the CNH market might anticipate how overnight developments are expected to influence the CNY during the subsequent onshore trading day.
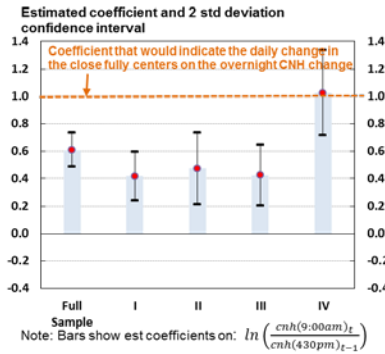
In Chart 9, we explore the degree to which the close-to-close change in the CNY centers on overnight changes in the CNH market, that is the change in the CNH from 4:30 pm CST the prior day to 9:00 am CST (i.e. before the announcement of that day's fix), as an alternative to the fix vs previous close differential. In the first row, Panels A to C, we show that that in practice the CNY centers more on a

Chart 9. Does the CNY Change Center on a Combination of the Fix & the Overnight CNH Change?
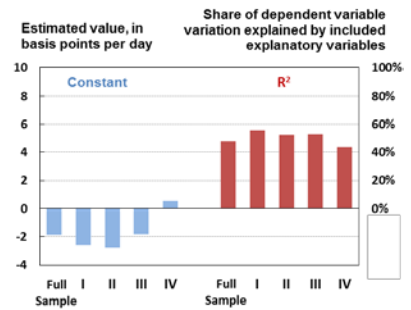
A. Response of CNY (Cls-Cls) to Fix vs Prior Close Differential

Estimated coefficient and 2 std deviation confidence interval

Note: Bars show est. coefficients on: $ln\left(\frac{cny(Fix)_t}{cny(Cls)_{t-1}}\right)$

B. Response of CNY (Cls-Cls) to Overnight CNH Change (430pm-9am)

Estimated coefficient and 2 std deviation confidence interval

Note: Bars show est coefficients on: $ln\left(\frac{cnh(9:00am)_t}{cnh(430pm)_{t-1}}\right)$

C. Constant Term and R²

Estimated value, in basis points per day — Share of dependent variable variation explained by included explanatory variables
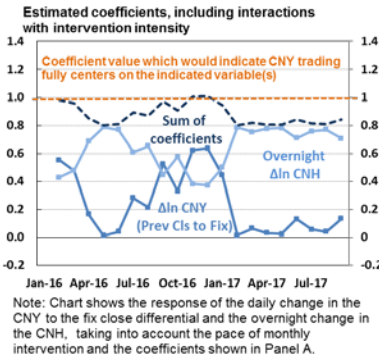

Sources: Author's estimates, Bloomberg

D. Response of CNY(Cls to Cls) to Indicated Variables

Estimated response coefficient and 2 std deviation confidence interval
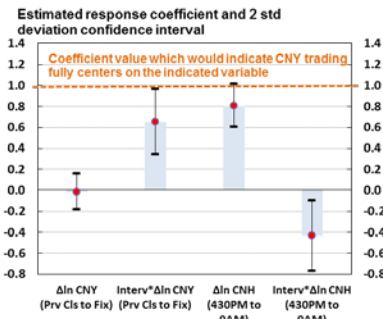
E. Implied Combined Response Coefficients, by Month

Estimated coefficients, including interactions with intervention intensity

Note: Chart shows the response of the daily change in the CNY to the fix close differential and the overnight change in the CNH, taking into account the pace of monthly intervention and the coefficients shown in Panel A.

F. Constant Term and R²

Estimated value, in basis points per day — Share of dependent variable variation explained by included explanatory variables

Sources: Author's estimates, Bloomberg and IIF

Note: Panels A-C report the results of regression of the daily log change in the USDCNY exchange rate (from close-to-close) on the log of the fix vs prior close differential and the overnight log change in the USDCNH exchange rate. Panels D-F report the same exercise for the full sample period, adding interactive terms for the monthly intervention intensity.

linear combination of the overnight CNH change and the fix-close differential than on one variable or the other. However, it can also be seen that the relative weights on the CNH change and fix-close differential vary significantly across subperiods, with the estimated coefficient on the fix-close differential (Panel A) highest during the subperiod with the highest intervention intensity (subperiod II), and lowest in subperiod IV, when intervention was apparently low. In contrast, in subperiod IV, we cannot reject the hypothesis that changes in the CNY fully center on overnight changes in the CNH, and shown in Panel B.

