THE ANATOMY OF A PEG

Saleem Bahaj (UCL) and Ricardo Reis (LSE)

May 2023

Exchange rate pegs usually fail

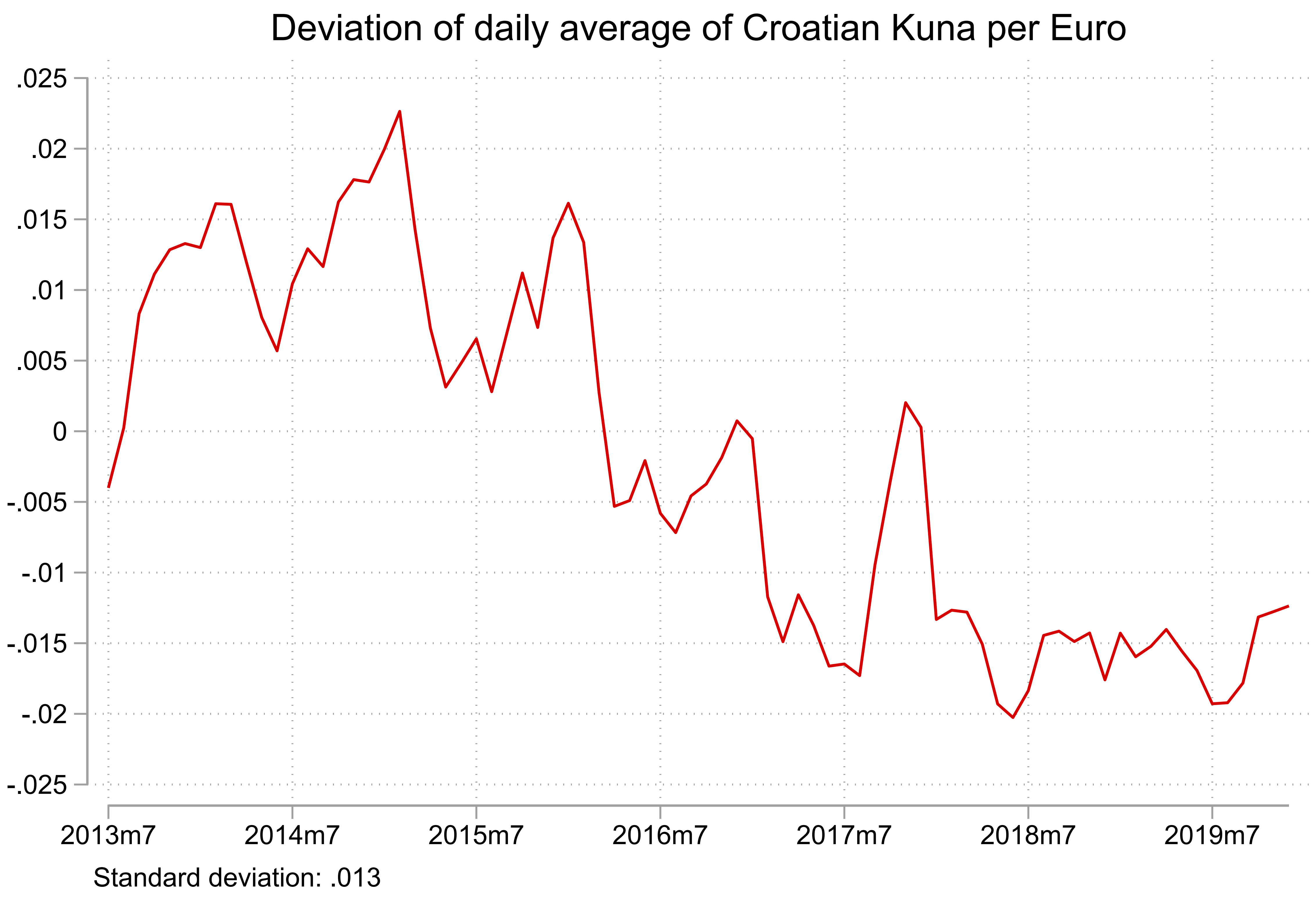
1. Countries want to pursue internal goals, and the impossible trinity bites.

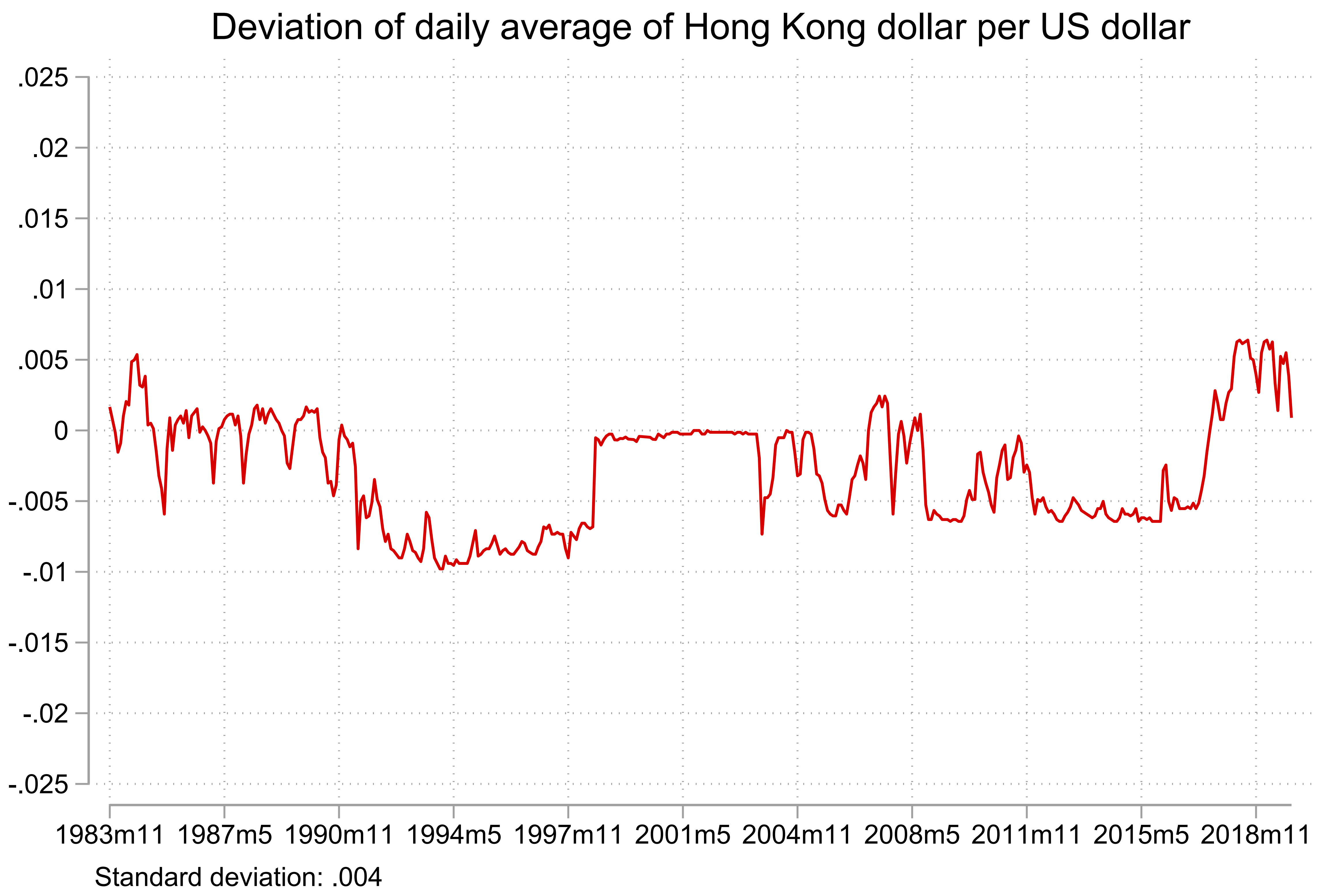
2. Countries do not have fiscal and political unity to accept large regional differences in economic performance. Price levels and real exchange rates adjust slowly to asymmetric shocks, it is faster/superior to have the nominal exchange rate adjust.

3. Countries do not have enough foreign currency, exposed to runs.

Goodhart *Money Information and Uncertainty*: chapters 17 and 18, with conclusion (p. 417):
"…my own conclusion has been that the authorities should intervene in exchange markets, but that their concern should not be to pick and to defend any particular level of rates, but to control the rate of change of parities, managing this rate of change to see that it never becomes too large to become a disruptive force."

But sometimes they work





How do pegs work? How are they implemented?

