10-2012

The Price Discovery Puzzle in Offshore Yuan Trading: Different Contributions for Different Contracts

David K. DING
Singapore Management University, davidding@smu.edu.sg

Y. Tse

M. Williams

The Price Discovery Puzzle in Offshore Yuan Trading: Different Contributions for Different Contracts

DAVID K. DING*, YIUMAN TSE and MICHAEL R. WILLIAMS

The People's Bank of China (PBC) lifted yuan trading restrictions in July of 2010 that led to offshore yuan spot trading in Hong Kong. Based on causality analyses, we find that price discovery is absent between the onshore and offshore spot markets. However, we document the presence of price discovery between onshore spot and offshore nondeliverable forward (NDF) rates. These seemingly inconsistent results present a puzzle wherein one offshore market appears to be more informationally integrated with the onshore market than another. We conclude that price discovery differences in the offshore markets stem from the offshore spot and forward contracts tracking different aspects of yuan rates (e.g., the offshore nondeliverable rate tracks onshore spot rates whereas the offshore spot rate tracks onshore interest rates). Moreover, the introduction of offshore spot trading in Hong Kong has led to an increase in cross-market price discovery between onshore spot and offshore NDF rates. © 2012 Wiley Periodicals, Inc. Jrl Fut Mark 34:103–123, 2014

1. INTRODUCTION

We examine the cross-market price discovery impact of introducing offshore yuan spot trading in Hong Kong. Although Chinese renminbi (RMB) deposits have been allowed in Hong Kong since 2004, the RMB became officially deliverable offshore in July 2010. The introduction of offshore spot trading is only one of many currency liberalizations taken by China within the past decade. The first major innovation occurred in 2004 when Hong Kong residents were allowed to open yuan-denominated accounts (Yiu, 2010). This action was followed up by the switching of the RMB from a fixed to managed-floating exchange rate in July 2005 (Staff, 2010). Other liberalizations include China allowing trade to be settled in yuan in July 2009 (Ren & Yiu, 2010) and allowing cross-border trade settlement in yuan between all foreign entities and 20 regions within China in June 2010 (Jiang, 2010).

Despite the prior innovations, few were as significant as the authorizing of offshore spot trading in Hong Kong. Specifically, on July 19, 2010, the People's Bank of China (PBC) and the Hong Kong Monetary Authority (HKMA) signed a Memorandum of Cooperation, which

David K. Ding is a Professor of Finance at the School of Economics and Finance, Massey University, Albany, Auckland, New Zealand and Lee Kong Chian School of Business, Singapore Management University, Singapore. Yiuman Tse is the Peter G. Schick Professor of Finance at the Department of Finance and Legal Studies, University of Missouri—St. Louis, St. Louis, Missouri. Michael R. Williams is an Assistant Professor of Finance at the College of Business, Public Administration, Governors State University, University Park, Illinois.

*Correspondence author, School of Economics and Finance, College of Business, Massey University, 0632 Albany, Auckland, New Zealand. Tel: (64) 9 414 0800 ext 9465, Fax: (64) 9 441 8177, e-mail: d.ding@massey.ac.nz

Received October 2011; Accepted June 2012

The Journal of Futures Markets, Vol. 34, No. 2, 103–123 (2014)

Published online 23 July 2012 in Wiley Online Library (wileyonlinelibrary.com).
DOI: 10.1002/fut.21575

allows Hong Kong's financial institutions to open yuan-based accounts where individuals, including foreigners, are able to transfer funds to and from these accounts. Further, Hong Kong banks are allowed to deal directly in the yuan as opposed to using the PBC as a clearing agency. Finally, Hong Kong's financial institutions have permission to offer yuan-denominated financial products, for example, securitized loans, interest rate swaps, and yuan-based insurance (Holland, 2010; Jiang, 2010; Pomfret, 2010). While account holders are limited to exchanging, at most, 4,000 yuan daily (Ren & Yiu, 2010), this step toward liberalization is significant given that offshore yuan delivery was previously forbidden and that foreign investors could only participate in the offshore nondeliverable forward (NDF) market.

Since the introduction of the offshore spot rate, RMB deposits in Hong Kong have increased to 510 billion yuan in June 2011. Further, daily offshore spot trading volume has expanded from a negligible amount to $1.3 billion daily (Cookson, 2011). Although banks such as HSBC offer additional yuan trading services in the United States, Japan, and Singapore, the bulk of trades are conducted in Hong Kong given its proximity and shared time zone with the Chinese mainland as well as its deeper levels of liquidity (Yiu, 2011a). Further, innovation in the offshore spot market has proceeded at a rapid pace with ICAP and Thompson Reuters introducing electronic trading in the Hong Kong yuan in September 2010 and Deutsche Bank introducing their own electronic platform in February 2011. Finally, European-style offshore yuan options became available in April 2011 (Staff, 2011).

Given these liberalizations and innovations, one would expect a fairly robust relationship between the onshore spot (CNY) and offshore spot (CNH) rates. We find that, despite increasing trading activity and interest, CNY and CNH returns provide little cross-explanatory power for each other. Further, the cross-market return impact is economically insignificant. Thus, the onshore and offshore spot markets provide little price discovery to each other. On the other hand, we find that offshore NDF returns have a significant and equal explanatory power for CNY returns (and vice versa). Moreover, we find that price discovery between the NDF and CNY increases after the introduction of the CNH.

Our results initially present a puzzle in that price discovery exists for the NDF exchange rate that is restricted to foreign participants and is settled in a foreign currency whereas the onshore exchange rate (CNY) has little linkage with the offshore exchange rate (CNH). We conclude that this puzzle arises from NDF rates being linked with onshore exchange rates (i.e., the NDF acts as a futures contract on the CNY) whereas CNH rates are linked with onshore interest rates. Thus, different offshore rates are connected in different ways to the onshore spot market leading each to have a different information relationship with the onshore spot rate. Further, the increased NDF/CNY explanatory power after the introduction of the CNH is due to CNH rates *completing* the forward market, which previously had no underlying spot rate.

2. BACKGROUND

2.1. Offshore Spot Market (CNH)

The CNH is traded in the Hong Kong interbank market and on selected electronic platforms. Relative to other offshore RMB products, the CNH is relatively illiquid with about $1.3 billion in daily trading activity (the NDF has a daily trading volume of about $3 billion; Cookson, 2011; Wallace, 2011). With the July 19, 2010 agreement, the CNH became deliverable offshore whereby CNH funds can be transferred among the accounts of banks and individuals. CNH pricing is influenced by individual/resident purchases, trade settlements, central bank swaps, and more importantly USD/RMB money market interest rates. Also, the

CNH forward curve resembles more of an interest rate curve than a futures curve of exchange rate expectations.

The CNH is observed to have pricing differences against the CNY and the NDF (see Figure 1, Chart A). Most CNH/CNY pricing differences stem from cross-border capital and currency controls, which include yuan deposit limitations in Hong Kong as well as the ability to remit the yuan back to the mainland (Yiu, 2011b). In contrast, most of the differences in CNH/NDF pricing stem from the impact of the underlying onshore interest rates. Interestingly, CNH/NDF arbitrage may increase CNH/CNY pricing differentials (Hui & Bunning, 2010).

Recently, the PBC has taken steps that are generally seen as improving CNH liquidity and relevancy. For example, the yuan clearing interest rate was dropped from 0.99% to 0.72% and was generally seen as increasing CNH liquidity by easing the remittance process (Ye, 2011). In June 2011, Hong Kong began providing a daily CNH/USD fixing rate, which was expected to increase the pricing transparency of RMB derivative products (Cookson, 2011). However, the PBC is sensitive to use of the offshore yuan, which they felt could lead to increased inflation and disadvantage domestic producers. Moreover, the yuan fixing rate already has been increased twice, which reduces the CNH's main attraction to foreign investors (Flatt, 2011b; Wang, 2011). Thus, despite promoting the CNH as a step toward full RMB liberalization, the PBC still maintains its capital controls and has recently tried to influence the CNH's development by promoting mainland, as opposed to international, CNH derivative rules.

2.2. Nondeliverable Forward (NDF) Market

Although the offshore spot rate's relevance has only begun to emerge, offshore nondeliverable RMB forwards (NDF) began trading in December of 1998 (Wang, 2010a). In general, NDFs act like futures contracts on the underlying onshore exchange rate and are settled in a foreign currency (Higgins & Humpage, 2005). NDFs can reflect appreciation expectations and are impacted by yuan supply and demand conditions. Further, NDFs may reflect expectations and market conditions that are not fully reflected in the onshore exchange rate of countries with capital controls.

