The Market for Inflation Risk

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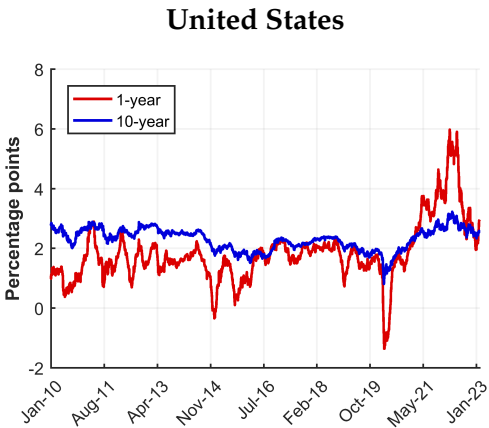
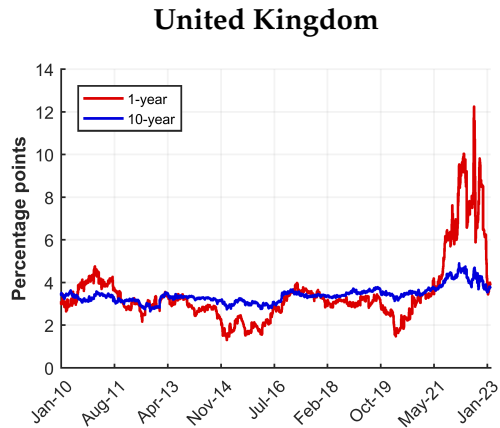
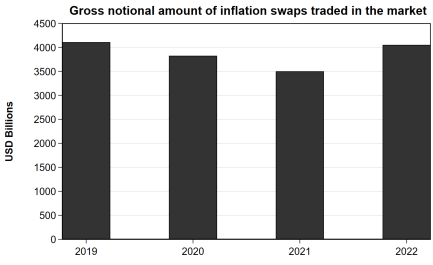
Prices of inflation swaps

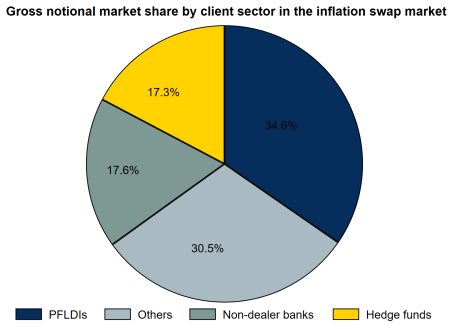




RPI vs CPI

THE QUANTITIES AND THE WHO BEHIND THE PRICES





Our contributions

1) **UK inflation swaps: a segmented market**
   - → Dealer banks are not neutral, hold large net positions (beyond holdings of indexed bonds, and uncorrelated with them).
   - → In long horizon market (=>10y), pension funds hold large positive net positions, actively trade.
   - → In short horizon market (<=3y), informed traders hold small net positions, very actively trade

Our contributions

1) **UK inflation swaps: a segmented market**

2) **Model and identification strategies for the demand for inflation risk**
   - → Portfolio model, segmented long/short markets with common dealer banks, separate pension and hedge funds
   - → Price of swaps: fundamentals (expectations and risk) and liquidity premium (frictions)
   - → Propose three identification strategies: (i) using high frequency, differential responsiveness and separation of banks' desks, (ii) using cross section per institution, instrument from granularity of positions, (iii) using time series, heteroskedasticity in data release dates.

Our contributions

1) **UK inflation swaps: a segmented market**

2) **Model and identification strategies for the demand for inflation risk**

3) **Empirical estimates**
   - → Daily data 01/2019 - 02/2023 for UK.
   - → Prices incorporate information very quickly
   - → Dealers supply to pensions funds very elastic, unlike supply to hedge funds
   - → Short horizon prices driven by liquidity, long horizon by fundamentals
   - → Liquidity of dealers not the dominant driver of liquidity premium
   - → Pandemic, Energy crisis, Trussonomics, state of the anchor

Connections to the literature

- Segmented markets (Vayanos Vila, 2021)
  - → A market that is strikingly segmented so the preferred habitat agents are easy to spot. Three identification strategies for this literature.
- Asset demand systems (Koijen Yogo, 2019)
  - → New market, connection to macro-monetary question, identification strategies.
- Swap markets and dealers (Jiang Matvos Piskorski Seru, 2023, McPhail Schanbl Tuckman, 2023, Hanson Malkhozov Venter, 2022)
  - → Banks hold large net positions, liquidity shocks to clients, cross validation.
- Expected inflation and liquidity premium (Cieslak Pflueger, 2020, Reis, 2020)
  - → Structural model of liquidity premia, cleaned measures of expected inflation
- EMIR trade respository data (Cenedense et al, 2020, 2021)

1. Data, summary statistics, stylised facts

The EMIR Trade Repository Data

- **Data source:** European Market Infrastructure Regulation, post-2008 reporting requirements for all transactions in almost real time.
- **The market:** OTC, centrally cleared, focus on dealer banks.
- **Observations:** all derivative transactions where a UK-regulated institution (including UK branches/subsidiaries of global banks) is a counterparty, includes hedge funds, pension funds and others.
- **Information:** counterparties' names and contract terms like length, price, index. Will focus on UK RPI today, but also have HICP for EA and CPI-U for US.
- **Frequency and span:** 3.5 billion observations since 31 Oct 2017, 25 million cleaned inflation swaps. Use daily observations from January 2, 2019 to February 10, 2023.