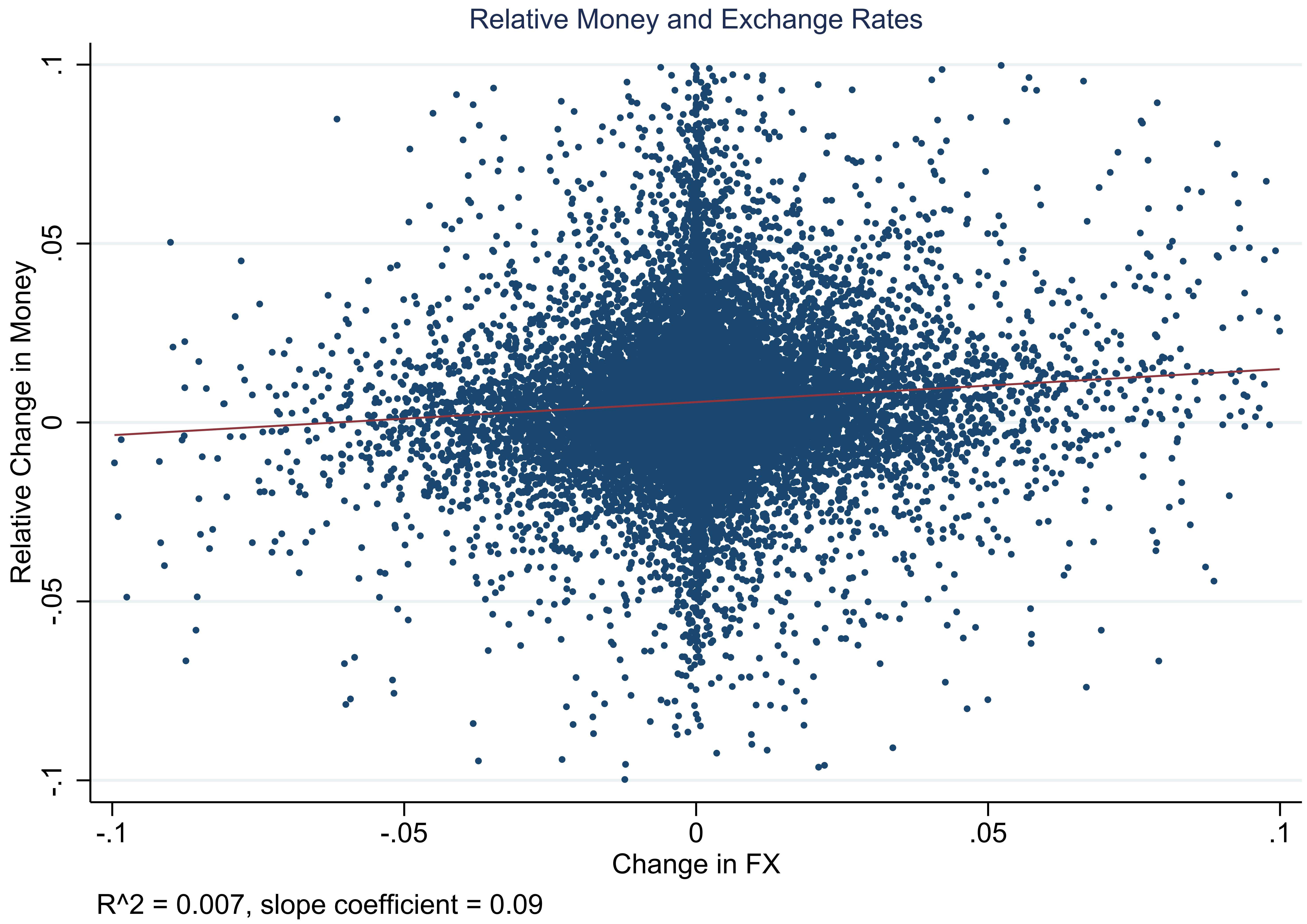
- Central banks control money supply. The exchange rate between two currencies is the relative value of two monies. So, just sell your currency when its exchange rate is too high, and buy the currency when the exchange rate is too low.

- *Monetary approach/theory of exchange rates (and balance of payments)*: "the exchange rate is the relative price of different national monies, rather than national outputs, and is determined primarily by the demand and supplies of stocks of different national monies." Mussa (1977)

- Broadly used in emphasis on financial markets. Narrowly, empirical failure from the start: Frankel (1983), Meese and Rogoff (1983a, 1983b) concluded "disaster".

- For instance, in our two countries:
  - For HK: regression of m on e has R^2 or 0.0072, and of Δm on lagged e is 0.0001
  - For Croatia: R^2's are 0.0866 and 0.1225, respectively.

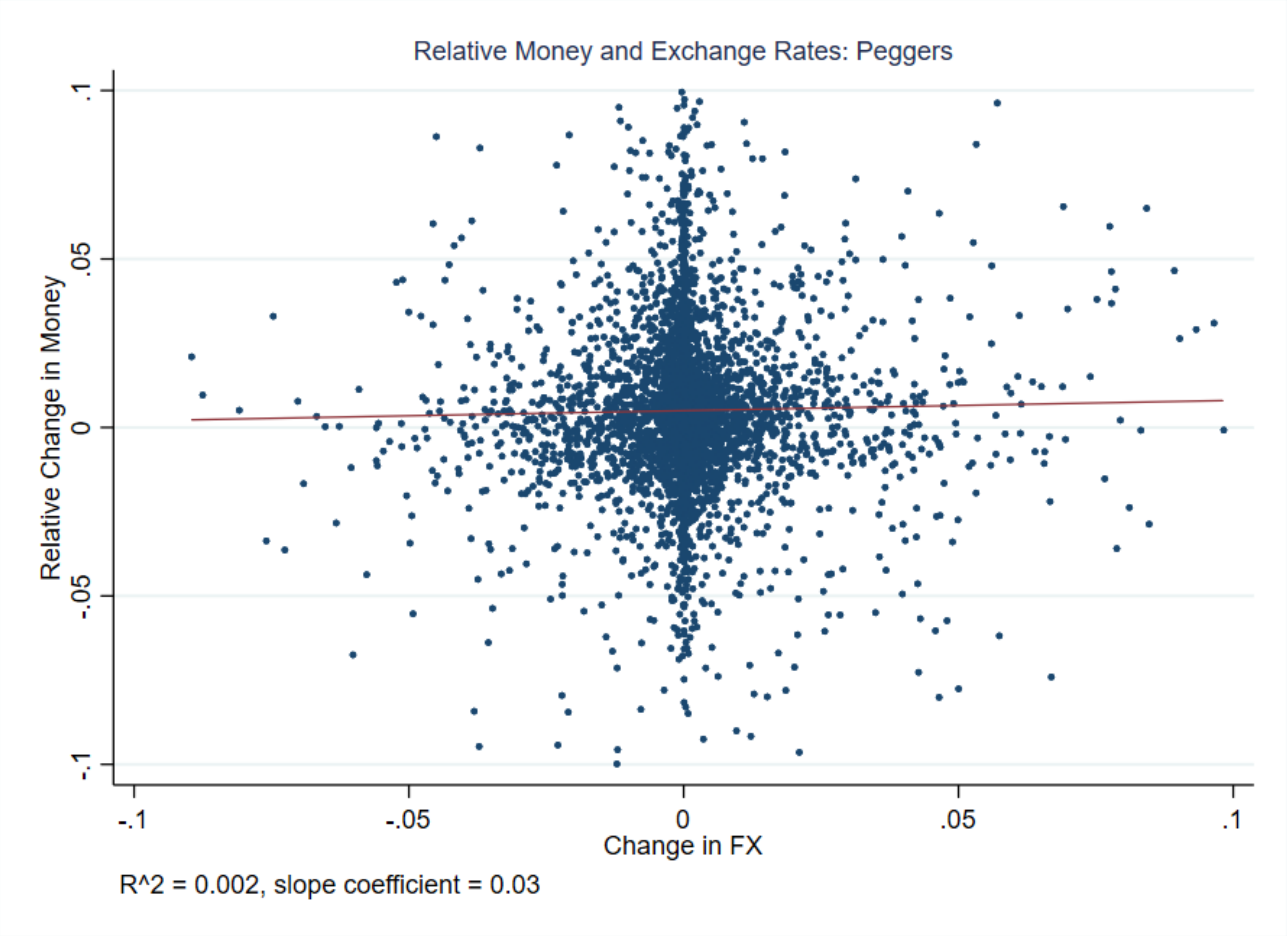
Exchange rates and money supplies



Monthly data 1959-2023, unbalanced panel of 95 countries, from IFS, all relative to USD - US M.

Monetarist theory of exchange rates failure: across countries and/or time, money growth and exchange rate changes are uncorrelated.

For pegs (Ilzetzki-Reinhart-Rogoff classification)



What will this paper do

1. Introduce one peculiar, prominent, and successful peg: the one that China conducts between CNY and CNH versions of the RMB.

2. Show that the peculiarities of this peg make it an ideal testing ground for the monetarist theory of the exchange rate.

3. Find that it works quite well! First evidence, as far as we know, in favor of monetarist view of exchange rates

4. Go deeper: structural model of financial institutions in Hong Kong, how they work, used to select the right measure of money and interest rates.

5. Even stronger evidence for monetarism!

1. THE MONETARIST MODEL AND THE CNY-CNH PEG

Monetarist model with modern shocks

Frenkel (1976, 1983) and Mussa (1974, 1977) model

$$i = i^o - \mathbb{E}(\Delta e) - w \qquad \text{UIP}$$

$$p + e = p^o + v \qquad \text{PPP}$$

$$m - p = -\eta i + u \qquad \text{Money demand}$$

$$m^o - p^o = -\eta i^o + u^o \qquad \text{Money demand, other}$$

Shocks, which traditional monetary approach assumed away:

- w - wedges to UIP from limits to arbitrage or capital controls (and non-RE)
- v - real exchange rate, deviations from PPP
- u - shock to money demand including income effect and money multiplier
- m^o, u^o - shock to other countries's money supply and money demand

Monetarist model: why it fails

- If floating exchange rates, exogenous money then have:

$$e_t = \sum_{j=0}^{\infty} \left(\frac{\eta}{\eta + 1} \right)^{j+1} \mathbb{E}_t \left[u_{t+j} - u^o_{t+j} + v_{t+j} + \eta w_{t+j} - (m_{t+j} - m^o_{t+j}) \right]$$

- If fixed exchange rates, then need rule for endogenous money:

$$m = m^0 + \eta w + v + u - u^o$$

- <u>Why monetarism fails?</u> Because shocks to u, v, w are larger than movements in m - m^o.