NDF trading typically emerges on offshore centers due to both high onshore capital controls (Ma, Ho, & McCauley, 2004; Dabelle, Gyntelberg, & Plumb, 2006) and when foreign investors become increasingly convinced that the onshore spot rate is mispriced. Conversely, offshore NDF markets become increasingly irrelevant when capital controls become less binding. NDFs generally are not ideally suited for hedging and risk management purposes given their embedded settlement risk, market holiday effects, and a lack of correlation with onshore macroeconomic risks. As such, offshore NDFs tend to attract more speculators than hedgers.[1]

RMB NDFs mainly trade in Hong Kong with limited trading in Singapore. Although not originally the case, NDF participation is strictly limited to foreign investors (Hui & Bunning, 2010). Despite this fact, RMB NDFs accounted for approximately 90% of the combined onshore and offshore forward market turnover in 2003 while this market has become increasingly deep (Ma et al., 2004) with daily volume approaching $3 billion in 2011 (Wee, 2011). The NDF is fixed against the onshore spot rate but, contrary to the CNH, the NDF behaves more like a futures contract for the underlying onshore spot rate (Hui & Bunning, 2010).

[1]Lipscomb (2005) reports that 60–80% of offshore forward participants are speculators.

Chart A: Offshore Rate Premiums

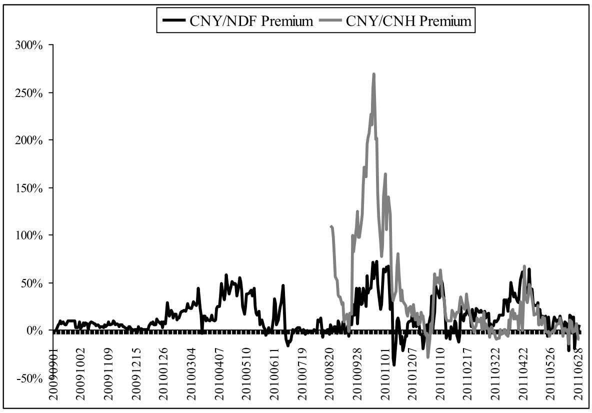

Chart B: Offshore Spot Bid-Ask Spreads

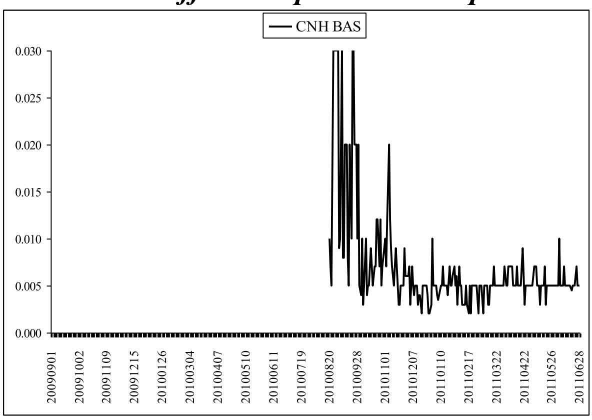

Chart C: Offshore Non-Deliverable Forward Bid-Ask Spreads

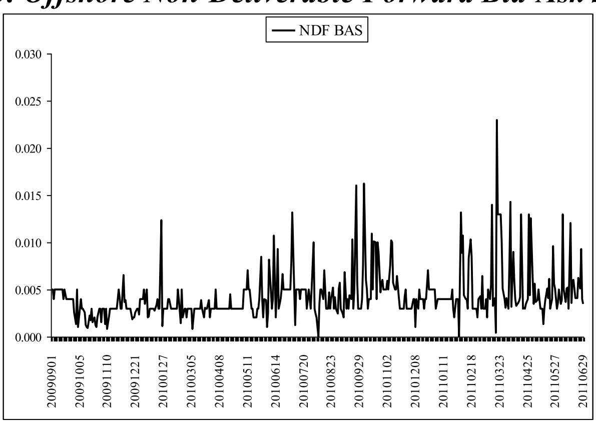

FIGURE 1

Offshore market premiums and bid–ask spreads. Chart A plots offshore spot (CNH) and nondeliverable forward (NDF) premiums across the entire sample. Premiums are defined as the difference between a given log offshore rate and the log onshore spot rate (CNY). Note that the NDF and CNH premiums are plotted in black and gray, respectively. Chart B (C) plots CNH (NDF) bid–ask spreads.

Determination of the onshore RMB spot rate is limited by participation restrictions, participant technical abilities and expertise, and poor trading infrastructure. The offshore NDF markets in Hong Kong and Singapore, on the other hand, are more developed. In addition to capital controls and the limitation of onshore participation, NDF rates are not fully tied to onshore economic fundamentals (Peng, Shu, & Yip, 2007) and NDF rates may deviate from onshore rates. In addition, although large multinational corporations may act as unofficial NDF/CNY arbitragers, their arbitrage capabilities are limited to "legitimate" business/trading needs (Hui & Bunning, 2010). Although NDF/CNY pricing differentials decreased after the July 2005 shift of the CNY from a fixed to managed-floating regime, cross-border monetary flows were and still are not sufficient to correct pricing differences (Ma & McCauley, 2008). Still, arbitrage between onshore spot and NDF rates has been steadily increasing (Staff, 2009).

2.3. Onshore Deliverable Forward Market

An onshore RMB deliverable forwards (ODFs) market serves domestic speculative and hedging demand. ODFs have traded since October 2005 on the China Foreign Exchange Trade System (CFETS) interbank market, headquartered in Shanghai. CFETS is a subdepartment of the PBC and is additionally regulated by the State Administration of Foreign Exchanges (SAFE). ODFs trade on an OTC basis where only (domestic) member-to-member transactions are allowed; foreign participation is not officially allowed. Although the true level of trading activity is officially unknown, daily transactions volumes are believed to be greater than $600 million. ODFs have standardized maturities of 1, 3, 6, 9, and 12 months whereas longer, less-liquid maturities occasionally trade (Wang, 2010b).

Despite the existence of a liquid spot market, persistent violations of Covered-Interest-Parity (CIP) exist for ODF rates (Wang, 2010b). Ultimately, CIP violations are a result of (onshore) spot conversion restrictions. Specifically, all ODF transactions must meet the approval of SAFE officials who are reluctant to approve forward transactions appearing to speculate on currency appreciation. Spot conversion restrictions lead to difficulty in covering forward positions, which, in turn, leads to the CIP violations.

Wang (2010b) finds that ODF CIP violations are a function of both a CIP-implied forward rate as well as spot rate appreciation expectations. Yet, higher conversion restrictions are associated with high CIP violations where the violations are not explained by ODF credit or liquidity risks. Wang (2010a) finds that ODF CIP violations are greatest for the longest maturity forwards and are time-varying where CIP violations were reasonably small and stable before May 2007 but increased until their peak in April 2008. What makes the issue of CIP violations in the ODF market so important is capital flight. Specifically, Cheung and Qian (2010) find that Chinese capital flight, defined as illicit financial flows to international destinations, is partially determined by onshore CIP violations. This is especially an issue given that Chinese capital flight may exceed foreign direct investment on a yearly basis.

2.4. Onshore Versus Offshore Currency Markets

Much work has been conducted on onshore spot and offshore NDF relationships. Specifically for the NDF, the extant literature finds that NDF/CNY rates are cointegrated (Chen, Gong, & Zheng, 2009; Huang & Wu, 2006; Sun & Niu, 2009; Wang & Shang, 2009) while Yang and Leatham (2001) note that rate cointegration only emerged once partial currency convertibility was allowed. Thus, the NDF and CNY markets share a long-run dynamic process wherein pricing differentials eventually correct, yet may be subject to policy shocks. The existing literature is mixed as to which market (CNY or NDF) is more influential to the other. For example, Sun, Sun, and He (2010) find that CNY rates transmit information to NDF rates. However, Wang and Shang (2009) find bidirectional spillovers between the NDF and CNY markets, whereas Sun and Niu (2009) suggest that, despite bidirectional spillovers, capital controls result in the CNY market serving as the main producer of pricing information. Peng et al. (2007) note that, despite trading and capital restrictions, sentiment can spill over between the onshore and offshore markets and that the relative contribution of price leadership has shifted between the onshore and offshore centers over time. However, beyond capital controls, Peng et al. (2007) note that NDF pricing efficiency is restricted by the lack of a benchmark spot curve.

Beyond its impact on the onshore spot market, Gu and McNelis (2011) find that the NDF links movements in the euro to Chinese markets through offshore speculative pressures, whereas no such effect is seen between the Korean won NDF and onshore won spot markets. Gu and McNelis note that the difference in NDF transmission between the Chinese and Korean markets is due to the relatively more restrictive Chinese capital controls.