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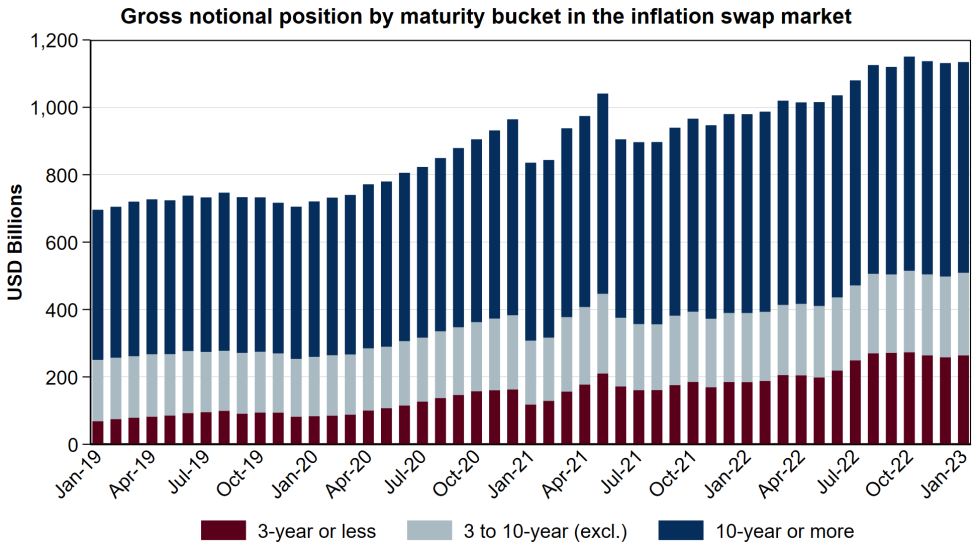
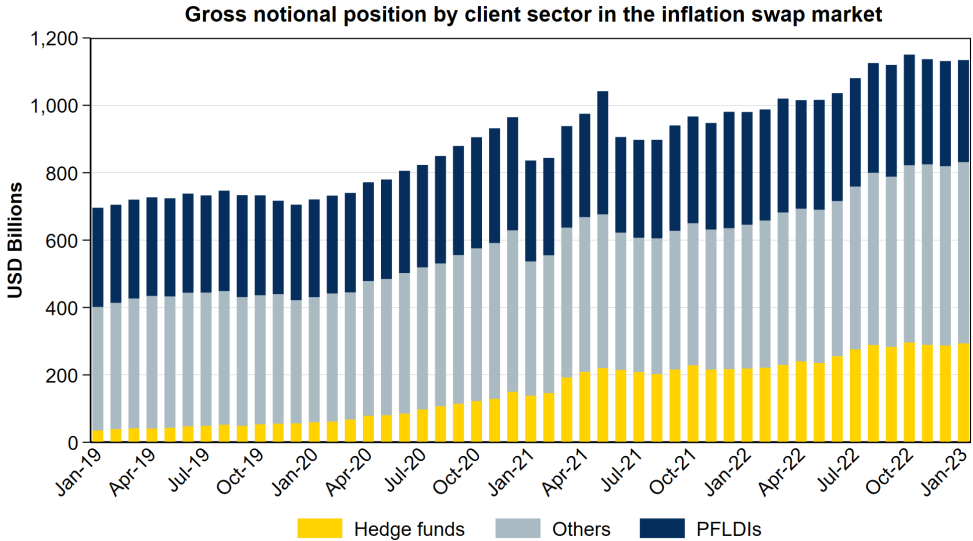
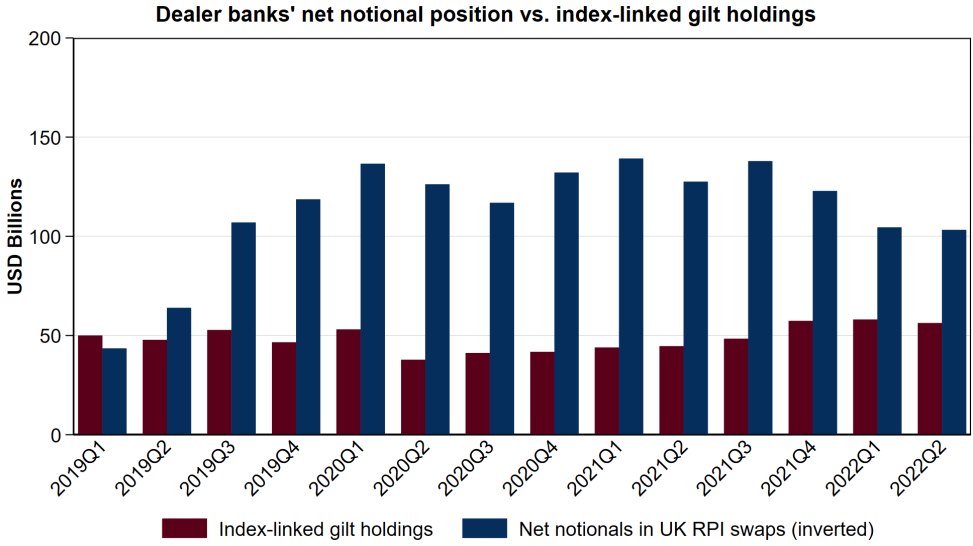
Maturity breakdown