- <u>Why pegs are hard to implement and fine tune?</u> Because central bank cannot keep track of u, v, w, u^o, m^o to adjust m that fast or accurately.

The peculiar CNY-CNH peg

- Deposits in Shenzhen are in CNY. Deposits in Hong Kong are in CNH.

- Capital controls (open CA, closed capital account). An offshore reserve not same as onshore reserve.
  - A Chinese citizen with a deposit in Shenzen, can withdraw RMB banknotes and coins, take the metro, deposit them in Hong Kong, and vice versa. Up to $50k per person.
  - There are quotas on exchanging CNH for CNY for purposes of investment.
  - A Chinese firm can trade and receive payment in either CNH or CNY. It cannot exchange CNY for CNH without an invoice (trade settlement scheme). Some firms accumulate large deposits in both
  - However, Chinese banks can borrow/lend in CNY-CNH and so consider relative returns.

- Limits on payments with CNY, including exchanging them for USD (or any FX). How PBoC intervenes in exchange rate using its large USD reserves.

- But, CNH market is completely free. Offshore in Hong Kong. Can buy/sell USD freely.

- PBoC controls the supply of both currencies. Pegs their exchange rate at $e = 0$.

Back to the model

- Banks can arbitrage between CNY and CNH if they have large balances of either:

$$w \approx 0$$

- No border for real goods between mainland China and Hong Kong:

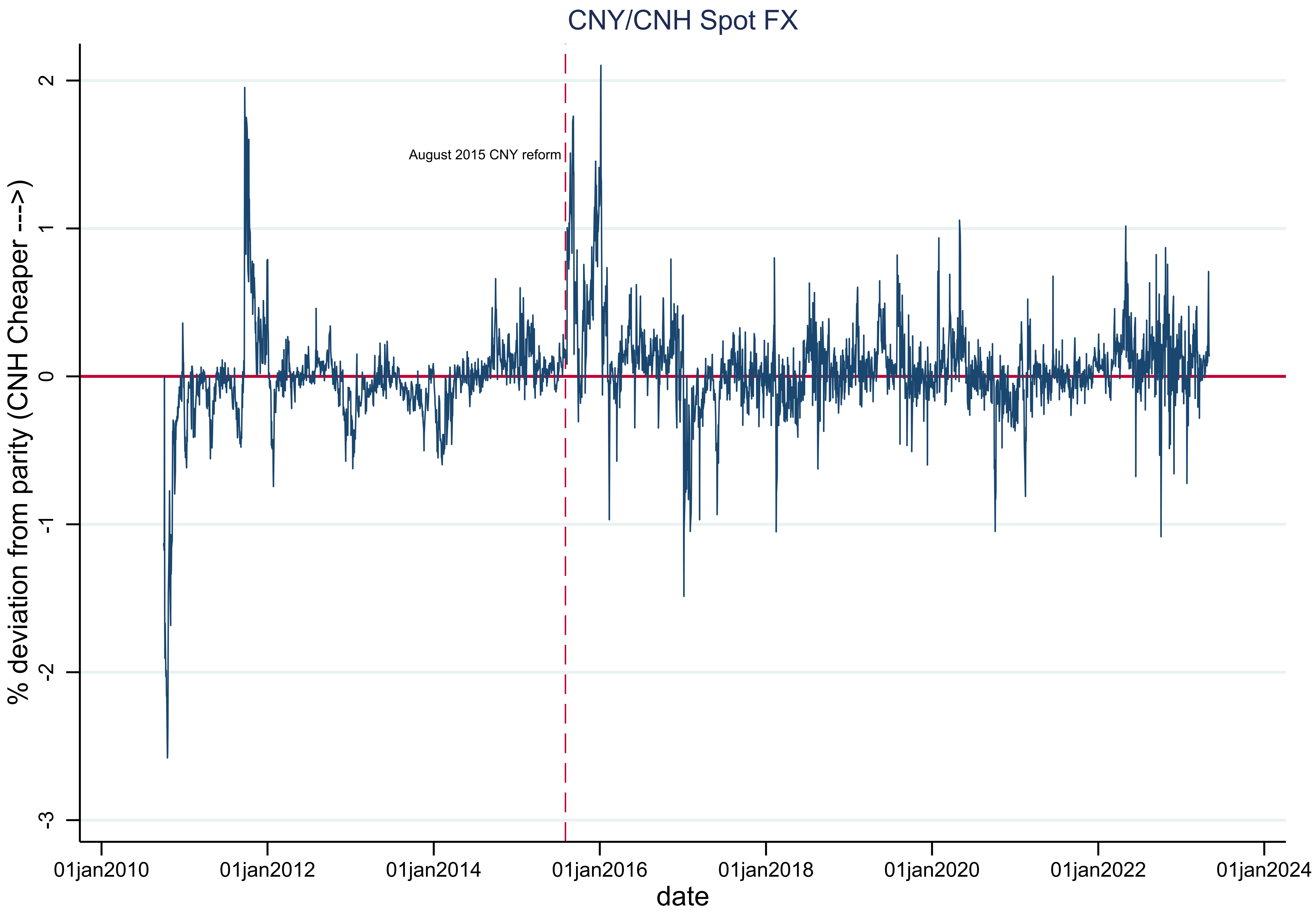
$$v \approx 0$$

- PBoC controls the relative supply of the two monies (including m^o):

$$m - m^0 = u - u^o$$

- So, to keep exchange rate at $e = 0$, only need to absorb money demand shocks.

How successful is the PBoC?