In Panels D to F, we show the results of adding interactive terms to test whether intervention intensity could be influencing the shifts, visible in panels A and B, in the relative centering on the close-fix differential vs. the overnight CNH change. Specifically, we estimate the following equation:

$$ln\left(\frac{cny(Cls)_t}{cny(Cls)_{t-1}}\right) = C + \beta_1 \cdot ln\left(\frac{cny(Fix)_t}{cny(Cls)_{t-1}}\right) + \beta_2 \cdot intervention_t \cdot ln\left(\frac{cny(Fix)_t}{cny(Cls)_{t-1}}\right) +$$

$$\beta_3 \cdot ln\left(\frac{cnh(9am)_t}{cnh(Cls)_{t-1}}\right) + \beta_4 \cdot intervention_t \cdot ln\left(\frac{cnh(9am)_t}{cnh(Cls)_{t-1}}\right) + \varepsilon_t \qquad (4)$$

where $cnh(9am)_t$ and $cnh(Cls)_t$ are the values for the CNH/USD exchange rate at 9:00 am CST and 4:30 pm CST (the official close for the onshore market. and ε_t is an error term, reflecting other factors that determine the change in CNY closing prices.

Our estimation results suggest that the intensity of intervention indeed has played an important role in determining the extent to which close-to-close CNY changes have centered on the fix vs on overnight CNH changes. As shown in the bars in panel D, we find a large and statistically significant positive coefficient on the interactive term between intervention intensity and the differential between the fix and the previous CNY close. In contrast, we find a economically and statistically significant negative coefficient on the interactive term between intervention intensity and overnight CNH changes.

As is illustrated in panel E, the coefficients in panel D imply that the responsiveness to the fix vs prior close differential peaked near the middle of our sample period, but was near zero in recent months, during the period of "countercyclical" adjustments to the daily fix. In contrast, the combined response coefficient to overnight changes in the CNH has been quite high in recent months, with point estimates approaching 0.8.

VIII.   Unpacking the differences between the fixing rule and the drivers of the CNY

The results of the previous section begs the question of why the fix doesn't provide more of a guide to changes in the CNY center in periods with less intervention. To gain insight, we regressed the log change in the CNY, from close-to-close, on the various components of our estimated model of the fix. Specifically, we included as right hand side variables, all of the variables equation (1), including our empirical estimates of the fix forecast error term. This approach allows us to see whether the variables that determine the fix, have similar importance and coefficient values for a model of the changes in CNY closing prices.

Of note, our inclusion of the estimated error terms, that is, our estimates of ε_t from equation (1), allows us to concretely explore whether "surprises" in the fix are consequential for subsequent performance of the currency. Some market observers have suggested that "surprise" deviations from the fixing rule are important, as they can be taken as signals of the authorities' preferences and can have outsized impacts on subsequent trading.

In addition, we included among our explanatory variables the *contemporaneous* change in the dollar-cross index, from the fix to close. Recall that in February 2017, the guidance for fix submissions was

changed such that changes in dollar crosses during the *previous* trading day should no longer be taken into account in setting the fix. This change likely reflected a view that such adjustments would be unnecessary because the CNY can respond contemporaneously to changes in the dollar crosses during the same onshore trading day.

To control for endogeneity, that is, for the possibility that the changes in the CNY/USD exchange rate cause some of the contemporaneous changes in dollar crosses rather than vice versa, we used an instrumental variables approach for our estimation. We instrumented the contemporaneous dollar cross index with a CFETS-weighted index of the USD/EUR, USD/YEN and USD/GBP exchange rates. This approach presumes that while endogeneity might be an issue for some currencies (such as EM Asian currencies, which might plausibly be sensitive to contemporaneous changes in the CNY/USD rate), these three intra-advanced economy exchange rates are independent of contemporaneous changes in the CNY/USD rate.
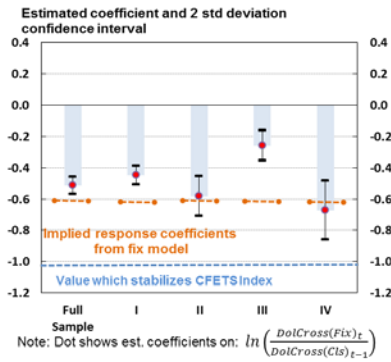
Finally, to gauge the impact of possible price discovery in the overnight CNH market, we included a variable which we call *CNH-Resid*. *CNH-Resid* is constructed as the residual from a regression of the overnight log change in the CNH on the overnight log change in the dollar-cross index. We follow this approach to facilitate interpretation of the coefficient on the dollar cross index.[8]

