The anatomy of a peg: lessons from China's parallel currencies[*]

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Abstract

A parallel offshore currency coupled with capital controls creates a wedge between domestic and foreign returns that policy can use to intervene in the exchange rate and manage the foreign balance. The Chinese experience with the mainland CNY and the offshore CNH validates this approach. Exploiting a rare instance of exogenous, transitory increases in the supply of money, we find causal evidence that they depreciate the exchange rate, and, using an instrument for shocks to money demand, we find that the scarcity of liquidity affects the exchange rate. Monetary and liquidity policies jointly manage the onshore-foreign exchange rate and the onshore-offshore peg in an integrated policy framework.

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1 Introduction

For more than a decade, Chinese authorities have conducted a large-scale monetary experiment. Their challenge has been to reconcile an open current account with a closed capital account. The former involves the free trade of goods by the world's largest exporter, requiring large international payments for diverse transactions. The latter imposes tight restrictions on financial flows and allows the state to steer the nation's external balance. The former provides a potent force for the yuan to be used internationally; the latter restricts it to be a domestic currency.

The Chinese answer was to create an offshore currency—the Hong Kong yuan (CNH)—that circulates in parallel with the onshore currency, the mainland yuan (CNY). The CNH is freely used for payments by anyone internationally, with no limits on convertibility or the accumulation of liquid balances. By 2023, CNH transactions amounted to ¥2 trillion per day, facilitating 14% of global trade. The CNY, instead, is used for onshore transactions and is required to invest directly in the mainland. Exchanges between the two currencies occur at par but require approval: current-account flows are convertible only against a trade invoice, while capital-account transactions face quotas. Since some Chinese agents hold both currencies—each with different transaction utilities and potentially different returns—there exists a market exchange rate between CNH and CNY.

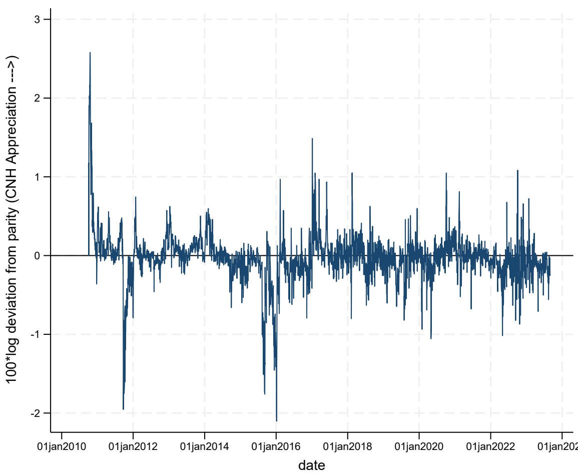
These parallel currencies embody two tensions. First, if one persistently loses value relative to the other, agents would want to convert it into the more valuable one. The capital controls that prevent the conversion would come under severe strain, and one of the currencies would stop being used or accepted. This is Gresham's law. One way to maintain parity is to allow unlimited one-to-one conversion, but this reveals the second tension. Since CNH is a claim on China that foreigners hold without restrictions, free flows between the two currencies would negate capital controls and end the management of the country's external position. Policymakers face a balancing act of maintaining an exchange rate peg while varying the quantity of CNH money to manage the current account balance. As Figure 1 shows, even though the yuan's value against the US dollar (USD) has fluctuated widely, the exchange rate between its two variants has been close to one, and even large fluctuations of more than 100bp are short-lived.

This paper studies this parallel currency system: its mechanics, the theory behind it, the mechanisms that sustain it, and its potential for external-balance management.

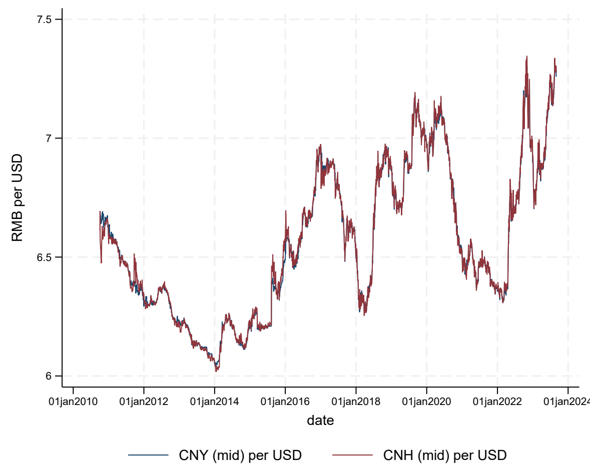
First, we characterize how the People's Bank of China (PBoC) and the Hong Kong Monetary Authority (HKMA) jointly implement CNH monetary and liquidity policies.

Figure 1: The relative value of the yuan

(a) Exchange rate of CNY with CNH



(b) Exchange rate of CNY or CNH with USD



Note: Sample period is all trading days between 1 October 2010 and 31 August 2023. In both panels, an increase is a yuan depreciation, either of CNY relative to CNH or ti USD, or of CNH relative to USD.

We show that the complex institutional architecture reduces to conventional principles with policy manipulating the scarcity of reserves to steer the CNH money supply and the onshore-offshore exchange rate.

Second, we show theoretically how combining scarce offshore money with capital controls creates a wedge between domestic and foreign currency returns. By controlling this wedge, policymakers can influence the foreign exchange rate and steer the external position. By altering the scarcity of offshore reserves, monetary and liquidity policies can implement the same outcomes as a tax on capital flows.

Third, we use the Chinese experience to empirically test the link between money and exchange rates. The peculiarities of the CNY-CNH system provide a rare opportunity for credible identification. We find that operationally-driven exogenous increases in the supply of offshore reserves depreciate the offshore currency's value relative to the onshore currency. We estimate the elasticity of reserve demand and find that offshore reserves have not been unusually scarce.

Fourth, we provide an anatomy of the policies that sustain the exchange-rate peg. Using an instrument for offshore money demand, we find that the authorities expand the money supply whenever the CNH appreciates, but that this accounts for only one-sixth of the return to parity. The remainder results from liquidity policies that alter the costs for banks to issue deposits and the liquidity value of reserves without changing the money supply. Together, monetary and liquidity policies allow policymakers to hit the two policy targets that reflect the two tensions described above.

Fifth, to investigate these liquidity policies and how they work, we write a microfounded model of the benefits of liquidity when reserves are scarce. The model shows that reserve requirements, discount-window rates, interbank-market regulations, and restrictions on liquidity flows between offshore and onshore markets are all effective tools. We find empirical support for their effects using data on interbank rates, facilities usage, bill auctions, and the 2015-16 crisis.

Sixth, we discuss the merits of this system relative to capital flow taxes. Parallel currencies can fit within the IMF policy toolkit for the management of external balances. From an academic perspective, our findings strongly support several key pillars of monetarism.

Outline, contributions, and links to the literature. Section 2 describes the policies of the PBoC and the HKMA that control CNY-CNH exchanges and supply CNH money, as well as the broader set of policies that affect the yuan's exchange rate against the USD.[1] Despite its peculiarities, the CNH monetary system ultimately relies on using tools that affect the supply and demand for liquidity to achieve policy goals, much like any standard quantity-based monetary system. Our contribution is to show that a setting that at first sight is opaque and complex reduces, upon inspection, to standard channels used by central banks around the world.[2] This analysis contributes to our understanding of monetary regimes and capital controls.

The Chinese experience is interesting in its own right, given the relevance of its economy in the international financial system.[3] Moreover, the institutional setup reveals what is required to internationalize a currency—at least as a medium of exchange—while maintaining capital controls.[4] Other countries may find this experiment with parallel currencies appealing, and this paper explains how it has been implemented.

[1]The two central banks independently conduct monetary policy for two other currencies—the CNY (Chen, Ren and Zha, 2018) and the Hong Kong dollar (Genberg and Hui, 2011)—which are not our focus.

[2]By creating an official parallel money market with policy-managed arbitrage, the authorities may have stymied the emergence of a private offshore market akin to the Eurodollar market (He and McCauley, 2012).

[3]In 1864, the US accidentally experienced a similar arrangement: the Civil War created parallel currencies whose exchange rate was driven by the relative supplies of money (Burdekin and Weidenmier, 2001).

[4]Naef et al. (2022) describe other components of China's internationalisation strategy, including the CNH, and Bordo, Monnet and Naef (2019) compare the role of the offshore Hong Kong market with the London gold market during the internationalisation of the USD. We add a more detailed description of the monetary channels and policies of the offshore system.

Section 3 introduces an intertemporal current account model to study the macroeconomic implications of combining capital controls with parallel currencies. The model mimics the key features of the Chinese arrangement, with an offshore banking system offering deposits that can be freely held by both domestics and foreigners.[5] Beyond capital controls that restrict asset holdings, the key ingredients are that Chinese households derive some utility benefit from holding offshore deposits and that Chinese banks face a liquidity cost when issuing them. Monetary and liquidity policies influence the latter.

We show that an appropriate mix of monetary and liquidity policies can replicate the effects of a tax on capital flows, with implications for the equilibrium onshore-offshore exchange rate.[6] Using standard monetary tools, the authorities can allow the onshore-offshore exchange rate to temporarily deviate from parity in order to influence the foreign exchange rate and the country's external position. This finding contributes to the literature on foreign exchange interventions by unveiling the use of offshore currencies as an effective policy instrument.[7]

Our theory relies on offshore money being scarce so that fluctuations in its supply affect prices and outcomes. Section 4 evaluates the scarcity of money by asking the central monetarist question: by how much does a 1% increase in the money supply depreciate the exchange rate? At one theoretical extreme, when policy sets the interest rate on reserves and the demand for liquidity is satiated, the effect is zero, as arguably has been the case in advanced economies after quantitative easing created ample reserves. At the other extreme, the quantity theory predicts a 1% depreciation, consistent with episodes of hyper-inflation. Empirically, identifying the causal link is challenging because money is endogenous, exchange rates move in anticipation of fundamentals, and many omitted variables affect both.[8]

We exploit changes in the timing of CNH monetary operations between 2019 and

[5] Segmenting markets to study exchange rates has a long tradition, but onshore-offshore markets motivate a different set of assumptions than in classic models (Alvarez, Atkeson and Kehoe, 2002).

[6] A modern literature equates the UIP wedge with capital controls (Bianchi and Lorenzoni, 2022); our model clarifies which restrictions generate a wedge that policymakers can target.

[7] Jermann, Wei and Yue (2022) study the PBoC's management of the CNY-USD exchange rate; we focus instead on the use of the onshore-offshore currencies.

[8] Meese and Rogoff (1983) found no correlation between measures of money and exchange rates. Progress has come from finding that measures of liquidity affect deviations from UIP (Engel and Wu, 2023), that foreign exchange interventions are effective (Bordo, Humpage and Schwartz, 2015), that quantitative easing announcements move the exchange rate (Dedola et al., 2021), and that the quantity of bonds in private hands affects their convenience yield (Jiang, Krishnamurthy and Lustig, 2021, Valchev, 2020, Gourinchas, Ray and Vayanos, 2022, Greenwood et al., 2023). We estimate directly how an increase in the stock of money, exchanged for short-term bills, changes the exchange rate.

2021 that produced nine exogenous, moderate, and transitory expansions in the offshore money supply. Methodologically, this follows the narrative-identification tradition.[9] We find that the onshore-offshore exchange rate depreciated on average by 0.11% during these events. While the literature has struggled to tightly estimate the interest elasticity of money demand, our model shows that two elasticities matter: the elasticity of demand for central-bank reserves and the elasticity of demand for bank deposits. We estimate that the former is approximately 50, comparable to estimates for the US in 2007 under a scarce-reserve system, suggesting that CNH liquidity need not be unusually scarce for the parallel-currency system to function.[10]

Having described the institutions and established evidence for the theoretical forces driving the CNY-CNH exchange rate, Section 5 provides an anatomy of how the PBoC maintains the peg.[11] The structure of the CNY-CNH-USD again suggests a novel identification strategy for identifying the policy rule. We show that movements in the CNY-CNH exchange rate proxy for changes in the demand for CNH money and that the PBoC's management of the CNY-USD exchange rate produces an instrument for these demand shocks. We find that, following an increase in demand for CNH money that raises the onshore-offshore exchange rate by 1%, the daily supply of CNH increases by 2.6% over the next five days to help restore the peg. This estimated monetary policy rule falls short of fully reestablishing the peg: we estimate that about five-sixths of the adjustment occurs through liquidity policies.

Section 6 describes these liquidity policies in theory and estimates their effectiveness in the Chinese context. We begin with a micro-founded model of the marginal benefit of liquidity, extended to the offshore setting.[12] The relevant liquidity instruments in the model are reserve requirements, the discount-window rate, regulations affecting match-

[9] Friedman and Schwartz (2008) is the classic reference. The closest predecessors are Velde (2009), who identifies three large monetary contractions in France in 1724, and Palma (2021) who uses discoveries of precious metals in America that increased the money supply in Europe. We complement this work by studying a recent experience with a modern central bank, by identifying high-frequency shocks to reserves rather than banknotes, by estimating the relevant elasticities, and by separating the role of monetary and liquidity policies.

[10] A vast literature estimates the impact of shocks to interest rates on exchange rates using time-series variation, e.g., Eichenbaum and Evans (1995). We instead use high-frequency narrative shocks, within a peg, with policy set via the quantity of money rather than interest rates, and in combination with liquidity tools. Chodorow-Reich et al. (2019) is closer, studying the Indian demonetization, but focussing on banknotes rather than reserves.

[11] Typical pegs do not last long, and parallel currencies usually collapse (Selgin, 2020).

[12] We adopt a version of the Poole (1968) model used by Bianchi and Bigio (2022) and Bianchi, Bigio and Engel (2021).

ing in the interbank market, and restrictions on liquidity flows of deposits and reserves within offshore and onshore banks.[13] These tools affect banks' willingness to issue offshore deposits (inside money) and to hold offshore reserves at the central bank (outside money), providing a fresh take on a wide set of policies that affect the exchange rate.[14]

We test three predictions for the impact of our identified shocks to money demand on money-market variables like interest rates, the demand for central bank bills, and central bank lending.[15] We further show that these tools have been used by the Chinese authorities, and we discuss the extreme events of 2015-16, which provide a sharp episode confirming the predictions of the model.[16]

Section 7 compares the relative merits of parallel currencies and capital-flow taxes. Although there is a rich literature on both capital controls and financial transactions taxes, there are few instances of countries successfully implementing a Tobin tax on cross-border capital flows due to many implementation challenges.[17] Brazil in 2009-13 is a notable exception with limited success that did not last long (Chamon and Garcia, 2016). China's successful sustained use of parallel currencies to manage capital flows over the past decade deserves greater attention as an alternative policy regime, and this paper analyzes its operation in detail.

Finally, Section 8 relates our findings to the core principles of monetarism dating back to the old Chicago School in their modern formulation: Friedman and Schwartz's dictum that increases in the money supply reduce the value of the currency; the Mussa-Frenkel principle that systematically expanding the money supply when the exchange rate appreciates is the way to keep a peg; Goodhart's law that stabilizing inflation requires liquidity policies that offset shifts in money demand; and Gresham's law that parallel currencies survive only when deviations from parity are temporary and short-lived. More speculatively, our results suggest that a coherent monetary and liquidity framework can sustain a peg, preserve parallel onshore-offshore currencies, and provide new tools for managing

[13]Other financial policies—like the liberalization of bond and stock holdings, discussed in Clayton et al. (2023) and He, Wang and Zhu (2023), respectively—also affect liquidity, but we focus on policies that target liquidity directly.

[14]A complementary literature studies the role of capital controls and regulations on credit, capital allocation, and financial stability (Hachem and Song, 2023, Song and Xiong, 2018, He and Wei, 2023).

[15]Combining our estimates of liquidity benefits with the models of Engel (2016) and Engel and Wu (2023), which link them to convenience yields, would link monetary and liquidity policies to output or inflation. We leave this link for future work.

[16]Monnet (2014) uses time-series variation to identify the joint impact of a menu of liquidity policies on aggregate variables in France in 1948–73. We instead use high-frequency data and a model of each policy to provide an anatomy of the channels through which each of them affects the exchange rate.

[17]See Honohan and Yoder (2010), Matheson (2011), and Erten, Korinek and Ocampo (2021).

the exchange rate with foreign currencies.

2 The setting: the offshore CNH market and monetary regime

We start by describing the Chinese setting, explaining in turn: (i) the presence of two distinct digital currencies, (ii) the restrictions on converting between them, (iii) the changes in the system in 2015–17, (iv) how offshore monetary policy is set, (v) the offshore liquidity policies, and (vi) onshore monetary policy and its relation with the USD.

2.1 The CNY and the CNH

There is a single physical currency in China—the renminbi (RMB)—but two separate digital currencies for deposits and electronic payments: CNY on the mainland and CNH in offshore centers such as Hong Kong.[18] A Chinese firm depositing RMB banknotes in Shenzhen receives a CNY claim, while a deposit a few miles away in Hong Kong is a CNH claim.

Payments clear through distinct settlement systems, and each currency has its own interbank, credit, and deposit markets.

Only banks domiciled in China can supply CNY deposits and have access to the onshore China National Advanced Payment System, where flows are settled using reserves at the PBoC. Only Chinese nationals can hold and use CNY deposits, with a few exceptions for authorized foreigners. Since CNY is required to directly transact in the onshore financial market, the limits in accessing CNY create a control over capital inflows.[19]

CNH can be held by anyone. Having first appeared in a limited form in 2004, CNH officially launched in July 2010 as part of a package of reforms to create an offshore market and jumpstart the international use of the yuan that would support China's role as the world's largest exporter.[20] Foreigners can freely hold CNH deposits, make payments, and convert CNH into foreign currency. International financial centers host clearing banks to settle payments between both Chinese and foreign banks that can issue CNH deposits. Chinese firms engaged in international trade can transact directly in CNH or convert CNH into other currencies for trade settlement.

[18] Around three-quarters of CNH transactions occur in Hong Kong, with London, Singapore, and Taiwan forming the other major offshore centers. Our analysis focuses on Hong Kong; comparisons across centers are left for future work.

[19] It is possible to buy onshore Chinese assets indirectly with CNH using various "Connect" schemes which execute using back-to-back trades (Clayton et al., 2023, He, Wang and Zhu, 2023). However, these schemes have quotas attached to them, so they are still subject to capital controls.

[20] See Bahaj and Reis (2026) on the jumpstart, and Chupilkin et al. (2023) on its recent rise.

In short, access to CNH is unrestricted, enabling the yuan's international use while use of CNY is restricted to nationals, thereby controlling capital inflows into the mainland.

2.2 Capital controls and restrictions on exchanging CNY and CNH

Two Chinese agents with RMB deposits onshore and offshore can pay each other in either CNY or CNH, and may contract to exchange the two currencies at a market exchange rate, which we denote E.[21] But to spend abroad, an agent holding only CNY must convert it. These limits on conversion act as controls on outflows. Official CNY–CNH conversion is one-for-one but subject to strict limits.

For investment purposes, inflows into CNY and outflows into CNH are subject to quotas.[22] Similar restrictions apply to firms seeking to import or export capital.

For trade purposes, Chinese exporting firms can convert CNH revenues into CNY only against invoices backing their foreign sales (and analogously for CNY-to-CNH conversions for imports). These trade-related conversions generate the largest flows between the currencies. Firms can choose when to convert, building up stocks of invoices and CNH deposits, and earning CNH interest rates. They can convert when it is profitable to do so, effectively arbitraging differences between CNY and CNH returns.[23]

Chinese banks operating offshore are the other major arbitrageurs. They can borrow and lend in both currencies and issue deposits in either. However, policy restricts which institutions may engage in cross-border interbank transactions and caps the volume of these flows. This segmentation of the interbank market limits arbitrage and reduces banks' ability to use CNY for CNH settlement and vice versa.

Finally, households face annual limits on transferring funds offshore and on bringing CNH onshore. Large cross-border movements of RMB cash are prohibited.

Taken together, these measures allow the authorities to control capital flows in and out of mainland China, since most of them ultimately involve exchanging CNY for CNH. But at the same time, whenever the CNY-CNH exchange rate deviates from parity, or expected returns differ, opportunities for arbitrage arise for various agents.

[21] Appendix B lists all data sources and variable definitions.

[22] Inflows are managed under the Renminbi Qualified Foreign Institutional Investor program; outflows under the Qualified Domestic Institutional Investor program.

[23] Hu and Yuan (2021) and Liu, Sheng and Wang (2022) show that firms exploit arbitrage opportunities arising from differences in CNY and CNH exchange and interest rates.

2.3 The peg and the tension in the system

The limits on convertibility constrain arbitrage and allow E to deviate from parity. However, if these deviations were large, so too would be the profits from evading capital controls. Chinese firms and households would make payments with the cheaper currency and hoard deposits in the more valuable one. Eventually, either the capital controls would fail, or one of the currencies would disappear from circulation. There is a dual tension embedded in the system: on the peg and on the capital controls.

Even if CNH monetary policy cannot perfectly keep $E = 1$, it will strive to keep next period's exchange rate E' close to parity. Figure 1 already showed its success over more than a decade: the daily standard deviation of the log of the CNY-CNH exchange rate was a mere 0.32% and exceeded 1% on just a handful of days. At the same time, the transaction costs on the triangular arbitrage trade of converting CNY to CNH via USD averaged about 0.04% over the sample. That deviations from parity routinely exceed this amount indicates that capital controls bind.

The tension in the system led to a structural break in the management of the peg in 2015–17. In August 2015, a reform in how the PBoC manages CNY-USD exchange rate triggered a new framework for managing the CNH market that was set up in 2016–17. These reforms were successful in sustaining the peg (see appendix Figure C.4). The standard deviation of the daily CNY-CNH exchange rate fell by half and the half-life of deviations from parity fell from 6 days to 1 day.[24] Similarly, the velocity of CNH money, which had been on a sharp upward trend since 2010, stabilized following the reforms, suggesting a more stable monetary regime.[25] Because of this break, from this point on we discuss the post-2017 system, and empirical tests use a sample from 1 April 2017 to 31 August 2023. Section 6 discusses and analyzes events in the 2015–17 period.[26]

2.4 The supply of offshore money

Since the CNY–CNH peg is not a regulatory requirement, maintaining it at parity requires deliberate policy actions. This is achieved by controlling the money supply, which is done by three official institutions. Their balance sheets are illustrated in Table 1, together with

[24] Appendix figure C.5 explores intraday data and shows that deviations from parity do persist throughout the trading day, justifying a focus on daily frequency.

[25] We define velocity as the ratio of annual CNH transactions in Hong Kong to the average stock of CNH deposits, it averaged 431 between 2018 and 2022. For comparison, velocity in the United States—defined as the annual ratio of Fedwire transactions to M1 less currency—averaged 450 between 2012 and 2019.

[26] For descriptions of the pre-reform and reform periods, see Funke et al. (2015), McCauley and Shu (2018).

Table 1: CNH Monetary Policy Implementation

People's Bank of China

Assets	Liabilities
(a) CNY Assets	(c) CNY Onshore Reserves
(b) FX Assets	(d) CNY Clearing Bank Reserves
	(e) CNH Bills
	(f) Equity, Others

Offshore Clearing Banks

Assets	Liabilities
(g) CNY Clearing Bank Reserves	(i) CNH Commercial Bank Sight Deposits
(h) Other Assets	(j) CNH HKMA Deposits
	(k) CNY Equity, Others

Hong Kong Monetary Authority CNH

Assets	Liabilities
(l) Deposits at Clearing Banks	(p) Equity, Others
(m) PLP Balances	
(n) Liquidity Facilities	
(o) Other Assets	

Hong Kong Commercial Banks CNH

Assets	Liabilities
(q) Deposits at Clearing Banks	(t) Deposits
(r) PBoC CNH Bills	(u) PLP Balances
(s) Loans, Others	(v) HKMA Facilities
	(w) Equity, Others

that for private banks. While there is a curious division of responsibilities between the three, they control the money supply by conventional means.

The first peculiarity is that the CNH reserves—the settlement asset in the offshore financial system—are not issued directly by the PBoC. Instead, they are issued by an offshore clearing bank in Hong Kong (with other clearing banks operating elsewhere). These clearing banks are formally private entities, but all are subsidiaries of large state-owned Chinese banks, and their activities are closely monitored by the PBoC. These CNH reserves, line (i) in the table, are backed one-for-one by CNY reserves that the clearing bank holds at the PBoC, line (d). They are sight deposits issued to commercial banks in Hong Kong and therefore appear as an asset on those banks' balance sheets, line (q). Settlement of offshore transactions occurs when banks exchange CNH sight deposits at the clearing bank. This is exactly as in a conventional payment system. Likewise, when a firm or household converts CNH into CNY to make an onshore payment, lines (q) and (t) fall at their commercial bank and lines (g) and (i) fall at the clearing bank, while line (d) falls and line (c) rises at the PBoC.[27]

The second peculiarity is that the PBoC has CNH-denominated liabilities in the form of bills that it issues offshore, line (e) on its balance sheet. The stock of bills gives the PBoC a tool to control the CNH money supply. Redeeming a bill involves the PBoC paying the clearing bank in CNY, a rise in lines (d) and (g) and fall in (e). The clearing bank then

[27]Banks domiciled in China can also access Cross-border Interbank Payment System (CIPS) settlement accounts to make cross-border payments for approved purposes or to act as agents for foreign banks. CIPS reserves are distinct from PBoC reserves, are remunerated differently, and are subject to separate liquidity policies. Hence, CIPS operates as an alternative offshore clearing bank, though with transaction volumes an order of magnitude smaller than CNH flows.

pays the bank of the holder of the bill in CNH, a rise in lines (i) and (q). If the bill is held directly by a bank then line (r) will fall; if the bill is held by a non-bank then line (t) rises. Since CNH reserves, the settlement asset, are more liquid than bills, redemption expands liquidity and can stimulate further private CNH money creation (an additional rise in lines (s) and (t)). The bills are short-term, with maturities of 3, 6 and 12 months and the PBoC issues them at roughly a monthly frequency at a predetermined schedule to maintain a target stock.

The third peculiarity is that a separate institution operates the higher-frequency fine-tuning of the money supply and the provision of lender of last resort financing. This is the HKMA, which holds a CNH balance at the clearing bank, lines (l) and (j), and operates two programs that supply CNH on demand to banks offshore.[28]

The first program is a repurchase facility with up to ¥18bn available to nine designated primary liquidity providers (PLPs), which are responsible for channeling liquidity to the CNH interbank and financial markets. A PLP borrowing from the HKMA increases CNH reserves immediately: the HKMA's deposits at the clearing bank fall (line (j)) and its PLP balances rise (line (m)), and the borrowing bank's balance sheet expands (lines (i), (q) and (u)). The second liquidity source consists of an intraday and an overnight repo facility, available on demand to all banks operating in Hong Kong that are willing to pay a penalty spread over the interbank rate. Borrowing from these facilities produces similar balance-sheet movements to the PLP facility. Unlike a typical discount window, these facilities are used heavily—daily and by several banks—and far more than the HKMA's Hong Kong dollar discount window, which was used only 11 times in 2021.[29]

Combined, the three institutions fulfill all the major functions of a monetary authority. The clearing bank settles payments; the HKMA handles high-frequency adjustments in the money supply and acts as CNH lender of last resort; and the PBoC manages the money supply at a lower frequency and is the ultimate issuer of the liabilities backing CNH reserves.[30]

[28]The table omits the permanent swap line between the HKMA and the PBoC. If demand for the HKMA's facilities exceeds its CNH balances at the clearing bank, it can obtain CNH through the swap line to prevent a liquidity shortage. As of July 2022, the swap-line limit was ¥800 bn—about equal to the total stock of CNH deposits in Hong Kong. The HKMA also maintains CNH-liquidity programs operating on longer settlement cycles than the PLP and intraday/overnight repo facilities; these are funded via the swap line and appear, anecdotally, to be used infrequently.