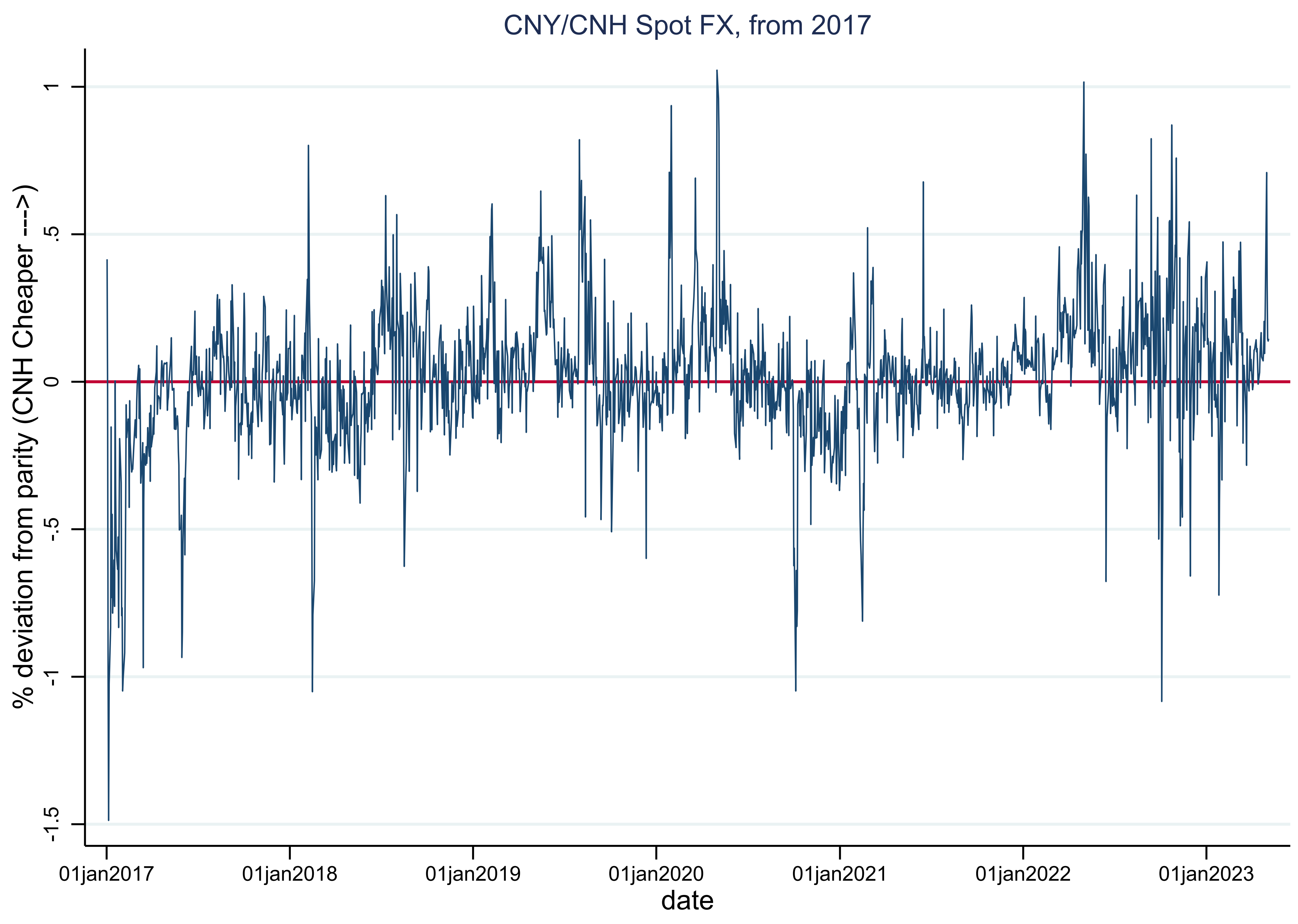


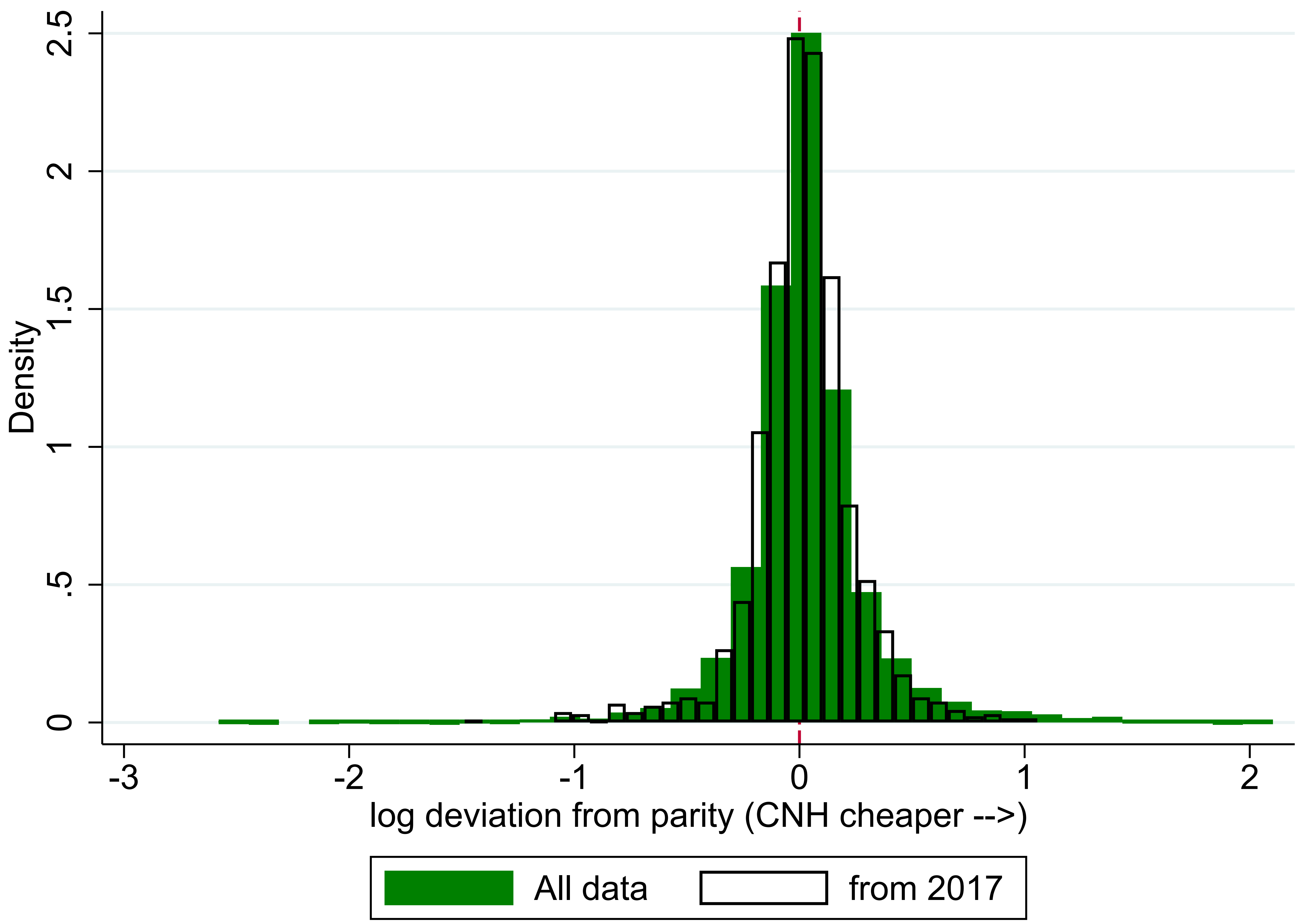
Quite successful. Comparable to Croatia and Hong Kong before, as well as other lasting pegs.

August 2015 reform: large deviation *e*, PBoC reacted with large rise in m-m^o. "Liquidity dry-up in offshore market" in 2015-16

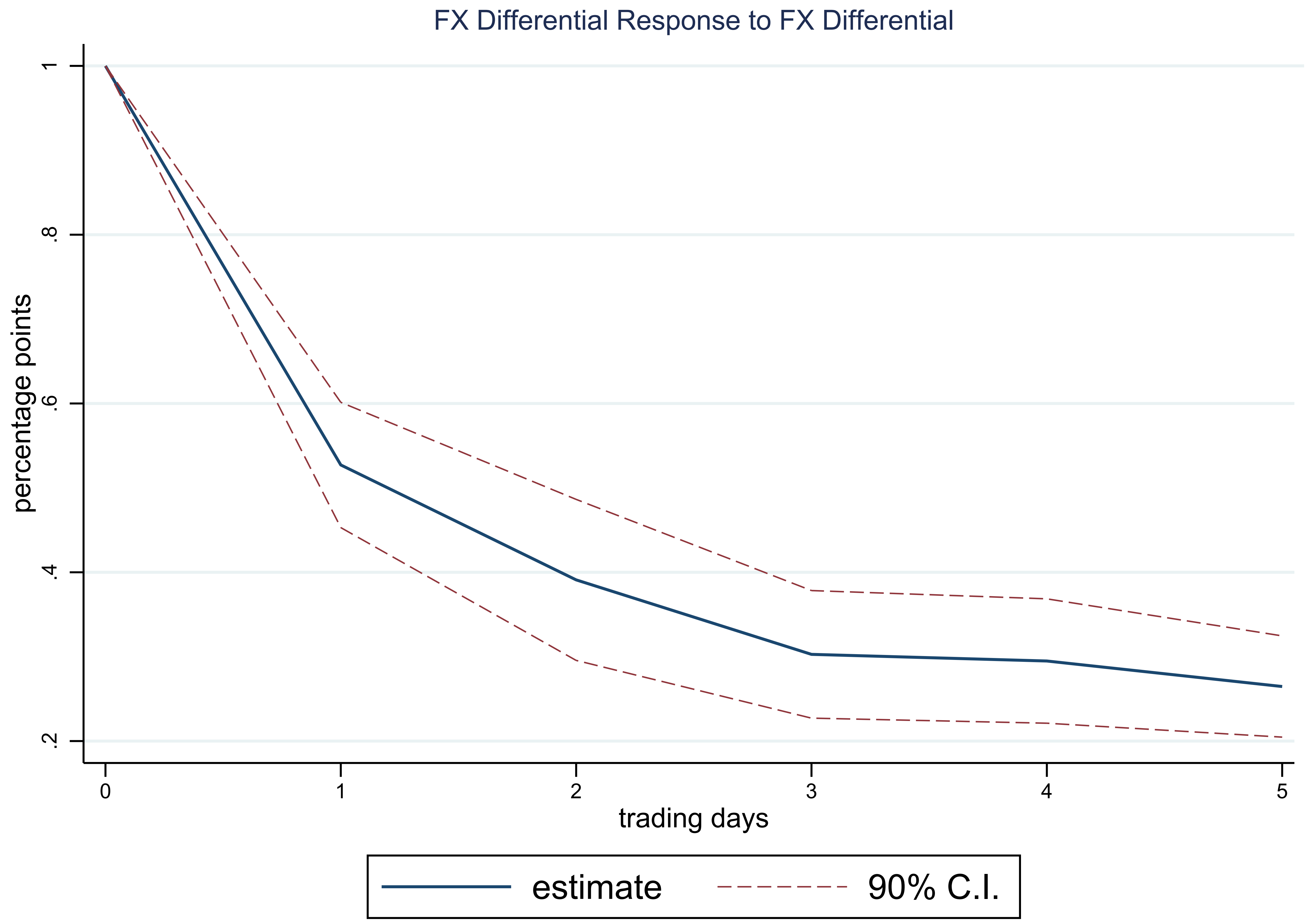
Adjustment of liquidity facilities to control m-m^o from 2017 onwards (UIP holding)