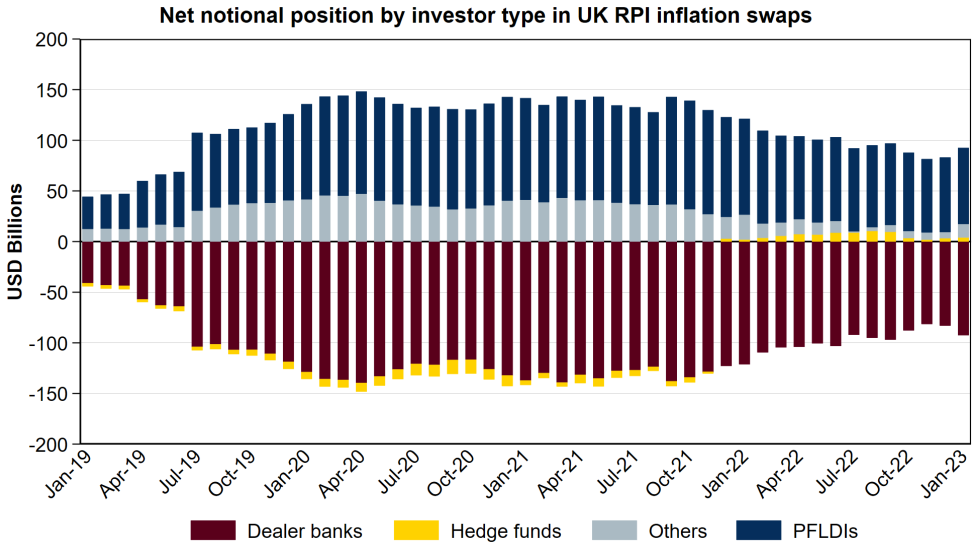
Client breakdown



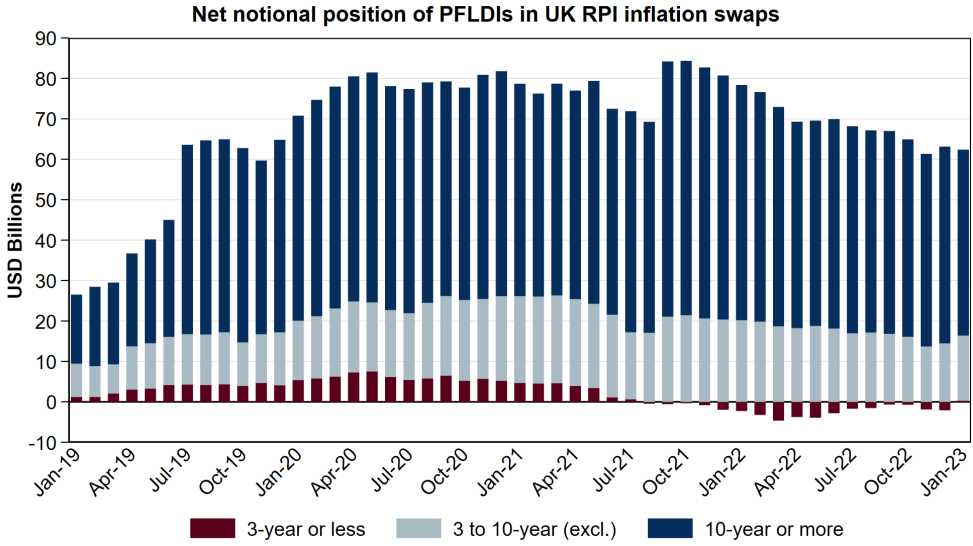
FACT 1: DEALERS ARE NOT NEUTRAL MARKET MAKERS



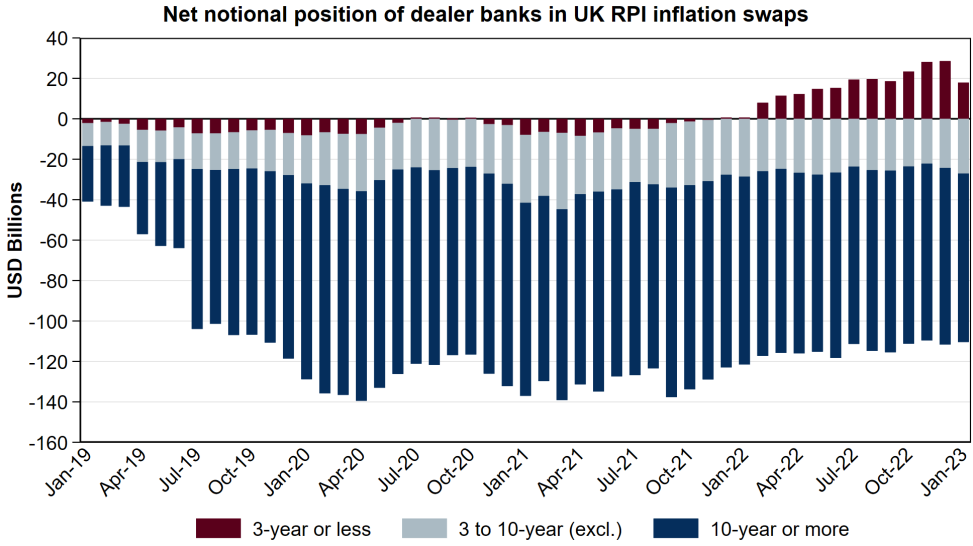
WHICH SIDE, AND WHO IS ON THE OTHER SIDE?



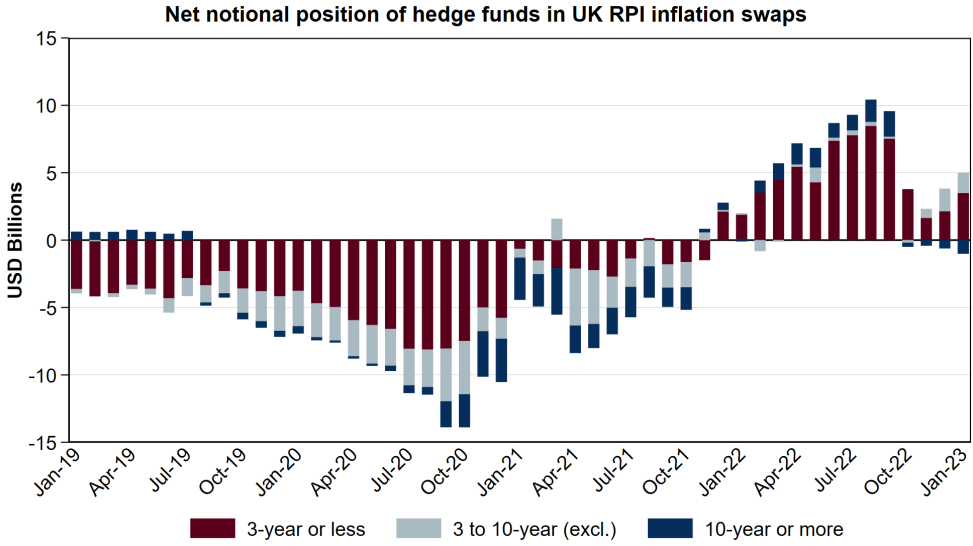
Fact 2: PFLDIs buy inflation protection at long horizons