[29]Because intraday funds can be rolled seamlessly into an overnight position, banks prefer the intraday facility, which embeds the option to repay early. As a result, the intraday facility is heavily used each day, while the overnight facility typically has balances close to zero (see appendix figure B.1).

[30]More subtle is which institution bears what risks. Most of the FX mismatch between CNH and CNY

How large is the CNH money supply that these three institutions manage? Between January 2018 and August 2023, the average stock of CNH deposits in Hong Kong banks was ¥730bn. We do not observe CNH reserves directly, but we know that banks' deposits at the clearing bank averaged ¥311 bn, of which ¥80 bn were absorbed by the outstanding stock of PBoC bills, and that the HKMA balance was around ¥35bn.[31] This implies that banks held roughly ¥196bn in CNH reserves, corresponding to a money multiplier of about 3.7. For comparison, the ratio of M1 (excluding currency) to reserves in the United States averaged 13.3 during 2004–06, when reserves were scarce, and 1.6 during 2021–23, when reserves were ample.

Finally, note that monetary policy in CNH does not involve setting interest rates. The interest rate on CNH clearing-bank deposits is zero, while the rates on PLP balances and liquidity-facility borrowing are endogenous, indexed to interbank market conditions. Because the supply of CNH money is scarce, these interbank rates lie well above zero.

2.5 Offshore liquidity policies

To keep an exchange rate at parity, a central bank must control the scarcity of its currency. It can do so by adjusting the supply of money and/or by using tools that influence the demand for liquidity, from reserve requirements to restrictions on interbank flows.

Demand for liquidity is shaped by financial regulation. The PBoC regulates banks onshore and the clearing bank, while the HKMA regulates banks in Hong Kong. Both authorities have the option to impose minimum reserve balance requirements on banks. The PBoC does so onshore, but this has little direct effect on offshore money demand, though relative liquidity conditions still matter for the exchange rate (see appendix D.2). The HKMA has not imposed CNH-specific reserve requirements, but the standard Basel III liquidity coverage ratio applies in Hong Kong. More importantly, the HKMA sets the interest rate on the CNH discount window. Currently, it is priced as 25 basis points above the three-day average of the overnight CNH interbank rate, so the cost to banks of covering CNH shortfalls rises precisely when liquidity is already scarce.

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sits on the clearing bank's balance sheet, not the PBoC's. Capital gains or losses from movements in the CNY–CNH exchange rate have been negligible so far, but if the peg were ever abandoned, the resulting gain or loss would fall on the clearing bank. Likewise, the credit risk associated with banks borrowing CNH lies with the HKMA rather than the PBoC. However, as all three institutions are, in essence, arms of the Chinese state, this distribution of risk is unlikely to matter outside a fiscal crisis and does not affect their joint control of the money supply.

[31] The HKMA's nine PLPs have a cap of ¥2bn each, while the two repo facilities have a cap of ¥10bn each, and the average amount outstanding in the PLPs was ¥3bn, giving: $2 \times 9 + 10 \times 2 - 3 = 35$bn. See appendix figure B.1 for daily usage.

The PBoC's regulation of the clearing bank places limits on the total flow of deposits and reserves between the onshore and offshore banking system. Policy can delay the authorization of payment flows, raising the risk of liquidity shortfalls offshore. These are heavy-handed tools, since these flows vary widely depending on households' and firms' liquidity needs. The clearing bank is also unique in that it is the only institution able to borrow and lend in both interbank markets simultaneously and arbitrage differences in interbank rates. The PBoC controls these cross-market flows as well, which likewise segments the interbank market and induces rates to vary widely between jurisdictions.

Finally, and anecdotally, Chinese state banks buy and sell CNH at the authorities encouragement. Effectively, these operations function as FX interventions, similar to targeted injections of CNH reserves to buy CNY government bonds.

2.6 Onshore monetary policy

Mainland monetary policy is set entirely by the PBoC. It involves traditional channels, setting interest rates and controlling the supply of money, with a focus on mainland variables and domestic goals. The CNY money supply is much larger than CNH's: roughly 200 times larger on average over 2018–23.[32] There is no evidence that, in our sample, the PBoC has changed onshore monetary policy in response to fluctuations in the CNY-CNH exchange rate. CNH monetary policy is set to manage conditions offshore precisely so that CNY monetary policy can ignore E almost entirely. Regressing each money stock on the CNY-CNH exchange rate reveals only a quantitatively and statistically significant correlation between E and CNH money, but not CNY money (appendix table C.1).

The PBoC actively manages the CNY-USD exchange rate: $E^{\$}$. It does so by setting a "central parity rate" each morning, $\bar{E}^{\$}$, and then intervening to prevent the deviation $\log(E^{\$}/\bar{E}^{\$})$ from exceeding 2% in absolute value. This is a managed float that prevents large daily appreciations or depreciations. Jermann, Wei and Yue (2022) describe how the parity rate is set; importantly, for our purposes, the CNY-CNH exchange rate does not appear in their discussion, supporting an exclusion restriction that E does not enter the decision rule for $\bar{E}^{\$}$, and so the latter can be used as an instrument for the former.

Over our sample, the central parity rate mostly adjusted to match the previous market rate and the trading band rarely bound. At times, however—such as during periods of rapid CNY depreciation—the PBoC did not adjust the parity rate quickly enough, intentionally slowing the pace of depreciation. When this happens, the CNY–USD rate hits

[32] Back to Table 1, line (c) is much larger than the sum of lines (i) and (j).

the bottom of the band, and further depreciation pressure remains unfulfilled. Anticipating further depreciation, market participants sell CNH, as no trading band constrains the offshore market. As a result, the CNH trades below parity.[33]

Finally, and for completeness, the medium of exchange for transactions in Hong Kong is a separate currency, the Hong Kong dollar. The HKMA manages it independently of CNH, with a separate balance sheet, and a separate set of policies. The HKD is not subject to capital controls and is pegged to the USD via a currency board backed by the HKMA's substantial foreign exchange reserves, which are distinct from China's. The HKD plays little role in understanding the CNY-CNH-USD setting.

2.7 Bottom line

China's monetary system combines two parallel currencies, the onshore CNY and the offshore CNH, whose exchange rate E can deviate from parity because of restrictions on exchanging one for the other that control capital flows in and out of the mainland. The tension in the system is that these expected deviations E' cannot be large without one currency disappearing from circulation or the capital controls failing. Offshore monetary policy therefore controls the money supply and deploys liquidity policies to keep E close to parity, while onshore monetary policy devotes itself to domestic goals, including active management of the exchange rate with the USD. The two monetary policies are interconnected, since ultimately both moneys are claims on China, and so alter its external position. Importantly, by segmenting the offshore market, the authorities have an additional margin for external management, either by allowing temporary deviations from parity or by engineering onshore-offshore interest differentials. The model in the next section formalizes this reasoning and analyzes the joint management of an offshore exchange rate and a country's external balance.

3 A model of capital controls with offshore money

We start with a canonical intertemporal model of the current account in which the government manipulates the country's external position using a tax on capital flows. Then, we

[33] The 2% band dates from March 2014, when it was widened from a 1% band set in April 2012. Prior to August 2015, the parity rate was nearly constant, but since then it has incorporated a countercyclical factor and a reference basket of currencies beyond the USD. After our sample ends in August 2023, the rule for setting the central parity rate reverted to a more stable configuration in which the parity rate no longer tracks the previous market close. As a consequence, the CNY–USD rate can deviate from the parity rate for extended periods and the trading band binds more often. This change has not altered the time-series behavior of the CNH–CNY rate but has altered its relationship with the central parity rate.

introduce in the same model a different policy arrangement: capital controls and parallel currencies. Mimicking the Chinese system, domestic private agents cannot invest abroad, foreigners cannot invest in domestic assets, but both can hold offshore deposits issued by banks. The main result of the section is that by changing monetary and liquidity policies offshore, the government can mimic the outcomes achieved by the tax on capital flows.

3.1 Managing the external position with taxes on capital flows

Environment: We consider a two-period endowment economy populated by a representative household that has perfect foresight.

Domestic household: She chooses the consumption of nontradable (c_{NT}) and tradable goods (c_T) today and in the future (c'_{NT}, c'_T) to maximize

$$u(c_{NT}, c_T) + \beta u(c'_{NT}, c'_T)\,, \tag{1}$$

where the function $u(.)$ is strictly increasing and concave in both arguments and $\beta \in (0,1)$ is a discount factor. The household has endowments of the two goods: $\{y_{NT}, y_T\}$ and $\{y'_{NT}, y'_T\}$. She saves b^h in domestic assets, returning R in nontradables, and $b^\$$ in foreign assets, returning $R^\$$ in tradables. The exchange rate $E^\$$ is the price of the tradable good in units of the nontradable, which we take as the numeraire. The budget constraints are

$$\begin{aligned} b^h + E^\$ b^\$ + E^\$ c_T + c_{NT} &= E^\$ y_T + y_{NT} \\ E^{\$\prime} c'_T + c'_{NT} &= E^{\$\prime} y'_T + y'_{NT} + R b^h + (1+\tau) R^\$ E^{\$\prime} b^\$ - T'\,. \end{aligned} \tag{2}$$

Households receive a subsidy τ for saving abroad (and pay a lump-sum tax T'). For concreteness, we consider the case $\tau > 0$, so the policymaker incentivizes agents to consume less and export the tradable output to generate an external surplus in the first period. The reverse intuition would apply to a tax and a deficit.

Foreigners: Foreign investors have deep pockets and can invest in both foreign and domestic assets. Their preferences pin down the return $R^\$$ exogenously. Foreigners pay an equivalent tax linked to τ when investing domestically.

Net foreign assets: The net foreign asset position $B^\$$ of the country is: $E^\$ B^\$ = E^\$ b^\$ + b^h$. Note that gross investment positions ($b^\$$, b^h) are not pinned down in equilibrium, but only the net foreign assets.

Market clearing: The consumption of nontradables equals their endowment, and the household's and investors' purchases of domestic assets sum to zero. The government balances its budget by financing the external subsidy with a lump-sum tax on households: $T' = \tau R^{\$} E^{\$\prime} B^{\$}$.

Equilibrium: An equilibrium arises when households maximize (1) subject to the constraints in (2) taking as given the subsidy τ and the foreign returns $R^{\$}$, and markets for goods and assets clear. To derive the equilibrium, we adopt three simplifications, which do not affect the model's logic but simplify the algebra. First, we assume log utility: $u(c_{NT}, c_T) = \ln(c_{NT}) + \iota \ln(c_T)$, with $\iota > 0$, which implies a first-period current account of $E^{\$} y_T - \iota$. Second, we set $y_{NT} = y'_{NT} = 1$, implying a constant equilibrium return on domestic assets: $R = \beta^{-1}$. Third, we assume that $(1+\tau)\beta y_T > y'_T / R^{\$}$ so that the country has positive net foreign assets $B^{\$} > 0$; we discuss deficit countries in Section 7.

Equilibrium conditions: There are three equilibrium conditions to solve for the exchange rates in both periods and the external position of the economy: $E^{\$}, E^{\$\prime}, B^{\$}$. The first follows from the optimal savings behavior of households abroad or, equivalently, from the absence of arbitrage opportunities for foreigners

$$R = \frac{(1+\tau) R^{\$} E^{\$\prime}}{E^{\$}} . \tag{3}$$

This is an interest parity condition equating the two returns in common units. The subsidy creates a wedge, favoring foreign over domestic assets.[34]

The second and third conditions are the balance-of-payments conditions equating the current account balance (on the left-hand side) to the net foreign asset position (on the right-hand side) in each period

$$E^{\$} y_T - \iota = E^{\$} B^{\$} \quad \text{and} \qquad E^{\$\prime} y'_T - \iota + R^{\$} E^{\$\prime} B^{\$} = 0 . \tag{4}$$

Capital taxes as policy: Combining these three conditions gives the equilibrium value of the exchange rate

$$E^{\$} = \frac{1 + \beta(1+\tau)}{1 + R^{\$-1} \frac{y'_T}{y_T}} \frac{\iota}{y_T} . \tag{5}$$

[34] The interest parity condition may include a further wedge reflecting financial frictions or risk-aversion as in Itskhoki and Mukhin (2021), Maggiori (2022). Such features do not alter the intuition behind the model so for simplicity we abstract from them.

A higher τ raises the wedge between the two returns in equation (3). Households consume less, save more abroad, and the current account surplus rises. As they buy more foreign assets, the value of the foreign currency rises. Therefore, $E^{\$}$ increases with τ.

By controlling the tax on capital flows τ, policy can manage its current account or, equivalently, its exchange rate. In this economy, it is sub-optimal to do so, although many elaborations of this canonical model feature externalities and financial frictions that make a non-zero τ desirable (Bianchi and Lorenzoni, 2022).

3.2 An alternative: capital controls and parallel currencies

Reflecting the Chinese context, we now introduce capital controls and a parallel currency issued by an offshore banking sector, while dropping the tax on capital flows.

Domestic household: The capital controls forbid the household from investing abroad: $b^{\$} = 0$. However, the household can now freely accumulate offshore deposits d^h in units of offshore currency. The offshore money is useful to make and receive payments abroad associated with trading the tradable good, and we capture this simply by including deposits in the utility function, with μ a preference parameter governing money demand. The price of a unit of offshore money in terms of the nontradable good is E and R^d is the return on the offshore deposits (in offshore units). The problem changes to

$$\begin{aligned} &\max \quad u(c_{NT}, c_T) + \mu \ln(d^h) + \beta u(c'_{NT}, c'_T) \quad \text{s.t.} \\ &E^{\$} c_T + c_{NT} + b^h + E d^h = E^{\$} y_T + y_{NT}, \\ &E^{\$\prime} c'_T + c'_{NT} = E^{\$\prime} y'_T + y'_{NT} + R b^h + R^d E' d^h - T'. \end{aligned} \tag{6}$$

Household money demand: Optimal savings behavior still implies $R = \beta^{-1}$. Demand for offshore deposits balances their liquidity value against their relative return:

$$d^h = \mu \left(E - \frac{E' R^d}{R} \right)^{-1}. \tag{7}$$

This demand function for money (deposits) has an interest semi-elasticity of $\varepsilon_d = R^d E' d^h / \mu E$.

Foreign investors: Capital controls on foreigners prevent them from investing in domestic assets. Like households, they can freely hold offshore deposits in an amount d^f. The absence of arbitrage is now between foreign assets and offshore deposits. Their returns are equated once they are converted into the same units:

$$\frac{R^d E'}{E} = \frac{R^{\$} E^{\$\prime}}{E^{\$}}\,. \tag{8}$$

Offshore banks: A continuum of competitive offshore banks choose how many deposits (d) to offer to domestic and foreign investors, and use these funds to invest in onshore assets (b^l) and offshore reserves (m), the latter returning R^m.[35] Like households, they also face capital controls and cannot invest abroad. Their problem is

$$\max\; Rb^l + E'\left(R^m m - R^d d\right) \quad \text{s.t.} \quad b^l + Em + E\phi(m/d,\lambda)d = Ed\,. \tag{9}$$

Liquidity costs: Banks incur a liquidity cost, $\phi(m/d,\lambda)$, per deposit reflecting the mismatch between liquid deposits and illiquid domestic assets. Within the period, there are random withdrawals of deposits that a bank must honor using reserves. If reserves are insufficient, the bank must borrow them at a cost from either other banks or the offshore discount window.

Section 6 explicitly microfounds $\phi(.)$ and shows that it has the four properties that, for now, we impose by assumption. First, it depends on the bank's reserve-deposit ratio m/d as well as on liquidity policies, λ. We treat λ as a policy tool. Second, $\phi(.)$ is non-negative, it reaches zero when the bank is narrow, $\phi(1,\lambda) = 0$, and when reserves go to zero, it is bounded, so that the bank will operate and issue deposits $\lim_{m/d\to 0}\phi(m/d,\lambda) \equiv \phi_0 < 1$. Third, $\phi(.)$ is decreasing in the reserve-deposit ratio, as the cost is lower when the bank's assets are more liquid relative to its liabilities. The marginal benefit $-\phi'(.) \equiv -\partial\phi(.)/\partial(m/d)$ is non-negative, reaches its minimum of zero when the bank is narrow, $-\phi'(1,\lambda) = 0$, and is bounded above by 1 so that reserve demand is finite. Fourth, there are diminishing marginal benefits to more reserves: $\phi''(.) \equiv \partial^2\phi(.)/\partial(m/d)^2 \geq 0$.

Banks' reserve demand: At an optimum, banks choose their reserves to satisfy the optimality condition

$$\left(\frac{E'}{E}\right) R^m - R\phi'(m/d,\lambda) = R\,. \tag{10}$$

The left-hand side is the marginal benefit of an offshore reserve, including both its return and the marginal reduction in liquidity costs. The right-hand side is the marginal

[35] In the appendix we consider an extension where the bank can also take deposits and hold reserves onshore. We abstract from the market power of banks or from financial repression suppressing deposit rates, so R^d clears a competitive market.

cost in foregoing investing in the onshore assets. Inverting this condition yields a demand function for reserves and a corresponding interest semi-elasticity of reserve demand: $\varepsilon_m = E'd/(REm\phi''(m/d,\lambda))$.

Banks' deposit demand: The zero-profit condition from perfect competition between banks gives

$$\left(\frac{E}{E'}\right) R^d + R\psi(m/d,\lambda) = R\,. \tag{11}$$

where $\psi(x,\lambda) \equiv \phi(x,\lambda) - x\phi'(x,\lambda)$ is the liquidity cost of issuing a deposit in equilibrium. It adds to the interest paid on that deposit on the left-hand side, which must equal the return on investing that deposit in onshore assets on the right-hand side.

The government: In the first period, the government issues reserves ($M > 0$) and borrows in the domestic financial market (B^g). It is also the only domestic institution that can invest abroad, an amount $B^\$ < y_T$. As in the Chinese context, and in most real-world cases of capital controls, private agents can invest abroad up to tight quantity limits, but the government remains the marginal investor, which is the relevant feature of our model. Finally, the government receives the liquidity costs because, in the micro-foundation, it earns these revenues by operating the discount window. The government's budget constraint is

$$E^\$ B^\$ = B^g + EM + E\phi(M/D,\lambda)D\,, \tag{12}$$

where D denotes aggregate deposits. In the second period, the government earns the returns on its assets and liabilities and taxes (or rebates) the net amount to the representative household

$$T' = RB^g + R^m E'M - R^\$ E^{\$'} B^\$\,. \tag{13}$$

Policy: The government sets monetary and liquidity policies (M,λ), together with the desired assets held abroad $B^\$$. Finally, the government credibly commits to delivering $E' = 1$. This is the constraint posed by Gresham's law. The onshore-offshore exchange rate can deviate from parity temporarily but not persistently. Otherwise, the private sector would find a way to violate the capital controls. Appendix D.1 relaxes this assumption and allows for partial credibility. This weakens—but does not overturn—the ability of monetary policy to influence the offshore money market.

Net foreign assets: The net external position of the economy is endogenous, given by $E^\$ B^\$ - Ed^f (= E^\$ y_T - \iota)$. If the government increases its foreign assets, returns will adjust, attracting or repelling foreign investors to the offshore market until markets clear.

Market clearing: Using capital letters to denote equilibrium values (or government choices), in the reserves market, $M = m$, while in the money market: $D = d = d^h + d^f$. In the domestic financial market, $B^g = b^h + b^l$, and in the market for nontradable goods: $c_{NT} = c'_{NT} = 1$.

3.3 Equilibrium with capital controls and parallel currencies

A key variable in the model is the aggregate reserve-deposit ratio. We denote it by $x \equiv M/D$, and it lies within $[0,1]$. An equilibrium consists of $\left(x, E, E^{\$}\right)$ solving the following three conditions.

The first combines reserve market clearing $(M = m)$, banks' reserve demand in equation (10) and the credible peg, to obtain a condition equilibrating the demand for reserves given the offshore exchange rate

$$\beta R^m E^{-1} = 1 + \phi'(x, \lambda)\,. \tag{14}$$

The second condition uses deposit market clearing, household and bank optimality conditions on deposits (equations (7) and (11)), the credible peg, and the balance-of-payments conditions from combining the budget constraints of households, banks, and government[36] to obtain

$$\frac{\mu}{E\psi(x,\lambda)} = \frac{M}{x} - \frac{1}{E}\left[E^{\$}(B^{\$} - y_T) + \iota\right]\,. \tag{15}$$

We assume that $B^{\$}$ is set by the government sufficiently large so that there are some offshore deposits held by foreigners: $Ed^f = E^{\$}(B^{\$} - y_T) + \iota \geq 0$.

The third condition combines the interest parity condition (8) and the balance-of-payment conditions to arrive at

$$E^{\$} = \frac{1 + \beta\left(1 - \psi(x,\lambda)\right)^{-1}}{1 + R^{\$-1}\frac{y'_T}{y_T}}\frac{\iota}{y_T}. \tag{16}$$

Finally, recall that $R^m, \mu, y_T, \iota, \beta$ are exogenous variables, while $M, \lambda, B^{\$}$ are exogenous policy variables.[37]

[36] The balance-of-payments conditions are: $E^{\$}y_T - \iota = E^{\$}B^{\$} - Ed^f$ and $E^{\$'}y'_T - \iota = R^d d^f - E^{\$'}R^{\$}B^{\$}$.

[37] For completeness, the solution for the other variables in the model is: $D = M/x$, $R^d = \beta^{-1}E(1-\psi(.))$, $d^h = D - d^f = D - E^{-1}\left(E^{\$}(B^{\$} - y_T) + \iota\right)$, $E^{\$'} = (R^d d^f + \iota)/(y'_T + R^{\$}B^{\$})$, $E^{\$}c_T = \iota$, $E^{\$'}c'_T = \iota$, $R = \beta^{-1}$.

3.4 An equivalence result

The appendix proves the following result:

Proposition 1. *There is a unique equilibrium $x, E, E^{\$}$ solving equations* (14)-(16) *for any policy tuple $(M, \lambda, B^{\$})$. Holding $(\lambda, B^{\$})$ fixed, for any equilibrium exchange rate $E^{\$}$ in the model with a tax on capital flows that solves* (5) *with a tax wedge $\tau \in [0, \phi_0/(1-\phi_0))$, there exists a policy choice $M > 0$ that achieves the same equilibrium $E^{\$}$ in the model with capital controls and parallel currencies.*

Scarce offshore liquidity creates a wedge between household returns from investing domestically and in offshore deposits. Likewise, it adds a wedge that lowers the return earned by foreigners on offshore deposits relative to R. Together, these wedges pin down the onshore-offshore exchange rate. In turn, this affects the desirability of saving abroad, which determines the current account and the foreign exchange rate.

Comparing (5) and (16) shows that they differ only in one term: with capital controls and parallel currencies, the term is $(1-\psi(.))^{-1}$, whereas with a capital flow tax, it is $1+\tau$. Allowing the onshore-offshore exchange rate to deviate from parity gives policy the room to choose M to target a wedge τ. In turn, the second instrument λ can keep the parity peg credible for the future. To target both $E = 1$ and a given value of $E^{\$}$ simultaneously requires at least two instruments. In Section 5, we show in the Chinese data that multiple policies are indeed used in the offshore market.

This is only possible if policy keeps offshore reserves scarce. If there are no more liquidity benefits to reserves ($\phi'(1,\lambda) = \psi(1,\lambda) = 0$), money becomes a pure financial asset and banks' reserve demand is horizontal ($\varepsilon_m \to \infty$). The supply of money becomes irrelevant for either of the equilibrium exchange rates.[38] Equation (14) becomes $RE = R^m$, so the offshore exchange rate is solely a function of the gap between two exogenous interest rates. The wedge τ would be nil.

The wedge τ is also bounded above and below. Its upper bound stems from the bound on the cost of liquidity not being able to exceed the cost of emergency liquidity support: recall, $\phi_0 \equiv \lim_{m/d\to 0} \phi(m/d, \lambda) < 1$. Insofar as the parameter ϕ_0 may be arbitrarily close to 1, then this upper bound will be slack. The lower bound is zero because the liquidity cost depresses the return of holding offshore money, and while policy can reduce this cost, it cannot flip its sign. This is adequate for our application, since we focus on a country

[38] This is often referred to as the cashless limit and has justified an ample-reserves system where central banks use the size of their balance sheet and the interest they pay on reserves as independent policy tools.

wishing to raise its external surplus. If a country instead wishes to reduce its external surplus or to prevent capital flight, this would require a negative τ. We extend the model to allow for a negative wedge in Section 7.

3.5 What is next

This section has shown that a wedge in the interest parity condition can be achieved either by a tax/subsidy on capital flows or by imposing capital controls and creating parallel currencies. In the data, we rarely observe either of them, with Brazil in 2009-13 being a rare example of the former, and China in the last decade an example of the latter. Sections 4-6 further investigate the scarce-liquidity approach by testing for its mechanisms in the Chinese data, before Section 7 discusses the merits of this approach relative to those of the tax/subsidy.

4 Money and the exchange rate

The model's features match the application to China's offshore market. At its heart, it is a monetary model, where controlling the quantity of M helps determine the exchange rate E and the country's external balance. This section fleshes out the causal link between M and E, explains why the CNY-CNH-USD setup is an ideal laboratory to test it, and uses data to do so. These estimates allow us to ask how scarce liquidity needs to be for the system to function.

4.1 The impact of an increase in the money supply on the exchange rate

The impact of an increase in the supply of money on the exchange rate depends on the elasticity of money demand. In our model, there are three relevant elasticities: banks' demand for offshore reserves (ε_m), domestic households' demand for offshore deposits (ε_d) and foreigners' demand for offshore deposits. Because we assumed that this last elasticity was infinity (equation (8)), to obtain quantitative results, we consider an offshore monetary expansion (M rises) where policy sterilizes the resulting capital inflows ($B^\$$ falls) so that foreign deposits stay the same (d^f constant). This renders the infinite elasticity of foreign demand irrelevant. Denoting the ratio of domestic to total offshore deposits by $\delta \equiv d^h/D$, Appendix A.2 proves the following result:

Proposition 2. *Following an increase in the supply of offshore reserves M:*

a) The offshore currency depreciates in value relative to the onshore currency, E falls.

b) If the monetary expansion is sterilized: $(d\log(E)/d\log(M))^{-1} = -\left[\delta + R^m(\varepsilon_m + \delta x \varepsilon_d)\right]$.

A monetary injection of offshore reserves leads to an increase in the equilibrium reserve-deposit ratio. As the banks' demand for liquidity is partially satisfied, the liquidity premium on reserves is lower. Then, the offshore exchange rate must be expected to appreciate for banks to keep holding reserves, which, under a credible peg, implies that the current offshore exchange rate must first depreciate. The magnitude of the movement depends on the two elasticities as described above.