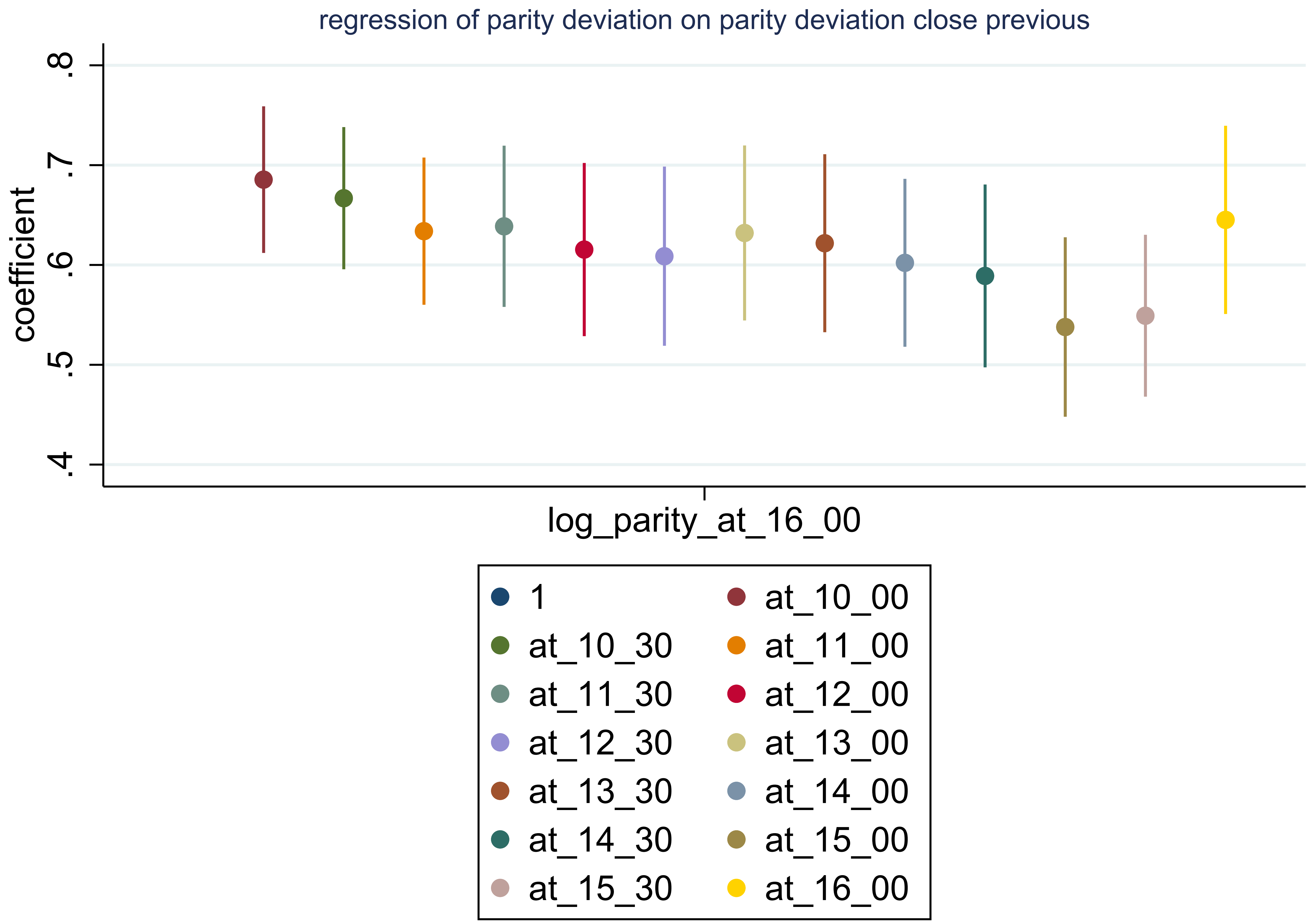
Focus on post-2017: small, symmetric, bell-shaped deviations





AR(1) with θ=0.5 across days, also intraday persistence





2. TESTING MONETARISM WITH THE CNY-CNH DATA

Adjusting the model to fit data

- Money demand shocks every day, hard to to track down in real time.

- Shocks: permanent term (growth) and an iid term, central bank cannot separate them, chooses relative monies today to match expectation of tomorrow's shock:

$$m_t - m_t^o \equiv \mathbb{E}_{t-1}(u_t - u_t^o) \quad \text{and} \quad u_t - u_t^o = p_t + \tau_t$$

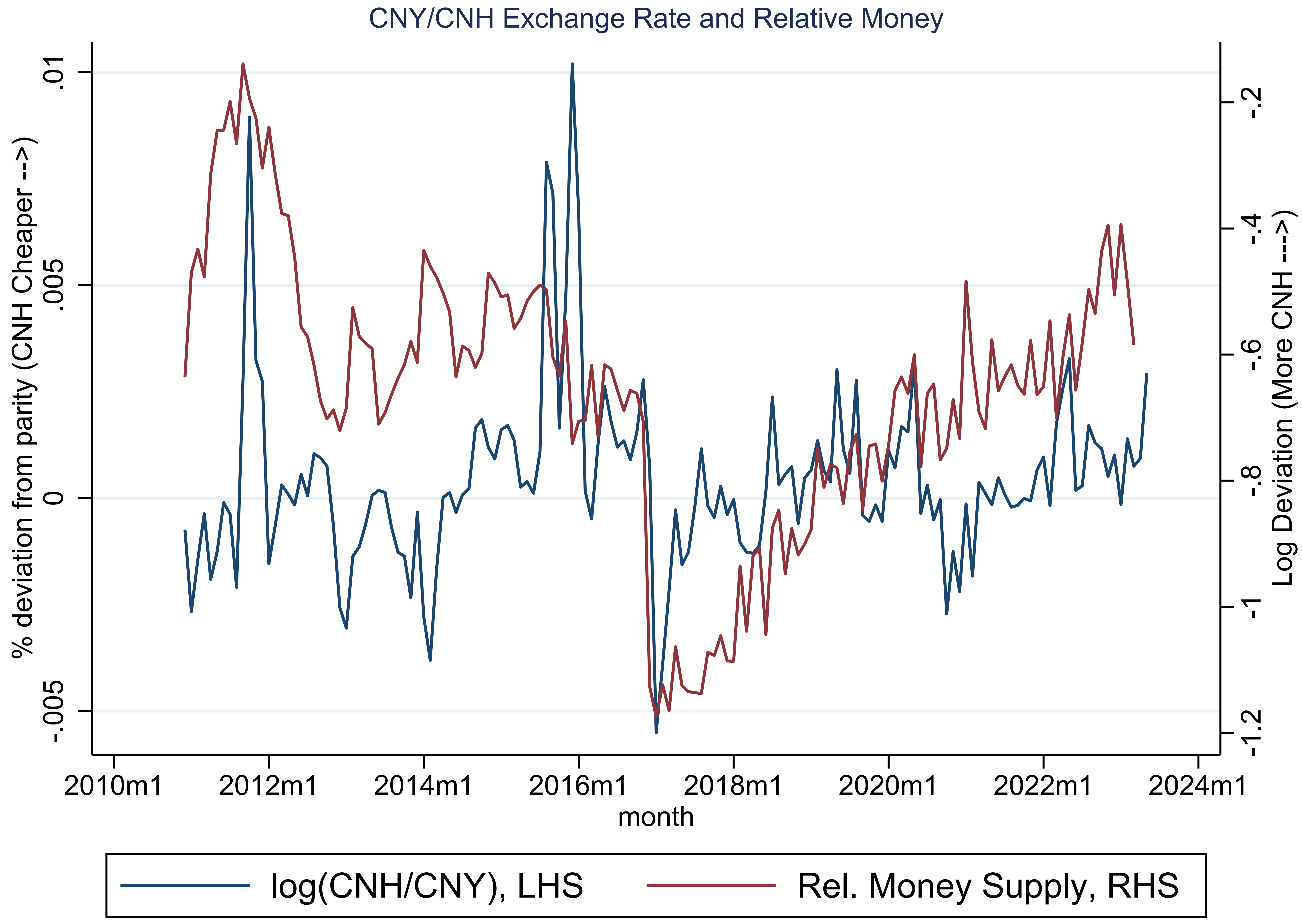
$$m_t - m_t^o - (u_t - u_t^o) = \varepsilon_t \quad \text{and} \quad \varepsilon_t = \theta\varepsilon_{t-1} + \tilde{\varepsilon}_t$$

- From there, exchange rates follow an AR(1) matching the data ($\theta \cong 0.5 \cong \eta$).

$$e_t = -\left(\frac{\eta}{1-\theta}\right)\varepsilon_t$$

- Monetarism without perfect control: see $e_t > 0$ today, do $\Delta(m_{t+1} - m^o{}_{t+1}) > 0$ to restore peg

First test: good, but not great



Using relative stock of sight deposits (≅M1).