The literature on non-Chinese onshore and offshore relationships notes that large differences between spot and NDF rates imply greater capital control effectiveness, appreciation expectations, forward market illiquidity (Ma et al., 2004), and the risk premium foreign investors expect during times of thin or volatile forward market trading (Higgins & Humpage, 2005). With respect to cointegration, Chen et al. (2009) find long-run dynamics between the Korean won and won NDFs, regardless of the sample period (and, therefore, policy regime), whereas Guru (2009) finds cointegration between the onshore rupee and offshore rupee forward rates. Park (2001), however, notes that won/forward cointegration is actually time-varying with lower policy restrictions leading to stronger long-run dynamics.

In terms of information transmission, Gu and McNelis (2011) find a unidirectional relationship from Korean won to Korean forward rates. Misra and Behera (2006) find that onshore and offshore Indian rupee rates transmit bidirectionality whereas Guru (2009) finds that, while initially bidirectional, offshore rupee forwards dominated transmission after the September 2008 introduction of rupee futures. Finally, Park (2001) finds that won-to-forward transmission switched to forward-to-won transmission during a postreform period.

2.5. Impact of Capital Controls on Onshore Versus Offshore Relationships

Capital controls and changes in capital controls can lead to changes in information integration between onshore and offshore markets. For example, Ma et al. (2004) find that capital controls segment onshore and offshore markets in Asian countries. Tsuyuguchi and Wooldridge (2008) state that capital controls are a strong reason why offshore currency markets develop. Park (2001) and Chen et al. (2009) find that different capital control policies may lead to different information transmission and price discovery patterns over time. Chen et al. (2009) note that lower capital market restrictions lead to higher market integration and that capital controls can be less effective once offshore NDF markets develop.

All of these facts are relevant to the present study given that Chinese capital controls have, at least historically, been binding (Ma & McCauley, 2008). Further, with PBC's currency liberalizations and the introduction of offshore spot trading, it is possible that information patterns between onshore and offshore RMB markets have changed over time.

3. METHODOLOGY

We collect daily exchange rate data for onshore spot (CNY), offshore spot (CNH), and one-month offshore NDF rates from Bloomberg. Although some studies opt for longer NDF maturities, we use one-month rates given one-month NDFs are less prone to purely speculative pressures, more liquid, and less susceptible to exaggerated price swings. We define the price of a given exchange rate as the mid-point between end-of-day quoted ask and bid rates. Where applicable, exchange rate returns are defined as the difference in their logarithmic rates. Offshore premiums are defined as the difference in the logarithm of offshore rates (spot or forward) and the logarithm of onshore spot rates. Finally, we use the difference in ask and bid rates as a proxy for market liquidity.

Our sample period spans September 2009 to June 2011. Given that CNH trading became permissible on July 19, 2010, we omit rates between July 1, 2010 and August 31, 2010 to account for the development of offshore trading and to eliminate spurious beginning-trading effects. Also, to analyze the impact of offshore spot trading, we split the sample into pre- and postintroduction subsamples, which span September 2009 to June 2010 and September 2010 to June 2011, respectively. These dates are selected to arrive at an approximately equal number of trading days in the two subsamples.

In addition to descriptive and contemporaneous correlation analyses, we examine own- and cross-market price discovery using a vector autoregression (VAR) framework as follows:

$$r_{i,t} = \alpha_{0,i} + \sum_{k=1}^{5} \beta_{k,i} r_{i,t-k} + \sum_{k=1}^{5} \gamma_{k,i} r_{j,t-k} + \varepsilon_{i,t}, \tag{1}$$

$$r_{j,t} = \alpha_{0,j} + \sum_{k=1}^{5} \beta_{k,j} r_{j,t-k} + \sum_{k=1}^{5} \gamma_{k,j} r_{i,t-k} + \varepsilon_{j,t}, \tag{2}$$

where $r_{i,t}$ and $r_{j,t}$ are the log returns of a given currency market pair. Each VAR uses five lags to take into account up to one trading week's worth of activity.

Post estimation, we perform two forms of causality analyses. The first uses Generalized Variance Decomposition Functions (GVDFs) introduced by Pesaran and Shin (1998) to determine the percentage of variation explained by own- and cross-returns. Traditional variance decompositions are subject to variable ordering whereby a given ordering may report a higher explanatory power than another ordering. This is especially true of two series that exhibit a strong contemporaneous correlation. Our use of GVDFs prevent ordering bias in our results.

The second causality analysis centers on using generalized impulse response functions (GIRFs) as proposed by Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998). Like the GVDFs, the GIRF results are robust to variable ordering. We report ±2 standard error bands based on 30,000 Monte Carlo simulations. As a robustness check, we reestimate the GIRF results based on the VAR(5) model using eight different GARCH specifications to examine whether the GIRF results are robust to conditional mean specification. As reported in the Appendix, we find that the GIRF results are qualitatively similar whether fixed or time-varying conditional exchange rate volatility is assumed and are therefore robust to time varying volatility.

We find no cointegration based on both the Johansen (1991) and Engle–Granger (1987) methodologies. As such, we do not account for long-run dynamics in the VAR specifications. Traditional, coefficient restriction-based Granger causality tests are not used due to the low potential rejection power from the small subsamples. As noted by Sims (1980), the relationships among variables may be economically but not statistically significant due to various econometric issues. Using both GVDFs and GIRFs allows us to examine economically significant relationships without being burdened by small pre- and postintroduction sample sizes.

4. RESULTS

4.1. Rate Premiums and Cointegration

We examine the premiums between the CNY against the CNH and the one-month NDF. From Table I, Panel A, we find that the CNH premium (the percentage difference between CNY and CNH) is more than double that of the NDF premium (the percentage difference between the CNY and the NDF). Further, the volatility of the CNH premium surpasses the NDF premium regardless of the sample period. Moreover, the NDF premium does not decline

TABLE I
Descriptive Statistics

Panel A: Premium Descriptive Statistics

	CNH premium	*NDF premium*	
Statistic	*Postperiod*	*Preperiod*	*Postperiod*
Mean	0.363	0.140	0.181
Standard deviation	0.545	0.149	0.208

Panel B: Liquidity Descriptive Statistics

	CNH BAS		*CNY BAS*		*NDF BAS*	
Statistic	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
Mean	–	0.0066	0.0002	0.0017	0.0034	0.0053
Standard deviation	–	0.0049	0.0007	0.0031	0.0016	0.0032

Panel C: Contemporaneous Correlations

		Preperiod			*Postperiod*		
		CNY BAS	*NDF BAS*	*CNH BAS*	*CNY BAS*	*NDF BAS*	*CNH BAS*
NDF BAS	Corr.	0.621	–	–	0.931	–	–
	p-Value	0.000	–	–	0.000	–	–
CNH BAS	Corr.	–	–	–	0.093	0.105	–
	p-Value	–	–	–	0.179	0.136	–
NDF premium	Corr.	−0.018	−0.013	–	0.060	0.116	0.070
	p-Value	0.797	0.861	–	0.393	0.095	0.325
CNH premium	Corr.	–	–	–	0.048	0.135	0.235
	p-Value	–	–	–	0.490	0.056	0.001
		R(CNY)	*R*(NDF)		*R*(CNY)	*R*(NDF)	
R(NDF)	Corr.	0.503	–		0.799	–	
	p-Value	0.000	–		0.000	–	
R(CNH)	Corr.	–	–		0.458	0.524	
	p-Value	–	–		0.000	0.000	

Note. In Panel A, we report descriptive statistics for offshore spot (CNH) and nondeliverable forward (NDF) premiums. Premiums are defined as the difference between a given offshore log rate and the log onshore spot rate (CNY). Note that the pre-CNH introduction sample (pre) spans September 2009 to June 2010 whereas the post-CNH introduction sample (post) spans September 2010 to June 2011. In Panel B, we report descriptive statistics for exchange rate bid–ask spreads (BAS). In Panel C, we report contemporaneous correlations among currency premiums and currency bid–ask spreads as well as across various exchange rate returns.

after the introduction of the CNH. To illustrate these differences, we plot the NDF (black) and CNH (gray) rate premiums in Figure 1, Chart A. The offshore yuan spot has almost consistently traded at a premium to the onshore yuan, reflecting the lack of fungibility between the CNH and CNY, and onshore spot appreciation expectations. Moreover, the large divergence is due to the capital controls on the CNY market and the allocated supply of yuan from the PBC to Hong Kong. The premium generally declines past the time of CNH introduction, indicating a general increase in the supply of yuan in Hong Kong. In other words, the positive premium reflects binding capital controls where such controls have weakened over time.

During the greater part of the overlapping sample period, the CNH premium is larger than the NDF premium. This provides evidence that, for most of its early trading days, the CNH had a higher rate disparity than the NDF (relative to the CNY rate) indicating a higher degree of market segmentation. This suggests that capital controls had a larger impact on the offshore spot rate than on the offshore NDF rate. We note that both series experience a peak around October 2010 and May 2011. The first spike is likely due to the PBC reaching its settlement quota in October and not expanding it due to concerns of speculative monetary flows into mainland China (Foley, 2010). The explanation for the second spike in premiums between April and May 2011 is less clear. However, its resolution during the beginning of May may be attributed to the PBC reducing the yuan clearing interest rate and increasing the onshore yuan fixing rate (Flatt, 2011a; Wang, 2011; Ye, 2011).