4.2 CNY-CNH as a laboratory to test monetarist predictions

The proposition that increasing the money supply of a currency lowers its relative value is at the heart of monetarism. Yet this proposition is notoriously hard to test.[39] The CNY–CNH market, however, provides an unusually clean laboratory that sidesteps several challenges.

A first challenge is that most central banks conduct monetary policy through interest rates, R^m, with M adjusting to accommodate changes in money demand. In contrast, CNH policy varies the quantity of reserves and sets $R^m = 1$.

Second, even when central banks implement a quantity-based system, M is chosen endogenously in response to multiple shocks and to reflect changes in information and expectations about macroeconomic outcomes. Offshore CNH monetary policy instead is targeted mainly at offshore financial conditions, with onshore policy left to stabilize China's overall macroeconomic environment.

Third, an exchange rate is a relative price, so financial and macroeconomic conditions, as well as policy, in the other jurisdiction also react to and affect E. However, in the context of CNH, the other jurisdiction is mainland China, and onshore CNY monetary variables are chosen in response to onshore variables, as we explained in Section 2. Moreover, recall that CNH and CNY are designed to intermediate transactions in Chinese goods and services. Therefore, there are relatively few non-monetary movements in the real onshore-offshore exchange rate.

Still, M is not randomly assigned. But the unique setting controls for many confounds, making it possible to identify exogenous variation in M, as we describe next.

[39]For surveys of the empirical literature see Boughton (1988), Rogoff (1999).

4.3 Exogenous shocks to CNH money supply

The PBoC started issuing CNH bills in November 2018 on a schedule designed to converge to a stock of ¥50bn outstanding, with ¥40bn of 3-month bills and ¥10bn of 12-month bills. However, in the summer of 2019, the PBoC altered the bill issuance schedule to increase the stock to ¥80bn, with ¥20bn of 3- and 6-month bills, and ¥40bn of 12-month bills (alongside a single one-month bill issued in June 2019). On 6 November 2020, the PBoC announced it would further lengthen maturities by switching the composition to ¥10bn of 3- and 6-month bills and ¥60bn of 12-month bills while holding the stock fixed. By 2022 the stock converged to ¥80bn with any deviation closed within a very short window. The bill stock was expanded once again in August 2023 to reach ¥110bn by the end of the year. There were further expansions in 2024 after the end of our sample.

The two changes in the schedule of auctions in 2019 and 2020 were likely an endogenous policy response to the demand for CNH (as was, more evidently, the change in 2023). However, because they shifted the maturity structure, and since the auctions for different maturities are on different schedules, they created future dates when certain bills exogenously rolled off without being replaced for at least five working days. In addition, the issuance of a 6-month bill in June 2023 was a few days later than usual, which created an extra period where the bill stock was diminished.[40]

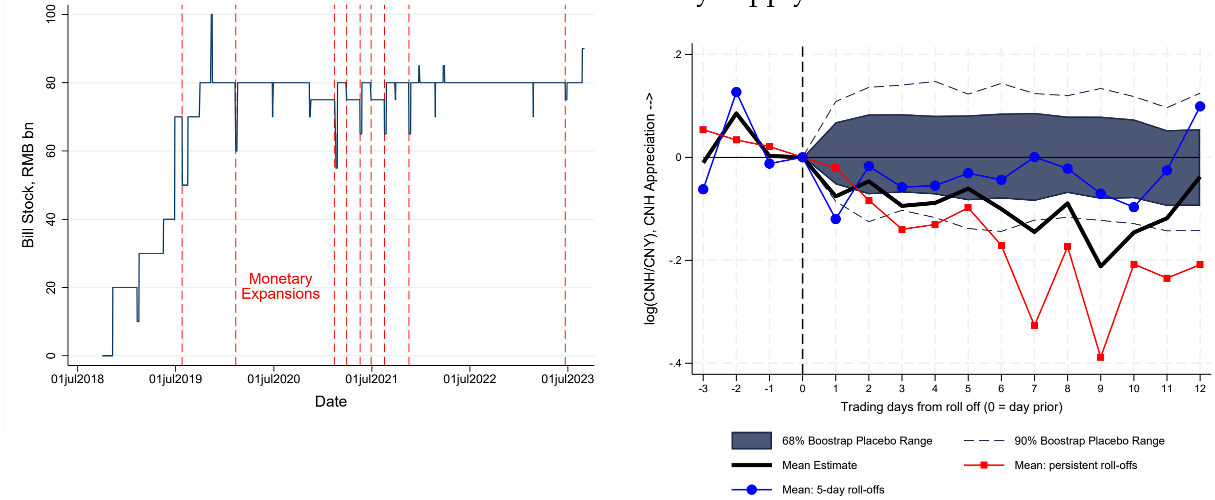
The left panel of Figure 2 plots the outstanding daily stock of bills. As a result of the variation in the schedule, at the nine dates indicated by the vertical lines, old bills rolled off without being immediately replaced by new issuances.[41] These events led to sharp declines in the stock of bills outstanding, averaging ¥11bn. Correspondingly, the CNH money supply expanded to redeem those bills at these dates. These monetary expansions were temporary. The previous supply of bills was re-established with the new issuance. In five of the roll-offs, the increase in money supply lasted 5 trading days, while in the other four the impact on money supply lasted on average for 25 trading days. Appendix Figure C.7(c) confirms that reserves were scarce: these expansions in money supply low-

[40] This last event was partly due to an operational constraint having to do with the days of weekends in June 2023. Our results are not sensitive to its inclusion.

[41] The dates are 26 July 2019, 10 February 2020, 15 February 2021, 29 March 2021, 18 May 2021, 28 June 2021, 17 August 2021, 16 November 2021, and 22 June 2023. This last event was due to an operational constraint arising from the timing of weekends in June 2023, which caused the issuance of a 6-month bill to be a few days later than usual; our results are not sensitive to the event's inclusion. We exclude the changes in the stock that arose immediately from the announcements on 20 June 2019, 8 August 2019 and 6 November 2020. We further exclude rolls-offs that were reverted within fewer than five trading days. Finally, we exclude periods when the stock of bills spiked due to a new bill being issued before an old bill matured.

Figure 2: Exogenous money supply shocks

(a) Money supply shocks through bill roll-offs **(b)** Response of the CNY-CNH exchange rate to money supply shocks



Note: Panel (a) shows the stock of PBoC bills outstanding and its short-lived fluctuations caused by the shift in maturity structure in June/August 2019 and in November 2020. Panel (b) shows 100 times the cumulative change in the log of the daily exchange rate from the trading day prior to the bill roll-off, averaged over the events, and bootstrapped placebo intervals from drawing 10,000 random samples of an equivalent number of event dates between 1 July 2020 and 1 November 2021, excluding dates that overlap with the original event window and schedule announcements.

ered the private opportunity cost of holding reserves measured by the CNH one-week interbank rate.

At a monthly frequency, these changes in money supply would barely be detectable, as they were reverted by the next auction. Theory suggests that they would have no effect on the exchange rate beyond a few weeks. Policymakers determined to keep the peg at parity would not see this as a problem and, as far as we know, made no adjustments to policy in response. But, at a daily frequency, these bill roll-offs provide exogenous variation in the supply of money.

4.4 A test of the causal effect of money on exchange rates

Panel (b) of Figure 2 shows the average response of the onshore-offshore exchange rate to these monetary expansions (the black line).[42] To assess statistical significance, the figure also shows a bootstrapped placebo distribution constructed by drawing nine non-overlapping events from other days in the sample. Finally, the blue and red lines show

[42]Figure C.7 in appendix C shows the response after each event.

the average split between the roll-offs that were reverted within five trading days and those that persisted longer, respectively (the size of the roll-offs is similar in both cases).[43]

Proposition 2a) predicts that E should fall, and the estimates confirm this prediction.[44] This effect dies out after around 12 trading days, which corresponds to the average time taken across events for the bill stock to revert to the normal level.

The average exchange rate depreciation of the CNH over a 10-day horizon is 0.11%. Splitting by duration of the monetary expansions, the short-lived ones cause an immediate exchange rate movement of 0.12% that is temporary and rapidly reversed. The longer-lived monetary expansions have a less detectable immediate impact but lead to a larger CNH depreciation that persists beyond 12 trading days.

In short, monetarism holds: raising the money supply depreciates the exchange rate.

4.5 The elasticity of money demand

These estimates are informative about the elasticity of demand for CNH money. Using the expression in Proposition 2b): the empirical estimate that the exchange rate depreciates 0.11% following an average roll-off of ¥11bn, together with the facts from Section 2 that $R^m = 1$, the average stock of reserves $M =$¥196bn and deposits $D =$¥730bn, and the foreign CNH deposits are about 10% of the total ($\delta \approx 0.85$) implies[45]

$$\varepsilon_m = \frac{11/196}{0.0011} - 0.85 - 0.85 \left(\frac{196}{730}\right) \varepsilon_d = 50.17 - 0.23\varepsilon_d \,. \tag{17}$$

This gives an upper bound for the interest semi-elasticity of reserve demand of 50, well below the cashless limit assumption of infinity. To account for ε_d, a long literature has estimated time-series regressions of the log of the real stock of M1 (deposits) on the log of the net nominal interest rate on short-term bonds. More recently, Benati et al. (2021) reports log-log coefficients across countries that lie between 0.1 and 0.5. Using the average 1-week CNH wholesale deposit rate of 2.75%, this implies $\varepsilon_d \approx 10$. Then $\varepsilon_m \approx 48$: banks are about five times more elastic than depositors in their demand for money.

Alternatively, Appendix C.2 describes a time-series regression of monthly CNH deposits on an aggregate instrument for CNH money demand shocks, described in the next

[43] Appendix D.4 shows that anticipation of the changes does not affect the validity of the test.

[44] The data five days before each event do not show clear pre-trends in the exchange rate, from either reversion from other shocks or from anticipation of the roll-offs.

[45] We proxy δ using BIS LBS data (see Appendix B). Independently, we would also expect d^f to be small, and so δ to be near one, as that Chinese foreign assets are approximately equal to foreign reserves.

section. This identifies ε_m imperfectly, given the monthly data frequency and the difficulty controlling for other variables that shift the demand function. Remarkably, the estimate of ε_m is 47 even though it relies on a different form of variation altogether.

How does this measure of ε_m compare to other monetary systems? For the United States, Lopez-Salido and Vissing-Jorgensen (2023) estimate ε_m at 500 during the ample reserve system of 2009-2022, while Afonso et al. (2022) put it at approximately 50 in the early 2009-10 period when reserves were relatively scarce in the US. The implication is that for the parallel-currency system to work, CNH reserves are kept scarce, as our model assumes; however, the degree of scarcity is not outside the range seen elsewhere.

5 An anatomy of the peg

A central bank committed to restoring E to parity by adjusting M should follow a rule whereby, if the offshore currency appreciates, it increases the offshore money supply. Similarly, a complementary policy choice to preserve the peg is to use liquidity policies to offset money demand shocks. This section exploits the CNY-CNH setting to construct exogenous shocks to money demand and estimate the relative contributions of monetary and liquidity policies to keep the peg.

5.1 Theory: the impact of demand shocks

The following proposition formalizes how policy can react to a money demand shock.

Proposition 3. *Following an increase in the demand for offshore deposits (μ):*

a) The onshore currency depreciates relative to the offshore currency (E rises).

b) Increasing the supply of offshore reserves (M rises) dampens the increase in the exchange rate and brings it back closer to parity (E rises by less).

c) Liquidity policies λ that either raise the banks' cost of supplying deposits $\psi(x, \lambda)$ or lower the marginal liquidity benefits of reserves $-\phi'(x, \lambda)$ bring the exchange rate back closer to parity (E rises by less).

An increase in μ raises the households' demand for deposits. This reduces banks' reserve-to-deposit ratios, causing banks to bid up the value of reserves, thus appreciating the value of the offshore currency. This is result (a) in the proposition.

Raising the supply of reserves meets some of this higher demand and so offsets this force, bringing E back towards parity (result (b)).

Result (c) shows that a complement to an increase in the offshore money supply is to enact liquidity policies. The authorities can increase the cost of supplying deposits, which raises the interest rate on deposits and curtails the initial rise in their demand. In this case, household's increase demand does not translate as much into an increase in the banks' demand for reserves, muting its impact on the exchange rate. Alternatively, liquidity policies that lower the benefits of reserves will lower the additional reserves demanded by the banks to meet the increase in deposit demand, and so also attenuate the impact of the shock on the exchange rate.

A central bank committed to restoring the parity peg would want to use predictions b) and c) to adjust monetary and liquidity policies in just the right amount to offset the demand shock at any date. Of course, frequent daily deviations from parity are inevitable because of the difficulty in identifying the shocks right away and the delays in implementing these policies. At a daily frequency, the HKMA will not be able to perfectly fine-tune the money supply, so the exchange rate will involuntarily appreciate following a positive demand shock, proposition 3a).

Moreover, the discussion in Section 3.4 points to a voluntary reason to not fully offset demand shocks. Equation (16) shows that the parallel currency system induces a co-movement between E and $E^{\$}$. In the case of the yuan, the PBoC has an explicit desire to smooth fluctuations in $E^{\$}$, the onshore-foreign exchange rate. Having the onshore-offshore exchange rate E temporarily deviate from parity will slow down the macro adjustment of the CNY with the USD (of course subject to the limit that E cannot deviate from parity too far for too long). The left panel of Figure 3 shows that there are deviations from parity, centered around zero and with a bell shape. High-frequency movements in E therefore proxy for money demand shocks.

5.2 Isolating money demand shocks

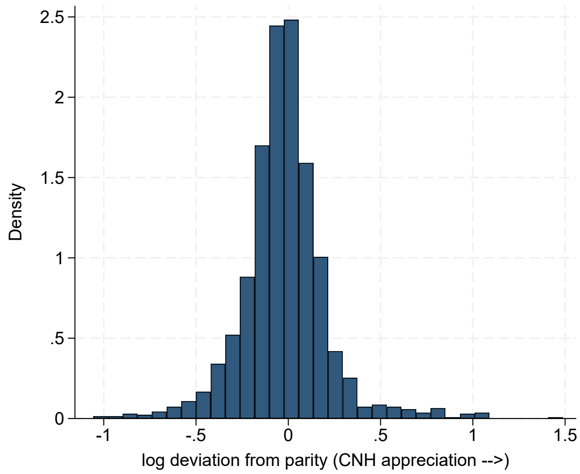
After a demand-driven appreciation of the offshore currency, we want to test whether and to what extent the authorities respond by raising M. Since we will be looking at data at a daily frequency, the relevant high-frequency policy tool is the HKMA's PLP facility. However, since the HKMA adjusts the PLP money supply within the day, and since there are other supply-driven factors influencing the exchange rate, regressing the money supply on the exchange rate would bias the estimated monetary response downward.[46]

The CNY-CNH setting provides an instrumental variable to correct for this downward

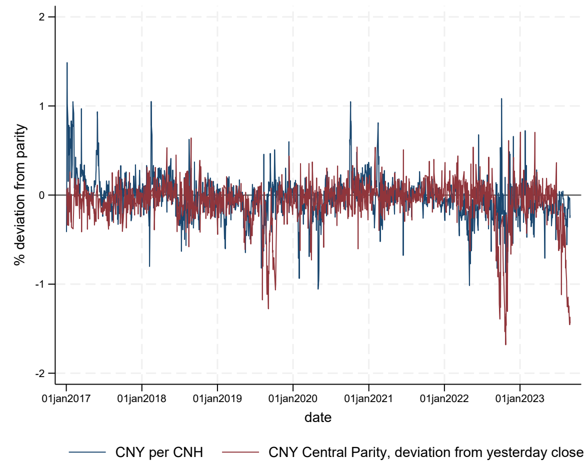
[46]Figure C.6 in appendix C confirms that PLP volumes react to the offshore exchange rate during the day.

Figure 3: Movements in the daily exchange rate as shocks to money demand

(a) Histogram of the log daily CNY-CNH exchange rate



(b) CNY-CNH exchange rate and the CNY-USD band deviation instrument



Note: Panel (a) shows the histogram of daily $\log(E_t)$ from April 2017 to August of 2023. Panel (b) shows the log deviation between the CNY-USD central parity band today and the CNY-USD exchange rate yesterday, together with the log of the CNY-CNH exchange rate today.

bias. Section 2 explained that the PBoC sets a central parity rate $\bar{E}_t^{\$}$ for the CNY-USD exchange rate at the start of the day and allows $E_t^{\$}$ to vary in a band of plus and minus 2%. When the CNY is depreciating quickly and the band is close to binding on the downside, the offshore currency depreciates relative to the onshore one in anticipation of future movements so that E_t falls (vice versa for appreciations). Since a good proxy for the band binding is whether the central parity rate tracks the previous close, the deviation of the CNY-USD exchange rate yesterday from the central parity rate today, $\log \bar{E}_t^{\$}/E_{t-1}^{\$}$, is an instrument for the proportional change in the CNY-CNH exchange rate between yesterday and today, $\log(E_t/E_{t-1})$. The right panel of Figure 3 verifies that the two variables are strongly related: the F-statistic for the instrument is 20.

The key identifying assumption is that, at a daily frequency, $\bar{E}_t^{\$}$ is orthogonal to changes in M or λ. This is likely to be the case, given the discussion in Section 2 that the central parity condition is part of onshore monetary policy, which does not respond to offshore variables. Moreover, since $\bar{E}_t$ is set in the morning, it is not contaminated by within-day PLP lending.[47] Identification does not require that $\bar{E}^{\$}$ is orthogonal to other exogenous

[47] The central parity rate is announced at 11am even if it is set before. Considering only PLP drawings between 11am and end of day yields similar results to using all drawings; see Figure C.8 in appendix C.

variables that could be moving E and $E^{\$}$, like shifts in μ or y_T. All that is needed is that money supply responds to these other shocks as well to preserve the peg.

5.3 Estimating systematic monetary policy

To estimate how M adjusts to E we estimate the local projection

$$z_{t+h} = \alpha_h + \beta_h \Delta \log(E_t) + \gamma_h \log(E_{t-1}) + \delta_h z_{t-1} + \text{controls}_{t-1} + \text{error}_t^h, \qquad (18)$$

where z_{t+h} denotes drawings from the PLP liquidity facility h days after a movement in E_t and controls_{t-1} include drawings from the HKMA's discount window facility as well as overnight and 1-week CNY and CNH interbank rates. If the estimates of β_h are positive, this confirms that money supply adjusts to accommodate changes in E. We estimate equation (18) using both ordinary least squares and an instrumental-variables specification, instrumenting for $\Delta \log(E_t)$ with $\log(\bar{E}_t^{\$}/E_{t-1}^{\$})$.

Figure 4 shows that both least squares and instrumental variables estimates are positive and statistically significant.[48] Moreover, as we expected, the IV results are larger. After a money demand shock that causes the offshore currency to appreciate by 1%, the HKMA's supply of money through the PLP rises by approximately ¥5bn to re-establish the peg, a 2.6% increase in the offshore money supply.

5.4 An anatomy of the peg

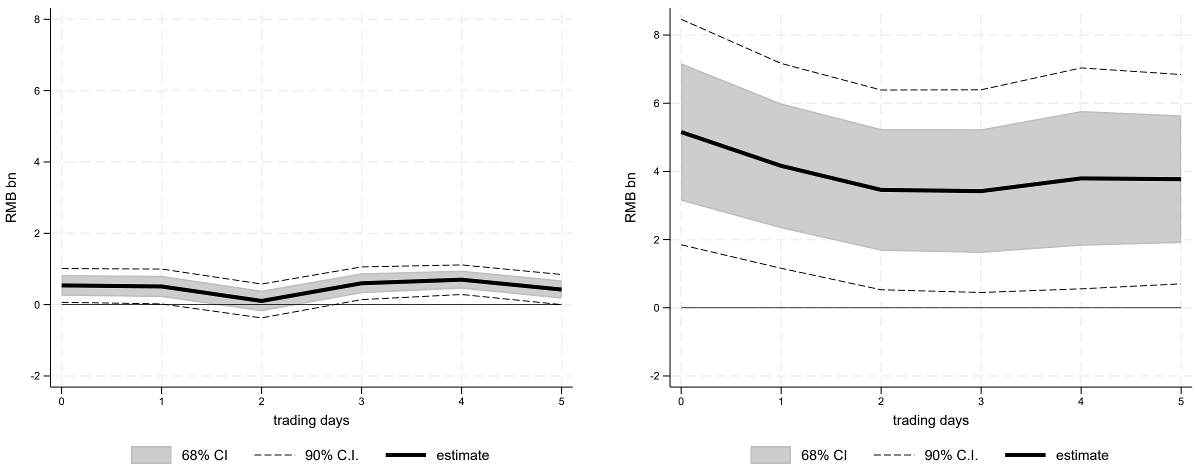
Figure C.9 in the appendix shows that five days after a demand shock that appreciated the offshore currency by 1%, E depreciates back by 0.83%. This can be explained by: (i) the demand shock dissipating or $\bar{E}^{\$}$ adjusting; (ii) *monetary policies* that expand the money supply, either its target (by the PBoC in bills' auctions) or elastically to accommodate demand (by the HKMA in the PLP); and (iii) a shift in *liquidity policies*, λ, that alter the liquidity cost function $\phi(x, \lambda)$ for a given M.

For component (i), the dynamic correlation of the instrument for demand shocks suggests that, after five days, 0.53% of the depreciation is accounted for by the transitory nature of these shocks and the associated adjustment in $\bar{E}^{\$}$. For component (ii), the estimated response of the money supply in Figure 4 was ¥5bn. The estimates in section 4.5 of the potency of monetary policy were that each billion depreciated the exchange rate by about 0.01%. Therefore, the monetary forces to re-establish the peg contributed a 0.05

[48]The complete set of coefficient estimates, including for the control variables, for horizon $h = 0$ is provided in Appendix Table C.2.

Figure 4: Response of the HKMA's PLP money supply to a money demand shock

(a) Local Projection - Least Squares **(b)** Local Projection - Instrumental Variables



Note: Estimates of equation (18) for PLP drawings. The sample includes all trading days between April 2017 and August 2023. The confidence intervals use White-robust standard errors, following Montiel Olea and Plagborg-Moller (2021). Panel (a) estimates the equation using least squares, whereas panel (b) uses an instrumental-variables specification with the deviation of the CNY/USD exchange rate from the trading band limit as an instrument for E_t.

percentage points depreciation. That leaves as a residual the role of liquidity policies. Plugging in the previous numbers, the size of (iii) is 0.25 percentage points, or five-sixths of the policy-induced correction in the exchange rate (the 0.30 percentage-point move from 0.53% to 0.83%). The next section unpacks this residual attributable to liquidity policies, describing the specific tools behind them and presenting direct evidence of their use in the CNH data.[49]

6 Modeling and identifying liquidity policies

We start in Section 6.1 with the Bianchi and Bigio (2022) microfoundation of the liquidity cost function $\phi(.)$ adapted to our setting to allow for onshore flows. Section 6.2 uses the model to pin down some liquidity policies and Sections 6.3-6.4 test the channels through

[49] In appendix C.1 we split our sample into episodes of CNY appreciation and depreciation vis-a-vis the USD and redo the exercise in this section for each subsample. We find that: (i) the peg is maintained regardless of the subsample, in the sense that the return to parity is equally rapid; (ii) however, in times of appreciation the authorities make greater use of monetary than liquidity tools. This could reflect that PLP lending has a lower bound requiring a switch to liquidity policies during times of depreciations. Or that the peg is less credible during depreciations which weakens the relative effectiveness of monetary tools in maintaining the peg (see appendix D.1).

which they work using the Chinese data.

6.1 A model of the liquidity cost function

Within the period, each bank faces payment-driven changes in its offshore deposits to which it responds by adjusting its liquid reserves.

Flow of funds within the offshore system: A bank is indexed by ω, an idiosyncratic shock standing for the fraction of start-of-period offshore deposits that are withdrawn by the end of the period. If $\omega = -1$ all of its deposits leave, whereas if $\omega = 0$ none do. Since one bank's outflows are another bank's inflows, some banks receive net inflows $\omega > 0$.

At the start of the period, ω is a random variable with support $[-1, \infty)$ and distribution $\Omega(\omega, W^d)$ that satisfies

$$\int_{-1}^{\infty} \omega d\Omega(\omega; W^d) = W^d \,. \tag{19}$$

Because offshore depositors can move their funds to the onshore market (and vice versa), the mean of ω is the proportional increase in deposits due to flows from onshore, which we denote by W^d. Reflecting the discussion in Section 2, policymakers can introduce frictions on payments and delay conversions, so we treat W^d as a policy tool.

Settlement and reserve requirements: By the end of the day, banks must honor all withdrawal requests by settling them for reserves. Settling a deposit yielding R^d with a reserve that yields R^m generates gains or losses, which would be zero in expectation if $W^d = 1$ and the offshore system was closed. For $W^d \neq 1$, we assume that the net gains accrue to the government (represented by the clearing bank). Banks face a requirement that reserves are at least as large as a share ρ of the deposits remaining after the withdrawals.

Bank's liquidity position: At the start of the period, the bank's liquidity was the excess of reserves over the requirement: $m - \rho d$. After withdrawals, liquidity increases by the inflow of deposits in excess of the reserve requirement: $\omega d(1 - \rho)$. Its net surplus of liquidity after a shock is

$$s(\omega) = m - \rho d + \omega d \,(1 - \rho) \,. \tag{20}$$

Liquidity deficits and surpluses: The condition $s(\bar{\omega}) = 0$ defines a liquidity threshold

$$\bar{\omega} = \frac{\rho - \frac{m}{d}}{1 - \rho} \,. \tag{21}$$

Banks with $\omega < \bar{\omega}$ will have a liquidity deficit. Those above it have a liquidity surplus. Naturally, the higher the reserve-deposit ratio m/d, which is x in aggregate, the less likely it finds itself in a deficit as the threshold $\bar{\omega}$ is lower.

Interbank market tightness: Banks with liquidity surpluses and deficits try to meet each other in an over-the-counter interbank market to lend and borrow offshore reserves. An amount W^m of reserves can be transferred from onshore to lend in the interbank market. Again following the discussion in Section 2, we treat W^m as a policy tool, since the PBoC has tight control over the clearing bank through which these transfers happen.[50] Borrowers and lenders must search for each other and tightness in this market θ is the ratio of the aggregate demand for liquidity to its aggregate supply

$$\theta = \frac{-\int_{-1}^{\bar{\omega}} s(\omega) d\Omega(\omega; W^d)}{\int_{\bar{\omega}}^{\infty} s(\omega) d\Omega(\omega; W^d) + W^m}, \tag{22}$$

which falls with $\bar{\omega}$ and hence rises with x. Each bank takes market tightness as given.