Some relation, and much stronger than other peggers

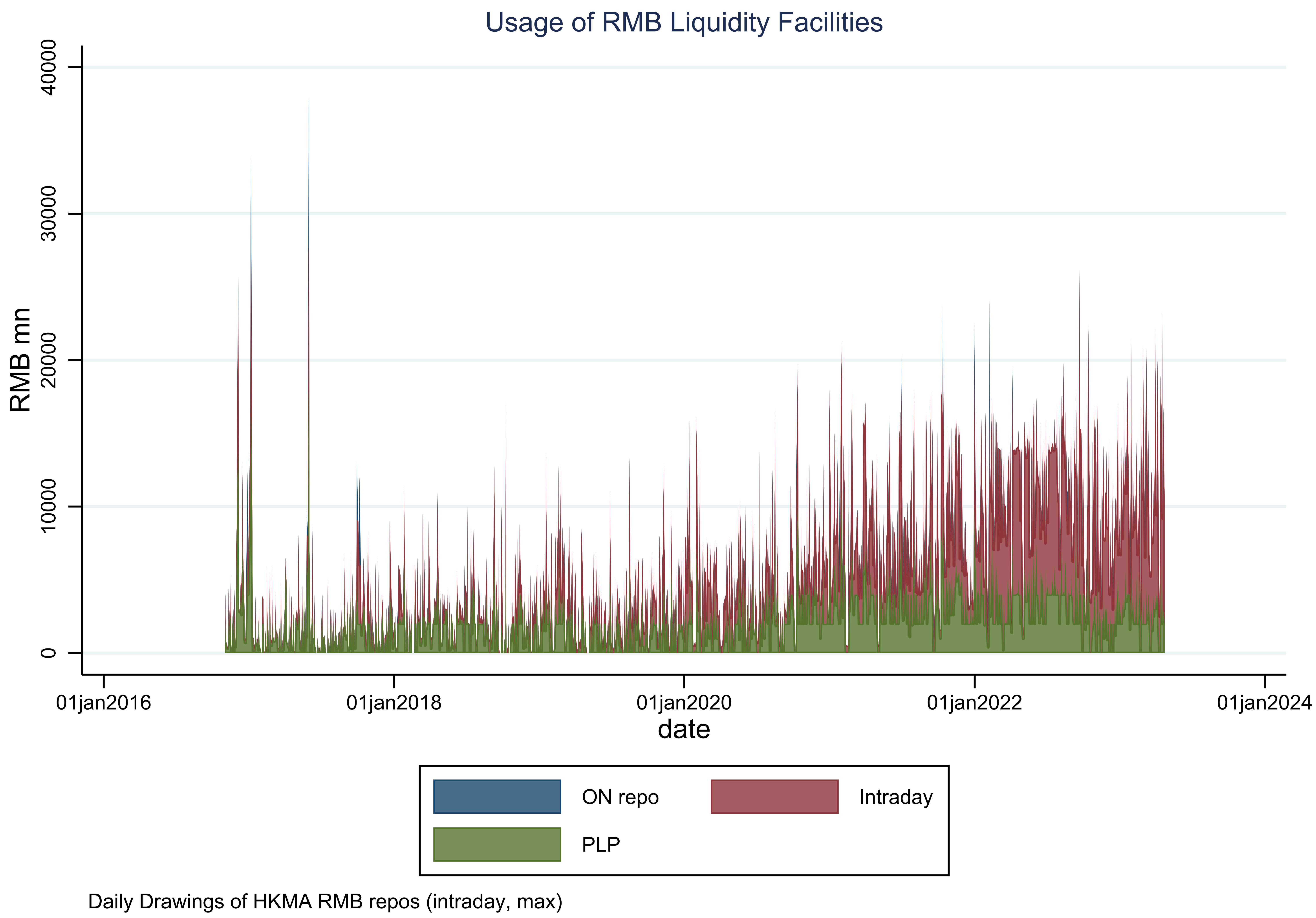
All driven by M in CNH

But still quite low R^2.

Relative Money Demand: $\Delta(m_t - m_t^o)$		
All countries	Peggers	China post 2017
-0.016	-0.066**	-9.40**
(0.01)	(0.03)	(5.53)
18,274	4615	75
95	38	1
0.002	0.002	0.02

3. MEASURING M

Measuring relative monies better



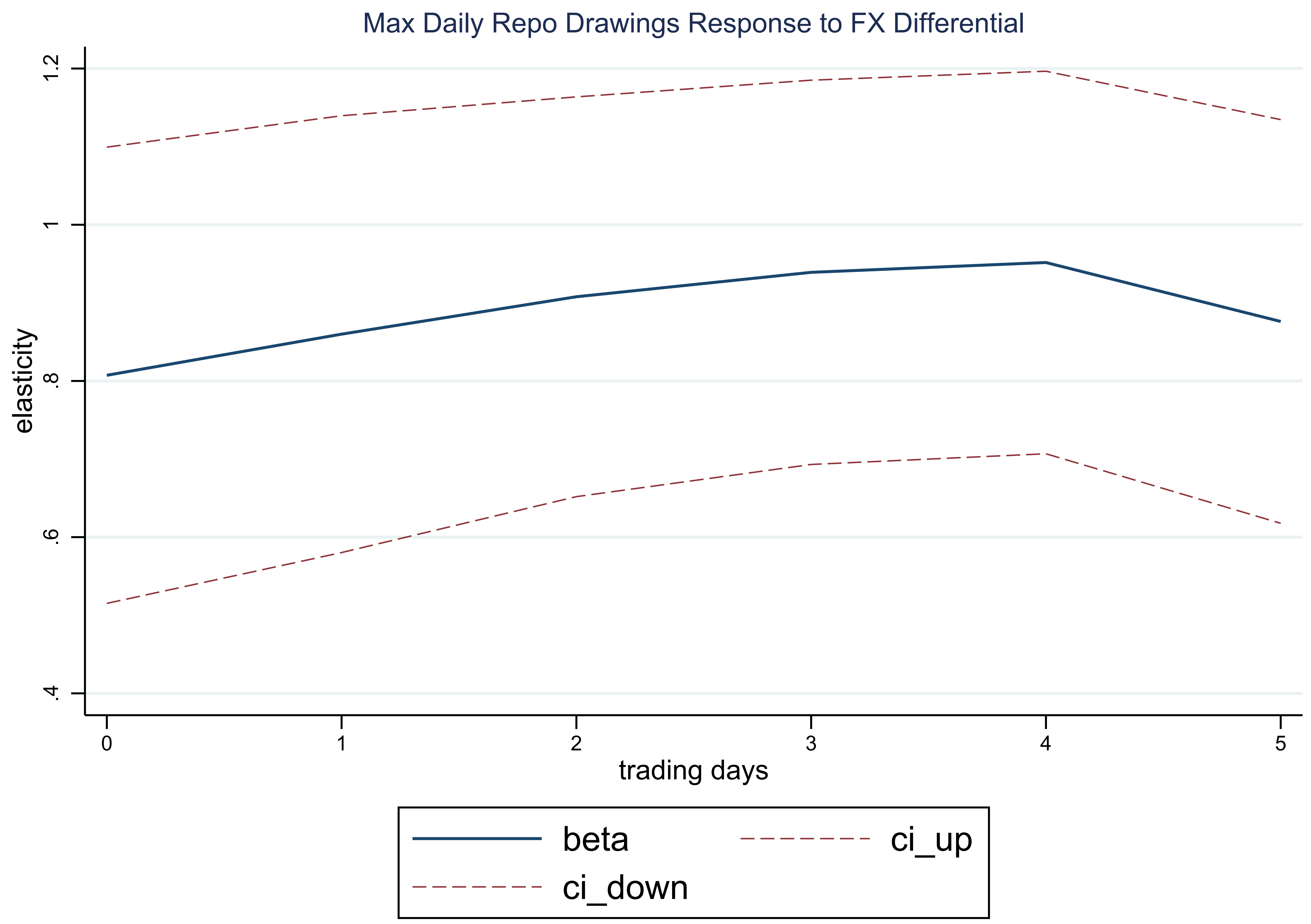
Sight deposits are endogenous and volatile from money multiplier

HKMA CNH liquidity facilities: repo operations for banks in HK to borrow CNH immediately.

Action in PLP+Intraday.

The direct instrument used in money markets, the $m_t^o - \bar{m}^o$ in the theory.

Test with proper measure of monies



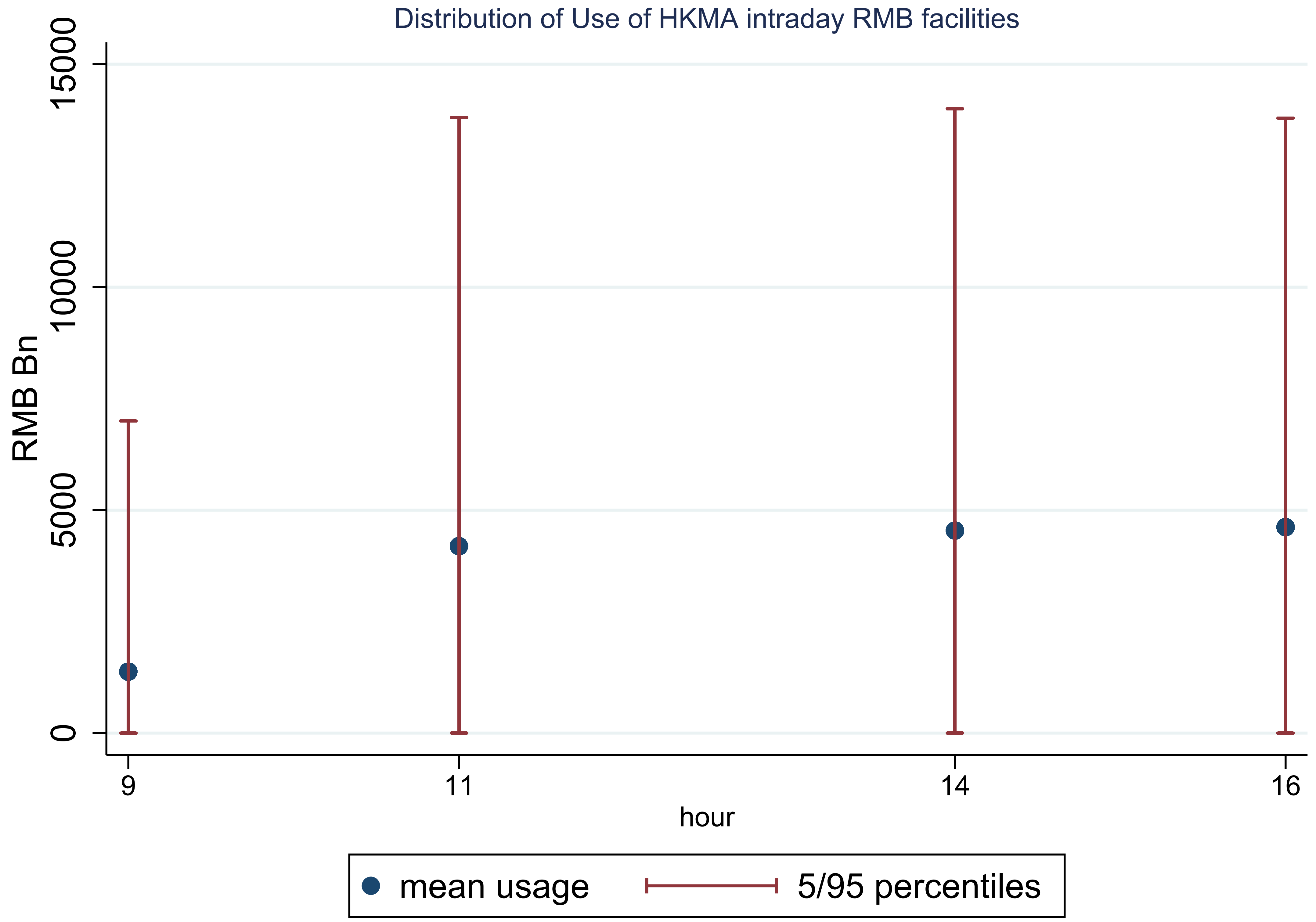
Regress $(m^o_{t+j} - \bar{m}^o)/\bar{m}^o$ on e_t