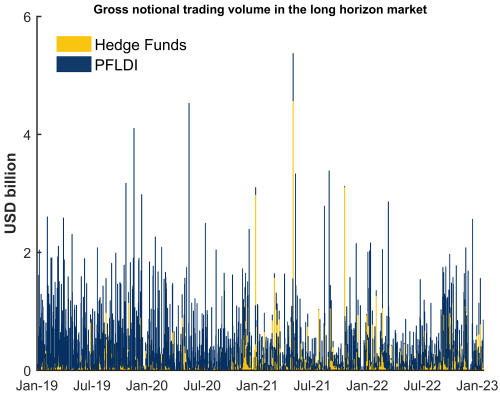
Fact 2: Dealers but no hedge funds on other side

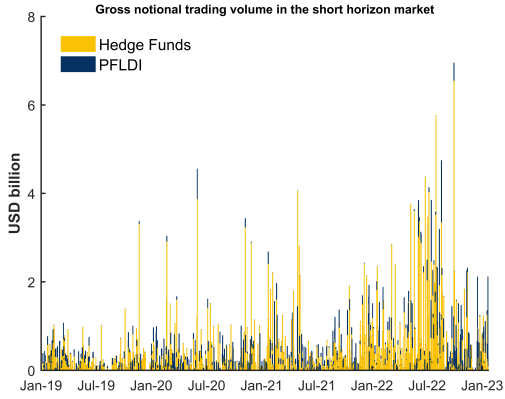


FACT 3: HEDGE FUNDS TRADE INFLATION RISK IN SHORT HORIZON



Segmentation in trading activity





Trades

2. A model of the demand for inflation risk

PENSION FUNDS PROBLEM

$$\max \mathbb{E}_{f,i}\left[-\exp\left(-\widetilde{\gamma}_{f,i}a'_{f,i}\right)\right] \qquad \text{with } \widetilde{\gamma}_{f,i} = \gamma_{f,i}/a_{f,i}$$

$$\text{s.t. } a'_{f,i} = a_{f,i} + (\pi - p)q_{f,i} + (d - s)e_{f,i} + y_{f,i}$$

$$\mathbb{E}_{f,i}(\pi) = \mu_{f,i}\pi^e \quad \text{with} \quad \sum_{i\in\Theta_f} \mu_{f,i} = 1$$

$$\text{normally distributed} \quad \pi, d, y$$

$$G_f(q_{f,i}, z_{f,i}) \geq 0 \qquad \text{with } g_{f,i} \equiv \partial G_f(q^*_{f,i}, z_{f,i})/\partial q_{f,i}$$

- **Assumption 1: Segmented markets.** *Pension funds do not participate in the short-horizon market $Q_{f,i} = 0$ and hedge funds do not participate in the long horizon market $q_{h,i} = 0$.*

Dealers' problem

- Dealers similar but in both markets:

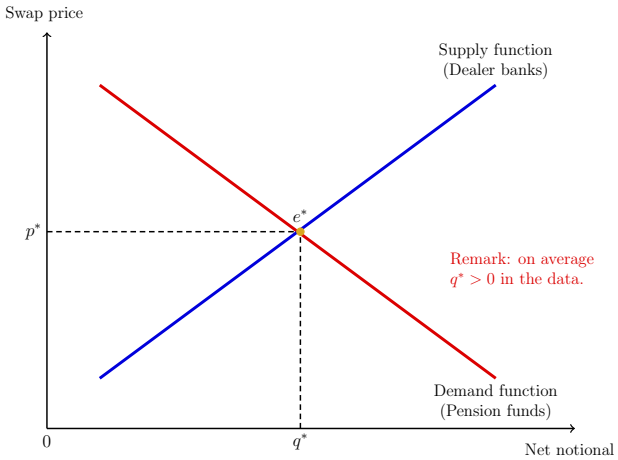
$$a'_{b,i} = a_{b,i} + (\pi - p)q_{b,i} + (\Pi - P)Q_{b,i} + (d - s)e_{b,i} + y_{b,i}$$

- **Assumption 2: Desk separation within the day.** *Dealers face separate capacity constraints:*

$$G_b^S(Q_{b,i}, z_{b,i}) \geq 0 \quad \textit{and} \quad G_b^L(q_{b,i}, z_{b,i}) \geq 0$$

so that $\partial G_b^S(\cdot,\cdot)/\partial q_{b,i} = 0$ *and* $\partial G_b^L(\cdot,\cdot)/\partial Q_{b,i} = 0$.

THE LONG MARKET



Why $q^*_{b,i} < 0 < q^*_{f,i}$ in data?

Because pension funds are:

(i) more risk averse: $\gamma_{f,i} > \gamma_{b,i}$

(ii) have more hedging need for their other assets: $rho_{\pi,d}$

(iii) more exposed to inflation-covarying background risk $\sigma_{\pi,y_{f,i}} > \sigma_{\pi,y_{b,i}}$

(iv) more tightly regulated on inflation risk $\lambda_{f,i} < \lambda^L_{b,i}$

FRICTIONLESS MARKET EQUILIBRIUM

- Complete markets so no background risk: $\sigma_{\pi,y_{b,i}} = \sigma_{\pi,y_{f,i}} = \sigma_{\pi,y_{h,i}} = 0$

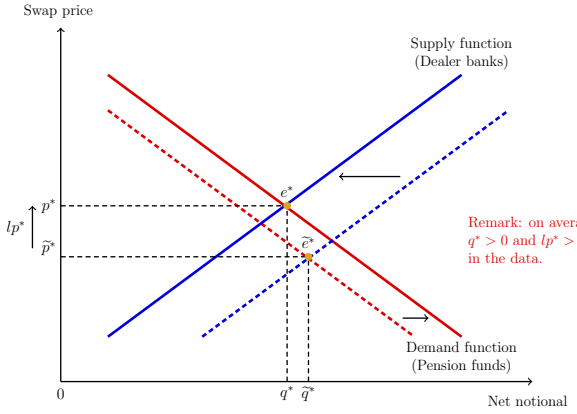
- Non-binding capacity constraints: $\lambda^L_{b,i} = \lambda_{f,i} = \lambda^S_{b,i} = \lambda_{h,i} = 0$