Search and bargaining in the interbank market: A bank with a liquidity deficit finds a lender bank with a surplus with probability $\Psi_-(\theta)$, that we assume falls in θ. A bank with a surplus matches with a borrower bank with probability $\Psi_+(\theta)$ that rises with θ. These probabilities of finding a match go to zero if the ratio of agents looking goes to infinity relative to those on the other side. If a borrower fails to find a lender (or does not agree on terms) it can borrow at the central bank's discount window facility at a spread r^z over R^m. In the interbank market, a lender and borrower that meet will bargain over the spread of the interbank interest rate over R^m, which we denote by $r^f(\theta)$. Since the outside opportunity of the lender is to earn the interest on reserves R^m, while that of the borrower is to go to the discount window at rate $R^m + r^z$, the function $r^f(\theta)$ has domain $[0, r^z]$, and we assume only that it is increasing in θ.

The result: Combining all the ingredients, if the bank finds itself in a surplus, because $\omega > \bar{\omega}$, it will find someone to lend to with probability $\Psi_+(\theta)$ and earn a profit of $r^f(\theta)$ per unit of reserves lent. Instead, if $\omega < \bar{\omega}$, the bank will have to cover its deficit by borrowing in the interbank market at cost per reserve of $r^f(\theta)$. With probability $1 - \Psi_-(\theta)$, the bank does not find a lender and must borrow from the discount window at the higher cost r^z.

[50] Appendix D.2 formally models scarce onshore reserves. The setup in the main text corresponds to one where onshore reserves are abundant and so earn R just like any other onshore asset. We assume, offshore interbank rates always exceed the onshore rate R so that any limit on W^m will bind.

Expected liquidity costs are

$$\phi(m/d,\lambda)d = -\underbrace{\Psi_{+}(\theta)}_{\text{prob. find borrower}} \times \underbrace{r^{f}(\theta)}_{\text{lending profit}} \times \underbrace{\int_{\bar{\omega}}^{\infty} s(\omega)d\Omega(\omega)}_{\text{liquidity surpluses}}$$
$$- \left[\underbrace{\Psi_{-}(\theta)r^{f}(\theta)}_{\text{interbank borrowing}} + \underbrace{(1-\Psi_{-}(\theta))r^{z}}_{\text{CB borrowing}}\right] \underbrace{\int_{-1}^{\bar{\omega}} s(\omega)d\Omega(\omega)}_{\text{liquidity deficits}}. \quad (23)$$

In Section 3.2 we assumed properties of the $\phi(m/d,\lambda)$ function that we can now verify against its micro-foundation: it depends on the ratio m/d; it is bounded below by 0 and above by r^z; and at the top of the domain $\phi(1,\lambda) = 0$. Note also that there is a slight inconsistency in timing because in Section 3 the liquidity cost was paid in the first period, while now it is paid in the second. But if all interest rates stated in onshore units, the two are the same.

6.2 Identifying liquidity policies

Since each bank takes interbank market conditions θ as given, its marginal benefit of liquidity evaluated at the equilibrium reserve-deposit ratio is given by

$$-\phi'(x,\lambda) = \Psi_{+}(\theta)r^{f}(\theta) + \Omega(\bar{\omega})(1-\Psi_{-}(\theta))r^{z} + \Omega(\bar{\omega})(\Psi_{-}(\theta) - \Psi_{+}(\theta))r^{f}(\theta). \quad (24)$$

Note that $\phi'(x,\lambda)$ is negative, increasing in x, and goes to zero when the aggregate reserve-to-deposit ratio goes to one, again consistent with the assumptions in Section 3.

The liquidity policies λ that we previously took as given are those that affected the equilibrium exchange rate by shifting the key variable $\phi'(x,\lambda)$. The expression above highlights five of them.

The first policy variable is the reserve requirement ρ. An increase in ρ raises the liquidity threshold $\bar{\omega}$ (recall equation (21)) and by the monotonicity of distribution functions like $\Omega(.)$, it raises the marginal benefit of liquidity as well. Intuitively, higher reserve requirements make it more likely that banks after the shock will find themselves scrambling for reserves, so it raises banks' demand for them before the shock.

The second policy is the discount window spread r^z. A higher r^z makes the backstop liquidity from the central bank more expensive, which raises the marginal benefit of holding on to reserves beforehand.

The third policy is the liquidity controls on the flow of payments from onshore to offshore. A lower W^d, makes liquidity deficits more likely and larger shifting the distribution $\Omega(\omega, W^d)$ rightwards.

Fourth are the limits on interbank flows between onshore and offshore. A lower W^m raises interbank market tightness, which raises interbank rates.

The fifth and final policy is banking regulation or moral suasion over the interbank market that affects the rate at which banks with a deficit meet and are able to negotiate with a bank with a surplus $\Psi_-(\theta)$. We label by φ a scalar that shifts this function, so that a higher φ captures regulations that lower the meeting rate for each level of tightness and so make liquidity shortfalls more expensive.

To conclude $\lambda = (\rho, r^z, W^d, W^m, \varphi)$, and between the PBoC and the HKMA can all five tools are available to policymakers in the CNH market.

6.3 Testing for liquidity channels after a money demand shock

We first test for liquidity channels behind these policies in response to a money demand shock. Appendix A.4 proves the following result.

Proposition 4. *A rise in money demand that is only partially offset by a rise in money supply (so E rises) leads to:*

a) an increase in the tightness in the interbank market θ;

b) an increase in the interbank rate $r^f(\theta)$;

c) greater use of the discount window liquidity facilities.

Tightness and bills auctions. Empirically, prediction (a) would show up in a decline in the bid rate for CNH bills by banks. Intuitively, the missing supply of HKMA money means banks are less willing to hand CNH reserves to the PBoC in exchange for bills. As we discussed before, the PBoC runs regular auctions for bills at a lower frequency than the HKMA can act. Between the PBoC announcing an auction and taking bids, on average six trading days go by, so at high frequency, the quantity of bills supplied does not respond to the demand for money. An appreciation of the offshore currency, reflecting a rise in demand for CNH money, will lower demand for bills.

Table 2: Regression of bill auction subscription rate on the exchange rate

Bill maturities	All	12M	6M	3M
	(1)	(2)	(3)	(4)
$\frac{1}{5}\sum_0^4 \log(E_{t-h})$	-2.76***	-3.38***	-2.78***	-3.38***
	(0.93)	(1.10)	(0.93)	(1.12)
Number of Auctions	35	19	16	19
R^2	0.142	0.335	0.131	0.324

Heteroskedasticity robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, ***$p < 0.01$

Note: The sample has 56 issuances of bills in 35 different auctions between November 2018 and May 2023. In 19 of these auctions, the PBoC issued 3M and 12M maturities, while in the other 16 auctions it issued the 6M maturity. The subscription rate is defined as bids divided by bills auctioned. Column (1) considers the subscription rate across all maturities at the auction date, and columns (2)-(4) each maturity separately. Columns (2) and (4) are estimated in a seemingly unrelated regressions framework to account for the fact the 3M and 12M subscriptions occur simultaneously.

Table 2 tests this negative effect by regressing the subscription rate on the average deviation from the peg in the five days prior to the auction to capture the interval after an auction is announced and before it takes place. The estimated coefficients are negative.[51]

Interbank rates. Proposition 4b) predicts that, when overall money demand rises, banks needing liquidity will turn to borrowing from other banks that have a surplus. This increase in demand in the interbank market raises the private-market price for liquidity.

Figure 5 estimates the same local projection as in equation (18), but with the overnight and one-week CNH interbank rate on the left-hand side. The least-squares estimates confirm the theory prediction that the rate rises. The effects are larger with the IV estimates on the right panel (note the change in the scale) but only at the overnight maturity.

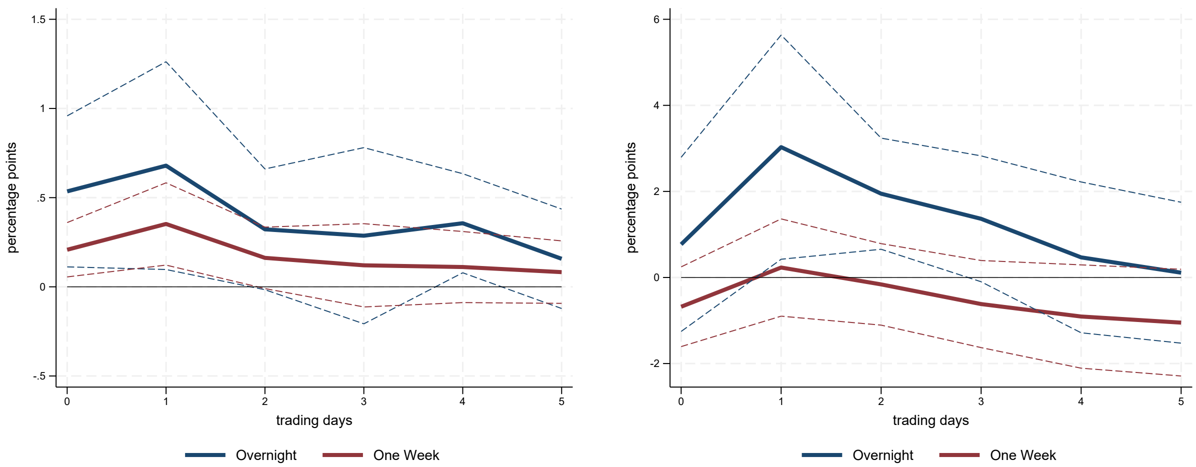
Discount window borrowing. The third and final prediction in proposition 4 arises because the money demand shock raises the deficit threshold $\bar{\omega}$. With more demand for money, a bank is more likely to be in a liquidity deficit, not find a lender with probability $1 - \Psi_{-}(\theta)$, and go to the discount window.

In the case of CNY-CNH, by keeping the money supply scarce, the PBoC ensures that in aggregate banks find themselves routinely having to take this route. Figure 6 shows

[51] Table C.3 in appendix C uses instead the exchange rate on the day of the auction. Because the auction results are only announced after the market closes, and the bills are settled two days later, they do not contaminate the exchange rate. The effect is less precisely estimated and weaker, but the conclusion holds.

Figure 5: Interbank rate response to a money demand shock

(a) Local Projection - Least Squares **(b)** Local Projection - Instrumental Variables



Note: Estimates of equation (18) for the overnight and one-week CNH interbank interest rate. The sample period is all trading days between April 2017 and August 2023. Confidence intervals use White heteroskedasticity robust standard errors, following Montiel Olea and Plagborg-Moller (2021). Panel (a) estimates the equation using least squares, whereas panel (b) does so using as an instrument the deviation of the CNY/USD exchange rate from the trading band limit.

estimates of the same regression as in equation (18), but now with drawings from the liquidity facilities as the measures of z_{t+h}.[52] The increase in money demand generates a rise in discount window borrowing of around ¥6bn.[53]

6.4 The effect of liquidity policies on the exchange rate

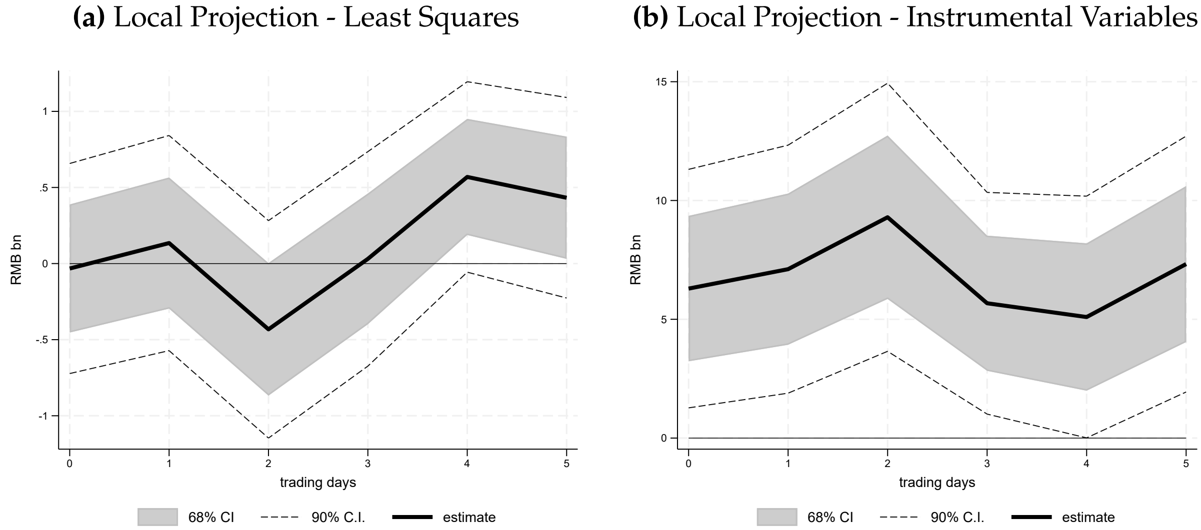
Our anatomy of the peg attributed five-sixths of the policy-induced return to parity after a money-demand shock to shifts in liquidity policies. Each of the five elements of the vector λ affects the marginal benefits and costs of liquidity and so the equilibrium offshore reserve-to-deposit ratio x and exchange rate E. With the exception of reserve requirements ρ—which are not heavily used in the offshore market—we can use data to inspect the effects of r^z, W^d, W^m and φ.

Evidence on r^z from an HKMA reform: Initially, when the HKMA intraday lending facilities started, banks could borrow paying a rate of 50bp above the previous day's

[52]The results in Figure 6 use only the intraday facility. Using the sum across the two facilities leads to almost identical results. The sample ends in July 2022 because of a reform that we will discuss next.

[53]Figure C.6 in appendix C splits the impact between different times of the day. The use of the discount window rises as soon as the market opens and persists during the day.

Figure 6: Response of HKMA discount window borrowing to a money demand shock



Note: Estimates of equation (18) for the liquidity facility drawings. The sample has all trading days between April 2017 and July 22, 2022 when the terms on the HKMA lending facilities changed. The confidence intervals use White robust standard errors, following Montiel Olea and Plagborg-Moller (2021). Panel (a) estimates the equation using least squares, whereas panel (b) does so using as an instrument the deviation of the CNY-USD exchange rate from the trading band limit.

overnight interbank rate. On April 5, 2016, the HKMA changed the lending rate to 50bp plus the average of the previous three days' overnight rates.

We estimate the following autoregressive distributed lag regression on a sample from November 4, 2015 to September 1, 2023, with a dummy variable $Post_t$ that takes the value one for observations after April 5, 2016, and controlling for three lags of $\log(E_t)$, the onshore overnight rate, and the offshore and onshore three-month rates (in parentheses are Newey-West standard errors)

$$\log(E_t) = \underbrace{-0.04}_{(0.23)} R^f_{t-1} - \underbrace{0.62^{***}}_{(0.23)} R^f_{t-2} - \underbrace{0.51^{***}}_{(0.12)} R^f_{t-3} - \underbrace{0.01}_{(0.17)} R^f_{t-4}$$
$$+ Post_t \times (\underbrace{0.57^{**}}_{(0.28)} R^f_{t-1} - \underbrace{0.52}_{(0.37)} \times R^f_{t-2} + \underbrace{\mathbf{1.25^{***}}}_{\mathbf{(0.29)}} \times \boldsymbol{R^f_{t-3}} + \underbrace{0.15}_{(0.27)} \times R^f_{t-4})$$
$$+ \text{controls}_t + \text{error}_t \,. \tag{25}$$

The key coefficient, in bold, is statistically significant and positive. This says that, after the reform, a higher overnight rate three days ago is now associated with an appreciation of the CNH. Consistent with the model, once this lagged rate became an indicator for the cost of lending from the discount window, a higher rate meant that emergency liquidity became more expensive, so the relative value of the offshore currency rose.

Evidence on W^d, W^m, φ from the 2015–16 financial crisis: In 2015–16, macro-financial forces led to a trend depreciation of the yuan relative to the dollar, visible in panel (a) of Figure 7.[54] Initially, the PBoC held the central parity rate, $\bar{E}^{\$}$, relatively constant. The CNY/USD exchange rate persistently traded at the lower bound of the trading band. In August 2015, the PBoC switched to fixing the parity rate near the previous day's close. This prompted a 3% depreciation in the CNY between August 11 and 13, marked with the first vertical dashed blue line in Figure 7. In line with the discussion in Section 5, the CNH depreciated one additional percentage point against the USD. The CNH traded at an average 0.6% discount relative to CNY throughout the remainder of 2015.

The PBoC's response in December 2015 was to tighten the liquidity controls on the flow of deposits and reserves (W^d and W^m in our model). Panel (b) shows the sharp fall in the flows from the onshore to the offshore market in the Chinese current account, by more than one-fifth right away, and a further two-fifths over the next few months.[55]

Panels (c) and (d) show the consequences for liquidity, which line up with our model and the identified empirical mechanisms. Panel (c) shows that the stock of CNH deposits (D in our model) fell by 20 log points relative to CNY deposits during the December 2015 tightening. Panel (d) shows that the PBoC's actions caused the three-month CNH interbank rates ($R^f(\theta)$ in the model) to spike above 10%, while equivalent CNY rates were stable at around 3%, again as predicted by our model as a result of increased tightness in the interbank market (θ). This intervention brought CNY-CNH closer to parity, but the scarcity of CNH meant that the internationalization of the RMB paused.

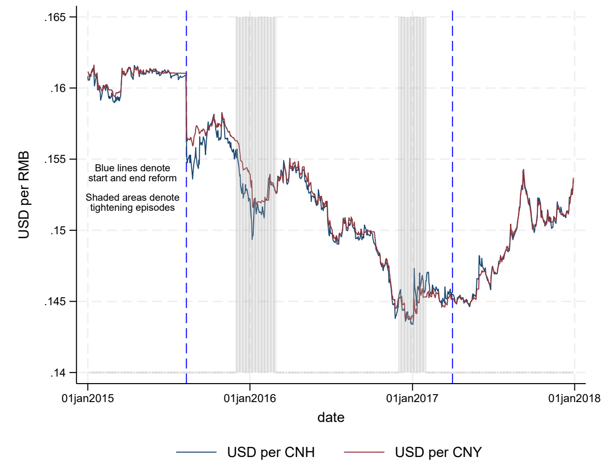
Over the course of 2016, the CNY remained on a depreciating trend, and the CNH successively traded below parity (panel (a)). When depreciation intensified at the end of the year, the PBoC repeated its intervention in December 2016 adding a tightening of financial regulation (φ) together with liquidity controls (panel (b)). CNH deposits fell by 40 log points on a relative basis (panel (c)), and interbank rates leapt (panel (d)), bringing about a sharp appreciation of CNY-CNH that pushed it above parity (panels (a) and (c)). This ended at the start of 2017, partly helped by the stabilization of the exchange rate with the USD, partly by setting up the framework described in Section 2.

[54]This episode involved sustained capital outflows and is an instance of capital flight. We discuss how such episodes fit in our framework in Section 7 and formalize them in Appendix D.3.

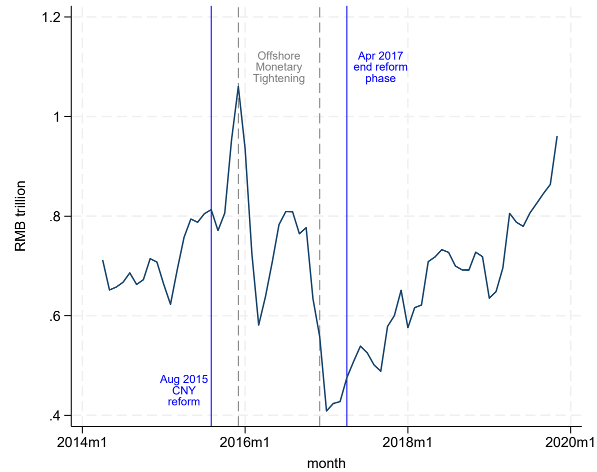
[55]The flows in the other direction are reported in appendix Figure C.10.

Figure 7: The monetary tightenings of 2015 and 2016

(a) CNH/USD and CNY/USD exchange rates

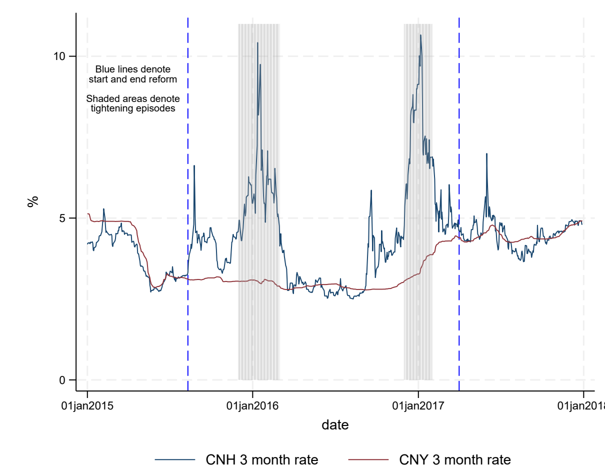


(b) RMB flows from onshore to offshore



(c) Relative CNY-CNH deposit stock and $\log(E)$

(d) 3-month interbank rates for CNY and CNH



Note: Panel (a) shows yuan exchange rates expressed so that a fall is a depreciation of the yuan. Panel (b) shows the conversion of CNH into CNY from the current account, at a monthly frequency. Panel (c) shows $\log(D_t^{\text{CNY}}) - \log(D_t^{\text{CNH}})$ against monthly average $\log(E_t)$. Panel (d) shows yuan interbank rates.

7 The relative merits of parallel currencies

So far, we have theoretically shown that a system with capital controls and parallel currencies can replicate a system with a capital flow tax. We have empirically found that the mechanisms of this system are supported by the Chinese evidence, and we have characterized the monetary-liquidity policy mix that manages the exchange rate and external balance. We now discuss the merits of this system and the broader lessons for the implementation of parallel currencies.

7.1 Comparison with capital flow taxes

The major disadvantage of capital flow taxes is that enforcing them is hard. There are many ways in which capital flows across borders, covering many diverse instruments, and as the Brazilian experience of 2009-13 showed, the law struggles to keep up with the financial innovations to get around the taxes. For example, capital flows can be masked by trading abroad derivatives over the assets, away from the reach of the tax collector.

The implementation of capital flow taxes is often done by charging the tax when the foreign currency is converted into domestic currency at an approved financial intermediary. That is, the tax/subsidy approach ends up taking a monetary route itself. What experience shows, however, is that a parallel black market emerges for these exchanges.

The parallel-currencies alternative, instead, effectively replaces the black market with a transparent free market where onshore and offshore currencies trade. This allows the policymaker to observe the demand shocks in that market in real time and respond to them to manipulate the exchange rate, as we showed the Chinese authorities do. Moreover, with this solution, the rents of black market intermediaries are replaced by seigniorage revenues for the monetary authorities.

A third and related enforcement advantage of the parallel-currency solution is that it does not tax gross flows. The offshore money can circulate between foreigners and home agents in order to settle payments related to trade without hindrance. Only the stock of deposits ends up exposed to the effective tax. With capital flow taxes, while in theory netting is straightforward, in practice delays between different legs of transactions create large liquidity requirements on different parties that raise the costs of many transactions.

7.2 Interest rates versus quantities

An apparent limitation of the parallel-currency system is that it seems to require a quantity-based monetary policy, unlike the traditional interest-rate policies that are popular among most central banks. However, in our model, what is required is for the monetary authority to control *two* tools given the two objectives of keeping the onshore-offshore peg while affecting the onshore-foreign exchange rate. Allowing R^m to be the policy variable as opposed to M would not change the logic of the system, as long as reserves are scarce.

Why did China use a quantity system? One reason may be path dependence: this is how the PBoC has traditionally operated, including with onshore monetary policy. Another is that changing the money supply can be implemented quickly and stealthily in response to high-frequency shocks to the exchange rate, unlike changes in interest rates that must be communicated to financial markets to have their effect. A third reason is that officially announcing different offshore and onshore policy rates would publicly make clear that the onshore-foreign exchange rate was being manipulated, and it might foster coordinated speculative attacks on deviations from the onshore-offshore peg.

7.3 An offshore system in deficit countries

We modeled the domestic economy as a surplus country attempting to discourage capital inflows and boost savings abroad to match the Chinese experience of the last few decades. This leaves two open questions: first, can the offshore system be used in the other direction to raise the current account deficit and discourage external saving, in the way that a tax on foreign saving would (i.e. a negative τ)? Second, in countries that are facing capital flight, can the offshore system mitigate these outflows and stabilize its external position just as temporary taxes on capital flows are sometimes used?

Appendix D.2 adapts our model to answer the first question. It shows how, if the onshore banking sector also operates in a system where liquidity is scarce, then, by making liquidity scarcer onshore than offshore, the policymaker can implement a negative τ.

In Appendix D.3, we extend the model to allow for outflows, $d^f < 0$, where foreign investors short the offshore currency by raising funds in the frictional offshore market. Intuitively, because tightening liquidity offshore raises the cost of going short, this acts as a tax on outflows. This aligns with the events of 2015–16 described above.

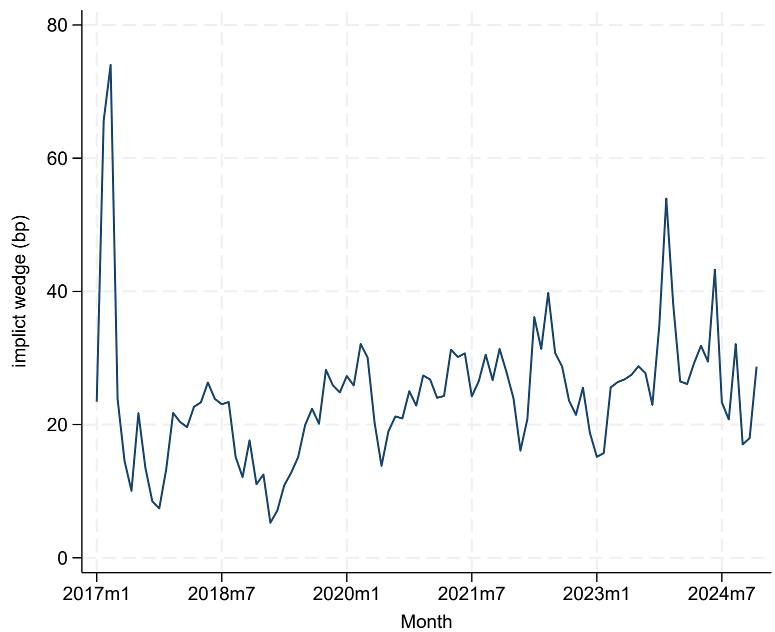
7.4 Quantifying the implicit subsidy

The equivalence result in Proposition 1 shows that the offshore system is equivalent to a tax/subsidy system with a rate: $\tau = \psi(.)/(1 - \psi(.))$. In turn, equations (23) and (24) provide formulae for the terms in $\psi(.)$.

Appendix D.5 expresses this formula in terms of observable interest rates and outstanding quantities in interbank markets and central bank lending facilities. It explains how to use monthly data for each of these model counterparts. Note that $\psi(.)$ measures only the expected financial costs to banks from shortfalls of liquidity, but leaves out the operational costs of managing scarce liquidity, the stigma in accessing central bank liquidity, and the opportunity costs of the collateral employed to do so. In that sense, our estimate of τ is a lower bound.

Figure 8 presents the estimated implicit τ using monthly averages in the data. Across the sample, it averages about 30 basis points. The implicit tax rate was especially high

Figure 8: Estimates of the wedge brought about by capital controls and parallel currencies



Note: The figure shows estimates of the implicit tax wedge $\tau = \psi(.)/(1-\psi(.))$ defined in Proposition 1 from calibrating the model to back out the value of $\psi(.)$ every month between January 2017 and December of 2024. The value is expressed in basis points. Appendix D.5 discusses the calibration.

before the end of the reform phase in 2017 and during the summer of 2023. By contrast, τ fell to a low in 2018, when the CNY was allowed to appreciate and the Chinese current account surplus shrank markedly.