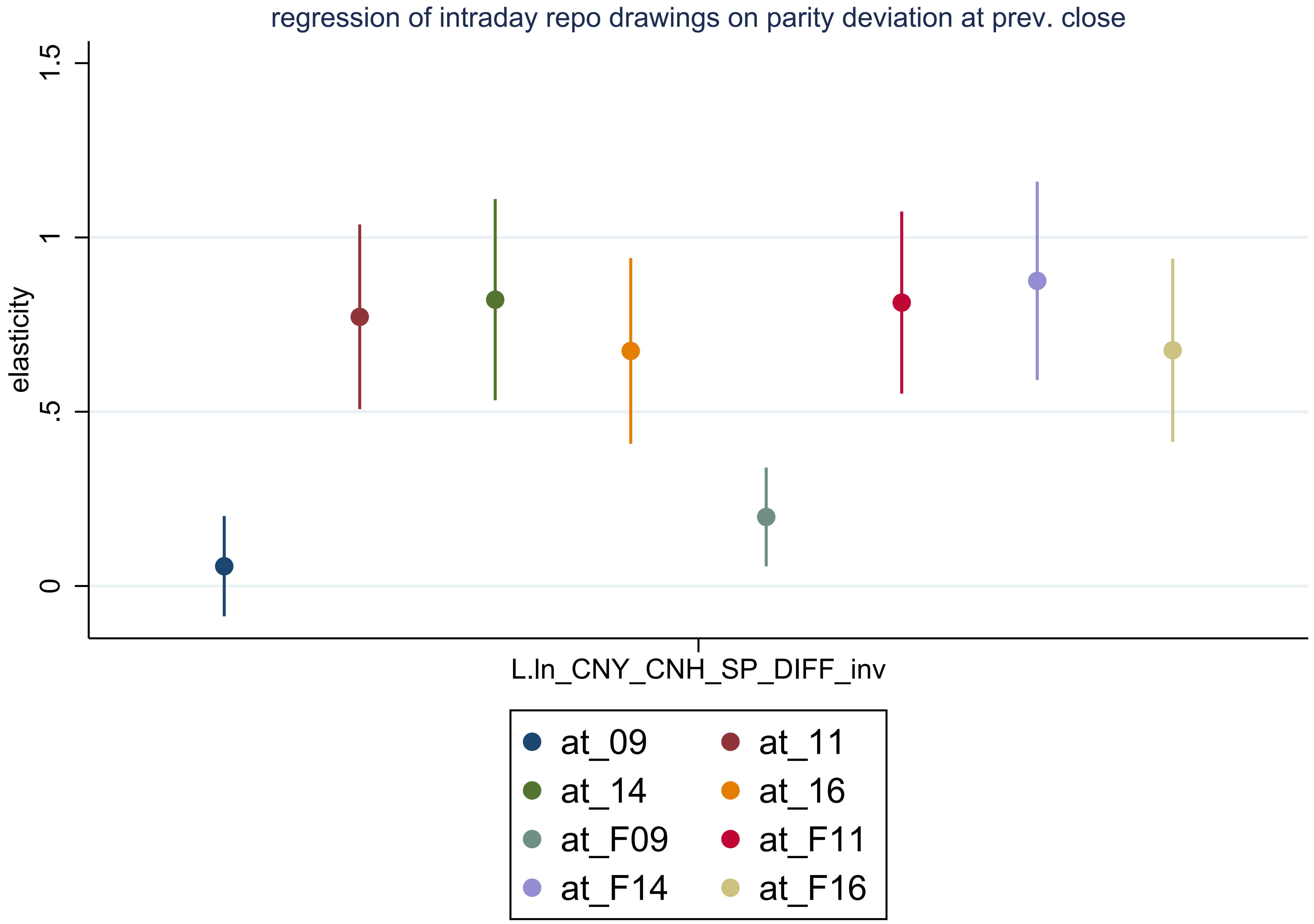
Significant improvement

Coefficient close to 1

Persistence on the stock as predicted by random walk model

Happens as market opens, flat during day





4. MEASURING I

Go deeper into financial institutions

- Since we are trying to get at u, then why not just estimate money demand?

$$m - m^0 = -\eta(i - i^o) + u - u^o$$

- Or, relaxing unrealistic assumption of same elasticity of demand for the two monies:

$$m - m^0 = -\eta i + \eta^o i^o + u - u^o$$

- But, which interest rates?

- Or, equivalently, where does this equation come from?

- Need micro-foundations, a model of demand for the two monies by depositors/banks.

Go deeper into financial institutions

Bank Balance Sheet

Assets	Liabilities
(onshore loans) x	c (capital)
(offshore loans) x'	d (onshore deposits)
(onshore reserves) m	d' (offshore deposits)
(offshore reserves) em'	(onshore official borrowing) z
(onshore net interbank borrowing) f	(offshore official borrowing) z'
(offshore net interbank borrowing) f'	

<u>3 periods</u>

At 0: bank takes in deposits (d) makes loans (x) and holds reserves (m)

At 1: bank suffers withdrawal shocks (ω) to deposits, goes to interbank market (f) and CB facility (z)

At 2: payoffs.

Supply and demand for liquidity

$s_j = \omega_j d + m \qquad s'_j = \omega'_j d' + m'$ Net surplus of liquidity of individual bank

$$S'_+ = \int_j \max\left\{s'_j, 0\right\} dj$$

S'_+ is total amount lent offshore

$$S'_- = -\int_j \min\left\{s'_j, 0\right\} dj$$

S'_- is total demand for liquidity offshore

$$\theta' = \frac{S'_-}{S'_+ + W}$$

Offshore market tightness

$\Psi_-(\theta)$ Probability borrower finds a match, falls with tightness

$\Psi_+(\theta)$ Probability lender finds a match, rises with tightness

Supply and demand for liquidity

CB liquidity line rate: R^z, Interbank lending rate: R^f

Marginal cost of investing surplus liquidity (taking θ as given)

$$\chi'_+(\theta) = \Psi_+(\theta')R'^f(\theta) + (1 - \Psi_+(\theta'))R'^m.$$

Marginal cost of financing shortfall in liquidity (taking θ as given)

$$\chi'_-(\theta) = \Psi_-(\theta)R'^f + (1 - \Psi_-(\theta))\tilde{R}'^z$$

Bank chooses m and interest on deposits (and so d) to maximize expected profits. Risk neutral, so expected marginal costs equated to interest rates.

Combining it all

Expected cost of borrowing from discount window in onshore and offshore market:

$$\chi(m,d) = \mathbb{E}_0\left[\left(1-\Psi_-\left(\theta\right)\right)\min\left\{\omega d + m, 0\right\}\left(R^z - R^d\right)\right],$$

$$\chi'(m',d') = \mathbb{E}_0\left[\left(1-\Psi'_-\left(\theta'\right)\right)\min\left\{\omega' d' + m', 0\right\}\left(\tilde{R}'^z - R^d\right)\right]$$

Optimality condition on R^m the interest on reserves held by a bank at the central bank:

$$R^m - R'^m = \chi'_m - \chi_m$$

LHS: opportunity cost of onshore versus offshore reserves

RHS: Log marginal rate of substitution between the two

Under money in utility model, a log-linearized RHS is $(1/\eta)(m - m')$. Here instead…