It is important to determine whether long-run dynamics exist for either of the two offshore yuan rates. We examine this issue using the Johansen (1991) cointegration test and allow for five lags in the test to account for any short-run dynamics. In robustness analyses, we find that the results are not qualitatively different across different lag specifications.

We find evidence in Table II that CNH and NDF rates are not cointegrated with CNY rates. As a robustness check on our results, we run several unit root tests *a la* Engle–Granger (1987) and find that the differences between the CNY/CNH and CNY/NDF rates are generally nonstationary (including specifications with an intercept). Based on these results, we conclude that both the CNH and NDF are not cointegrated with the CNY. This may, in turn, indicate that there is no long-term mean reversion (or long-term dynamics) between the onshore and offshore rates and that only short-run dynamics may be present.

TABLE II
Cointegration Analysis

Number of Cointegrating Vectors	*CNY vs. CNH*		*CNY vs. NDF*			
	Post		*Pre*		*Post*	
	Trace	*Max{Eigen}*	*Trace*	*Max{Eigen}*	*Trace*	*Max{Eigen}*
Ho: $r = 0$	0.181	0.327	0.604	0.800	0.212	0.117
Ho: $r = 1$	0.208	0.208	0.346	0.346	0.815	0.815

Note. In this table, we report Johansen (1991) cointegration test results between onshore spot versus offshore spot rates (CNY versus CNH) as well as onshore spot versus offshore nondeliverable forward rates (CNY vs. NDF). Values under Trace and Max {Eigen} are the MacKinnon–Haug–Michelis (1999) *p*-values for the trace and maximum eigenvalue cointegration tests, respectively. Note that the pre-CNH introduction sample (pre) spans September 2009 to June 2010 whereas the post-CNH introduction sample (post) spans September 2010 to June 2011. Also note that the results below are robust to lag specification.

Hitherto, prior literature shows that cointegration exists, or at least did exist, between the NDF and CNY (e.g., see Chen et al., 2009; Huang & Wu, 2006; Sun & Niu, 2009; Wang & Shang, 2009). Our results stand in contrast to those in the prior literature and may be due to a lack of long-run onshore versus offshore dynamics (which would be at odds with the prior literature). It may be argued that the relatively small sample size led to a low rejection power in the various cointegration tests. However, this is not likely given the consistency between both the Johansen and Engle–Granger methodologies. Instead, we believe that destabilizations in the relationship between onshore and offshore rates created by policy changes are driving the results.

Specifically, Park (2001) notes that Korean spot and NDF rates have a cointegrating, long-run relationship but that this relationship is time varying and subject to capital control policy shocks. Thus, the lack of NDF/CNY and CNH/CNY cointegration may be due to the market relationships being disrupted through a succession of policy shocks or the uncertainty revolving around expected policy shocks. In turn, given that the extant literature finds cointegration between the onshore and offshore yuan markets, our findings indicate that long-run dynamics may once again emerge for the NDF/CNY and CNH/CNY pairs once market participants become accustomed to the new policy regimes.

4.2. Liquidity Versus Premiums

Despite the lack of long-run relationships with the onshore spot rate, the offshore spot premiums exhibit a downward trend as seen in Figure 1, Chart A. Although there have been many innovations in the offshore yuan market such as an increase in total dim-sum bond issuances, changes in appreciation expectations, and so on, one of the largest changes has been an increase in offshore spot liquidity. From Table I, Panel B, we find that CNH bid–ask spreads (BASs) are higher and more volatile than the CNY and NDF BASs indicating that offshore spot liquidity is lower and more volatile than liquidity in the NDF and CNY markets. Yet, CNH BASs have been decreasing since October 2010 as depicted in Figure 1, Chart B. This increase in CNH liquidity is likely due to the increased trading interest in offshore spot trading (both interbank and electronic) and increased yuan deposits in Hong Kong.

A valid question is whether the increase in CNH trading activity and liquidity can explain the decrease in CNY/CNH premiums over time. In Table I, Panel C, we find that only CNH liquidity is associated with decreases in the CNH/CNY premium. However, CNY and NDF liquidity are not associated with either NDF or CNH premiums. Thus, increased participation in the offshore market is associated with a moderate decline in mispricing in the offshore spot market relative to the onshore spot market. Emphasizing that there exists some form of imperfect integration between the CNH and CNY markets, we find that CNH liquidity is not correlated, economically or statistically, with CNY or NDF liquidity. On the other hand, CNY/NDF correlation increases from 0.621 to 0.931 after the CNH is introduced. Thus, the established offshore NDF market shares liquidity commonalities with the onshore CNY market whereas the recently introduced offshore CNH market does not share any liquidity commonality with either established rate. As discussed in Section 4.3, the increased (lack of) liquidity coupling between the onshore spot and offshore NDF (spot) markets is due to the CNH providing an underlying offshore spot rate for the preexisting offshore NDF contract.

4.3. Onshore Spot Versus Offshore Spot Rates

We now examine the relationship between onshore and offshore spot returns. In Table I, Panel C, we find that the correlation between CNY and CNH returns during the entire postsample is statistically and economically significant (0.458). Examining rolling 30-day correlations, we find that cross-return correlations increase and hold steady between 0.409 and 0.809 after mid-December. Also, CNH/CNY return comovement is not radically different from CNH/NDF return comovement but is markedly different from the NDF/CNY comovement (0.799). Although the comovement results indicate that the CNY and CNH markets are integrated to some degree, although not as much as the CNY and NDF markets, the results do not reveal whether and how price discovery flows between the markets.

To examine cross-market price discovery, we compute GVDFs and GIRFs. As seen in Figure 2, the own-to-own GVDFs for CNH and CNY are 81.68% and 80.08%, respectively. The CNH-to-CNY and CNY-to-CNH cross-GVDFs are 18.32% and 19.92%, respectively. Thus, CNH (CNY) returns have at most 18.32% (19.92%) explanatory power for CNY (CNH) returns. In other words, preliminary evidence suggests that price discovery largely does not

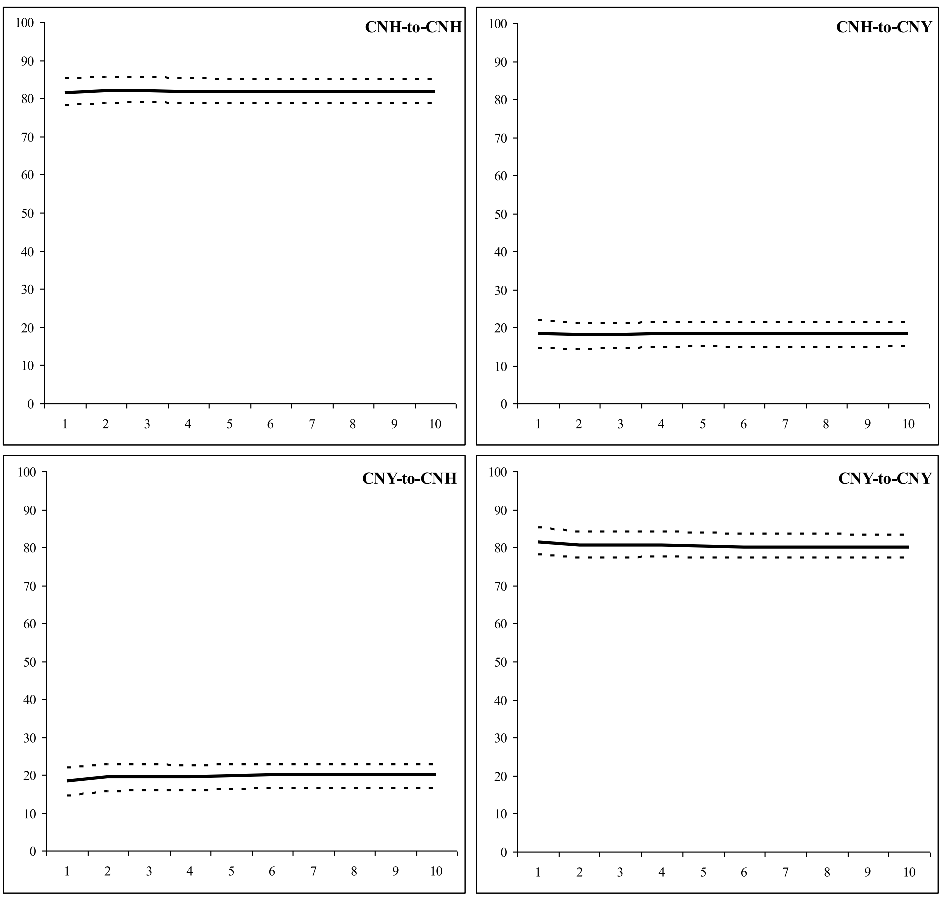

FIGURE 2

Generalized variance decompositions: onshore versus offshore spot. The following charts report generalized variance decompositions for offshore (CNH) and onshore (CNY) spot returns estimated with a vector autoregression using five lags during the post-CNH introduction sample (September 2010 to June 2011). Note that we rescale the generalized variance decomposition functions so that the sum of each market's decompositions is equal to one. Finally, each decomposition is reported for up to ten trading days and ±2 standard error bands are reported in dashes.

exist between the CNY and CNH markets, and that they are, to a degree, not informationally integrated.