The results of this exercise are summarized in the various panels of Chart 10. In each panel, we show the coefficient value that we would expect to find, if the close-to-close change in the CNY/USD rate were fully centered on the fix-vs-prior close differential, as well as our estimated coefficient and confidence interval. It can be seen that for most of the variables that determine the fix, the estimated response coefficients for the close-to-close change in the CNY/USD rate are quite different from what the empirical model of the fix would imply. In particular, we find that the CNY close-to-close changes tends to be less sensitive than the fix to price changes that took place during the prior trading day (Panels B, E and F), and that surprise deviations of the fix from our empirical model have limited predictive power for subsequent trading day changes in the CNY (Panel D).
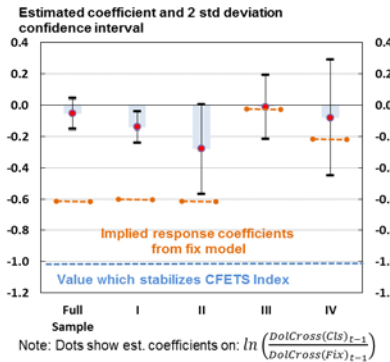
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[8] Overnight changes in the CFETS-weighted dollar-cross index explain about 70 percent of the daily changes in the CNH during the overnight period. The estimated coefficient on the overnight change in the dollar-cross index has been stable at about -0.5 over the past year and a half.

Chart 10. Estimated Determinants of the One-Day Change in the CNY/USD Closing Price
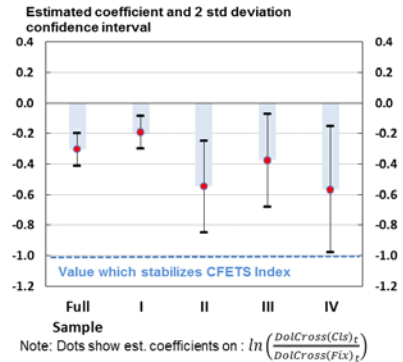
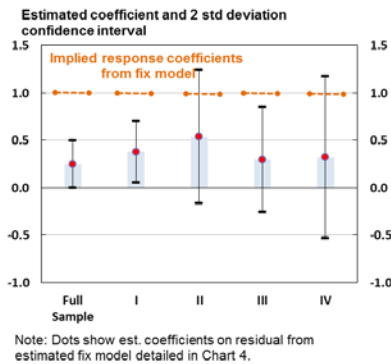### A. Response to Overnight Changes in the Dollar Cross Index

Estimated coefficient and 2 std deviation confidence interval

Implied response coefficients from fix model

Value which stabilizes CFETS Index

Full Sample / I / II / III / IV

Note: Dot shows est. coefficients on: $ln\left(\frac{DolCross(Fix)_t}{DolCross(Cls)_{t-1}}\right)$

B. Response to Previous Trading Day Changes in Dollar Cross Index

Estimated coefficient and 2 std deviation confidence interval

Implied response coefficients from fix model

Value which stabilizes CFETS Index

Full Sample / I / II / III / IV

Note: Dots show est. coefficients on: $ln\left(\frac{DolCross(Cls)_{t-1}}{DolCross(Fix)_t}\right)$

C. Response to Same Trading Day Changes in the Dollar Cross Index

Estimated coefficient and 2 std deviation confidence interval

Value which stabilizes CFETS Index

Full Sample / I / II / III / IV

Note: Dots show est. coefficients on : $ln\left(\frac{DolCross(Cls)_t}{DolCross(Fix)_t}\right)$

D. Response to Fix Forecast Error

Estimated coefficient and 2 std deviation confidence interval

Implied response coefficients from fix model

Full Sample / I / II / III / IV

Note: Dots show est. coefficients on residual from estimated fix model detailed in Chart 4.