- If $\widetilde{p}$ is the frictionless price of a long horizon inflation swap, in equilibrium, it is:

$$\widetilde{p}^* = \underbrace{\left[\frac{\sum_{i\in\Theta_f}\widetilde{\gamma}^{-1}_{f,i}\mu_{f,i}}{\sum_{i\in\Theta_f}\widetilde{\gamma}^{-1}_{f,i}+\sum_{i\in\Theta_b}\widetilde{\gamma}^{-1}_{b,i}} + \frac{\sum_{i\in\Theta_b}\widetilde{\gamma}^{-1}_{b,i}\mu_{b,i}}{\sum_{i\in\Theta_f}\widetilde{\gamma}^{-1}_{f,i}+\sum_{i\in\Theta_b}\widetilde{\gamma}^{-1}_{b,i}}\right]}_{\text{size-weighted dispersion of beliefs}} \underbrace{\pi^e}_{\text{expected inflation}} - \underbrace{\frac{\theta_d - \widetilde{s}^*}{\sigma_d^2}\sigma_{\pi,d}}_{\text{risk premium}}$$

Liquidity premium

Figure 9 The frictionless equilibrium



$$lp^* = \underbrace{-\frac{\sum_{i\in\Theta_b}\left\{\sigma_{\pi,y_{b,i}} + \frac{\lambda^L_{b,i}g^L_{b,i}}{\widetilde{\gamma}_{b,i}}\right\}}{\sum_{i\in\Theta_f}\widetilde{\gamma}^{-1}_{f,i} + \sum_{i\in\Theta_b}\widetilde{\gamma}^{-1}_{b,i}}}_{\equiv\varepsilon_b,\ \textit{the supply friction from dealer banks}} + \underbrace{-\frac{\sum_{i\in\Theta_f}\left\{\sigma_{\pi,y_{f,i}} + \frac{\lambda_{f,i}g_{f,i}}{\widetilde{\gamma}_{f,i}}\right\}}{\sum_{i\in\Theta_f}\widetilde{\gamma}^{-1}_{f,i} + \sum_{i\in\Theta_b}\widetilde{\gamma}^{-1}_{b,i}}}_{\equiv\varepsilon_f,\ \textit{the demand friction from pension funds}}$$

3. Identification strategies

THE PROBLEM

- Observe (p, P) that are driven by $\boldsymbol{\varepsilon} = (\varepsilon_h, \varepsilon_f, \varepsilon_b, \varepsilon_\pi)$
- We have data $\mathbf{Y} = (Q, P, q, p)$ on prices and quantities 2 Jan 19 to 10 Feb 23, so 879 daily observations of:
  - $\rightarrow$ q: net purchases of swaps by PFLDI with $\geq$ 10 year maturity.
  - $\rightarrow$ p: daily price of 10-year zero-coupon RPI inflation swap.
  - $\rightarrow$ Q: net purchases of swaps by hedge funds $\leq$ 3year maturity.
  - $\rightarrow$ P: daily price of 1-year zero-coupon RPI inflation swap.
- **Identification problem**: Need to learn about 4x4 matrix $\boldsymbol{\Psi}$

$$\mathbf{Y} = \boldsymbol{\Psi}\boldsymbol{\varepsilon}$$

First identification strategy: heterogeneity in reactivity

- **Assumption 3a) Differential reactiveness to fundamental news about inflation.** *Dealer banks respond more to fundamental long-horizon expected inflation than pension funds but less to fundamental short-horizon expected inflation than hedge funds:*

$$\frac{\sum_{i\in\Theta_h}\widetilde{\gamma}_{h,i}^{-1}\mu_{h,i}}{\sum_{i\in\Theta_h}\widetilde{\gamma}_{h,i}^{-1}+\sum_{i\in\Theta_b}\widetilde{\gamma}_{b,i}^{-1}} > \frac{\sum_{i\in\Theta_b}\widetilde{\gamma}_{b,i}^{-1}\mu_{b,i}}{\sum_{i\in\Theta_f}\widetilde{\gamma}_{f,i}^{-1}+\sum_{i\in\Theta_b}\widetilde{\gamma}_{b,i}^{-1}} > \frac{\sum_{i\in\Theta_f}\widetilde{\gamma}_{f,i}^{-1}\mu_{f,i}}{\sum_{i\in\Theta_f}\widetilde{\gamma}_{f,i}^{-1}\sum_{i\in\Theta_b}\widetilde{\gamma}_{b,i}^{-1}}$$

- Exploit high frequency of data

First identification strategy: heterogeneity in reactivity

- Shock ε_π: supply function shifts more than demand function, p rises and q falls.
- Shock ε_f: shifts out demand, raises p and q.
- Shock ε_d: shift supply down, raises p and lowers q. But, in short market would also see P rise and Q fall. Use the other market to separate it (and assumption 1)
- Finally, assumption 2 rules out spillovers across markets from capacity constraints binding.

$$\Psi = \begin{pmatrix} + & 0 & - & + \\ + & 0 & + & + \\ 0 & + & - & - \\ 0 & + & + & + \end{pmatrix}$$

Second identification strategy: granularity

- Write asset demand system as an interactive fixed effects factor model:

$$\frac{q_{f,i,t}}{a_{f,i,t}} = \boldsymbol{\omega}'_{f,i}\mathbf{F}_t + \widetilde{\varepsilon}_{f,i,t}$$

- Construct instrument as a weighted sum of the residuals:

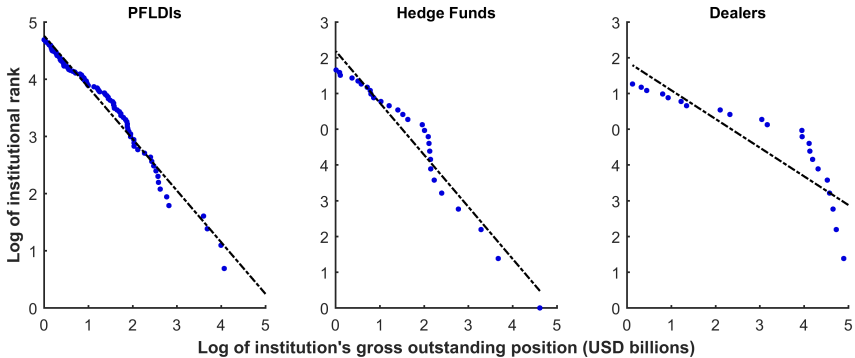
$$GIV_{f,t} = \sum_{i \in \Theta_f} a_{f,i,t}\tilde{\varepsilon}_{f,i,t}$$

$\mathbf{F}_{f,t}$ spans demand: $\mathbb{E}(GIV_{f,t}\varepsilon_{\pi,t}) = \mathbb{E}(GIV_{f,t}\varepsilon_{b,t}) = 0$. Ass. 1: $\mathbb{E}(GIV_{f,t}\varepsilon_{h,t}) = 0$.

- **Assumption 3b: Granularity of the institutions.** *Asset positions are granular:*

$$\mathbb{E}(GIV_{f,t}\varepsilon_{f,t}) \neq 0 \quad \text{and} \quad \mathbb{E}(GIV_{b,t}\varepsilon_{b,t}) \neq 0 \quad \text{and} \quad \mathbb{E}(GIV_{h,t}\varepsilon_{h,t}) \neq 0 \tag{1}$$

Second identification strategy: granularity



PFLDIs: 210 institutions, Pareto parameter 0.13, power law coefficient -0.9, first-stage F-stat of 18. For hedge funds, -.73 and 66, for dealer banks, -0.40 and 38.

THIRD IDENTIFICATION STRATEGY: HETEROSKEDASTICITY

- 48 dates (out of 879) where monthly inflation data is released plus September 6th 2022 (Truss energy cap). In total 51 days out of 879 where swap prices move a lot, lumpy arrival of news.

- **Assumption 3c: Heteroskedascity at known dates due to fundamentals.** *If $\mathbf{\Sigma}_h$ is the variance-covariance matrix of the shocks $\boldsymbol{\varepsilon}$ at data release dates, and $\mathbf{\Sigma}_l$ the one at other dates, then the largest diagonal element of $\mathbf{\Sigma}_h'\mathbf{\Sigma}_l$ is the one associated with the variance of the fundamentals ε_π.*

- In data, the maximum eigenvalue is 7.6. Wald test Lutkepohl (2021): reject null of no heteroskedasticity at 0.1% significance level.

Dynamics and implementation for all strategies

- For dynamics: VAR, implemented as Bayesian VAR with diffuse priors and 3 lags:

$$\mathbf{Y}_t = \mathbf{c} + \sum_{\ell=1}^{L} \mathbf{\Phi}_\ell \mathbf{Y}_{t-\ell} + \mathbf{u}_t \quad \text{and} \quad \mathbf{u}_t = \mathbf{\Psi}\boldsymbol{\varepsilon}_t$$

- Timing identification: as in Arias, Rubio-Ramirez and Waggoner (2018), sign restrictions on $\mathbf{\Psi}$ for set identification.

- Granularity identification: as in Stock and Watson (2018), using *GIV* as proxy instrumental variables

- Heteroskedasticity identification: VAR as in Brunnermeier, Palia, Sastry, Sims (2021),

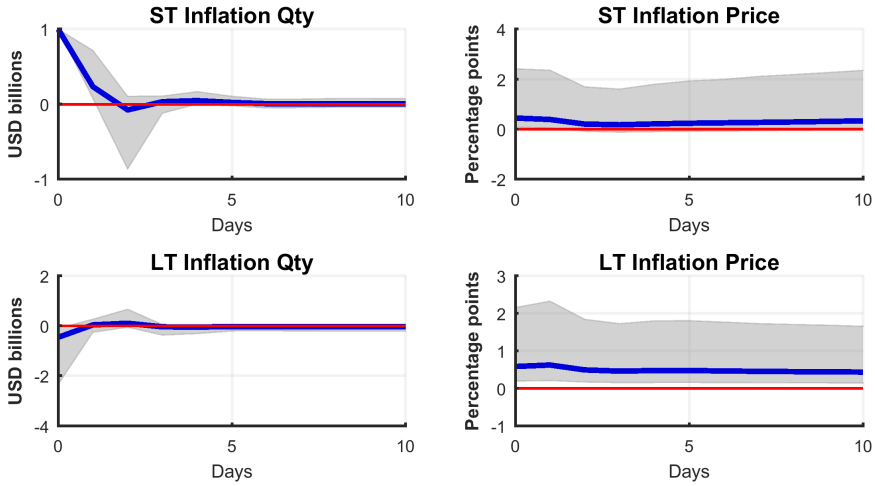
Cross checks of identification strategies

- IRF under the other two identification strategies has p, P, q, Q satisfy sign restrictions of timing strategy
- Timing strategy fundamental shocks variance at release dates are 1.3 more volatile than at other dates, and above one 91% of the times.
- The shocks $\hat{\varepsilon}_{\pi,t}$ estimated from the other two approaches $\frac{1}{T}\sum_{t=1}^{T} GIV_{\nu,t}\hat{\varepsilon}_{\pi,t}$ is -0.006, 0.030, and 0.032 for $\nu = f, h$, and b
- Correlations of estimated fundamental shocks from each of the three strategies.