From Figure 3, we find that both own and cross-causality exists given that at least one day's impulse is statistically positive. As is customary, the own responses are economically much larger than the cross-responses. However, the economic magnitude of the cross-responses is low (in both relative and absolute terms). Specifically, a one standard deviation increase in CNH returns only leads to a 0.0637 standard deviation increase in CNY returns. From the other direction, a one standard deviation increase in CNY returns only leads to a 0.0825 standard deviation increase in CNH returns. In other words, although the markets appear to transmit in a statistical sense, the economic significance of the spillovers is negligible.

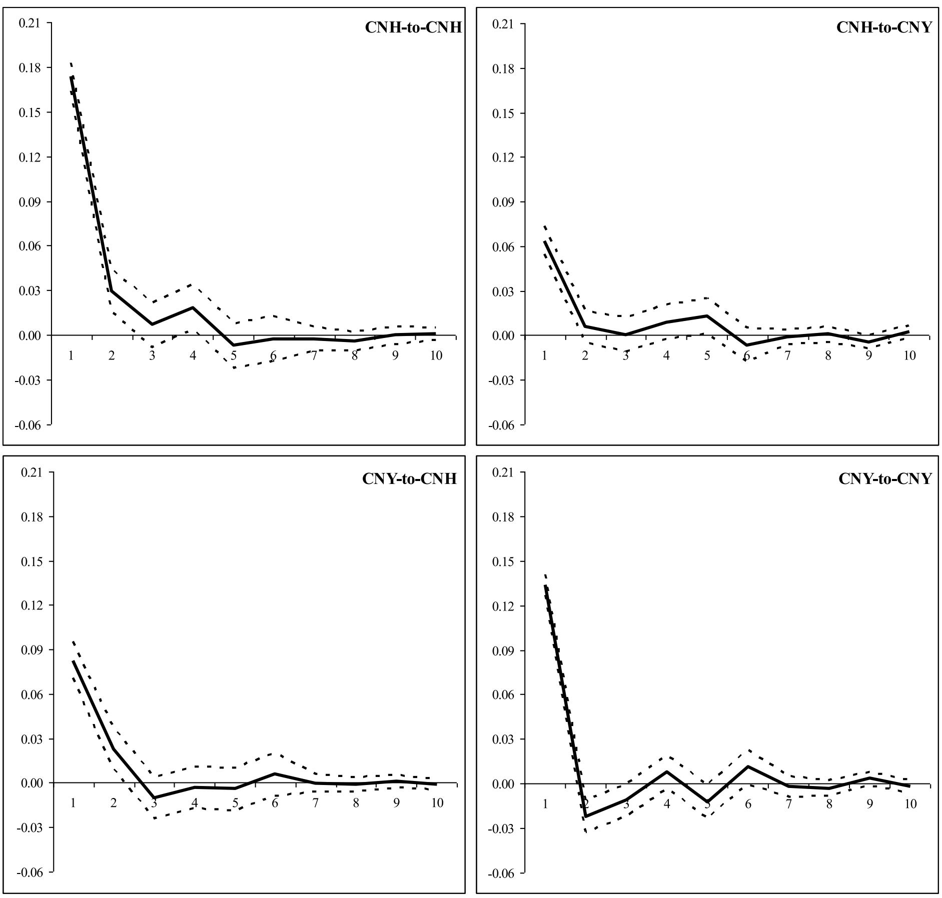

FIGURE 3

Generalized impulse response functions: onshore versus offshore spot. The following charts report generalized impulse response functions for offshore (CNH) and onshore (CNY) spot returns using a vector autoregression with five lags estimated during the post-CNH introduction sample (September 2010 to June 2011). Note that the generalized impulse response functions are robust to variable ordering, are plotted for up to ten trading days, and ±2 standard error bands are reported in dashes.

In sum, our onshore versus offshore spot returns analyses indicate that both markets have a moderate level of comovement. However, based on the GVDF and GIRF causality analysis, there is little indication of price discovery from one market to the other given that each market has a low ability to explain the returns variation of the other market and that cross-market causality is economically trivial. Thus, there exists a low level of information integration between onshore and offshore yuan spot rates.

4.4. Onshore Spot Versus Offshore Forward Rates

We now shift our focus to both contemporaneous and lead-lag relationships between onshore yuan spot rates and offshore NDF rates. Examining the cross-market contemporaneous correlations in Table I, Panel C, we find that CNY/NDF comovement in the preintroduction period is statistically significant and of similar magnitude (0.530) with the postperiod CNY/CNH comovement (0.458). For the postperiod, however, we find that NDF/CNY comovement increases to 0.799. The returns results are in line with the liquidity results indicating an increase in both rate and liquidity commonality between the CNY and NDF markets after the introduction of CNH trading.

Unlike the CNH/CNY GVDFs, the NDF/CNY GVDFs in Figure 4 indicate a high level of cross-return explanatory power. Specifically, for the preintroduction period, we find that 74.45% of NDF returns are explained by its own returns whereas 25.55% of NDF returns are explained by CNY returns. During the postintroduction period, we find that 60.08% of NDF returns are explained by its own returns whereas 39.92% of NDF returns are explained by CNY returns. Looking in the other direction during the preperiod, we find that 72.68% of CNY returns are explained by its own returns whereas 27.32% of CNY returns are explained by NDF returns. For the postperiod, we find that 61.15% of CNY returns are explained by its own returns whereas 38.85% of CNY returns are explained by NDF returns.

There are three main findings from the GVDF analysis above. First, regardless of the time period, both onshore spot and offshore NDF returns explain a nontrivial percentage of the other's returns. Also, the levels of cross-market explanatory power are greater than that for the CNY/CNH pair. Second, cross-market explanatory power increases during the post-introduction period whereas own-market explanatory power decreases after the introduction of offshore spot trading. Taken together, and unlike the CNY/CNH relationships, the CNY/NDF relationships point to significant and increased information contribution (increased price discovery) between the two markets in the postperiod.

The third and final finding from the GVDF analysis is that the magnitude of cross-explanatory power is not markedly different for either market, regardless of the time frame under examination. This finding indicates that both markets are equally important in explaining the returns of the other market. In other words, regardless of market conditions, each market contributes equally to the other market's rate movements, indicating that no market holds the relative price discovery advantage.

From the GIRFs in Figure 5, we find that the impact of both own-to-own and cross-to-own shocks increase after the introduction of the CNH. With respect to the cross-to-own reactions, we find that a one standard deviation increase in NDF returns leads to a 0.105 standard deviation increase in CNY returns in the postperiod. From the other direction, we find that a one standard deviation increase in CNY returns leads to a 0.152 standard deviation increase in NDF returns. In line with the above GVDF results, the magnitude of the cross-to-own responses is highly similar and higher after the CNH's introduction. Unlike the onshore versus offshore spot results, the NDF/CNY GIRFs are economically larger. Specifically, the postintroduction NDF-to-CNY (CNY-to-NDF) impact is approximately 1.65 (1.84) times larger than the CNH-to-CNY (CNY-to-CNH) causal impact.