8 Conclusion

To reconcile capital controls with the international use of the yuan, Chinese monetary authorities created an offshore currency that could be used freely for foreign transactions, while imposing strict controls on the exchange of this offshore currency for its onshore counterpart. This allowed for capital controls over the flows in and out of mainland China's onshore yuan, while allowing the offshore yuan to be used as an international currency, as long as the exchange rate between the two currencies remains close to parity.

This paper explained this system. Using a general intertemporal model of the current account, we showed that capital controls and parallel currencies can implement the same outcomes for the net foreign asset position and the foreign exchange rate as a capital flow tax/subsidy. Using the Chinese regime of parallel currencies, we showed that, once one unpacks its components, the system is managed using conventional monetary and liquidity tools.

We used the system's peculiarities to find credible evidence that exogenous, transitory increases in the money supply depreciate the exchange rate. The implied interest-rate elasticity of the demand for reserves at the central bank around 50, significantly less than the infinity of ample reserve frameworks or cashless-limit theories, but more than the zero of the simple quantity theory. In the data, monetary policy has responded to increases in the demand for money by raising the money supply, but sustaining the peg has also required a large and significant role for liquidity policies. We found evidence that increases in the demand for money reduced the demand for bonds, raised interbank rates, and increased borrowing from the discount window. Reforms to the emergency lending facility affected the exchange rate via the marginal benefit of an extra offshore reserve. Finally, a tightening of liquidity controls offset a large shock, but with severe consequences for liquidity as measured by deposits or interbank rates. Altogether, monetary and liquidity policies have prevented the usual demise of parallel currencies and have allowed for interventions to affect the exchange rate and the current account.

Along the way, we revisited some of the fundamental pillars of monetarism:

(i) if you raise the money supply, you will reduce the value of the currency (Friedman-Schwartz);

(ii) if you want to peg this value, respond to rises in it by printing money (Mussa);

(iii) liquidity policies to steer money demand complement control of the money supply (Goodhart);

(iv) parallel currencies survive by keeping a tight peg between their values (Gresham).

China's unusual offshore system allowed us to test these and reach the following conclusions with respect to each one of them: (i) yes, with an elasticity reserve demand of around 50; (ii) yes, but only one-sixth, with the remaining five-sixths achieved by liquidity policies; (iii) yes, and these include reserve requirements, the discount window rate, liquidity restrictions, and regulation of the interbank market; and (iv) yes, provided they are embedded in a coherent overall framework.

Looking ahead, the theory of parallel-currencies and the practical success of the Chinese system suggest an alternative to capital flow taxes. Moreover, this system integrates well with the IMF's Integrated Policy Framework, which emphasizes that monetary policy, exchange-rate management, macroprudential tools, and capital-flow measures jointly shape external outcomes. The parallel-currency arrangement also allows for a partial relaxation of the classic trilemma, as the country can manage its external balance and retain onshore monetary autonomy, while still permitting a portion of money-like claims to be freely convertible and used as an international medium of exchange.

References

Afonso, Gara, Domenico Giannone, Gabriele La Spada, and John C. Williams. 2022. "Scarce, Abundant, or Ample? A Time-Varying Model of the Reserve Demand Curve." *Federal Reserve Bank of New York Staff Report 1019*.

Alvarez, Fernando, Andrew Atkeson, and Patrick J. Kehoe. 2002. "Money, Interest Rates, and Exchange Rates with Endogenously Segmented Markets." *Journal of Political Economy*, 110(1): 73–112.

Bahaj, Saleem, and Ricardo Reis. 2026. "Jumpstarting an International Currency." *Review of Economic Studies*, forthcoming.

Benati, Luca, Robert E. Lucas, Juan Pablo Nicolini, and Warren Weber. 2021. "International Evidence on Long-Run Money Demand." *Journal of Monetary Economics*, 117: 43–63.

Bianchi, Javier, and Guido Lorenzoni. 2022. "The prudential use of capital controls and foreign currency reserves." In *Handbook of International Economics: International Macroeconomics, Volume 6*. Vol. 6 of *Handbook of International Economics*, , ed. Gita Gopinath, Elhanan Helpman and Kenneth Rogoff, 237–289. Elsevier.

Bianchi, Javier, and Saki Bigio. 2022. "Banks, Liquidity Management, and Monetary Policy." *Econometrica*, 90(1): 391–454.

Bianchi, Javier, Saki Bigio, and Charles Engel. 2021. "Scrambling for Dollars: International Liquidity, Banks and Exchange Rates." *NBER working paper 29457*.

Bordo, Michael D., Owen F. Humpage, and Anna J. Schwartz. 2015. *Strained Relations: US Foreign-Exchange Operations and Monetary Policy in the Twentieth Century.* University of Chicago Press.

Bordo, Michael, Eric Monnet, and Alain Naef. 2019. "The Gold Pool (1961–1968) and the Fall of the Bretton Woods System: Lessons for Central Bank Cooperation." *Journal of Economic History*, 79(4): 1027–1059.

Boughton, James M. 1988. "The Monetary Approach to Exchange Rates: What Now Remains?" *Essays in International Finance*, 171: 1–28.

Burdekin, Richard C.K., and Marc D. Weidenmier. 2001. "Inflation Is Always and Everywhere a Monetary Phenomenon: Richmond vs. Houston in 1864." *American Economic Review*, 91(5): 1621–1630.

Chamon, Marcos, and Márcio Garcia. 2016. "Capital controls in Brazil: Effective?" *Journal of International Money and Finance*, 61: 163–187.

Chen, Kaiji, Jue Ren, and Tao Zha. 2018. "The Nexus of Monetary Policy and Shadow Banking in China." *American Economic Review*, 108(12): 3891–3936.

Chodorow-Reich, Gabriel, Gita Gopinath, Prachi Mishra, and Abhinav Narayanan. 2019. "Cash and the Economy: Evidence from India's Demonetization." *Quarterly Journal of Economics*, 135(1): 57–103.

Chupilkin, Maxim, Beata Javorcik, Aleksandra Peeva, and Alexander Plekhanov. 2023. "Exorbitant privilege and economic sanctions." *EBRD working paper 281*.

Clayton, Christopher, Amanda Dos Santos, Matteo Maggiori, and Jesse Schreger. 2023. "Internationalizing Like China." *CEPR discussion paper 17781*.

Dedola, Luca, Georgios Georgiadis, Johannes Gräb, and Arnaud Mehl. 2021. "Does a Big Bazooka Matter? Quantitative Easing Policies and Exchange Rates." *Journal of Monetary Economics*, 117: 489–506.

Eichenbaum, Martin, and Charles L. Evans. 1995. "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates." *Quarterly Journal of Economics*, 110(4): 975–1009.

Engel, Charles. 2016. "Exchange Rates, Interest Rates, and the Risk Premium." *American Economic Review*, 106: 436–474.

Engel, Charles, and Steve P. Y. Wu. 2023. "Liquidity and Exchange Rates: An Empirical Investigation." *Review of Economic Studies*, 90(5): 2395–2438.

Erten, Bilge, Anton Korinek, and José Antonio Ocampo. 2021. "Capital controls: Theory and evidence." *Journal of Economic Literature*, 59(1): 45–89.

Friedman, Milton, and Anna Jacobson Schwartz. 2008. *A Monetary History of the United States, 1867-1960.* Princeton University Press.

Funke, Michael, Chang Shu, Xiaoqiang Cheng, and Sercan Eraslan. 2015. "Assessing the CNH-CNY Pricing Differential: Role of Fundamentals, Contagion, and Policy." *Journal of International Money and Finance*, 59: 245–262.

Genberg, Hans, and Cho-Hoi Hui. 2011. "The Credibility of Hong Kong's Link from the Perspective of Modern Financial Theory." *Journal of Money, Credit and Banking*, 43(1): 185–206.

Gourinchas, Pierre-Olivier, Walker D Ray, and Dimitri Vayanos. 2022. "A Preferred-Habitat Model of Term Premia, Exchange Rates, and Monetary Policy Spillovers." *NBER Working Paper 29875*.

Greenwood, Robin, Samuel Hanson, Jeremy C Stein, and Adi Sunderam. 2023. "A Quantity-Driven Theory of Term Premia and Exchange Rates." *The Quarterly Journal of Economics*, 138(4): 2327–2389.

Hachem, Kinda, and Zheng Song. 2023. "Liquidity Rules and Credit Booms." *Journal of Political Economy*, 129(10): 2721–2765.

He, Dong, and Robert N McCauley. 2012. "Offshore markets for the domestic currency: monetary and financial stability issues." In *The evolving role of China in the global economy*. , ed. Yin-Wong Cheung and Jakob de Haan, 302–338. Cambridge: MIT Press.

He, Zhiguo, and Wei Wei. 2023. "China's Financial System and Economy: A Review." *Annual Review of Economics*, 15(1): 451–483.

He, Zhiguo, Yuehan Wang, and Xiaoquan Zhu. 2023. "The Stock Connect to China." *AEA Papers and Proceedings*, 113: 125–30.

Honohan, Patrick, and Sean Yoder. 2010. "Financial Transactions Tax: Panacea, Threat, or Damp Squib?" *World Bank Policy Research Working Paper 5230*.

Hu, Jiafei, and Haishan Yuan. 2021. "Interest Arbitrage Under Capital Controls: Evidence from Reported Entrepot Trades." *Journal of Banking and Finance*, 127: 106–129.

Itskhoki, Oleg, and Dmitry Mukhin. 2021. "Exchange Rate Disconnect in General Equilibrium." *Journal of Political Economy*, 129(8): 2183–2232.

Jermann, Urban J, Bin Wei, and Vivian Z Yue. 2022. "The Two-Pillar Policy for the RMB." *Journal of Finance*, 77(6): 3093–3140.

Jiang, Zhengyang, Arvind Krishnamurthy, and Hanno Lustig. 2021. "Foreign Safe Asset Demand and the Dollar Exchange Rate." *The Journal of Finance*, 76(3): 1049–1089.

Liu, Renliang, Liugang Sheng, and Jian Wang. 2022. "Faking Trade for Capital Control Evasion: Evidence from Dual Exchange Rate Arbitrage in China." manuscript.

Lopez-Salido, David, and Annette Vissing-Jorgensen. 2023. "Reserve Demand, Interest Rate Control, and Quantitative Tightening." Federal Reserve manuscript.

Maggiori, Matteo. 2022. "International Macroeconomics with Imperfect Financial Markets." In *Handbook of International Economics*. Vol. 6, , ed. Gita Gopinath, Elhanan Helpman and Kenneth Rogoff, Chapter 5, 199–236. Elsevier.

Matheson, Thornton. 2011. "Taxing Financial Transactions: Issues and Evidence." *IMF working paper 11/54*.

McCauley, Robert N, and Chang Shu. 2018. "Recent RMB Policy and Currency Co-movements." *BIS working paper 727*.

Meese, Richard A., and Kenneth Rogoff. 1983. "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample?" *Journal of International Economics*, 14: 3–24.

Monnet, Eric. 2014. "Monetary Policy without Interest Rates: Evidence from France's Golden Age (1948 to 1973) Using a Narrative Approach." *American Economic Journal: Macroeconomics*, 6(4): 137–69.

Montiel Olea, José Luis, and Mikkel Plagborg-Moller. 2021. "Local Projection Inference Is Simpler and More Robust Than You Think." *Econometrica*, 89(4): 1789–1823.

Naef, Alain, Eric Monnet, Camille Macaire, Arnaud Mehl, and Barry Eichengreen. 2022. "The Renminbi's Unconventional Route to Reserve Currency Status." *VoxEU column*.

Palma, Nuno. 2021. "The Real Effects of Monetary Expansions: Evidence from a Large-scale Historical Experiment." *Review of Economic Studies*, 89(3): 1593–1627.

Poole, William. 1968. "Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy." *Journal of Finance*, 23(5): 769–791.

Rogoff, Kenneth. 1999. "Monetary Models of Dollar/Yen/Euro Nominal Exchange Rates: Dead or Undead?" *The Economic Journal*, 109(459): F655–F659.

Selgin, George. 2020. "Gresham's Law." *Handbook of the History of Money and Currency*, , ed. Stefano Battilossi, Youssef Cassis and Kazuhiko Yago, 199–219. Springer Singapore.

Song, Zheng (Michael), and Wei Xiong. 2018. "Risks in China's Financial System." *Annual Review of Financial Economics*, 10(1): 261–286.

Valchev, Rosen. 2020. "Bond Convenience Yields and Exchange Rate Dynamics." *American Economic Journal: Macroeconomics*, 12(2): 124–66.

Velde, François R. 2009. "Chronicle of a Deflation Unforetold." *Journal of Political Economy*, 117(4): 591–634.

A Appendix: Proof of propositions

A.1 Proof of proposition 1

Since the statement of the proposition is conditional on a given $(M, \lambda, B^{\$})$, we suppress functional dependencies on these variables to save on the length of the expressions.

The equilibrium is the solution to the three equations: (14), (15), and (16) for three variables $(E, E^{\$}, x)$. Using equation (14) to solve for the offshore exchange rate

$$E = \frac{\beta R^m}{1 + \phi'(x)}, \tag{A.1}$$

we substitute E out from equations (15) and (16) to have a system of two equations in two unknowns $E^{\$}$ and x

$$E^{\$} = f(x) \equiv \left(\frac{1}{y_T - B^{\$}}\right)\left[\iota + \frac{\mu}{\psi(x)} - \frac{\beta R^m M}{x[1 + \phi'(x)]}\right], \tag{A.2}$$

$$E^{\$} = g(x) \equiv \underbrace{\left(\frac{\iota / y_T}{1 + R^{\$-1}\frac{y_T'}{y_T}}\right)}_{\equiv W}\left[1 + \frac{\beta}{1 - \psi(x)}\right], \tag{A.3}$$

where we introduce the two new functions $f(x), g(x)$, and a new constant W.

Recall that we have assumed that $y_T > B^{\$}$ and that $W > 0$. Recall also that the marginal benefit of liquidity has the properties, by assumption: $\phi'(x) < 0, \phi''(x) \geq 0$ and that $\phi'(1) = 0$ and $\lim_{x \to 0} \phi'(x) \geq -1$. Finally, the liquidity cost of a deposit $\psi(x) \equiv \phi(x) - x\phi'(x) \geq 0$ has the properties $\psi(1) = 0$, $\lim_{x \to 0} \psi(x) \equiv \phi_0 < 1$, and $\psi'(x) = -x\phi''(x) \leq 0$. Using these properties, it is then straightforward to show that the $g(x)$ function has the following properties

$$g(x) \text{ is continuous and has domain } (0, 1] \tag{A.4}$$

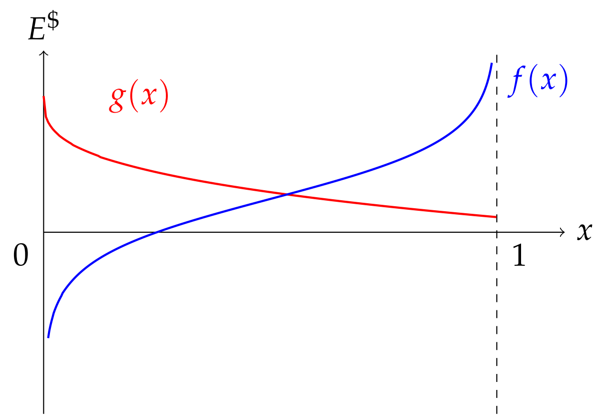
$$g(1) = W(1 + \beta) > 0 \text{ and } < \infty \tag{A.5}$$

$$\lim_{x \to 0} g(x) = W\left(1 + \frac{\beta}{1 - \phi_0}\right) > 0 \text{ and } < \infty \tag{A.6}$$

$$g'(x) = \frac{W\beta\psi'(x)}{(1 - \psi(x))^2} \leq 0. \tag{A.7}$$

Therefore, the $g(x)$ function starts at a positive value and then continuously declines to

Figure A.1: Solution of the model with capital controls and parallel currencies



end at another positive value. This is shown in figure A.1.

Likewise for the $f(x)$ function:

$$f(x) \text{ is continuous and has domain } (0,1] \tag{A.8}$$

$$\lim_{x \to 1} f(x) = \frac{1}{y_T - B^{\$}} \left[\iota + \frac{\mu}{0} - \frac{\beta R^m M}{x} \right] = +\infty \tag{A.9}$$

$$\lim_{x \to 0} f(x) = \frac{1}{y_T - B^{\$}} \left[\iota + \frac{\mu}{\phi_0} - \lim_{x \to 0} \frac{\beta R^m M}{x[1 + \phi'(x)]} \right] = -\infty \tag{A.10}$$

$$f'(x) = \frac{1}{y_T - B^{\$}} \left[-\frac{\mu \psi'(x)}{\psi(x)^2} + \frac{\beta R^m M(1 + \phi'(x) + x\phi''(x))}{x^2[1 + \phi'(x)]^2} \right] \geq 0\,. \tag{A.11}$$

where the last result follows from the assumed properties of the liquidity-cost function: $\psi'(x) = -x\phi''(x) \leq 0$, $\phi''(x) \geq 0$, and $-1 < \phi'(x) \leq 0$, which together imply $f'(x) \geq 0$ on $(0,1]$. The $f(x)$ function is plotted in the figure A.1 as well.

Clearly, there is a unique intersection of the two functions, and therefore a unique equilibrium value of x and of $E^{\$}$. From (A.1), since the $\phi'(x)$ function is monotonic, there is also then a unique equilibrium value of E. This completes the proof of the first part of the proposition.

For the second part of the proposition, note that in any equilibrium of the model with capital controls and parallel currencies, equation (16) holds. Likewise, in any equilibrium of the model with taxes on capital flows, equation (5) holds. Therefore, the two models will give the same equilibrium exchange rate if

$$\tau = \tau(x) \equiv \frac{\psi(x)}{1-\psi(x)}. \tag{A.12}$$

Now, using the assumptions on the properties of the $\psi(x)$ function, we know that:

$$\tau(x) \text{ is continuous and has domain } (0,1] \tag{A.13}$$

$$\lim_{x\to 1} \tau(x) = \frac{\psi(1)}{1-\psi(1)} = 0 \tag{A.14}$$

$$\lim_{x\to 0} \tau(x) = \frac{\phi_0}{1-\phi_0} > 0 \tag{A.15}$$

$$\tau'(x) = \frac{\psi'(x)}{(1-\psi(x))^2} \leq 0. \tag{A.16}$$

The limits and the monotonicity of the function give the range stated in the proposition.

Finally, when M rises, the solution $x = x(M)$ changes. We can then write the composite function $\hat{\tau}(M) \equiv \tau(x(M))$. We want to characterize the properties of that function.

First, from the definition of the $f(x)$ function in equation (A.2), when M rises, it shifts downward in figure A.1. Therefore, the equilibrium x rises. Therefore $\tau(x)$ falls. So $\hat{\tau}'(M) < 0$.

Second, when M goes to infinity, $f(x)$ goes to minus infinity for all $x < 1$. We showed already that $\lim_{x\to 1} f(x) = +\infty$ for any finite M. Therefore for an M that is finite but arbitrary large $x \to 1$ and so $\tau(x) \to 0$. Therefore: $\lim_{M\to\infty} \hat{\tau}(M) = 0$ the lower bound in the range of wedges.

All that remains is to show that as $M \to 0$, the equilibrium reserve–deposit ratio $x(M)$ converges to zero and so $\tau(x(M))$ rises to its upper bound. When $M \to 0$, from the definition of the $f(x)$ function in equation (A.2) we have

$$f_0(x) \equiv \lim_{M\to 0} f(x; M) = \frac{1}{y_T - B^{\$}} \left[\iota + \frac{\mu}{\psi(x)} \right]. \tag{A.17}$$

Using the same steps as for the generic $f(x; M)$, $f_0(x)$ is continuous, satisfies $\lim_{x\to 1} f_0(x) = +\infty$, and has $f_0'(x) \geq 0$ on $(0,1]$. Moreover, for each fixed $x \in (0,1]$, $f(x; M)$ converges to $f_0(x)$ as $M \to 0$, and since $\partial f/\partial M < 0$, as M decreases $f(x; M)$ shifts upward towards $f_0(x)$. We would then be assured that, for M sufficiently small, the unique equilibrium

$x(M)$ solving $f(x;M) = g(x)$ lies arbitrarily close to zero, provided that

$$\lim_{x\to 0} f_0(x) \geq \lim_{x\to 0} g(x) \;\Rightarrow\; \frac{1}{y_T - B^{\$}}\left[\iota + \frac{\mu}{\phi_0}\right] \geq W\left(1 + \frac{\beta}{1-\phi_0}\right). \tag{A.18}$$

Now, replace out that $y_T - B^{\$} = ()E^{\$}) - 1(\iota - Ed^f)$, and replace out $E^{\$}$ using the definition of $g(x)$ in equation (A.3). This inequality can be written as

$$\mu/\phi_0 \geq -Ed^f\,. \tag{A.19}$$

which is always true as μ/ϕ_0 are both positive.

A.2 Proof of proposition 2

The proof of part a) was already part of the proof of proposition 1 in section A.1. When M rises, the schedule $f(x)$ in figure A.1 shifts down, so the new equilibrium has a higher x. Then from the first equilibrium condition in equation (14) the solution for the offshore exchange rate $E(M)$ is given implicitly by

$$E(M)(1 + \phi'(x(M))) = \beta R^m\,. \tag{A.20}$$

Taking derivatives with respect to M and using the implicit function theorem

$$E'(M)(1 + \phi'(x)) + E\phi''(x)x'(M) = 0\,, \tag{A.21}$$

where we slightly abuse notation and define $E'(M)$ as the partial derivative of the function $E(M)$. Since $x'(M) > 0$ and we assumed that $\phi''(x) \geq 0$ and $1 + \phi'(x) > 0$ it follows that $E'(M) \leq 0$. This proves part a).

Turning to part b), first recall the definition of the two elasticities

$$\varepsilon_m \equiv \frac{\partial \ln(m)}{\partial R^m} = \frac{\beta}{Ex\phi''(x)}\,, \tag{A.22}$$

$$\varepsilon_d \equiv \frac{\partial \ln(d^h)}{\partial R^d} = \frac{\beta\delta D}{\mu}\,. \tag{A.23}$$

Then, differentiating equation (A.20) with respect to E and recalling that $x = \exp(\ln(M) -$

$\ln(D)$) gives

$$\frac{d\ln(M)}{dE} - \frac{d\ln(D)}{dE} = -\frac{1+\phi'(x)}{Ex\phi''(x)} = -\frac{\beta R^m}{E^2 x\phi''(x)} = -\frac{R^m \varepsilon_m}{E}, \tag{A.24}$$

where the second equality uses equation (A.20) to replace out $\phi'(x)$ and the third equality uses the result for ε_m in equation (A.22) and the property $\psi'(x) = -x\phi''(x)$.

Finally, start with equation (15) written as

$$E\psi(x)(D - d^f) = \mu\,. \tag{A.25}$$

Differentiate this with respect to E and use the sterilization condition that d^f is constant (as well as recall that $\delta = (D - d^f)/D$) to get

$$\psi(x)\delta D + E\psi'(x)x\left[\frac{d\ln(M)}{dE} - \frac{d\ln(D)}{dE}\right]\delta D + E\psi(x)D\left(\frac{d\ln(D)}{dE}\right) = 0\,. \tag{A.26}$$

Now, combining equations (A.25) and (A.23), we learn that $\psi(x) = \beta/(E\varepsilon_d)$. From equation (A.22), we also know that $\psi'(x) = -\beta/(E\varepsilon_m)$. Replacing out $\psi(x)$ and $\psi'(x)$ in the expression then gives:

$$\frac{\delta}{E} - \frac{\delta x\varepsilon_d}{\varepsilon_m}\left[\frac{d\ln(M)}{dE} - \frac{d\ln(D)}{dE}\right] + \frac{d\ln(D)}{dE} = 0\,. \tag{A.27}$$

Replace out for $d\ln(D)/dE$ using equation (A.24) and simplify to get:

$$\frac{\delta}{E} + \frac{\delta x\varepsilon_d R^m}{E} + \frac{d\ln(M)}{dE} + \frac{R^m\varepsilon_m}{E} = 0\,. \tag{A.28}$$

Rearranging delivers the result in part b) of the proposition.

A.3 Proof of proposition 3

For part a), recall Figure A.1 in Section A.1. From the definition of $f(x)$ in equation (A.2), an increase in μ shifts $f(x)$ upward. Since f is increasing and g is decreasing in x, the unique intersection between f and g moves to a lower value of x. From equation (14),

$$E = \frac{\beta R^m}{1+\phi'(x)},$$

and because $\phi'(x)$ is increasing in x with $\phi'(1) = 0$, a lower x implies a lower $1 + \phi'(x)$ and hence a higher E. Thus, following an increase in μ, the onshore currency depreciates relative to the offshore currency (E rises), which proves part a).

Part b) is a restatement of proposition 2a.

For part c), go back to the definition of the $f(x, \lambda)$ and $g(x, \lambda)$ functions in equations (A.2)-(A.3) in section A.1 now making explicit that they depend on λ because the liquidity functions depend on liquidity policies: $\phi(x, \lambda)$ and $\psi(x, \lambda)$. From the chain rule of differentiation

$$\frac{\partial g(x,\lambda)}{\partial \lambda} = \left[\frac{W\beta}{(1-\psi(x))^2}\right]\frac{\partial \psi(x)}{\partial \lambda} \tag{A.29}$$

$$\frac{\partial f(x,\lambda)}{\partial \lambda} = \frac{1}{y_T - B^{\$}}\left[-\left(\frac{\mu}{\psi(x)^2}\right)\frac{\partial \psi(x)}{\partial \lambda} + \left(\frac{\beta R^m M}{x[1+\phi'(x)]^2}\right)\frac{\partial \phi'(x)}{\partial \lambda}\right]. \tag{A.30}$$

Next, go back to equation (14) making explicit the dependence on λ:

$$E(\lambda)(1 + \phi'(x(\lambda), \lambda)) = \beta R^m \tag{A.31}$$

This equation implicitly defines the equilibrium exchange rate E as a function of liquidity policies λ. Differentiate with respect to λ by using the implicit function theorem:

$$E'(.)(1+\phi'(.)) + E(.)\phi''(.)x'(.) + E(.)\frac{\partial \phi'(.)}{\partial \lambda} = 0\,, \tag{A.32}$$

and rearranging yields

$$E'(\lambda) = \underbrace{-\frac{E(.)}{1+\phi'(.)}}_{<0}\left[\underbrace{\phi''(.)}_{\geq 0}x'(.) + \frac{\partial \phi'(.)}{\partial \lambda}\right]. \tag{A.33}$$

Since $E > 0$ and $1 + \phi'(.) > 0$, the sign of $E'(\lambda)$ is the opposite of the sign of the bracketed term.