E. Response to Previous Day Change in CNY (Close vs Prior Fix)

Estimated coefficient and 2 std deviation confidence interval

Implied response coefficients from fix model

Full Sample / I / II / III / IV

Note: Dots show est.coefficients on: $ln\left(\frac{cny(Cls)_{t-1}}{cny(Fix)_{t-1}}\right)$

F. Response to Previous Day Change in CNY (Fix vs Prior Close)

Estimated coefficient and 2 std deviation confidence interval

Implied response coefficients from fix model

Full Sample / I / II / III / IV

Note: Dots show est. coefficients on: $ln\left(\frac{cny(Fix)_{t-1}}{cny(Cls)_{t-2}}\right)$

G. Response to Overnight Change in *CNH-Resid* (9am vs Prior 430pm)

Estimated coefficient and 2 std deviation confidence interval

Full Sample / I / II / III / IV

Note: Bars show estimated coefficients on the residual from a regression of the overnight log change in the CNHUSD exchange rate on the overnight change in the DolCross Index (from 4:30 pm to 9:00am CST).
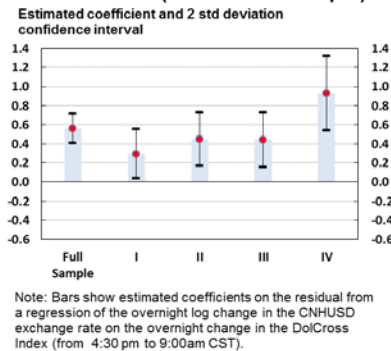
H. Response to Previous Day Overnight Change in *CNH-Resid*

Estimated coefficient and 2 std deviation confidence interval

Full Sample / I / II / III / IV

Note: Bars show estimated coefficients on the previous day's residual from a regression of the overnight log change in the CNHUSD exchange rate on the overnight change in the DolCross Index (from 4:30 pm to 9:00am CST).

I. Constant Term and R^2

Estimated value, in basis points per day

Share of dependent variable variation explained by included explanatory variables

Constant / R^2

Full Sample I II III IV / Full Sample I II III IV

Sources: Author's estimates, Data from Bloomberg

We find the closest correspondence between the behavior across trading closes and the response implied by the fix model with regard to overnight changes in the dollar-cross index. As seen in Panel A, in all four subperiods, we find that overnight changes in the dollar crosses lead to economically and statistically significant changes in the value of the CNY/USD exchange rate across trading closes. The estimated impact (our estimated coefficients range between -0.3 and -0.6) is generally somewhat

smaller in magnitude than the coefficient in the fixing rule would imply. But our full sample estimate of -0.47 appears reasonably similar to the -0.6 response coefficient in the estimated fixing rule.

As shown in panel B, the sensitivity of the CNY during the *current* trading day to changes in dollar crosses during the *prior* trading day is well below the coefficient implied by the fixing rule (-0.6) during periods I and II. This differential largely disappears in subperiod III, when the fixing rule itself no longer incorporated an adjustment for cross-rate changes during the previous onshore trading day, but then widens somewhat in subperiod IV, when the countercyclical mechanism appears to have brought back some sensitivity in the fix to dollar cross change during the previous trading day.

Panel C shows that the sensitivity of the CNY to *contemporaneous changes in the dollar crosses* (that is, dollar cross changes during the onshore trading session) increases in magnitude over our sample period, reaching -0.6 in period IV; in contrast, Panel B shows that the estimated sensitivity of the CNY/USD change to *previous trading day* dollar crosses becomes indistinguishable from 0 in periods III and IV. This shift toward contemporaneous responses could reflect a shift in how the authorities are managing the currency, to more actively guide it against the current day's dollar crosses. But given the apparently modest pace of intervention since February 2017, it seems more plausible that this pattern reflects a greater willingness to let market forces push the currency weaker (or stronger) on days of broad dollar strength (or weakness).