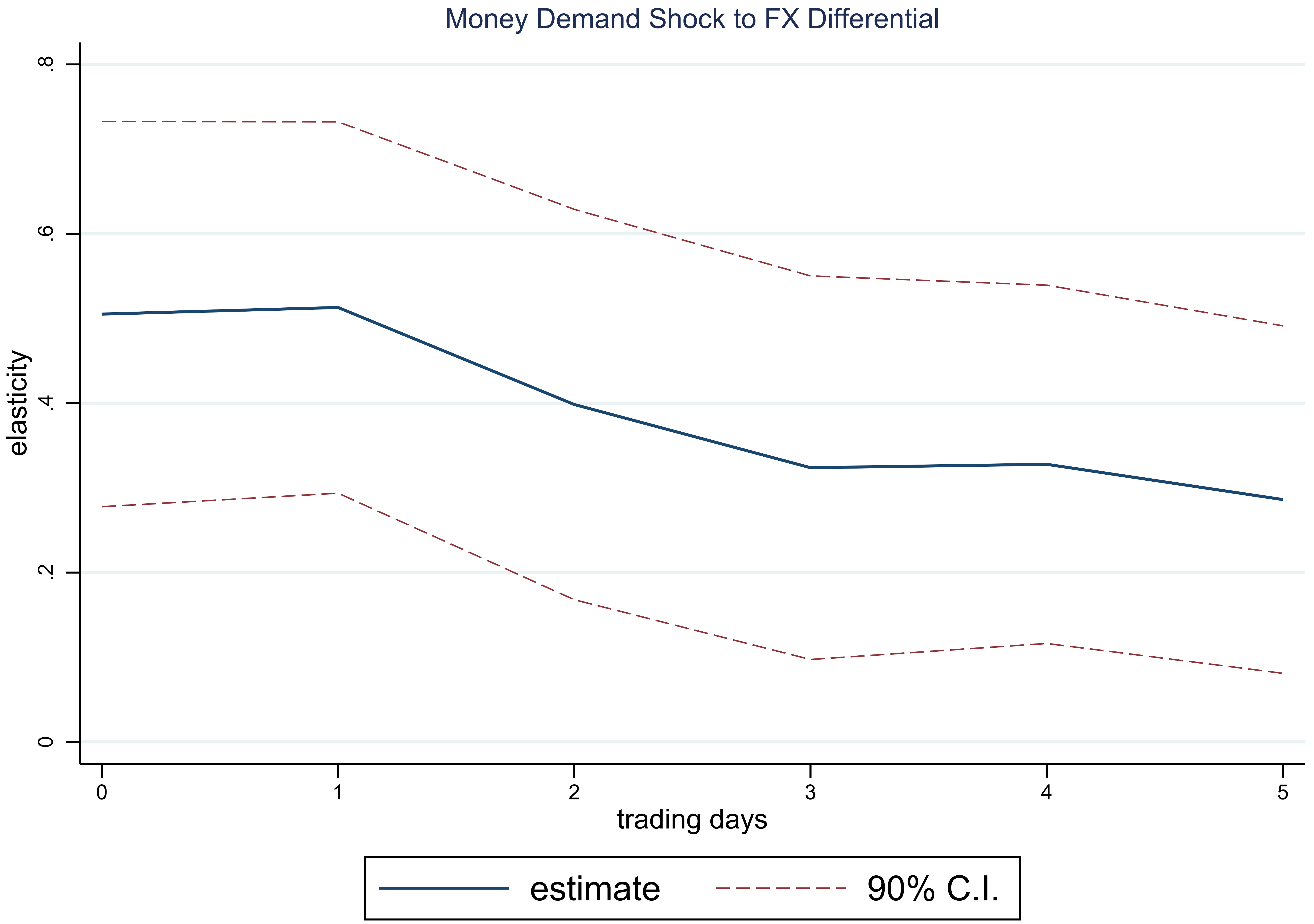
Relative demand for reserves onshore/offshore

After log-linearization of this demand for reserves by banks

$m_t^o - m_t$	PBoC liquidity facilities
$= \tilde{\eta}^o i_t^o - \tilde{\eta} i_t$	- Gap in interest on reserves with respective elasticities
$+ \tilde{\eta}^o \alpha_1 \left(i_{f,t}^o - i_t^o\right)$	- Interbank rate premium as it affects cost of shortfall
$+ \tilde{\eta}^o \alpha_2 \left(i_{z,t}^o - i_t^o\right)$	- Discount window premium as affects cost of shortfall
$- \tilde{\eta} \alpha_3 \left(i_{f,t} - i_t\right)$	- Same interbank premium offshore
$- \tilde{\eta} \alpha_4 \left(i_{z,t} - i_t\right)$	- Same discount window premium offshore
$+ u_t^o - u_t$	- Shocks to deposits

Right measure of interest rates is mix of several rates. Can calibrate/estimate. **Build u's**

Testing the model: residual u's on monies



- Regress $(m^o_{t+j} - \bar{m}^o)/\bar{m}^o$ on $\hat{u}_t$
- This coefficient should be close to θ, the autocorrelation of the exchange rate
- We estimated θ to be 0.5
- This is close to 0.5.

Improvement from micro foundations

	UIP: e_{t+1}/e_t	Money Demand: m_t		
	(1)	(2)	(3)	(4)
$i_t^{f,CNH} - i_t^{f,CNY}$	0.853*	0.071***		
	(0.45)	(0.01)		
i_t^{CNY}				-2.832***
				(0.20)
$i_t^{f,CNY}$			-1.037***	-0.177***
			(0.062)	(0.062)
$i_t^{z,CNY}$				-1.438***
				(0.144)
i_t^{CNH}				-
				-
$i_t^{f,CNH}$			0.045***	0.077***
			(0.01)	(0.02)
$i_t^{z,CNH}$				-0.062***
				(0.012)
N	1,598	1,598	1,598	1,598
R^2	0.016	0.02	0.20	0.41

Newey-West standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

(1) Checking UIP holds post 2017 as we've assumed

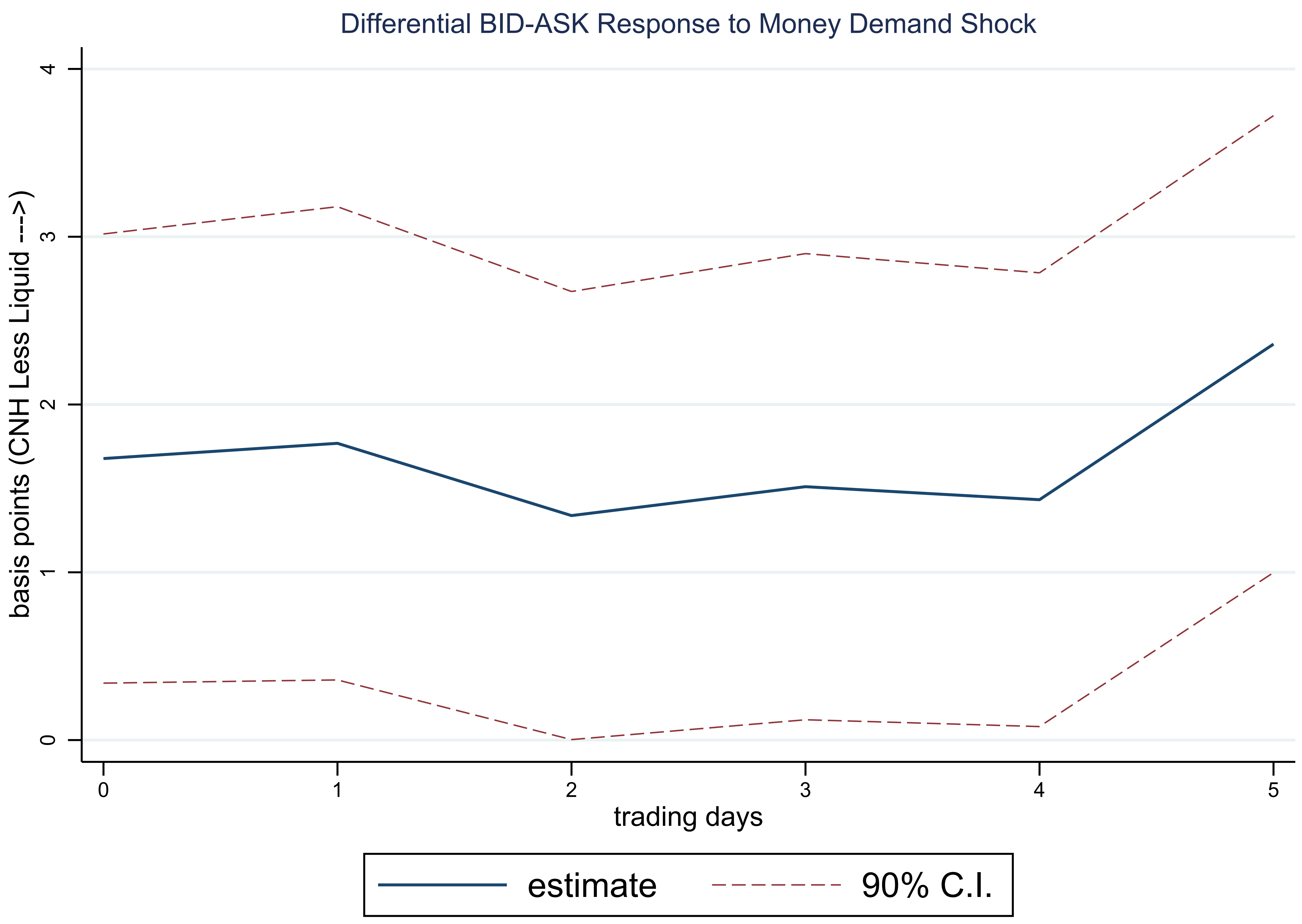
(2) Estimating Frenkel-Mussa money demand using overnight rates

(3) Frenkel-Mussa with different elasticities

(4) Our model. All but one coefficients right signed.

Big improvement in R^2

Another test on the procedure



- Higher excess demand for CNH relative to CNY (high u^o - u)
- Scarcity of relative reserves. Should mean an increase in the relative bid-ask spread
- Alternative measures of liquidity shocks
- Positive relation in the data

5. CONCLUSION

In honor of Charles Goodhart

- **Charles E. A. Goodhart's work:**
  - Exchange rate markets and money markets.
  - Monetary economics with money, while understanding why correlations of inflation or exchange rates with monetary aggregates were so weak.
  - Meticulous study of how banks actually work and how the plumbing of liquidity facilities affects monetary policy, inflation and financial stability.

- **This paper is in his honor:**
  - A peculiar, but useful FX market, where a peg has been successfully implemented.
  - The first successful test of the monetary theory of exchange rates.
  - Careful measuring of relative monies and their opportunity costs by considering how banks work in this market.