Then, consider the first set of liquidity policies. They raise the costs of supplying deposits $\partial\psi(x, \lambda)/\partial\lambda > 0$. From the expressions in equations (A.29)-(A.30), in figure A.1 the $f(x, .)$ schedule shifts down, and the schedule $g(x, .)$ shifts up. Therefore, the new equilibrium must imply a rise in x (while the impact on $E^{\$}$ may be ambiguous). Turning to equation (A.33), since $x'(.) > 0$, then $E'(\lambda) < 0$, and so the offshore exchange rate falls, as stated in the proposition.

The second set of policies lower the marginal benefit of reserves, so they shift the demand for reserves from banks down $\partial\phi'(x,\lambda)/\partial\lambda > 0$. Then, from equations (A.29)-(A.30), the $f(x,.)$ schedule shifts up while the $g(x,.)$ is unchanged. The equilibrium x falls.

Turning to equation (A.33), since $x'(.) < 0$, then the first term in the square brackets is negative, while the second term is positive. The effect is ambiguous because while this policy lowers the demand for reserves per unit of deposits, it also leads the banks to issue more deposits. If the increase in that marginal benefit is sufficiently large, the second term dominates and the offshore exchange rate falls $E'(\lambda) < 0$. The necessary condition for the second term to dominate is

$$\phi''(.)x'(.) + \frac{\partial\phi'(.)}{\partial\lambda} > 0\,. \tag{A.34}$$

Applying the implicit function theorem to the equilibrium condition $f(x,\lambda) = g(x,\lambda)$, we can solve for $x'(.)$

$$x'(.) = -\frac{\left[\frac{\partial f(x,\lambda)}{\partial\lambda} - \frac{\partial g(x,\lambda)}{\partial\lambda}\right]}{f'(.) - g'(.)}. \tag{A.35}$$

Using equations (A.29)-(A.30) and focusing just on a change $\partial\phi(x,\lambda)/\partial\lambda > 0$, equation (A.35) becomes

$$x'(.) = -\frac{\left(\frac{\beta R^m M}{x[1+\phi'(x)]^2}\right)\frac{\partial\phi'(x)}{\partial\lambda}}{(y_T - B^{\$})\left(f'(.) - g'(.)\right)}, \tag{A.36}$$

which confirms that $x'(.)$ is indeed negative. Substituting this expression into the initial condition and rearranging shows that the necessary condition for $E'(\lambda) < 0$ is

$$(y_T - B^{\$})\left(f'(.) - g'(.)\right) > \left(\frac{\beta R^m M\phi''(.)}{x[1+\phi'(x)]^2}\right). \tag{A.37}$$

Since $g'(.) \leq 0$ (equation (A.7)) and inspecting the expression for $f'(.)$ (equation (A.11)), we know that $(y_T - B^{\$})f'(.) > \left(\frac{\beta R^m M}{x[1+\phi'(x)]^2}\right)$. Hence, $E'(\lambda) < 0$. This completes the proof.

A.4 Proof of proposition 4

Consider a change in the exchange rate in response to a money demand shock $d\mu$ that is only partially accommodated by a rise in dM so that

$$dE = dM\frac{dE}{dM} + d\mu\frac{dE}{d\mu} > 0\,. \tag{A.38}$$

From the proofs of proposition 2 and 3, we know that

$$\frac{dE}{dM} = -\frac{E}{xR^m\varepsilon_m}\frac{dx}{dM}, \quad \text{and} \quad \frac{dE}{d\mu} = -\frac{E}{xR^m\varepsilon_m}\frac{dx}{d\mu}\,. \tag{A.39}$$

Therefore

$$dE = -\frac{\varepsilon_m^{-1}}{xR^m}\left(dM\frac{dx}{dM} + d\mu\frac{dx}{d\mu}\right) \equiv -\frac{\varepsilon_m^{-1}}{xR^m}dx \tag{A.40}$$

and so we know that $dE > 0$ then $dx < 0$.

Recall the threshold for a liquidity surplus $\bar{\omega} = (\rho - x)/(1-\rho)$. If $dx < 0$, then $d\bar{\omega} > 0$. Also, recall the definition of market tightness in equation (22). Since θ is increasing in $\bar{\omega}$ then market tightness increases in response to the shock $d\theta > 0$. This completes the proof of part a).

Part b) holds immediately as $r^f(\theta)$ is increasing in θ by assumption.

Finally, for part c), total discount window borrowing is $-(1-\Psi_-(\theta))\int_{-1}^{\bar{\omega}} s(\omega)d\Omega(\omega)$. Since $\Psi_-(\theta)$ is decreasing in θ and the total value of deficits, $-\int_{-1}^{\bar{\omega}} s(\omega)d\Omega(\omega)$, is increasing in $\bar{\omega}$, then discount window borrowing increases in response to the shock. This completes the proof.

Online appendix

B Data appendix

All data were last accessed on July 24, 2025 unless stated otherwise.

FX data: Daily FX data were sourced from LSEG Datastream. The CNYUSD MID daily price has ticker TDCNYSP, the CNHUSD MID daily price has ticker TDCNHSP. The CNHCNY exchange rate is the ratio of the two.

Interbank rates: All interbank rates were sourced from LSEG Datastream. As an example, for 3-month tenors we use the onshore ticker CHIB3MO and offshore ticker HIBOR3M.

PBoC CNH Bills: The tender announcements and auction results from the PBoC's issuance of CNH bills were hand-collected from press releases from the HKMA and PBoC.

HKMA RMB Facilities: Data on the usage of the HKMA's RMB facilities were downloaded directly from the HKMA's website, via an API. The usage statistics are available at 9am, 11am, 2pm and 4pm Hong Kong time. We take the maximum of the intraday figures when computing a daily series.

Deposits: Total customer deposits in CNH in Hong Kong banks are sourced from the HKMA via LSEG Datastream (ticker HKCUSTOTA). The onshore money supply is customer deposits at mainland Chinese banks sourced from the PBoC via Datastream (ticker CHCNBXLLM).

The balance sheet of the offshore clearing bank: The balance sheet of the offshore clearing bank, Bank of China (Hong Kong) Limited, is sourced from BankFocus at a quarterly frequency in US dollars. We convert it to CNH using the exchange rate at the date of the accounts. The relevant item is deposits from banks on the liabilities side.

Ratio of domestic to total CNH deposits in Hong Kong (δ): To calibrate δ we use the restricted version of the BIS locational banking statistics, accessed via the Bank of England. We proxy D as deposit liabilities of Hong Kong banks to non-bank customers not denominated in HKD, USD, EUR, JPY, CHF, or GBP. The idea here is that, once those currencies are excluded, that CNH accounts for the bulk of the residual. The residual series tracks the official HKMA series for CNH deposits, which lacks a locational breakdown, closely. We measure domestic deposits (d^h) as deposits to customers in Hong Kong or in mainland China, and foreign deposits (d^f) are crossborder deposits from other jurisdictions.

We compute $\delta = d^h/(d^h + d^f)$; the figure used of 0.85 is approximately the average of all quarters between 2016 and 2024.

Hong Kong banks' sources of liquidity: To calibrate the effective capital flow tax, it is necessary to compute the ratio of interbank borrowing and discount window borrowing for the CNH business of banks in Hong Kong. Again, we use the restricted version of the BIS locational banking statistics, accessed via the Bank of England to do this. We measure the local liabilities of Hong Kong banks not denominated in HKD, USD, EUR, JPY, CHF, or GBP, as above, the idea being that CNH accounts for the bulk of the residual. We then take the ratio of borrowing from the central bank to borrowing from other banks.

B.1 The HKMA facilities

The HKMA runs five CNH facilities, all using repurchase agreements. Three of them settle on the day so that banks have immediate access to CNH liquidity. They are: a dedicated liquidity facility for primary liquidity providers, an intraday repo facility, and an overnight repo facility. The other two are at term with a $T+1$ settlement cycle and a maturity of one day and one week, respectively.

The primary liquidity providers' facility allows each of the nine provider banks access to ¥2bn available either intraday or overnight. The rates and collateral requirements on the facility are institution-specific and are not disclosed, but they are on preferential terms.

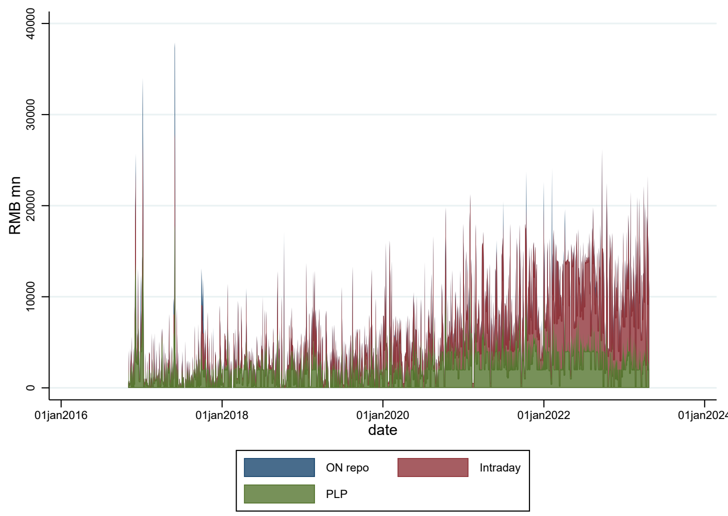
The intraday repo facility allows authorized institutions to borrow up to ¥20bn (prior to July 22, 2022, it was ¥10bn) against a range of debt securities at a penalty rate equal to the average of the three most recent overnight CNH HIBOR fixings plus 25bp (prior to July 22, 2022, it was plus 50bp). Interest is charged on a per minute basis and the repo converts automatically to the overnight facility if it is not repaid by 5am on the next calendar day.

The overnight repo facility allows authorized institutions to borrow up to ¥20bn (prior to July 22, 2022, it was ¥10bn) on the same terms as the intraday facility. The two facilities have separate limits so in principle the HKMA could lend ¥20bn intraday and ¥20bn overnight to the same bank, and then convert the intraday borrowing into overnight for a total of ¥40bn. Overnight borrowing is repaid by 2pm the following trading day.

Figure B.1 shows the daily usage of the different types of liquidity facilities offered by the HKMA. The overnight repo is rarely used, likely because intraday borrowing converts into overnight borrowing automatically.

The term facilities operate on a $T+1$ settlement cycle and are funded using the HKMA's

Figure B.1: Usage of the HKMA on-demand lending programs



Note: Maximum daily usage of the HKMA's RMB liquidity facilities by trading day, November 2016 to May 2023.

swap line with the PBoC as opposed to from the HKMA's deposits at the clearing bank. Interest rates on these are not disclosed apart from a reference to prevailing market rates, nor is information on their usage. This suggests these facilities are designed to be used as a backstop if the other facilities are exhausted and the HKMA needs to channel emergency liquidity from the PBoC.

C Additional empirical results

C.1 Maintaining the peg in times of depreciations versus appreciations

Over the course of our sample, the CNY-USD exchange rate went through episodes of appreciation and depreciation. Figure C.1(a) illustrates this, with the periods of CNY depreciation shaded.

We now ask whether the management of the CNY-CNH exchange rate peg varies during these different periods by re-estimating equation (18) using our instrument while allowing the coefficient of interest to vary depending on whether the overall exchange rate is depreciating or appreciating. Figure C.1(b)-(d) presents the results. Panel (a) shows the persistence of our innovation to money demand, that is, the deviation of the central parity rate from the previous close, split into the two different regimes. As can be seen, when the overall CNY exchange rate is depreciating, money demand shocks persist for longer. That is, any deviation between the CNY exchange rate and the central parity rate is longer lasting. One interpretation of this is that Chinese authorities attempt to smooth the CNY-USD exchange rate more when it is depreciating than when it is appreciating.

In spite of this difference, panel (b) shows that the response of the CNY-CNH exchange rate to shocks returns to parity with the same delay in both states. This would suggest that there is a larger monetary response in the offshore market to stabilize the peg in episodes of depreciations rather than appreciations. However, panel (c) shows this is not the case. Rather, there is a larger monetary expansion when the overall exchange rate is appreciating. This indicates that it is instead liquidity policies that are more heavily used in times when the overall CNY exchange rate is depreciating and monetary expansions when it is appreciating.

This asymmetry may reflect the design of the policy tools themselves. The PLP facility is bounded below by zero: the HKMA can choose to inject less liquidity, but it does not have a tool to drain liquidity from the market. Hence, the monetary response will appear muted in episodes when the shocks are more likely to require a contraction. At a lower frequency, the PBoC can drain liquidity by issuing more bills offshore. Indeed, it raised its target bill stock toward the end of the sample and again in 2024, coincident with depreciation episodes. This is not picked up in the high-frequency empirical analysis.

An alternative interpretation is that during episodes of depreciation the credibility of the CNY-CNH peg is imperfect. The theoretical analysis in appendix D.1 shows that, with imperfect credibility, monetary variation has a diminished effect on the exchange rate. In that case, it may be preferable to use liquidity policies.

C.2 Monthly variation and time series identification of the elasticity of demand for CNH reserves

Monetary data on the stock of CNH deposits are only available monthly. In this appendix, we switch to a monthly frequency and first confirm that the behavior of CNH deposits aligns with our description of how the market works, and second use monthly variation to estimate an alternative value for ε_m.

As a starting point, we consider whether episodes of CNH appreciation compared to CNY are also ones where CNH money (deposits) is relatively scarce compared to CNY money. Table C.1 regresses the relative growth rate of the money stock in CNY and CNH on the lagged change in the exchange rate at a monthly frequency. Money is measured using customer deposits in RMB at banks operating on the mainland and in Hong Kong.

Of course, both D and E are endogenous with respect to other variables. At the monthly frequency, the PBoC and the HKMA vary the CNH reserves that back these sight deposits in response to shocks, and private banks respond to shocks to the demand for CNH liquidity. Table C.1 shows that the associated regression coefficient is large. However, with only 71 monthly observations, precision is weak, and the estimate is only statistically significant at the 10% level.

Figure C.2 plots the data behind the regression in table C.1 to confirm the weak relation. Columns (2) and (3) in the table also confirm that the entire correlation is driven by the supply of CNH, as expected. Consistent with the idea that the offshore system insulates onshore monetary policy, the money stock in CNY, for mainland China, is not explained by the CNY-CNH exchange rate and is instead driven by other factors.

We now turn to how the monthly data can be used to get an alternative read on ε_m. The demand for reserves in equation (10) implies that in equilibrium:

$$\left(\frac{E'}{E}\right) R^m = R(1 + \phi'(m/d, \lambda)) \,. \tag{C.1}$$

In the neighborhood of a peg and assuming stable interest rates, the elasticity of M with respect to $\frac{E'}{E}$ is equal to $\varepsilon_m = (x\phi''(.))^{-1}$.

If one assumes that policy will adjust the money supply to maintain a stable x (and so ε_m is also stable), D is proportional to M, so the elasticity of D with respect to E should also match ε_m. We measure E and have an instrument for it from the shocks to the demand for deposits discussed in section 5. Figure C.3 shows the estimates from a local projection of $\log(D_t)$ on $\Delta \log(E_t)$ and controls, including lagged deposits, at a monthly frequency using the monthly average of our daily measure of money demand shocks as an instrument for the exchange rate.

This estimate of ε_m comes with three important caveats. First, we only have a monthly measure of D. Therefore, we need more observations, and so the estimates come from an extended sample from the inception of CNH in 2010 until August 2023, which includes the pre-reform periods. Second, identification is less tight with this specification. We do not have a monthly measure of shifts in money supply that can be used as a control. Recall that part of our case for the exogeneity of the instrument was the high frequency of our data. At a monthly frequency, a supply response is more likely. So identification is less sharp with this specification. Third, the estimates rely on x being stable which may not be the case if λ also varies or if China alters the desired implicit tax τ.

With these caveats in mind, we find that the impact of a money demand shock that raises the exchange rate by 1% is to raise deposits by 47% on average over the first six months, consistent with $\varepsilon_m = 47$ and matching the estimate from Section 4.5.

C.3 Miscellaneous results and robustness checks

Impact of the 2015-2017 reforms: Figure C.4 shows the impact of the reforms. The left panel shows the improvement in maintaining the peg: the standard deviation of the exchange rate fell by half and the half-life of deviations from parity went from six days to one day. The right panel shows the velocity of CNH money, by dividing all CNH RTGS transactions in Hong Kong in one year by the average stock of CNH deposits. The 2015–2017 reforms significantly increased this velocity, which averaged 431 between 2018 and 2022, and brought about a period of stability.

Intraday results: Figure C.5 shows the persistence of the deviation of the offshore exchange rate within the day by regressing the intraday exchange rate on the previous close at different intraday time periods. Deviations from parity are not reversed at an intraday frequency, which supports the daily frequency used in the main text.

Figure B.1 already showed the total daily usage of the facilities that are settled within the day. The HKMA also publishes data on drawings from the PLP and the intraday facilities at different points in time during the day. Figure C.6 shows the projections of the drawings from both the PLP and the liquidity intraday facility during the day on the exchange rate at the close of the previous day. The pattern shows that most of drawings occur at 11am and are then stable throughout the day.

Further results on exogenous monetary expansions: Figure C.7 presents results regarding monetary expansions (equivalent to those presented in Figure 2b) for one-week interbank rates on average (panel c) and for the exchange rate and interbank rates for each individual bill roll-off (panels (b) and (d)).

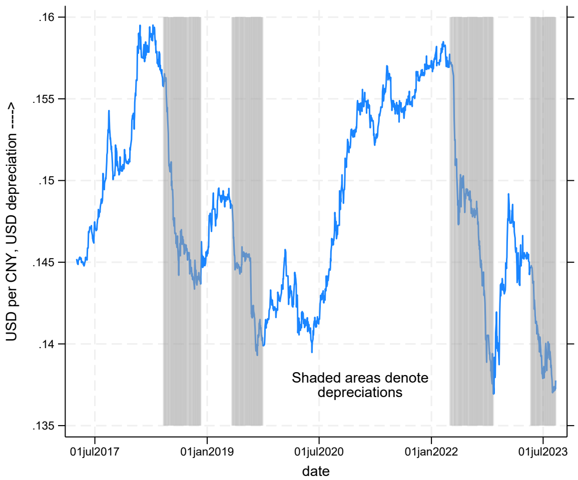
Further results on exogenous money demand shocks: Figure C.8 is the equivalent of Figure 4 panel (b), but using only drawings between 11am and 4pm to reflect that the central parity rate is announced at 11am. Figure C.9 shows how the CNY-CNH exchange rate reacts to the money demand shock, this figure gives us the result, used in Section 5, that 0.83 of the exchange rate response to a money demand shock decays within five days. Table C.2 presents the coefficients behind the estimates in Figure 4, including control variables, at horizon $h = 0$.

Table C.3 presents the subscription rate results using the exchange rate on the day of the auction.

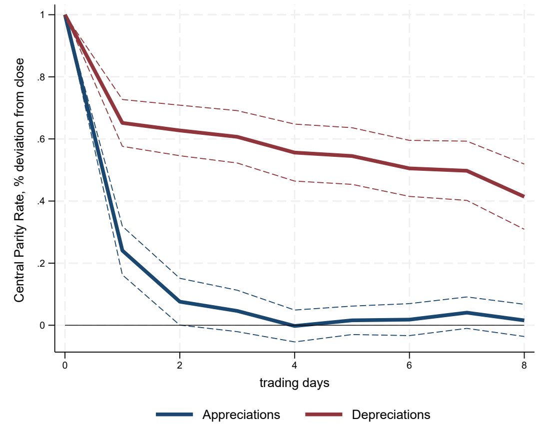
Figure C.10 shows the flows of RMB from offshore to onshore during the 2015–16 episode. They also show a contraction, in line with figure 7.

Figure C.1: Differences in dynamic responses to a money demand shock between appreciations and depreciations.

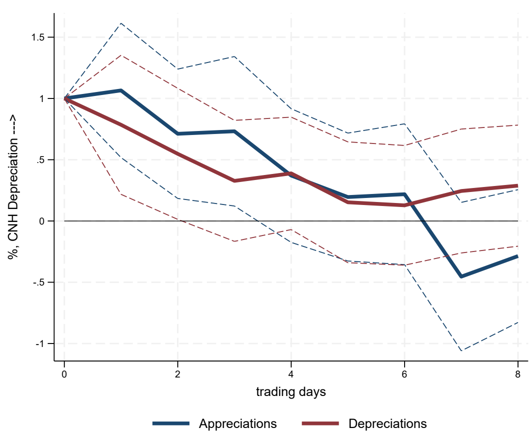
(a) The CNY-USD exchange rate: split by appreciations and depreciations.



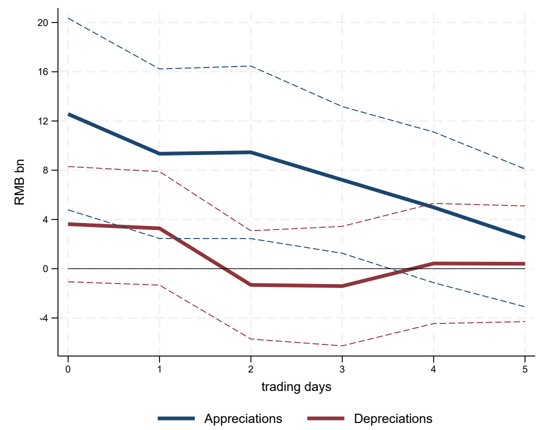
(b) Response of $\log \bar{E}^{\$}_t / E^{\$}_{t-1}$ to itself.



(c) Response of E to money demand



(d) Response of money supply



Note: Panel (a): CNY-USD Mid-exchange rate, periods of CNY depreciation shaded. Panel (b)-(d): Estimates of equation (18) where β_h is interacted with a dummy for whether the overall CNY exchange rate is depreciating or appreciating against the USD. The sample includes all trading days between April 2017 and August 2023. The confidence intervals use White robust standard errors, following Montiel Olea and Plagborg-Moller (2021). Panel (b): sets $z_{t+1} = \log \bar{E}^{\$}_{t+1} / E^{\$}_t$ and includes z_t as the focal variable in the regression equation (dropping $\Delta \log (E_t)$). Estimation by least squares. Panel (c): as figure **??** except estimates of β_h split by a dummy indicating appreciation/depreciation. Panel (d): as figure 4(b) except estimates of β_h split by a dummy indicating appreciation/depreciation.

Table C.1: The correlation between the exchange rate and the relative stock of money

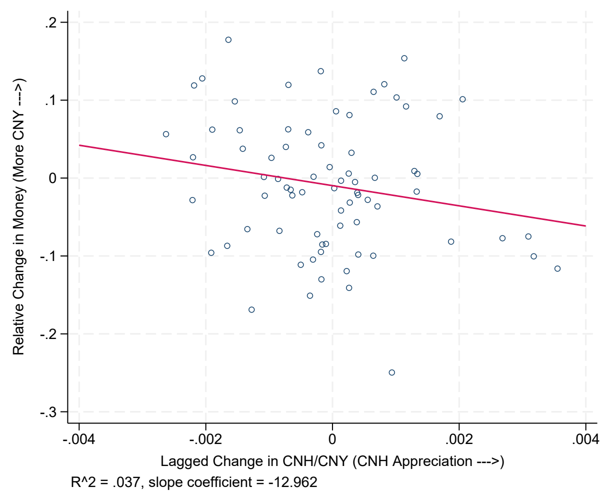
	$\Delta\left(\log(D_t^{\text{CNH}}) - \log(D_t^{\text{CNY}})\right)$	$\Delta \log(D_t^{\text{CNH}})$	$\Delta \log(D_t^{\text{CNY}})$
$\Delta \log E_{t-1}$	-12.63*	12.99*	0.35
	(7.3)	(6.9)	(2.7)
N	71	71	71
R^2	0.036	0.044	0.000

Heteroskedasticity robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

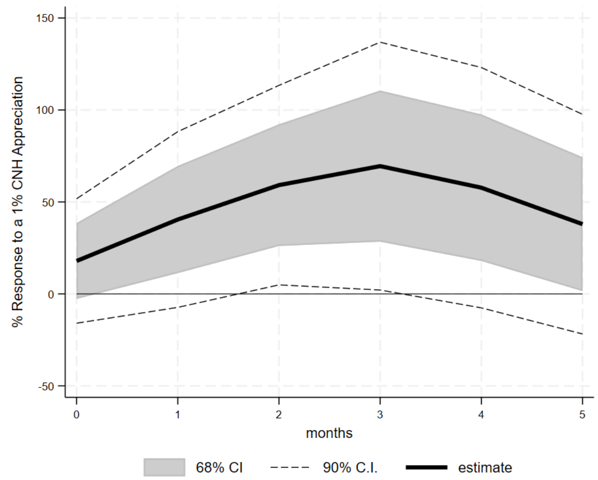
Note: OLS regressions of money growth ()offshore and onshore) on the lagged monthly change in the CNY-CNH exchange rate. See the notes to figure C.2 for a description of the data.

Figure C.2: The CNY-CNH exchange rate and the relative stock of monies



Note: Scatter plot of the lagged monthly change in the CNY-CNH exchange rate (horizontal axis) against relative money growth offshore and onshore (vertical axis). The horizontal axis show the average of the logarithm of the exchange rate across all trading days in the month, so an increase is a CNH appreciation. Onshore money, $\log(D_t^{\text{CNY}})$, is the logarithm of onshore bank customer deposits. Offshore money, D_t^{CNH}, is the value of deposits in Hong Kong banks. The vertical axis is $\log(D_t^{\text{CNY}}) - \log(D_t^{\text{CNH}})$, the difference between onshore and offshore money. The sample is monthly, April 2017–April 2023.

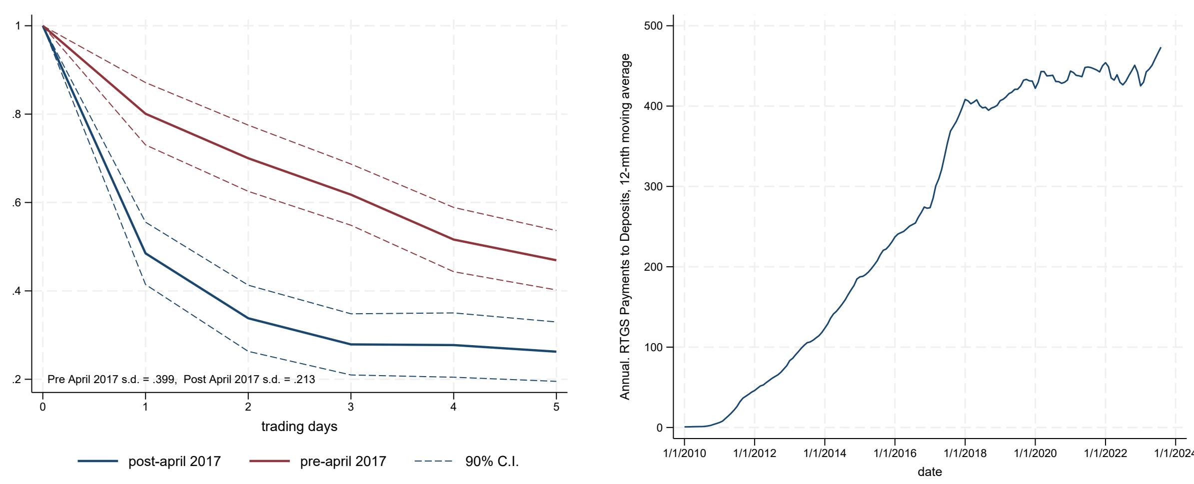
Figure C.3: Monthly response of deposits to money demand shocks



Note: Estimates of local projection in equation (18) by instrumental variables with $\log(D_t)$ at a monthly frequency left-hand side, the variable of interest is $\Delta \log(E_t)$ instrumented with the monthly average of our daily measure of money demand shocks. Controls include three lags of $\log(E_t)$, $\log(D_t)$ and the equivalents for onshore deposits. The sample is all monthly observations between October 2010 and August 2023. The confidence intervals are constructed using White robust standard errors.