Overall, our estimated response coefficients to overnight and contemporaneous changes in the dollar crosses (-0.5 and -0.6, respectively in period IV) suggest that the CNY would still tend to appreciate vis-à-vis the authorities' reference basket (the CFETS index) on days when the dollar strengthens, but by less than half as much as when the currency was being managed mostly against the dollar, and there was very little response to changes in dollar crosses.

Panel D shows the estimated response coefficient to the fix forecast error. The results here suggest that the "surprises" in the fix generally have little explanatory power for explaining or predicting subsequent changes in the CNY across trading day closes.[9] Only during the first sub-period can we reject the hypothesis that the response to forecast errors is equal to zero, and even then, the coefficient is not

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[9] The results shown here use the residuals from the fix models estimated for each subperiod. This latter approach assumes that participants know the relevant rule during each period and when the rule changes. This seems reasonable given that fix is said to represent the trimmed weighted average of submissions by domestic dealer banks. When we repeated the exercise with estimated the fix surprises from a single fix model estimated for the entire sample period, we obtained qualitatively similar results.

very significant economically, given the small variance of the forecast error (recall that the model residual accounts for only 5 percent of the daily variance of the fix). This result casts doubt on the notion that surprises in the fix send a market-moving signal regarding the authorities' preferences.

The estimated coefficients in panel E and F suggest that the previous day's differential between the CNY/USD fix and close generally has little impact on the change in CNY during the current trading day. This is consistent with the official guidance that the fix should be set with reference to the previous day's close, but is not consistent with our estimated models of the fix during periods II and IV. In both of those two periods, we found that the fix appeared to be set somewhat counter-cyclically, in that the fix would not fully pass through (i.e., would be set to partially reverse) previous day changes between the fix and the close, as shown by the orange lines in panel E. In Period II, we do find some evidence that the CNY closes varied inversely with the previous day's fix-to-close differential, in line with the estimated fixing behavior; our estimated response coefficient to the prior day differential is negative, at -0.2, broadly in line with what would be suggested by the fixing rule. However, we cannot reject at the 10 percent level the null hypothesis that the true response coefficient is zero in this period.

In contrast, in Period IV (since mid-May 2017), we estimate a small *positive* coefficient on the prior day's fix-to- close differential, though again, this estimate is not significantly different from zero at a 10 percent level. This slight evidence of positive serial correlation in daily CNY changes suggests if anything a degree of *procyclicality* in the most recent period, which stands in sharp contrast with the incorporation of a *countercyclical* element into the fix during this period, shown by the orange line. This divergence is an important contributor to the weak centering of the daily close-to-close CNY change on the fix during subperiod IV.

Finally, our estimated coefficients in Panels G and H suggest that overnight changes in the CNH have useful incremental predictive power for changes in the onshore market, particulary in recent months. These panels show the response of the change in CNY closes to the constructed variable *CNH-Resid*, the overnight change in the USDCNH exchange rate not explained by the overnight change in the dollar-cross index. Our estimates also suggest that the CNH residuals have provided a less noisy signal more recently, with the response coefficient rising from an average of around 0.45 in periods II and III, to 0.9, almost full pass-through, in period IV. Interestingly, in the first two sub-periods, the estimated coefficients on the previous day's *CNH-Resid* have negative coefficients, suggesting that the impact of surprise overnight CNH changes tended to be partially reversed the next day. In contrast, in the last two

subperiods, the coefficient on prior day innovations in the overnight CNH market are not statistically different from zero at any conventional confidence level.

IX.   Summary and interpretation

In this note we have explored how the mechanics of the PBOC's daily fixing for the CNY/USD exchange rate have evolved in recent years, focusing in particular on the period since mid-February 2016, when the authorities introduced a new framework for setting the daily fix, which serves as the midpoint for FX trading. We have also investigated how the CNY/USD exchange rate responds to changes in the fix, as well as the influence of other factors, including contemporaneous changes in the broad value of the dollar and overnight developments in the offshore CNH market.

Our results confirm that daily changes in the fix have become both quite predictable and quite responsive to market forces. However, the ability of the fix itself to predict or guide changes in the bilateral exchange rate during the ensuing trading day is uneven. Daily changes in the exchange rate appear to have centered reasonably strongly on the differential between the fix and the previous close during periods of heightened intervention, but the fix at best appears to only provide directional cues in months with low intervention intensity, such as in recent months.