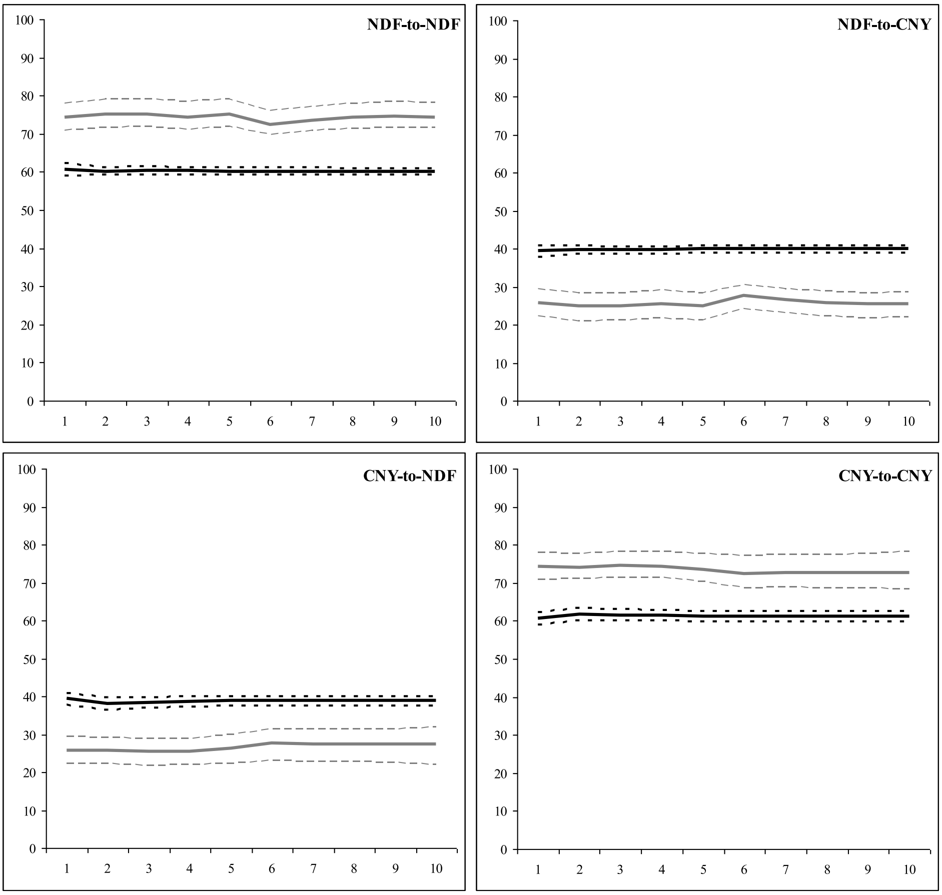

FIGURE 4

Generalized variance decompositions: onshore spot versus offshore forward. The following charts report generalized variance decompositions between one-month offshore nondeliverable forward (NDF) and onshore spot (CNY) returns estimated with a vector autoregression using five lags estimated for both the pre-CNH (September 2009 to June 2010; gray) and post-CNH (September 2010 to June 2011; black) introduction samples. Note that we rescale the generalized variance decomposition functions so that the sum of each market's decompositions is equal to one. Finally, each decomposition is reported for up to ten trading days and ±2 standard error bands are reported in dashes.

In sum, when examining onshore spot trading against offshore NDF trading, we find that each market contributes information to the other market and that each market's contribution to price discovery is approximately equal. Further, the introduction of offshore spot trading is associated with an increase in both cross-market comovement (higher returns correlations) and information contribution. Thus, the CNY and NDF markets became even more informationally integrated after the CNH began trading.

Our results indicate that exchange rate markets settle into delicate price discovery patterns that are shaped by the participation of both onshore and offshore investors as well as capital controls. When new capital controls and currency trading restrictions/liberalizations are enacted, price discovery relationships may change as market participants' ability to transmit information (through the trading process) is altered. This is in line with the prior

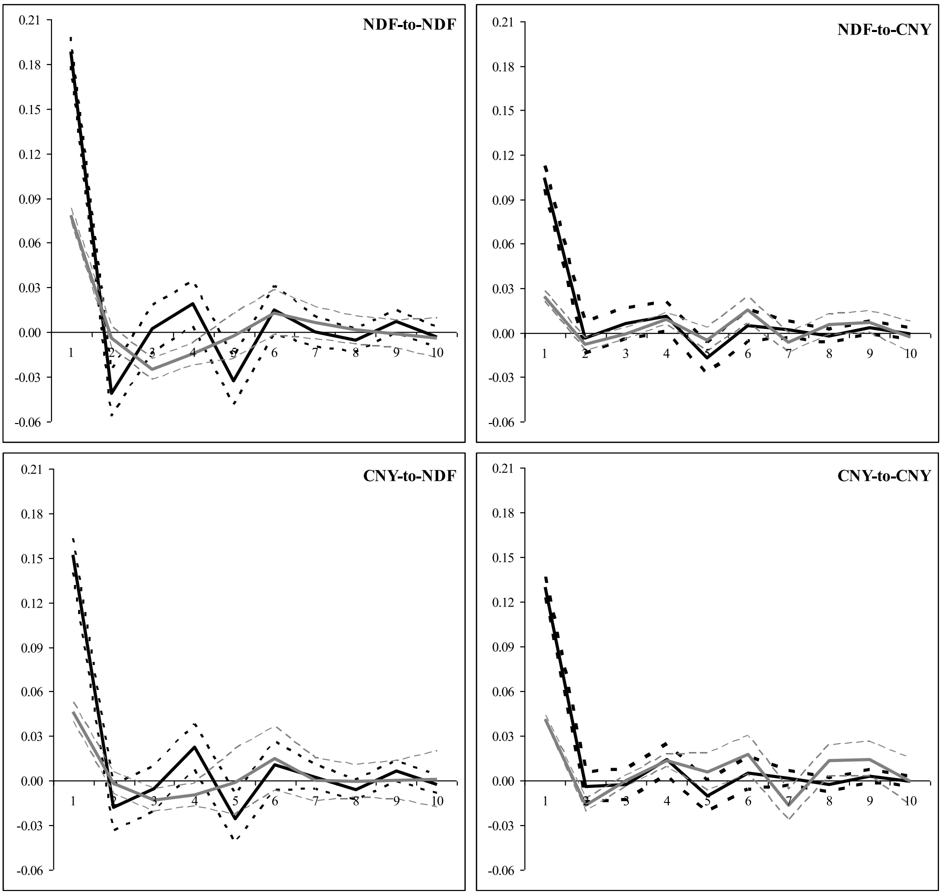

FIGURE 5

Generalized impulse response functions: onshore spot versus offshore forward. The following charts report generalized impulse response functions for one-month offshore nondeliverable forward (NDF) and onshore spot (CNY) returns using a vector autoregression with five lags estimated for both the pre-CNH (September 2009 to June 2010; gray) and post-CNH (September 2010 to June 2011; black) introduction samples. Note that the generalized impulse response functions are robust to variable ordering, are plotted for up to ten trading days, and ±2 standard error bands are reported in dashes.

literature that finds that onshore versus offshore exchange rate causality can change over different time periods (Huang & Wu, 2006) and across different capital control regimes (e.g., Park, 2001). In addition, introducing offshore currency products, such as the CNH in the case of China, can lead to a type of "market completion" and thus new patterns of onshore versus offshore price discovery wherein the CNY and NDF markets became more informationally integrated.

5. RESOLUTION OF THE PUZZLE

The onshore spot versus offshore forward results provide an interesting contrast to the onshore versus offshore spot results. On the one hand, the overall results do not support the market expectation that "the offshore [spot] yuan market can provide feedback on investors' perceptions of the yuan's true value" (Ip, 2010) nor do they support fears that CNH trading and currency liberalizations have lead to inflationary "hot money flows" into the mainland.

On the other hand, the spot/forward results indicate that the onshore spot and offshore forward markets exhibit a high level of returns and liquidity comovement, the markets are informationally integrated, and that price discovery flows bidirectionally in approximately equal magnitudes. Also, we find that liquidity and returns comovement as well as information integration increases once the CNH began trading. Thus, a puzzle exists as to why one offshore market is informationally integrated with the onshore market whereas another offshore market is not. An important and related part of this puzzle is why cross-market price discovery increased between the spot and forward markets after the introduction of CNH trading. We believe that the puzzle can be resolved partially by PBC restrictions as well as the fact that different offshore rates (spot and forward) track different aspects of the onshore spot rate.

We begin with the first piece of the puzzle: PBC restrictions and interventions. Pricing differentials between onshore and offshore yuan spot rates steadily decrease over the beginning of the offshore spot contract's life. Further, rapid increases (declines) in premiums are associated with capital control impacts (liberalizations). Finally, in addition to the decrease in CNH premiums, we also find a large increase in CNH liquidity and, according to numerous news articles (e.g., see Ashburn, 2011; Wei, 2011), an increase in offshore spot trading.

According to our liquidity analysis, the decrease (increase) in CNH BASs (liquidity) was only moderately associated with a decrease in CNH premiums. Thus, increased CNH liquidity is not likely responsible for the lower CNH premiums. Rather, a more likely explanation is the steady loosening of both onshore spot trading restrictions and capital controls. Yet, although decreased PBC restrictions led to decreased CNH pricing errors, they did not lead to significant onshore/offshore spot price discovery. So, although the PBC interventions have had some impact (mainly relieving pricing differentials), a second resolution of the puzzle comes from the fact that offshore spot and NDF rates track different aspects of the Chinese currency market.

Specifically, while the NDF is a contract whose forward curve acts like a futures curve on onshore yuan spot rates, the CNH is a spot rate whose forward curve acts more like an onshore interest rate curve. Thus, NDF rates more closely track onshore yuan spot rates whereas CNH rates more closely track onshore interest rates (Hui and Bunning, 2010; Soh & Chatterjee, 2010). This explanation is in line with our finding that the CNY and NDF markets informationally contribute to each other and are highly correlated, whereas the CNH and CNY do not informationally contribute to one another and are only moderately correlated.