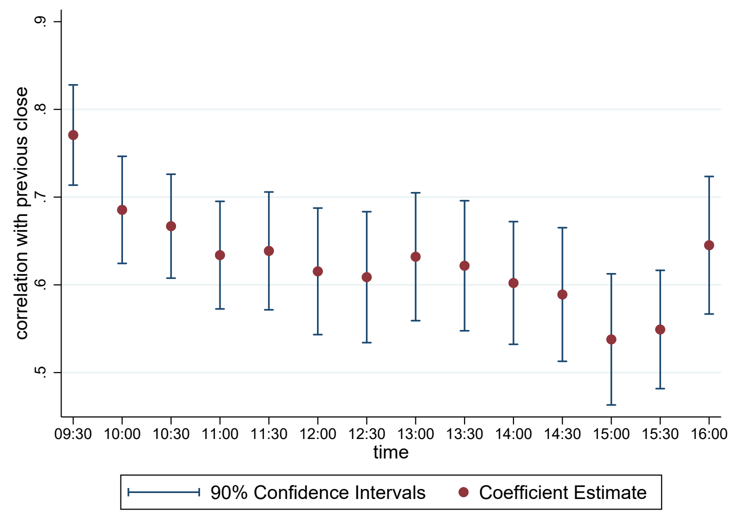
Figure C.4: The impact of the 2017 reforms

(a) Autocorrelograms of $\log(E)$ pre/post 2017 **(b)** CNH velocity



Note: Panel (a) compares the daily autocorrelograms in $\log(E_t)$ between October 2010 and March 2017 in red, and between April 2017 and May 2023 in blue. Panel (b) shows the ratio of annualized payments from the RTGS system to the stock of CNH deposits.

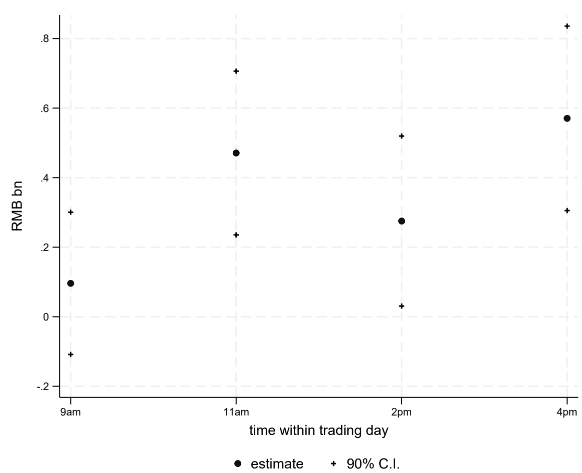
Figure C.5: Intraday CNY-CNH exchange rate persistence



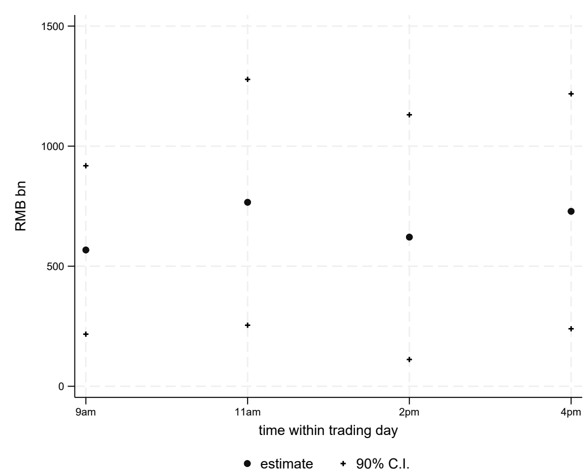
Note: Correlation coefficients between the CNY-CNH exchange rate at close and observations on the following trading day at 30-minute intervals.

Figure C.6: Usage of the HKMA lending programs during the day

(a) PLP lending

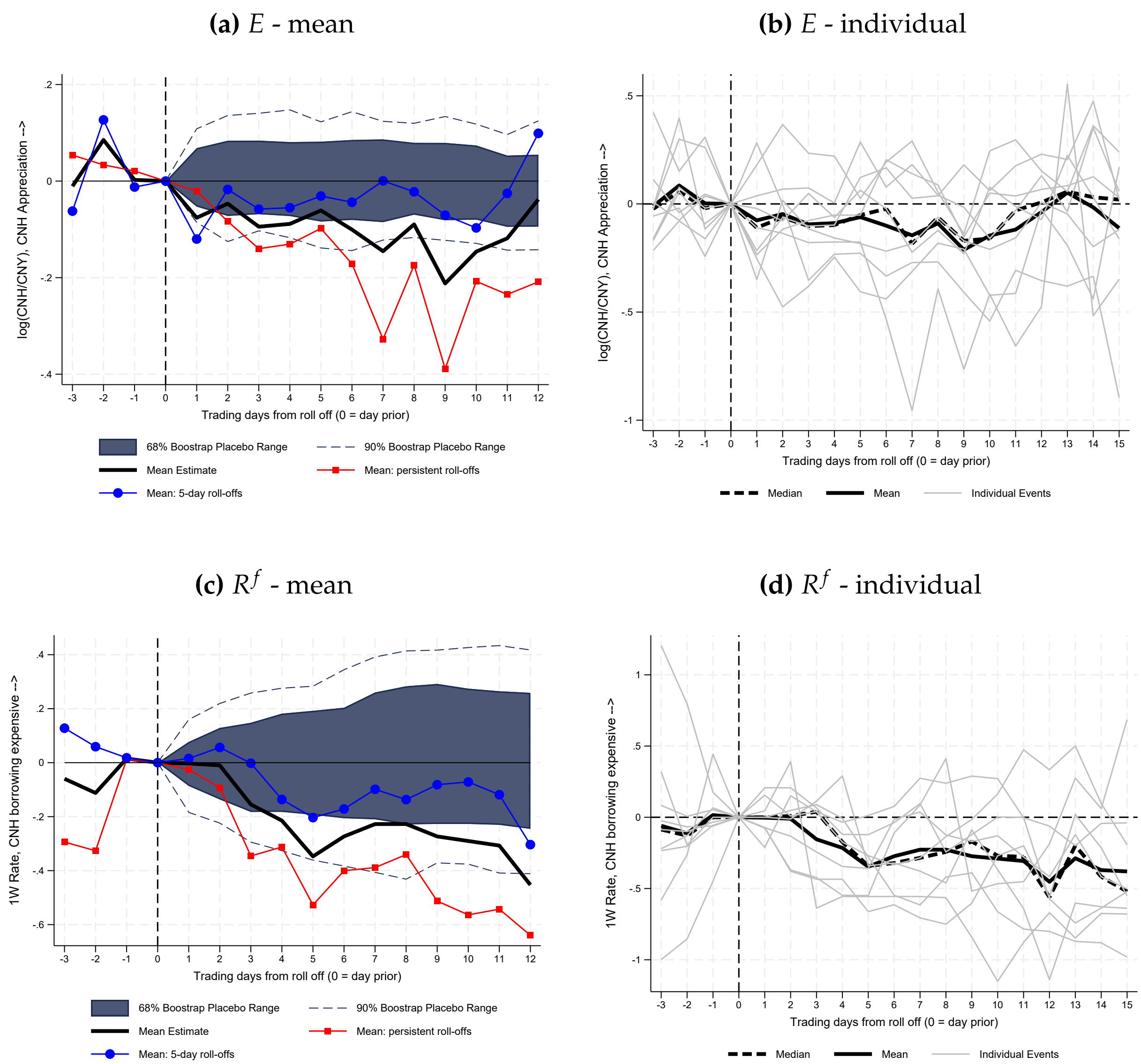


(b) Intraday facility



Note: Regressions of drawings from (a) the PLP liquidity facility and (b) the intraday facility at 9am, 11am, 2pm and 4pm on the deviation between the CNY central parity rate and the CNY-USD exchange rate at the previous day's close. The confidence intervals are constructed using White robust standard errors.

Figure C.7: Response of exchange rates and interest rates to money supply shocks



(a) E - mean

(b) E - individual

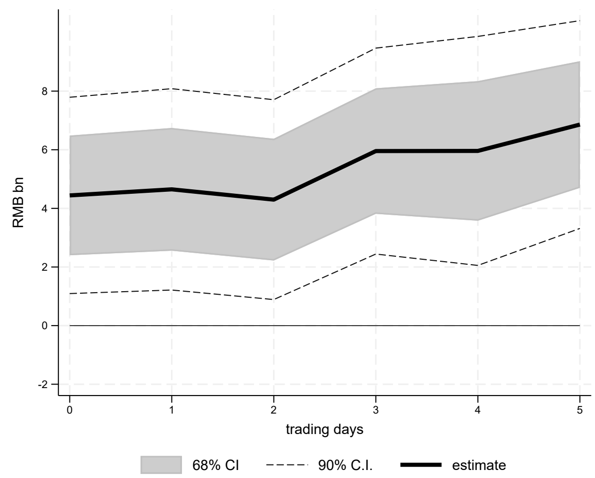
(c) R^f - mean

(d) R^f - individual

Note: Panel (a) is identical to figure 2b): 100 times the cumulative change in the log of the daily exchange rate from the trading day prior to the bill roll-off, averaged over the events, and bootstrapped placebo intervals from drawing 10,000 random samples of an equivalent number of event dates between 1 July 2020 and 1 November 2021, excluding dates that overlap with the original event window and schedule announcements. Panel (b) then breaks the average in panel (a) into individual events. Panel (c) is equivalent to panel (a) except it shows the response of CNH one-week interbank rates relative to the trading day prior to the bill roll-off, averaged across the monetary expansion events. Panel (d) then shows the interbank rate response split by individual events.

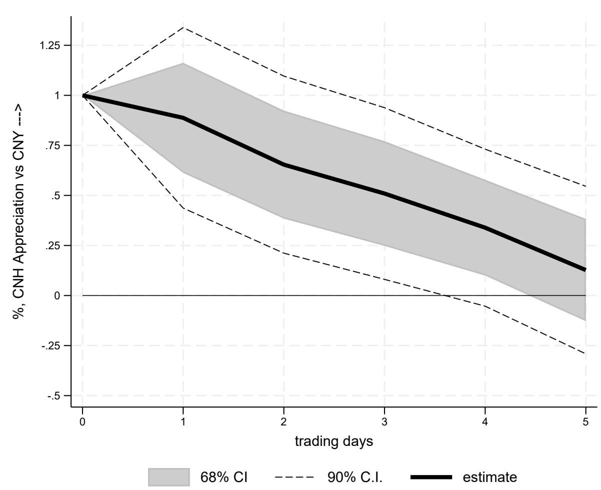
Figure C.8: Response of HKMA PLP facility to a money demand shock after 11am

(a) Local Projection - Instrumental Variables



Note: Same as figure 4, but using only the flows between 11am and 4pm, inclusive.

Figure C.9: CNY-CNH exchange rate after an expansion in money demand



Note: The figure shows estimates of equation (18) replacing z_t with $\log(E_{t+h})$, dropping the corresponding control, and instrumenting with our exogenous shift of money demand shocks. The confidence intervals use White-robust standard errors, following Montiel Olea and Plagborg-Moller (2021). The sample covers April 2017 to August 2023.

Table C.2: Complete coefficient estimates behind the local projection estimates of the effect of E on M.

	OLS	IV
	(1)	(2)
$\Delta \ln(E_t)$	0.5383*	5.2264***
	(0.289)	(2.015)
$\ln(E_{t-1})$	0.0987	-1.6899*
	(0.264)	(0.952)
PLP Facility Drawing$_{t-1}$	0.3369***	0.3052***
	(0.035)	(0.039)
Intraday Facility Drawing$_{t-1}$	0.0410**	0.0584***
	(0.016)	(0.020)
Offshore 1W Interbank Rate$_{t-1}$	0.1747	0.0878
	(0.226)	(0.201)
Onshore 1W Interbank Rate$_{t-1}$	-1.4896***	-1.7331***
	(0.274)	(0.300)
Offshore O/N Interbank Rate$_{t-1}$	0.0205	0.0104
	(0.147)	(0.127)
Onshore O/N Interbank Rate$_{t-1}$	0.2861*	0.3779**
	(0.161)	(0.172)
T	1521	1521
Kliebergen-Paap F-stat		22.10

Heteroskedasticity robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: Estimates of equation (18) for PLP drawings at horizon $h = 0$. The sample includes all trading days between April 2017 and August 2023. The confidence intervals use White-robust standard errors, following Montiel Olea and Plagborg-Moller (2021). Column (1) estimates the equation using least squares, whereas Column (2) uses an instrumental-variables specification with the deviation of the CNY/USD exchange rate from the trading band limit as an instrument for E_t .

Table C.3: Bill Auction Subscription Rates

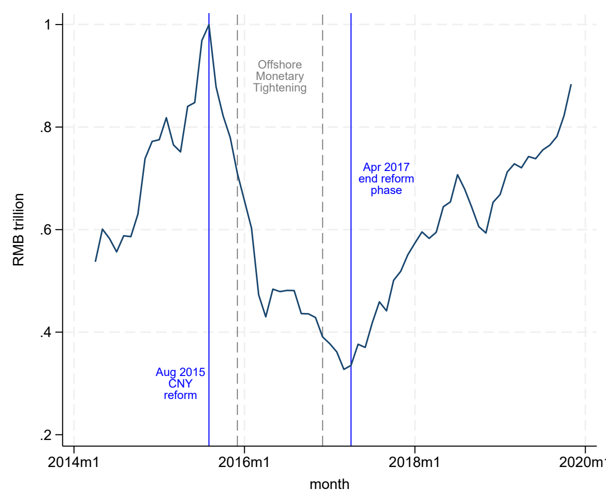
Bill maturities	All	1Y	6M	3M
	(2)	(4)	(6)	(8)
$\log(E_t)$	-1.28	-1.68*	-2.68**	-1.45
	(0.85)	(0.92)	(1.12)	(0.95)
Number of Auctions	35	19	16	19
R^2	0.142	0.335	0.131	0.324

Heteroskedasticity robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, ***$p < 0.01$

Note: Same as table 2 but using the exchange rate on the day of the auction.

Figure C.10: RMB flows from offshore to onshore



Note: Plots the quantity of RMB flows from offshore to onshore through the Chinese current account between January of 2014 and December of 2019.

D Additional theoretical results

This appendix presents several extensions of the baseline model presented in Section 3.2. Appendix D.1 considers the case of a non-credible peg. Appendix D.2 introduces a frictional onshore market to show that the implicit tax wedge in proposition 1 can be negative. Appendix D.3 introduces situations where the Home economy experiences capital flight to show that monetary tightening can be used to tame outflows in these circumstances. Appendix D.4 considers a fully dynamic model to derive the response to an anticipated monetary expansion consistent with our empirical exercise regarding bill roll-offs.

D.1 Non-credible pegs

Throughout the paper, we maintained the assumption that $E' = 1$. In this appendix, we consider how our model's conclusions would change if this assumption were not the case. To begin, reconsider equation (14), the equilibrium in the reserves market. No longer imposing $E' = 1$, this becomes

$$E' R^m = RE\left[1 + \phi'(x, \lambda)\right] \tag{D.1}$$

Equation (15), the market clearing condition in the deposit market, is still

$$\frac{\mu}{E\,\psi(x, \lambda)} = \frac{M}{x} - E^{-1}\left(E^{\$}(B^{\$} - y_T) + \iota\right) \tag{D.2}$$

Finally, repeating the steps from the main text of the paper, but now without imposing $E' = 1$, yields the following expression for the balance of payments condition in equation (16):

$$E^{\$}(x) = \frac{1 + R^{-1}\left[1 - \psi(x, \lambda)\right]^{-1}}{1 + R^{\$-1}\frac{y'_T}{y_T}} \frac{\iota}{y_T}. \tag{D.3}$$

An equilibrium is a solution of these three equations for E, x, and $E^{\$}$ as before, but now also for E'.

The missing equation is for the expected dynamics of the exchange rate. Assume that the deviations from parity persist, so that $E' = E^{\alpha}$ with $\alpha \in [0, 1)$. The baseline model has $\alpha = 0$. If $\alpha > 0$, the peg is only partially credible and the exchange rate is expected to move only somewhat toward parity next period. If $\alpha = 1$, today's exchange rate will not revert to parity.

For the moment, focus on the case where $0 < \alpha < 1$. Rewrite equation (D.1) as

$$E^{\alpha-1} R^m = R\left[1 + \phi'\left(x, \lambda\right)\right] \tag{D.4}$$

Substituting $E' = E^\alpha$ and $E^{\alpha-1} = \dfrac{R\left[1 + \phi'\left(x, \lambda\right)\right]}{R^m}$ into equations (D.2)-(D.3) to substitute out E, we obtain

$$\left(\frac{R^m}{R\left[1 + \phi'\left(x, \lambda\right)\right]}\right)^{\frac{1}{1-\alpha}} \frac{M}{x} + \left(E^{\$} y_T - \iota - E^{\$} B^{\$}\right) = \frac{\mu}{\psi\left(x, \lambda\right)} \tag{D.5}$$

and

$$E^{\$} = \frac{1 + R^{-1}\left[1 - \psi(x, \lambda)\right]^{-1}}{1 + R^{\$-1} \frac{y'_T}{y_T}} \frac{\iota}{y_T} \tag{D.6}$$

The equilibrium for $(E^{\$}, x)$ now solves this system of two equations.

A property of the system is that, conditional on the offshore reserve-to-deposit ratio x, $E^{\$}$ is unaffected by the perceived persistence of E, since α does not enter equation (D.6) above. The intuition for this property of the model is that the persistence of E distorts the returns earned by both banks and depositors in the offshore market. Hence, the gross change in the offshore exchange rate ends up being irrelevant for the return on offshore deposits in onshore terms and so the return on foreign saving for domestic households is unaffected.

An implication of this property is that Proposition 1 is still valid. The additional term in equation (D.5) does not affect the existence and uniqueness of the equilibrium. Nor does it affect the equivalence result.

What α influences is how a change in the monetary base affects conditions in the offshore money market. To see this, imagine that $B^{\$}$ is set to ensure that d^f is approximately zero ($\delta = 1$), so that equation (D.5) can be written as

$$M = \left(\frac{R\left[1 + \phi'\left(x, \lambda\right)\right]}{R^m}\right)^{\frac{1}{1-\alpha}} \frac{\mu x}{\psi\left(x, \lambda\right)} \tag{D.7}$$

consider a sterilized change dM just as in Proposition 2, such that $B^{\$}$ adjusts to absorb the resulting capital inflows. At an initial equilibrium close to parity, $E = \left(\frac{R^m}{R\left[1+\phi'(x,\lambda)\right]}\right)^{\frac{1}{1-\alpha}} = 1$. Therefore:

$$\frac{dx}{d\log(M)} = \left[\frac{1}{x} + \frac{\varepsilon_d}{\varepsilon_m} + \frac{1}{(1-\alpha)\,R^m\,x\,\varepsilon_m}\right]^{-1} \tag{D.8}$$

This expression shows that with a higher α, a given increase in M causes x to rise by less. In words, a more persistent expected deviation from parity dampens the transmission of an increase in money to the reserve-to-deposit ratio in the offshore market.

Moreover, taking the total derivative of equation (D.4), we obtain

$$\frac{d\log(E)}{d\log(M)} = -\left[1 + R^m(1-\alpha)\left(\varepsilon_m + x\varepsilon_d\right)\right]^{-1} \tag{D.9}$$

For $0 \leq \alpha < 1$, a monetary expansion still depreciates the exchange rate (the derivative is negative). However, the higher is α, the less of the current depreciation in the exchange rate is expected to be offset by the next period. This makes deposits cheaper to issue since they will be repaid in a currency that is worth relatively less. As a result, the interest on deposits R^d rises by relatively more in response to an increase in money M, and so does the quantity of deposits D. This dampens the rise in x, the reserve–deposit ratio. As x rises by less, offshore reserves are scarcer and the offshore money market loosens by less. Therefore, the liquidity wedge and the effective capital flow tax move less in response to a given change in M.

As α tends to 1, banks no longer anticipate any future appreciation in response to a monetary expansion. In the limit, the supply of offshore deposits rises one-for-one with the money supply, so x remains stable. Because the offshore exchange rate depreciates one-for-one, the value of the offshore money stock in onshore units is unchanged, and the same is true of the onshore value of offshore deposits. Effectively, the offshore currency has been re-denominated. In this limiting case, money is neutral, and there are no other economic consequences from the increase in the money supply.

Going further, if $\alpha > 1$, then a depreciation today is expected to continue tomorrow, so deposit supply rises even further and x can decline in response to a monetary expansion.

The bottom line is that the offshore currency must have a partially credible peg ($0 \leq \alpha < 1$) for monetary expansions to loosen the offshore money market. If there is no prospect of a return to parity, then monetary policy can be ineffective or even counter-productive. Moreover, the effective capital flow tax is solely a function of x, and the transmission of M to x is diminishing in α. Diminished credibility therefore hinders the ability of policy to implement changes in the effective tax by altering the monetary base. Hence, alongside Gresham's law considerations, maintaining a credible peg is also beneficial from the perspective of allowing the active management of the country's external position.

D.2 Negative wedges through a frictional onshore market

In the model in the main text, policy subsidized capital outflows and discouraged inflows. This manipulates $E^{\$}$ upward (weakens the domestic currency) and induces a positive net foreign asset position. It is consistent with the general perception of Chinese policy being geared towards making the country a net saver that runs a current account surplus.

However, this also implied that the implicit wedge that could be implemented, τ was non-negative, so the equivalence result only held for capital flow subsidies, but not taxes. This was partly a consequence of the onshore financial market being frictionless. In this appendix, we introduce equivalent liquidity frictions into the onshore market and show that the wedge will depend on the relative scarcity of onshore versus offshore money, so it can be positive or negative. This setup still relies on the country being a net saver and, in the absence of capital controls, it would have private capital inflows at the prevailing foreign exchange rate. In the next appendix we will extend the model further to allow for capital flight.

Changes to the household's problem: The household no longer holds onshore bonds directly but instead holds onshore deposits d^o, issued by banks that pay $R^{d,o}$ in onshore units. Like their offshore equivalent, onshore deposits offer a convenience benefit. The household objective is

$$\ln(c_{NT}) + \iota \ln(c_T) + \mu \ln(d^h) + \mu^o \ln(d^o) + \beta \left(\ln(c'_{NT}) + \iota \ln(c'_T)\right), \tag{D.10}$$

with corresponding budget constraints

$$E^{\$} c_T + E d^h + c_{NT} + d^o = E^{\$} y_T + y_{NT}, \tag{D.11}$$

$$E^{\$'} c'_T + c'_{NT} - R^{d,o} d^o - E' R^d d^h = E^{\$'} y'_T + y'_{NT} + T'. \tag{D.12}$$

The household's problem gives rise to the following optimality conditions (under a credible peg $E' = 1$):

$$\mu = \left(E - \beta R^d\right) d^h, \tag{D.13}$$

$$\mu^o = \left(1 - \beta R^{d,o}\right) d^o. \tag{D.14}$$

Note that, since the household no longer holds bonds directly, we are no longer guaranteed that the onshore bond interest rate is $R = \beta^{-1}$.

Changes to the banks' problem: As before, banks can invest in the onshore bond market, earning return R. But now, they can fund those bond holdings by raising deposits both onshore and offshore. Onshore deposits expose banks to an onshore liquidity cost $\phi\left(\frac{m^o}{d^o}, \lambda^o\right)$ per deposit raised, which can be reduced by holding onshore reserves, m^o, that offer a return $R^{m,o}$. The term λ^o captures onshore liquidity policies. The function $\phi\left(\frac{m^o}{d^o}, \lambda^o\right)$ shares the properties of its offshore equivalent discussed in the main text.

The bank's objective is to maximize profits

$$Rb^l + R^{m,o}m^o - R^{d,o}d^o + E'\left(R^m m - R^d d\right) \quad \text{s.t.} \tag{D.15}$$

$$b^l + m^o + \phi\left(\frac{m^o}{d^o}, \lambda^o\right) d^o + Em + E\phi\left(\frac{m}{d}, \lambda\right) d = d^o + Ed \tag{D.16}$$

This results in two new optimality conditions, again imposing $E' = 1$

$$R^{m,o} = R\left[1 + \phi'\left(x^o, \lambda^o\right)\right], \tag{D.17}$$

$$R^{d,o} = R\left[1 - \psi\left(x^o, \lambda^o\right)\right], \tag{D.18}$$

where $x^o = \frac{M^o}{D^o}$ and $\psi\left(x^o, \lambda^o\right)$ is the marginal liquidity cost of issuing an onshore deposit, defined analogously to its offshore equivalent. The optimality conditions for offshore variables remain the same as in the baseline model (equations (10) and (11)).

Other agents: As in the baseline model, foreigners hold offshore deposits subject to the same interest parity condition. The government acts in the same way except that it also issues onshore reserves and is the recipient of the onshore liquidity costs paid by banks.

Equilibrium: The addition of frictions onshore does not change the equations that govern the country's external position. Equation (16) still holds, repeated here for convenience

$$E^{\$} = \frac{1 + R^{-1}(1 - \psi(x,\lambda))^{-1}}{1 + R^{\$-1}\frac{y_T'}{y_T}} \frac{\iota}{y_T}. \tag{D.19}$$

Likewise, the offshore reserve and deposit market conditions are the same as before, in equations (14) and (15).

However, now R is endogenous and depends on the tightness of onshore monetary conditions, via equation (D.17). The onshore deposit market clearing condition can be obtained by combining onshore household deposit demand, equation (D.14); bank reserve demand, equation (D.17), and bank deposit supply, equation (D.18). All combined this gives

$$\frac{\mu^o x^o}{M^o} = 1 - \beta \frac{R^{m,o}[1 - \psi(x^o, \lambda^o)]}{1 + \phi'(x^o, \lambda^o)}. \tag{D.20}$$

An equilibrium is now a tuple $(E^{\$}, E, x, x^o, R)$ that solves equations (14)-(16), (D.14) and (D.20). Note that the equilibrium has a recursive structure. Onshore policy variables (M^o, λ^o) pin down onshore financial conditions (x^o, R) through equations (D.14) and (D.20). In turn, R, coupled with (M, λ) solves for external variables $(E^{\$}, E, x)$ via equations (14)-(16) in exactly the same manner as in the baseline model.