The fix's weak predictive power appears to reflect the fact that the fix is often influenced by lagged information, from the prior trading session. In contrast, the trading day change in the CNY (from close-to-close) responds mostly to developments during the same time window (between closes), especially in more recent subperiods. As a result, it is difficult to see much of an imprint on the behavior of the CNY/USD exchange rate from the introduction, in May 2017, of a countercyclical, backward-looking element to the fixing rule. Whereas our estimated fixing rule for the period since mid-May 2017 suggests that the fix more recently has been calibrated to reverse nearly 1/3 of the previous day's change in the CNY vs the previous day's fix, we find that if anything, the tendency during the ensuing trading day is to slightly extend the previous day's change, although this slight procyclical behavior is not statistically significant.

Our analysis can be interpreted as pointing to a number of ways in which the Chinese currency's behavior has come to more closely resemble the short horizon random walk behavior typically found in freely floating currencies (Sarno and Taylor 2001), as well as ways in which it still differs. As noted above, we have found that in more recent periods the exchange rate has responded mostly to

developments within the trading day, particularly overnight and contemporaneous changes in dollar cross rates. And changes to the exchange rate level during the trading day tend to persist over time— we do not find evidence of positive or negative serial correlation in daily price changes in the more recent periods. Also, reliance on sustained intervention appears to have subsided considerably since the turn of the year.

That said, daily volatility in the CNY remains quite low compared to freely floating currencies. It is also worth pointing out that some commentators have suggested that, while recent months have seen less reserve sales, there have been signs of intervention through other means. For instance, on several occasions, discrete currency moves during the onshore trading day have been viewed by some observers as reflecting indirect intervention, through publicly owned entities. And an unexplained temporary surge in offshore CNH interest rates in late May 2017, which led to a strengthening of the CNH and the CNY against the dollar, was also viewed by some market participants as reflecting indirect intervention.

Overall, we would argue that the evolving behavior of the CNY during the trading day merits more analytical attention going forward. Rather than just focus on the fix, as much commentary to date has done, it seems fruitful to also examine the evolving sensitivity of the CNY to variables such as movements in onshore and offshore markets, including dollar crosses and short and longer-term rates, economic news, and signs (or their absence) of active management through discrete intervention. Finally, monitoring realized volatility of the onshore currency market could provide clues as to the authorities' evolving tolerance for allowing market forces to have a freer hand.

The importance of understanding the CNY's trading day behavior is underscored by the authorities' stated intention to transition to a freer float over time, and their ongoing efforts to liberalize foreign investors' access to China's local markets, including by offering foreign investors greater access to local currency hedging instruments.

X.   Concluding thoughts

In some important respects, China's recent approach to managing the fix, and the exchange rate more broadly, appears to have been a success. Having the fix visibly and predictably react to short-term dollar cross movements may have helped desensitize global markets to fluctuations in the value of the Chinese currency driven by broad dollar movements. And by avoiding large sudden moves, and dampening daily volatility, the authorities afforded themselves room to allow or guide a material adjustment in the

multilateral and bilateral exchange rate over the course of 2016 without sparking volatility in global markets. Moreover, since late 2016, the currency has held broadly stable against the authorities' preferred reference basket, fluctuating within a 2 percent range, even as the authorities appear to have sharply scaled back currency market intervention, and have recently relaxed some controls on short forward positions.

However, the analysis above suggests that the stabilizing properties of the fixing regime itself should not be overstated, given that the fix passes through prior changes in the bilateral exchange rate. And as we have shown, the fix does not appear to obviously guide daily currency changes in periods when the authorities are not intervening.

Moreover, while foreign investors may now be less inclined to infer intent from short run dollar-driven CNY weakness, the future behavior of Chinese residents remains an open question. The pattern of recent years has been for Chinese residents to accumulate dollar assets and repay dollar debt whenever the bilateral exchange rate weakens, or appears at risk of doing so. Broad dollar depreciation during much of 2017 and associated upward pressure on the CNY, as well as tightened controls on resident outflows starting in late 2016, appear to have played an important role in the ebbing of Chinese capital outflows this year. It remains to be seen how domestic flows will respond to future periods of market-driven CNY weakness.