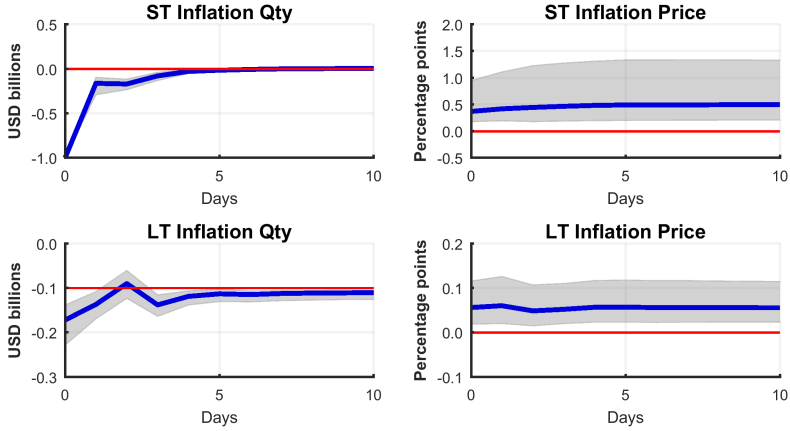
$$\begin{bmatrix} 1 & 0.979 & 0.842 \\ \cdot & 1 & 0.783 \\ \cdot & \cdot & 1 \end{bmatrix}$$

4. Estimates and applications

1. Speed of adjustment to fundamentals



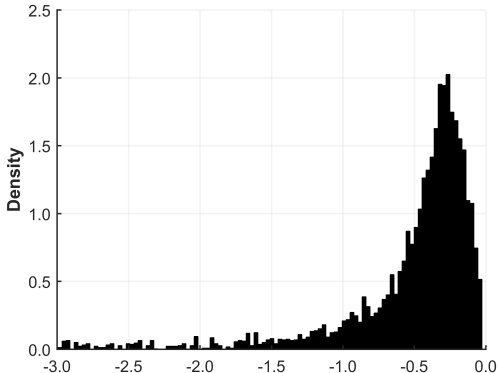
2A. RESPONSE TO LIQUIDITY SHOCKS TO DEALERS