The wedge: Substituting equations (D.17) and (14) into the expression for $E^{\$}$ gives

$$E^{\$} = \frac{1 + (R^{m,o})^{-1}(1 + \phi'(x^o, \lambda^o))(1 - \psi(x,\lambda))^{-1}}{1 + R^{\$-1}\frac{y_T'}{y_T}} \frac{\iota}{y_T}. \tag{D.21}$$

One should interpret $R^{m,o}$ as the frictionless onshore interest rate since, if onshore liquidity were satiated, we would have $R^{m,o} = R$. Then, contrasting equation (D.21) with equation (5), the wedge in this extended model can be written as

$$1 + \tau = \underbrace{(1 + \phi'(x^o, \lambda^o))}_{\text{Onshore wedge}} \times \underbrace{(1 - \psi(x,\lambda))^{-1}}_{\text{Offshore wedge}}, \tag{D.22}$$

The implicit capital flow tax/subsidy can now be decomposed into the product of two terms, one relating to liquidity in the onshore market, and the other to liquidity in the offshore market. From the proof of Proposition 1, we know that the equilibrium offshore wedge is decreasing in the offshore reserve-to-deposit ratio, x. Likewise, since $\phi''(x^o, \lambda^o) > 0$, then an increase in the onshore liquidity raises the wedge. Therefore, expanding liquidity offshore or contracting it onshore has an equivalent effect on $E^{\$}$. Moreover, and most importantly given our goal, since $\phi'(x^o, \lambda^o)$ is negative, a negative τ can be implemented by having sufficiently scarce reserves onshore (x^o low) relative to offshore (x high). In that case, the onshore wedge $(1 + \phi'(x^o, \lambda^o))$ becomes small enough that the overall product falls below one.

An issue with this approach is that it partly subordinates onshore policy, through the onshore market interest rate R, to achieving external objectives. This could be seen as defeating the purpose of having a parallel-currency system in the first place. However, $\tau < 0$ is most likely to be relevant in situations when the economy experiences capital outflows $d^f < 0$, rather than inflows. In the next appendix, we extend the model to allow for outflows and show how the offshore system can be adapted to implement a negative τ in those circumstances.

D.3 Capital flight

In the baseline model, we assumed that in the absence of capital account restrictions, the domestic economy would attract private capital from abroad. This is equivalent to $d^f \geq 0$. The policies we studied were directed towards boosting net savings and therefore diminishing the offsetting inflows represented by d^f.

An economy experiencing capital flight would have $d^f < 0$. We think of capital flight as foreign banks issuing offshore deposits to lend abroad and thereby extracting capital from Home. The relevant on funding cost on these positions becomes R^d plus a liquidity cost. As in the main text, we maintain the assumption $E' = 1$.

Foreign banks: Foreign banks are competitive and operate offshore. They raise d^f from the offshore deposit market, buy offshore reserves m^f, and invest abroad earning the return $R^\$$ in foreign units. Now, d^f is an external asset of the domestic economy rather than a liability, so it switches sign in the country's balance of payments. Foreign banks face a liquidity cost $\phi^f\left(\frac{m^f}{d^f}, x, \lambda^f\right)$ per deposit where, as before, x is the aggregate reserve-to-deposit ratio, $\frac{m^f}{d^f}$ is the equivalent ratio specific to foreign banks and λ^f denotes liquidity policies targeted at foreign banks. Reserves still yield R^m in offshore units.

The profits of foreign banks in offshore units are

$$\frac{E^{\$'}}{E^\$} \times E \times R^\$ b^f + R^m m^f - R^d d^f \quad \text{s.t.} \tag{D.23}$$

$$b^f + m^f + \phi^f\left(\frac{m^f}{d^f}, x, \lambda^f\right) d^f = d^f. \tag{D.24}$$

Maximization of profits together with free entry yields two interest parity conditions from foreign banks' optimal decisions in the offshore deposit and reserve markets

$$R^d = \frac{E^{\$'}}{E^{\$}} ER^{\$} \left[1 - \psi^f \left(\frac{m^f}{d^f}, x, \lambda^f \right) \right], \tag{D.25}$$

$$R^m = \frac{E^{\$'}}{E^{\$}} ER^{\$} \left[1 + \phi^{f'} \left(\frac{m^f}{d^f}, x, \lambda^f \right) \right], \tag{D.26}$$

where $\psi^f(.) \equiv \phi^f(.) - \frac{m^f}{d^f} \phi^{f'}(.)$ is the net liquidity cost per unit of deposit for foreign banks. Combining equations (D.25) and (D.26) yields the modified interest parity condition:

$$R^d = \frac{R^m [1 - \psi^f(\frac{m^f}{d^f}, x, \lambda^f)]}{1 + \phi^{f'}(\frac{m^f}{d^f}, x, \lambda^f)}. \tag{D.27}$$

Home banks: They operate as before, except that foreign banks now have an impact on their liquidity costs through their participation in the offshore market. Home banks raise offshore deposits, d^l and can invest in domestic bonds (b^l) and offshore reserves (m^l). As before, raising a deposit comes with an average liquidity cost $\phi^l \left(\frac{m^l}{d^l}, x, \lambda^l \right)$ per unit raised, and $\psi^l(.)$ denotes the marginal cost. The bank's problem is to maximize profits in onshore units:

$$Rb^l + R^m m^l - R^d d^l \quad \text{s.t.} \tag{D.28}$$

$$b^l + Em^l + E\phi^l \left(\frac{m^l}{d^l}, x, \lambda^l \right) d^l = Ed^l \tag{D.29}$$

This gives rise to a similar set of interest parity conditions as in the baseline model

$$R^d = ER[1 - \psi^l \left(\frac{m^l}{d^l}, x, \lambda^l \right)], \tag{D.30}$$

$$R^m = ER[1 + \phi^{l'} \left(\frac{m^l}{d^l}, x, \lambda^l \right)]. \tag{D.31}$$

Other agents: Home households act as before and their deposit supply is given by

$$x \equiv \frac{M}{D} = \left(E - \frac{R^d}{R} \right) \frac{M}{\mu}. \tag{D.32}$$

The government acts in the same way as before, and is the recipient of all the liquidity costs.

Market clearing for money: The two types of banks jointly clear the reserve market $M = m^f + m^l$ and the deposit market $D = d^l + d^f$, where D denotes total deposits raised. As this version of the model is designed to analyze episodes of capital flight we abstract from the inflows of deposits from foreign investors (these would be nil in equilibrium).

Balance of payments: The balance of payments conditions in the first and second period now are

$$\left(E^{\$}y_T - \iota\right) - E^{\$}B^{\$} - E\left(1 - \frac{m^f}{d^f}\right)d^f = 0, \tag{D.33}$$

$$\iota - E^{\$'}y_T' - \left(R^d + \phi^f\left(\frac{m^f}{d^f}, x, \lambda^f\right)\right)d^f - R^{\$}E^{\$'}B^{\$} + R^m m^f = 0 \tag{D.34}$$

In comparison to the baseline model, now d^f is an external asset rather than a liability, m^f is an external liability, and the liquidity cost paid by foreign banks accrues to the Home country.

Equilibrium: Equilibrium in this modified model is a tuple $\left(E, E^{\$'}, E^{\$}, R^d, x, d^f, d^l, m^f, m^l\right)$ such that offshore reserve and deposit markets clear; bank and household optimality conditions—equations (D.25)-(D.32)—are satisfied; and the two balance-of-payments conditions in equations (D.33)-(D.34) hold.

The wedge: Rederiving the τ wedge in this model requires a few extra steps. First, combining equations (D.27), (D.33) and (D.34) we can obtain a similar inter-temporal balance of payments condition to the baseline model

$$E^{\$} = \frac{\left(\frac{E^{\$'}}{E^{\$}}R^{\$}\right)^{-1} + 1}{1 + R^{\$-1}\frac{y_T'}{y_T}}\frac{\iota}{y_T}. \tag{D.35}$$

Then, combining the deposit market optimality conditions of domestic and foreign banks, equations (D.25) and (D.30), yields

$$\frac{E^{\$'}}{E^{\$}}R^{\$} = R\left[1 - \psi^l\left(\frac{m^l}{d^l}, x, \lambda^l\right)\right]\left[1 - \psi^f\left(\frac{m^f}{d^f}, x, \lambda^f\right)\right]^{-1}. \tag{D.36}$$

Combining equations (D.35) and (D.36) gives the following expression

$$E^{\$} = \frac{1 + R^{-1}\left[1 - \psi^l\left(\frac{m^l}{d^l}, x, \lambda^l\right)\right]\left[1 - \psi^f\left(\frac{m^f}{d^f}, x, \lambda^f\right)\right]^{-1}}{1 + R^{\$-1}\frac{y'_T}{y_T}}\frac{\iota}{y_T}. \tag{D.37}$$

Compared to the equivalent expression in the baseline—equation (16)—there is an extra term of the opposite sign capturing the liquidity position of foreign banks.

Consider an equilibrium where $\lambda^l = \lambda^f$, and returns are such that $\frac{m^l}{d^l} = \frac{m^f}{d^f}$. Then symmetry means $\psi^l\left(\frac{m^l}{d^l}, x, \lambda^l\right) = \psi^f\left(\frac{m^f}{d^f}, x, \lambda^f\right)$ and the implicit capital flow tax is nil. If capital outflows increase and d^f starts rising then we have $\psi^f > \psi^l$. This is equivalent to a tax on capital outflows. Tightening the money supply offshore raises this implicit tax and discourages capital flight.

In contrast, again starting from the symmetric point, a relative reduction in outflows, i.e. d^f falling, raises $\psi^l(x, \frac{m^l}{d^l})$ relative to $\psi^f(x, \frac{m^f}{d^f})$ and we go back to the situation where outflows are subsidised. Cutting M, holding d^f fixed, will raise the value of this subsidy. This is close to the situation studied in the main text.

Thinking of symmetric liquidity cost functions is useful to build intuition, but in practice the policymaker has tools to shift the liquidity cost functions on a relative basis so that $\lambda^l \neq \lambda^f$. It can change reserve requirements on onshore versus foreign assets or their value as collateral when accessing liquidity facilities. It can allow more generous flows of liquidity from onshore financial markets for institutions investing offshore, or give them preferential access to liquidity facilities. In this regard, the point at which $\psi^l = \psi^f$, so that any further capital outflow results in the implicit tax switching sign to discourage capital flight, is also a policy choice.

Discussion: This setup raises two further questions: first, can the case of capital inflows, as in the main text, and outflows, as in this appendix, be combined into one model? And, second, what is the interpretation of the foreign banks introduced here?

On the first point, the answer is yes. Imagine that d^f denotes net lending from offshore to the rest of the world (as in this appendix). The case where $d^f < 0$ such that there are capital inflows corresponds to the baseline model (although the sign of d^f has flipped). Foreign banks are inactive and so $\psi^f\left(\frac{m^f}{d^f}, x, \lambda^f\right)$ is nil. Foreign investors instead buy offshore deposits. Equilibrium condition (16) still holds and the relevant interest parity condition with foreign currency is given by equation (8). The offshore system effectively subsidises foreign saving (or, equivalently, taxes inflows) as described in the main text.

As d^f rises and switches sign, foreign investors exit the deposit market and foreign banks raise deposits instead, $\psi^f\left(\frac{m^f}{d^f}, x, \lambda^f\right)$ is positive. As d^f becomes sufficiently large such that the economy is experiencing capital flight, the implicit wedge switches from operating as a tax on inflows to a tax on outflows as described above.

Figure D.1 visualises the combined model graphically showing how the τ wedge implicit in equations (16) and (D.37) varies with d^f, holding the stock of offshore deposits held by Home households fixed. The figure shows the switch in sign in the effective tax. Moreover, a monetary tightening results in a general steepening of the tax schedule: boosting the tax on outflows in the case of capital flight and the subsidy on external saving in the case of large inflows. In this way offshore monetary policy can stabilize a country's external position in both directions.

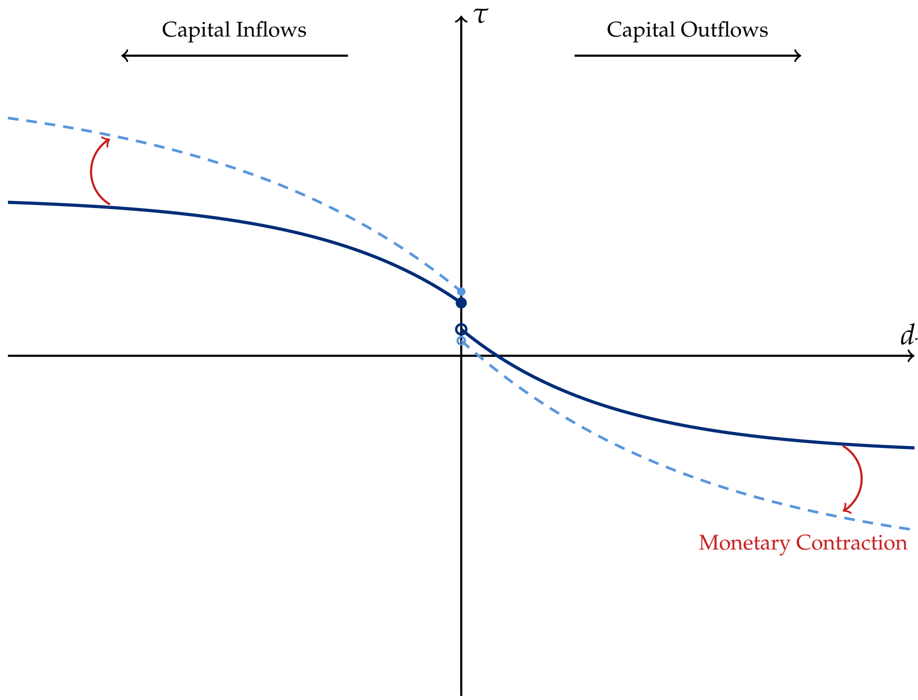
Turning to the second question, on the interpretation of foreign banks in the model, first note that we do not require foreign banks to directly engage in speculation. Imagine that capital flight takes place through speculators who are betting on depreciation of the offshore currency, borrowing in the offshore market and lending in foreign currency. If such loans are funded through foreign banks raising money offshore, then this is isomorphic to the model presented here. More broadly, while the label foreign banks is useful to fix ideas, they need not be completely separate institutions. All that is required is a wedge that segments the balance sheet between offshore and foreign lending so that the two assets are funded differently. For example, it could be that home banks have a separate business line engaging in lending in foreign currency that raises deposits separately and the two separate lines are unable to perfectly hedge each other against liquidity risk.

D.4 Anticipation effects

The changes in the money supply due to the bill roll-offs used in Section 4.4 were predictable weeks ahead and therefore led to predictable movements in the exchange rate. In the model, we assumed iid shocks and a credible peg so that $\mathbb{E}(E') = 1$. Here, we drop these assumptions and consider a dynamic setup where monetary shocks are anticipated.

Time runs from $t = 0, \ldots, \infty$. To simplify the analysis, we assume $B_t^{\$}$ adjusts to set $d_t^f = 0$. The model is then separable: the foreign exchange rate, $E_t^{\$}$, does not affect conditions in the offshore market. We can solve in closed form for the onshore-offshore exchange

Figure D.1: Illustration: implicit capital-flow wedge, τ as a function offshore flows, d^f.



Note: dashed (light-blue) line shows the tightened schedule. Red arrows indicate the direction of the monetary contraction effect.

rate E_t and offshore deposits D_t over time that jointly solve the two equations

$$E_t R = \mathbb{E}_t(E_{t+1}) \frac{R^m}{1 + \phi'(M_t/D_t)}$$

$$\mu D_t^{-1} = E_t \psi \left(\frac{M_t}{D_t} \right)$$

taking as given the path for M_t, and holding the other policy and exogenous variables fixed.

Assume that at date 0 we learn that $M_t = \bar{M}$ at all dates with the exception of $M_T = \bar{M} + \Delta$ where Δ is the transitory bill roll-off. Moreover, the peg is credible in that with $\bar{M}$ from T onwards, for $t > T$, the equilibrium D_t is such that $\phi'(\bar{M}/D_t) = \frac{R^m}{R} - 1$ and so $E_t = 1$. The question is what happens to the exchange rate between 0 and T.[56]

[56] $E_t^\$$ will also adjust to the shock, but given the role played by $B^\$$, this does not affect D_t and E_t.

At date T, using the equations:

$$E_T R = \frac{R^m}{1 + \phi'((\bar{M} + \Delta)/D_T)}$$
$$\mu D_T^{-1} = E_T \psi \left(\frac{\bar{M} + \Delta}{D_T} \right)$$

As in Proposition 2, the higher is Δ, the lower is E_T and the greater is D_T. Call this value $E^* < 1$.

At date $T - 1$ instead, the equation for the exchange rate is

$$E_{T-1} R = E^* \frac{R^m}{1 + \phi'(\bar{M}/D_{T-1})}$$

If $E^* = 1$, then we would have $E_{T-1} = 1$ at the intersection as well. But since $E^* < 1$, then the reserve-market condition in (E, x) space is shifted down proportionally while the deposit-market condition is unchanged. Given their slopes, this means that at the equilibrium $E^* < E_{T-1} < 1$.

At date $T - 2$ the same logic applies: E_{T-2} satisfies $E_{T-2} R = E_{T-1} \frac{R^m}{1+\phi'(\bar{M}/D_{T-2})}$, and by similar reasoning $E^* < E_{T-2} < E_{T-1} < 1$. By backwards induction, the same applies all the way to date 0.

In other words, when the announcement happens at date 0, the offshore currency loses value (E falls). We only have two announcement dates and no guarantee that the announcements were not timed to coincide with other shocks. Therefore, we cannot test for these effects in the data.

Then, at date T when the bills roll off, the increase in the supply of reserves makes the exchange rate move further in the same direction (E falls again). This is anticipated and yet does not violate arbitrage. The reason is that this expected subsequent appreciation between T and $T + 1$ (as $E_T < 1$ but $E_{T+1} = 1$) just offsets the reduction in the liquidity premium of reserves. The return, inclusive of those liquidity costs, is indeed the same across dates and there is no scope for arbitrage. Or, in other words, money is not a pure financial asset, and its demand slopes downwards.

It is this depreciation of the offshore currency relative to the onshore currency (fall in E) that we test for and find evidence for in the data.

D.5 Calibrating the capital flow tax

This appendix discusses how we calibrate the model to compute our empirical estimate of the tax wedge τ.

Combining equations (14) and (16), and comparing to the canonical model of a capital flow tax given in equation (5) reveals

$$(1+\tau) = (1-\psi(x,\lambda))^{-1}. \tag{D.38}$$

Since $\psi(x,\lambda) = \phi(x,\lambda) - \phi'(x,\lambda)\, x$, the question is how to calibrate $\phi(.)$ and its derivative. At the outset, we conduct the calibration under the simplifying assumption that $W^m = 0$ and $W^d = 0$.

Recall the microfoundations of $\phi(x,\lambda)$ given by equation (23):

$$\begin{aligned}\phi(x,\lambda) = & -\Psi_+(\theta)\, r^f(\theta) \int_{\bar{\omega}}^{\infty} \frac{s(\omega)}{d}\, d\Omega(\omega; W^d) \\ & - \left[\Psi_-(\theta)\, r^f(\theta) + \left(1-\Psi_-(\theta)\right) r^z\right] \int_{-1}^{\bar{\omega}} \frac{s(\omega)}{d}\, d\Omega(\omega; W^d),\end{aligned} \tag{D.39}$$

where: (i) ω is a withdrawal shock, (ii) θ is market tightness (endogenous in equilibrium but taken as given by the bank), and (iii) $s(\omega) \equiv m - \rho d + \omega(1-\rho)\, d$ is the bank's ex-post surplus liquidity with required reserves pinned down by parameter ρ.

As before, there is a threshold realization $\bar{\omega} \equiv \frac{-x+\rho}{1-\rho}$ such that if $\omega < \bar{\omega}$ the bank has a liquidity deficit. The proportion of deficits financed in the interbank market is given by $\Psi_-(\theta)$, where interbank funding is charged at a spread $r^f(\theta)$ over R^m; similarly, the proportion of surpluses lent in the interbank market is given by $\Psi_+(\theta)$. Deficits not covered by interbank borrowing are financed through the central bank liquidity facility (discount window) at a spread r^z. Unlent surpluses simply return the interest on reserves, R^m.

Under the assumption that $W^m = 0$, in equilibrium, the total amount borrowed in the interbank market must equal the amount lent. Hence,

$$-\Psi_+(\theta) \times \int_{\bar{\omega}(x)}^{\infty} \frac{s(\omega)}{d} d\Omega(\omega; W^d) - \Psi_-(\theta) \times \int_{-1}^{\bar{\omega}(x)} \frac{s(\omega)}{d} d\Omega(\omega; W^d) = 0. \tag{D.40}$$

Equations (D.39) and (D.40) together imply that we can write

$$\phi(x,\lambda) = -\left(1-\Psi_-(\theta)\right) r^z(\theta) \int_{-1}^{\bar{\omega}(x)} \left[x - \rho + \omega(1-\rho)\right] d\Omega(\omega; W^d). \tag{D.41}$$

In addition, since the bank takes interbank market conditions θ as given, its marginal benefit of liquidity is given by

$$-\phi'(x,\lambda) = \Psi_+(\theta) r^f(\theta) + \Omega(\bar{\omega})(1-\Psi_-(\theta)) r^z + \Omega(\bar{\omega})(\Psi_-(\theta) - \Psi_+(\theta)) r^f(\theta). \quad \text{(D.42)}$$

where we drop dependencies of $\bar{\omega}$ on x for compactness.

This yields the final expression for the wedge that we shall calibrate

$$\psi(x,\lambda) = -\left(1-\Psi_-(\theta)\right) \times r^z(\theta) \times \int_{-1}^{\bar{\omega}(x)} \left[\omega\left(1-\rho\right) - \rho\right] d\Omega(\omega) + \\ x r^f(\theta) \left(\Psi_+(\theta) + \Omega(\bar{\omega}; W^d)(\Psi_-(\theta) - \Psi_+(\theta))\right). \quad \text{(D.43)}$$

Mapping to empirical analogues. At first glance, equation (D.43) looks intractable. However, the expressions within it can be mapped to observable money-market aggregates.

In particular, let W be total discount window lending, F be total interbank lending and D be deposits. Then

$$\left(1-\Psi_-(\theta)\right) = \frac{W}{W+F} \quad \text{(D.44)}$$

and

$$\int_{-1}^{\bar{\omega}} \frac{s(\omega)}{d} d\Omega(\omega) \equiv \int_{-1}^{\bar{\omega}} \left[x - \rho + \omega\left(1-\rho\right)\right] d\Omega(\omega) = -\frac{W+F}{D}. \quad \text{(D.45)}$$

The above can be re-expressed as

$$\frac{W+F}{D} = -x\Omega(\bar{\omega}) - \int_{-1}^{\bar{\omega}} \left[\omega\left(1-\rho\right) - \rho\right] d\Omega(\omega), \quad \text{(D.46)}$$

which means we have the following expression for the first term in equation (D.43)

$$-\left(1-\Psi_-(\theta)\right) r^z(\theta) \int_{-1}^{\bar{\omega}(x)} \left[\omega\left(1-\rho\right) - \rho\right] d\Omega(\omega) = \left[\frac{W}{D} + \frac{W}{W+F} x\Omega(\bar{\omega})\right] r^z(\theta). \quad \text{(D.47)}$$

Turning to the second term in equation (D.43), interbank market clearing condition (D.40) implies that

$$\frac{F}{D} = \Psi_+(\theta) \int_{\bar{\omega}(x)}^{\infty} \frac{s(\omega)}{d} d\Omega(\omega; W^d). \quad \text{(D.48)}$$

Deducting the expression for deficits given by (D.45) from integral of $s(\omega)/d$ over the complete support of ω yields

$$\int_{\bar{\omega}(x)}^{\infty} \frac{s(\omega)}{d} d\Omega(\omega; W^d) = x - \rho + \frac{W+F}{D}. \tag{D.49}$$

Hence,

$$\Psi_+(\theta) = \frac{F}{D}\left[x - \rho + \frac{W+F}{D}\right]^{-1}. \tag{D.50}$$

Combining equations (D.44) and (D.50) allows us to solve for the second term in (D.43)

$$\Psi_+(\theta) + \Omega(\bar{\omega}; W^d)(\Psi_-(\theta) - \Psi_+(\theta)) = (1 - \Omega(\bar{\omega}))\frac{F}{D}\left[x - \rho + \frac{W+F}{D}\right]^{-1} + \Omega(\bar{\omega})\frac{F}{F+W} \tag{D.51}$$

Empirical analogues for the various ratios in equations (D.47) and (D.51) exist in the data. So too does the spread $r^z(\theta)$: the discount window rate is a fixed spread over the prevailing overnight interbank rate and $R^m = 1$.

To determine $\Omega(\overline{\omega})$—the probability of a deficit—one needs to make a distributional assumption over ω. We follow Bianchi and Bigio (2022) and assume

$$\ln(1+\omega) \sim N(-\tfrac{1}{2}\sigma^2, \sigma^2), \tag{D.52}$$

where the mean is set so that deposit outflows are nil in expectation (recall $W^d = 0$) and σ^2 is a parameter to be calibrated. This implies that

$$\Omega(\bar{\omega}) = \Phi\left(\frac{\ln(\bar{\omega}+1) + \frac{1}{2}\sigma^2}{\sigma}\right), \tag{D.53}$$

where $\Phi(.)$ is the cumulative density function of a standard normal distribution.

Calibration: As the highest frequency data on CNH deposits is monthly we conduct our calibration at that frequency. Data sources are in Appendix B.

Starting with interest rates, we set $R^m = 1$. We set $r^f(\theta)$ as the monthly average value of the overnight CNH interbank rate. Finally, we calibrate r^z with an additional 50 basis point spread in line with the HKMA's pricing of its intraday liquidity facility until August 2022 when the spread switched to 25bp. We do not assign any stigma value to drawing from the facility.

The stock of D is the total monthly value of CNH deposits reported by the HKMA. Consistent with the discussion in the main text, the monetary base M is defined as deposits by other banks as recorded on the liabilities side of the balance sheet of the Hong Kong CNH clearing bank (Bank of China (Hong Kong) Limited) less (i) the monthly average value of the stock of bills issued by the PBoC (see Figure 2()a) and (ii) the unlent portion of the HKMA's liquidity facilities (see Appendix B.1). This allows us to calibrate a monthly value for $x \equiv M/D$.[57]

Discount window lending, W, is directly reported by the HKMA. We take the maximum value drawn on a day and average it over the month.

We set reserve requirements ρ to be 0.1 in line with the Basel III liquidity coverage ratio; the HKMA has no further reserve requirement in CNH.

Interbank lending in CNH is not reported by the HKMA. However, the restricted version of the BIS locational banking statistics breaks down, at quarter ends, for banks in Hong Kong, their interbank lending and their borrowing from the central bank in all currencies excluding the HKD, USD, JPY, GBP, EUR and CHF. Once those six currencies are excluded, the bulk of activity is likely to be in CNH. This allows us to compute the ratio $W/(W+F)$ and we interpolate it to a monthly frequency. The sample average is 18.6%.

With values for M, W, D and W/F, all the ratios that enter equations (D.47) and (D.51) are measured.

What remains is to calibrate σ^2. Given x and ρ, we set σ^2 to target the ratio $(W+F)/D$ on average over our sample using equation (D.45). This yields a value of $\sigma^2 = 0.22$.

[57] The balance sheet of the clearing bank is only available quarterly so we interpolate its value.