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Annex 1.   The CFETS Index and the CFETS-weighted Dollar Cross Index—Further Discussion

The CFETS index (named for the China Foreign Exchange Trade System, run by the Peoples Bank of China) is a geometrically weighted index of the foreign currency value of the CNY:

$$CFETS(t) \ = \ \frac{\prod_{k=1}^{n}[CNYFX_k(t) \ ]^{\alpha_k}}{\prod_{k=1}^{n}[CNYFX_k(t_0) \ ]^{\alpha_k}} \cdot 100$$

where $CNYFX_k(t)$ is the foreign currency value/cost of a Chinese yuan (CNY) in the kth foreign currency (e.g. euros or yen per yuan) at time t, and t_0 is the base period for the index, α_k is the weight of the kth currency, and the sum of the n weights totals to one.

Given that the foreign currency value of the CNY in kth currency can be expressed as the product of the foreign currency value of the dollar of the kth currency, and the US dollar value of the yuan:

$$CNYFX_k(t) = \ USDFX_k(t) \ \cdot \ CNYUSD(t)$$

we can re-write the CFETS index as the

$$CFETS(t) = \frac{\prod_{k=1}^{n}[USDFX_k(t)]^{\alpha_k}}{\prod_{k=1}^{n}[USDFX_k(t_0)]^{\alpha_k}} \ \cdot \ \frac{CNYUSD(t)}{CNYUSD(t_0)} \cdot \ 100$$

We can define DolCross as a CFETS-weighted index of dollar cross rates for the n-1 non-dollar currencies included in the n currency CFTS basket:

$$DolCross(t) = \frac{\prod_{k=2}^{n} USDFX_k(t)^{\alpha_k}}{\prod_{k=2}^{n} USDFX_k(t_0)^{\alpha_k}} \cdot 100$$

Since the value of the dollar in dollars is always one, we have that:

$$CFETS(t) = \ DolCross(t) \ \cdot \ \frac{CNYUSD(t)}{CNYUSD(t_0)} \cdot \ 100$$

Putting things in terms of log changes, it can be seen that over any window:

$$\Delta \ln(CFETS) = \Delta \ln(DolCross) \ + \ \Delta\ln(CNYUSD)$$

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Annex 2.   Data

Our empirical analysis uses exchange rate data from Bloomberg and estimates of intervention activity from the Institute of International Finance (IIF). Daily observations for the fix of the CNY against the USD dollar (Bloomberg code: CNYMUSD) and the constituent currencies of the CFETS Index (e.g. CNYMEUR), are from the Peoples Bank of China's China Foreign Exchange Trading System, via Bloomberg. We construct the dollar cross index at the time of the fix using the methodology detailed in Annex 1, where the dollar cross for each currency is (e.g. EUR/USD) is taken as the ratio of the CNY/USD fix and the CNY fix for that currency. For example, for the euro, our dollar cross is calculated as CNYMEUR/ CNYMUSD. Note that for advanced economy currencies (e.g. Bloomberg code: CNYMEUR), the CNY fixes are typically expressed in CNY per unit of foreign currency, and for emerging market currencies (e.g. Bloomberg code: CNYMTHB) the fixes are typically expressed in units of local currency per CNY; for these currencies the dollar cross is calculated as 1/(CNYMTHB*CNYMUSD).

For our closing CNY/USD prices, dollar cross rates at the Chinese close, and overnight changes in the CNH/USD exchange rates, we use the Bloomberg BFIX data. As detailed in Bloomberg (2016), the BFIX data provide snapshots of BGN prices (Bloomberg generic prices) observed at 30-minute intervals through the trading day. For our prices at the 4:30 pm official close, we use the CNY/USD exchange rate, the CNH/USD rate, and the dollar crosses for the currencies included in the CFETS index at 5:30 pm Tokyo Standard Time, equivalent to 4:30 pm China Standard Time (CST). Our opening price for the CNY, used for the analysis in Chart 6, is the BGN open price for the given trading day, and is equivalent to the BFIX price as of 9:30 am CST.