We provide initial evidence of the above explanation in Table III. Specifically, we calculate correlation coefficients between the different markets' currency returns and changes in SHIBOR (Shanghai Interbank Offered Rate) rates across different maturities for the postintroduction sample. We collect SHIBOR rates from the CFETS and Nation Interbank Funding Center website and use the average of all major dealer quotes for each day. Using a 5% significance level, we find that offshore (onshore) spot returns are positively and significantly related to 9- and 12-month (nine-month) SHIBOR rate changes. Offshore NDF returns, however, are not related to SHIBOR rate changes. Although the correlations present in Table III are in no way intended to explain the entirety of yuan return variability, they do provide evidence that offshore spot rates are related to onshore interest rates whereas offshore forward rates are not.

What makes this explanation more attractive is that the extent of cross-market activity between the CNY and NDF markets increases after the introduction of CNH trading. Although the CNH is more closely aligned with onshore interest rates, its introduction

TABLE III
Interest Rates and Currency Returns

SHIBOR Maturity		*CNH*	*CNY*	*NDF*
Overnight	Corr.	−0.005	−0.090	−0.094
	p-Value	0.940	0.208	0.195
1 Week	Corr.	0.043	−0.005	0.037
	p-Value	0.559	0.945	0.616
2 Weeks	Corr.	0.057	−0.032	0.100
	p-Value	0.432	0.652	0.171
1 Month	Corr.	0.024	0.019	0.128
	p-Value	0.737	0.794	0.077
3 Months	Corr.	0.069	0.021	0.082
	p-Value	0.344	0.773	0.258
6 Months	Corr.	0.125	0.033	0.000
	p-Value	0.084	0.649	0.997
9 Months	Corr.	0.208	0.056	0.046
	p-Value	0.004	0.432	0.532
12 Months	Corr.	0.238	0.143	0.130
	p-Value	0.001	0.045	0.074

Note. In this table, we report correlation coefficients and their *p*-values between offshore spot (CNH), onshore spot (CNY), and offshore nondeliverable forward (NDF) returns and changes in SHIBOR (Shanghai Interbank Offered Rate) rates across different SHIBOR maturities for the postintroduction (September 2010 to June 2011) sample.

"completed" the offshore NDF market. Specifically, before the existence of the CNH, the offshore NDF had no related and unrestricted underlying spot market. The introduction of the CNH thus increased the relevance of the NDF in explaining future onshore yuan movements. This explanation is in line with Peng et al. (2007) who find that NDF pricing efficiency is restricted from the lack of a benchmark spot curve. The launch of CNH trading reduced the existing pricing inefficiencies in the NDF market, leading to higher information relevance of the CNH to the onshore market. We see this in that NDF returns become more associated with onshore spot returns (the correlation increases from 0.503 to 0.799 in the postperiod).

6. CONCLUSION

On July 19, 2010, The PBC approved offshore yuan spot trading in Hong Kong. Ever since, the offshore yuan market (CNH) has experienced a rapid increase in trading activity, liquidity, and market development. Although the previously existing offshore nondeliverable yuan forward market (NDF) continues to dwarf the CNH in terms of trading activity, liquidity, and market development, it is clear that offshore spot trading has a unique and growing place in international currency transactions.

Yet, despite the rapid advances in the CNH market, we find that offshore spot (CNY) returns provide little explanatory power to CNH returns (and vice versa) indicating that the onshore and offshore spot markets are not informationally integrated. The NDF market, on the other hand, shares an equal and nontrivial role in CNY price discovery that has increased after the introduction of CNH trading. The lack of CNH/CNY price discovery presents a puzzle where one offshore rate better tracks the onshore rate than the other offshore rate.

The resolution of this puzzle is that CNH rates are related more with onshore interest rates than they are with onshore spot exchange rates. Further, the existence of capital controls ensures that some form of partial interest rate parity will not align on/offshore spot rates. NDF rates, on the other hand, act as futures on the underlying onshore spot rate. As such, NDF rates are more relevant to CNY rates (and vice versa) than CNH rates, leading to higher NDF/CNY information integration and little CNH/CNY information integration. Further, introducing offshore spot trading *completes* the offshore market by providing an underlying spot rate for the preexisting offshore forward rate. Thus, NDF rates are even more relevant to onshore spot rates, leading to higher levels of NDF/CNY cross-market price discovery and information integration.

From a policy perspective, our analysis indicates that, despite the increased relevance of offshore NDF rates, Chinese capital controls remain largely binding. As a result, some form of market segmentation remains between onshore and offshore exchange rates. Further, as long as PBC capital controls and yuan trading restrictions remain sufficiently binding, expectations of price discovery flows between onshore and offshore spot markets are not likely to emerge in excess of CNY/NDF price discovery regardless of the level of liquidity/activity on the offshore spot market. Consequently, policy makers and appreciation-motivated traders are advised to use NDF forward rates, and not CNH rates, to determine future, market-based, yuan movements.

It should be noted that our analysis is only concerned with the initial impact of RMB offshore spot trading. As noted above, the absence of cointegration between the onshore and offshore markets may be a temporary effect brought about by policy changes or policy change uncertainty. It is entirely possible that cointegration will once again emerge between the CNY and NDF (or between the CNY and CNH) once traders fully utilize all the markets at their disposal and once the markets have had time to stabilize from the sequence of policy shocks. Also, future capital control liberalizations may bring about increased relevancy of the offshore spot market, partially eroding the price discovery function of the offshore NDF market. We leave these topics for future research.

REFERENCES

Ashburn, E. (2011). Offshore yuan FX trades seen at $1 billion by year end: Deutsche. Reuters, February 23, 2011.

Bollerslev, T. (1990). Modelling the coherence in short-run nominal exchange rates: A multivariate generalized ARCH model. Review of Economics and Statistics, 72, 498–505.

Bollerslev, T., Engle, R. F., & Wooldridge, J. M. (1988). A capital-asset pricing model with time-varying covariances. Journal of Political Economy, 96, 116–131.

Chen, R., Gong, J., & Zheng, Z. (2009). Information flows across non-deliverable forwards, deliverable forwards, and spot markets: Evidence from Korean won and RMB. Management and Service Science International Conference, Wuhan/Beijing, China, September 2009.

Cheung, Y. W., & Qian, X. (2010). Capital flight: China's experience. Review of Development Economics, 14, 227–247.

Cookson, R. (2011). HK to start daily renminbi benchmark. Financial Times, June 23, 2011.

Dabelle, G., Gyntelberg, J., & Plumb, M. (2006). Forward currency markets in Asia: Lessons from the Australian experience. Bank for International Settlements Quarterly Review, September, 53–64.

Engle, R. (2002). Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. Journal of Business and Economic Statistics, 20, 339–350.

Engle, R., & Granger, C. (1987). Cointegration and error-correction: Representation, estimation, and testing. Econometrica, 55, 251–276.

Engle, R. F., & Kroner, K. F. (1995). Multivariate simultaneous generalized ARCH. Econometric Theory, 11, 122–150.

Flatt, D. (2011a). Renminbi rises to 18-year record on inflation fears. Asiamoney, April 7, 2011.

Flatt, D. (2011b). RMB bulls stymie offshore cross-currency swap liquidity. Asiamoney, May 2011.

Foley, J. (2010). The yuan needs a small leap forward. The Business Times: Singapore, December 8, 2010.

Gu, L., & McNelis, P. D. (2011). Euro volatility and Chinese fear of floating: Pressures from the NDF market (working paper). Fordham University.

Guru, A. (2009). Non-deliverable forwards market for Indian rupee: An empirical study. Indian Journal of Economics and Business, 8, 245–260.

Higgins, P., & Humpage, O. F. (2005). Nondeliverable forwards: Can we tell where the renminbi is headed? Federal Reserve Bank of Cleveland Economic Commentary, September, 1–4.
Holland, T. (2010). Hong Kong bankers face long wait to fully appreciate yuan. South China Morning Post, July 23, 2010.
Huang, X., & Wu, C. (2006). The interaction between the RMB offshore NDF and onshore spot rate: Before and after the foreign exchange reform. Journal of Financial Research, 11, 83–89.
Hui, D., & Bunning, D. (2010). The offshore renminbi: A practical primer on the CNH market (working paper). HSBC Global Research.
Ip, F. (2010). Trading yuan in Hong Kong. Bloomberg Markets, December 2010.
Jiang, Y. (2010). Analysis: China boosting RMB's internationalization in 3 areas. Asia Pulse, September 28, 2010.
Johansen, S. (1991). Cointegration and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica, 59, 1551–1580.
Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. Journal of Econometrics, 74, 119–147.
Lipscomb, L. (2005). An overview of non-deliverable foreign exchange forward markets. Federal Reserve Bank of New York, May.
Ma, G., Ho, C., & McCauley, R. N. (2004). The markets for non-deliverable forwards in Asian currencies. Bank for International Settlements Quarterly Review, June, 81–94.
Ma, G., & McCauley, R.N. (2008). Efficacy of China's capital controls: Evidence from price and flow data. Pacific Economic Review, 13, 104–123.
MacKinnon, J. G., Haug, A. A., & Michelis, L. (1999). Numerical distribution functions of likelihood ratio tests for cointegration. Journal of Applied Econometrics, 14, 563–577.
Misra, S., & Behera, H. (2006). Non deliverable foreign exchange forward market: An overview. Reserve Bank of India Occasional Papers, 27, 25–55.
Park, J. (2001). Information flows between non-deliverable forward (NDF) and spot markets: Evidence from Korean currency. Pacific-Basin Finance Journal, 9, 363–377.
Peng, W., Shu, C., & Yip, R. (2007). Renminbi derivatives: Recent development and issues. China and World Economy, 15, 1–17.
Pesaran, M. H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. Economics Letters, 58, 17–29.
Pomfret, J. (2010). Factbox: Hong Kong's role as offshore yuan settlement centre. Reuters, August 4, 2010.
Ren, D., & Yiu, E. (2010). Shanghai drops offshore yuan trading hub dreams: Mainland city to complement HK in global currency drive. South China Morning Post, July 22, 2010.
Sims, C. (1980). Macroeconomics and reality. Econometrica, 48, 1–48.
Sin, C. Y. (2005). Impulse response and variance decomposition in the presence of time-varying volatility: With applications to price discovery (working paper). Hong Kong Baptist University.
Soh, K., & Chatterjee, S. (2010). Offshore yuan takes off: Tracking dim-sum bonds, deliverable forwards, and deposits in Hong Kong's fast-growing yuan market. Reuters Analysis, December 1, 2010.
Staff. (2009). Dollar lending jumps on tightening RMB credit and appreciation expectations. China Stakes, October 30, 2009.
Staff. (2010). Analysis: China's exchange rate more flexible since 2005 reform. Asia Pulse, July 22, 2010.
Staff. (2011). China starts yuan options to provide more hedging tools. Xinhua News Agency, February 16, 2011.
Sun, D., & Niu, D. (2009). Interrelation analysis of the RMB spot and offshore markets. Management and Service Science International Conference, Wuhan/Beijing, China, September 2009.
Sun, D., Sun, J., & He, P. (2010). RMB revaluation, NDF, and Chinese capital market. Management and Service Science International Conference, Wuhan, China, August 2010.
Tsuyuguchi, Y., & Wooldridge, P.D. (2008). The evolution of trading activity in Asian foreign exchange markets. Emerging Markets Review, 9, 231–246.
Wallace, C. (2011). Offshore renminbi market grows in Hong Kong. Institutional Investor, April 6, 2011.
Wang, Y. D. (2010a). Anomaly in China's Dollar-RMB forward market. China and World Economy, 18, 96–120.
Wang, Y. D. (2010b). Convertibility restriction in China's foreign exchange market and its impact on forward pricing (working paper). Stanford Institute for Economic Policy Research.
Wang, X. (2011). Central bank pegs yuan rate at new record high. China Daily, May 10, 2011.
Wang, H., & Shang, Y. (2009). Information flows between RMB offshore markets and domestic markets: Evidence from non-deliverable forward (NDF) and spot markets. Management and Service Science International Conference, Wuhan/Beijing, China, September 2009.
Wee, D. (2011). Offshore RMB bonds face hurdles, but offer huge promise. FinanceAsia, January 27, 2011.
Wei, L. (2011). Beijing considers new hub for yuan. Wall Street Journal, April 9, 2011.

Williams, J., & Ioannidis, C. (2006). Multivariate GARCH models with impulse responses in mean, variance, and covariance (working paper). University of Aberdeen.
Yang, J., & Leatham, D.J. (2001). Currency convertibility and linkage between Chinese official and swap market exchange rates. Contemporary Economic Policy, 19, 347–359.
Ye, B. (2011). Interest rates cut on yuan deposits. The Standard, April 1, 2011.
Yiu, E. (2010). Big hurdles still block yuan from going global: Bankers, brokers say currency still too inaccessible offshore. South China Morning Post, October 11, 2010.
Yiu, E. (2011a). HK faces stiffer race as yuan trade centre: More banks in offshore financial centres begin offering services in mainland currency. South China Morning Post, January 13, 2011.
Yiu, E. (2011b). HSBC set for yuan-linked liftoff. South China Morning Post, May 23, 2011.

APPENDIX

GARCH ROBUSTNESS CHECKS

Some of our main findings are based on generalized impulse response functions (GIRFs). Given our sample size, we do not take into account time-varying conditional volatility in our vector autoregression (VAR) estimations (i.e., GARCH effects). Yet, as noted by Sin (2005), i.i.d. impacts in a VAR framework are likely to be larger when the conditional volatility is higher. Also, the decomposition method used in specifying the VAR directly depends on time variation in the system's conditional volatility. Williams and Ioannidis (2006) find that failing to incorporate GARCH effects can lead to substantially different impulse response functions than those produced by models incorporating GARCH effects. This may include not only different impulse patterns but also lengthened responses.

Thus, a valid concern regarding our GIRF results is whether they are biased by our (implicit) assumption of time-invariant conditional volatility.[2] In this Appendix, we report GIRF plots for nine models.

Model	*Conditional*	*Conditional*	*Variance Covariance Matrix*	*Distribution*
	Mean	Volatility	Specification	Assumption
1	VAR(5)	None	None	Normal
2	VAR(5)	GARCH(1,1)	BEKK	Normal
3	VAR(5)	GARCH(1,1)	BEKK	Student's *t*
4	VAR(5)	GARCH(1,1)	Dynamic Conditional Correlation	Normal
5	VAR(5)	GARCH(1,1)	Dynamic Conditional Correlation	Student's *t*
6	VAR(5)	GARCH(1,1)	Conditional Correlation	Normal
7	VAR(5)	GARCH(1,1)	Conditional Correlation	Student's *t*
8	VAR(5)	GARCH(1,1)	VECH	Normal
9	VAR(5)	GARCH(1,1)	VECH	Student's *t*

Specifically, with the exception of the base model (no GARCH effects; Model 1), we estimate the returns of each market pair using a VAR(5) for the conditional mean equations and a (multivariate) GARCH(1,1) specification for the conditional volatility equations.

In addition, we use four different assumptions regarding the variance–covariance matrix and thus, cross-market volatility dynamics: the BEKK specification of Engle and Kroner ('95), the dynamic conditional correlation specification of Engle (2002), the constant correlation model of Bollerslev ('90), and the VECH specification of Bollerslev, Engle, and Wooldridge ('88). Finally, we allow each of the four GARCH specifications to be estimated under

[2]We thank an anonymous referee for bringing this issue to our attention.

multivariate normal and Student's t-distribution where the latter allows for estimable degrees of freedom.

We plot the GIRFs for onshore spot (CNY) versus offshore spot (CNH) returns for the postintroduction period (September 2010 to June 2011), CNY versus NDF returns for the preintroduction sample (September 2009 to June 2010), and CNY versus NDF returns for the postintroduction sample.[116] We use standardized residuals to compute the GARCH GIRFs. We find that there is little variation in the average and median GARCH GIRFs. Thus, although different GARCH models do produce different GIRFs, the difference in GIRF output is relatively symmetric among the various models. With respect to the differences in GARCH versus non-GARCH GIRFs, we examine two aspects: time paths and decay times. With respect to time paths, we find that most non-GARCH GIRFs are highly similar to the GARCH GIRFs. Not only are the impulse directions highly consistent, but also the magnitudes of each impulse are similar. Two exceptions are the NDF-to-CNY and CNY-to-CNY impulses for the NDF versus CNY preintroduction estimation. Here, the non-GARCH impulses are more volatile and persistent than the GARCH impulses. However, although significant, many of the latter responses are not economically significant especially when compared to the initial impulse. Thus, the differences in GARCH and non-GARCH responses likely do not represent a major issue.

The second issue is persistency. As Williams and Ioannidis (2006) note, GARCH GIRFs may be more persistent than non-GARCH GIRFs. Yet, both the GARCH and non-GARCH GIRFs plots are economically insignificant past the initial responses. In sum, although different GARCH specifications produce different general impulses and differences do exist between GARCH and non-GARCH GIRFs, these differences are rarely large in an absolute sense and insignificant in an economic sense. Thus, we conclude that our non-GARCH results reported in the main text are robust to assumptions of the underlying conditional volatility process.

[3]These plots (not shown) are available upon request.