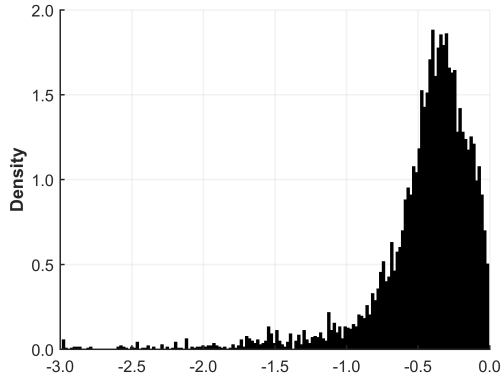
Banks Hedge funds

2B. SLOPE OF DEMAND FUNCTIONS

Hedge fund demand function

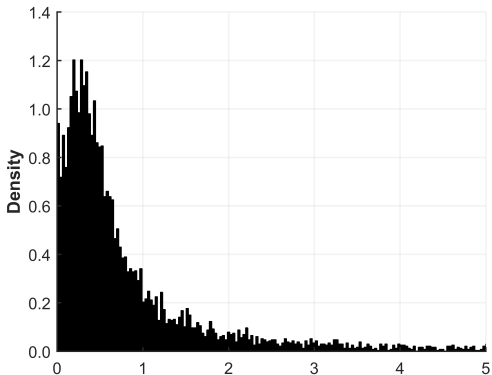


PFLDI demand function

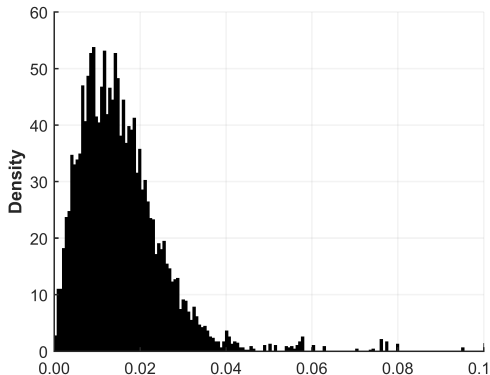


2B. SLOPE OF SUPPLY FUNCTIONS

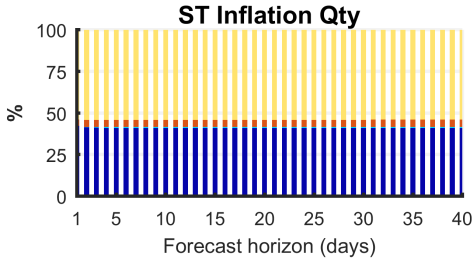
Dealers' supply function

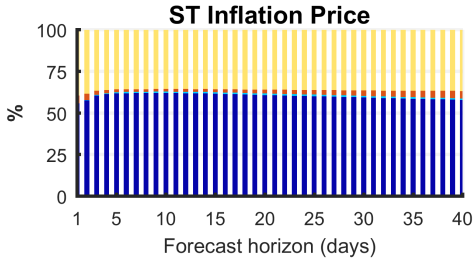


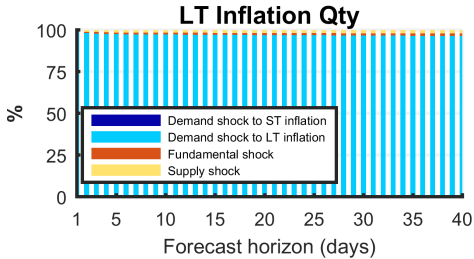
Dealers' supply function

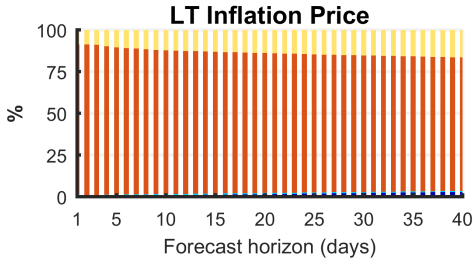


3. Forecast error variance decomposition

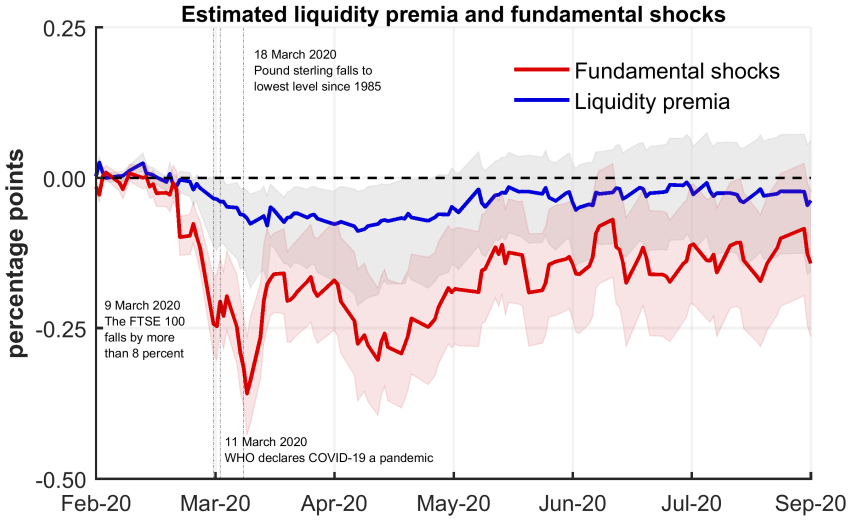




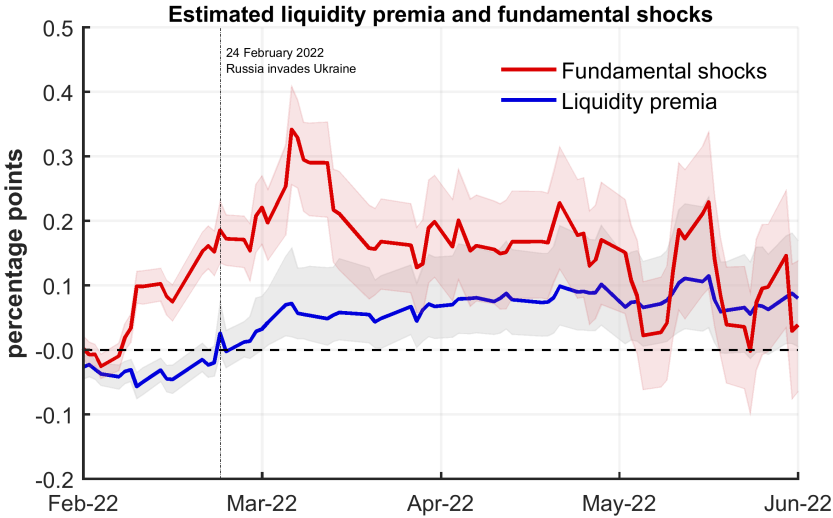




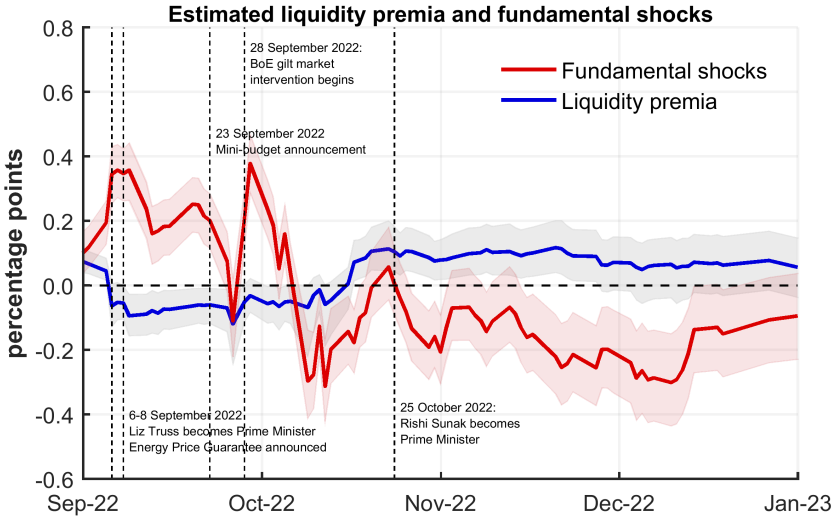
4A. HISTORY: COVID



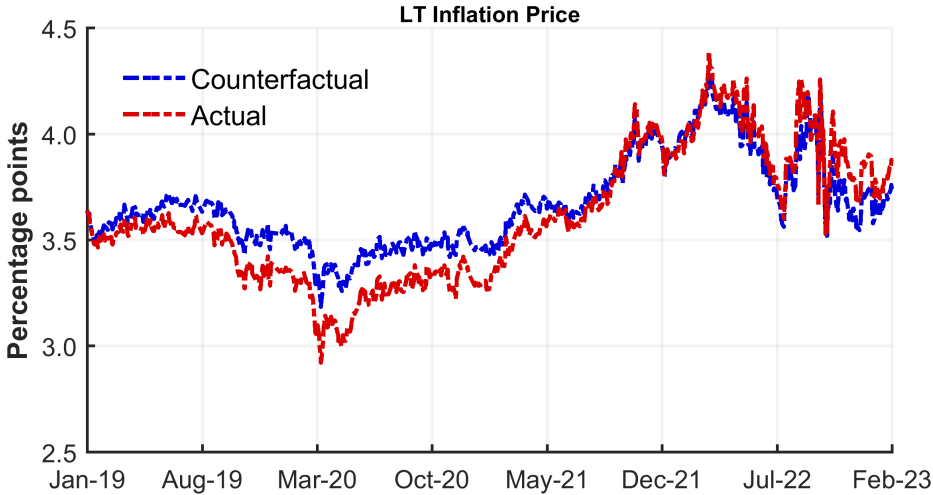
4B. HISTORY: UKRAINE



4C. HISTORY: MINI BUDGET AND LDIS



4D. HISTORY: CURRENT ANCHORING



5. Conclusion

Lessons

1) High-frequency trading data at the institution-level, for four years with many news, using three separate identification strategies gives robust results.

2) In short horizons, hedge funds and dealers alternate between negative and positive net positions. In long horizons, dealers provide inflation protection to pension funds.

3) Prices seem to fully reflect information after two to three days.

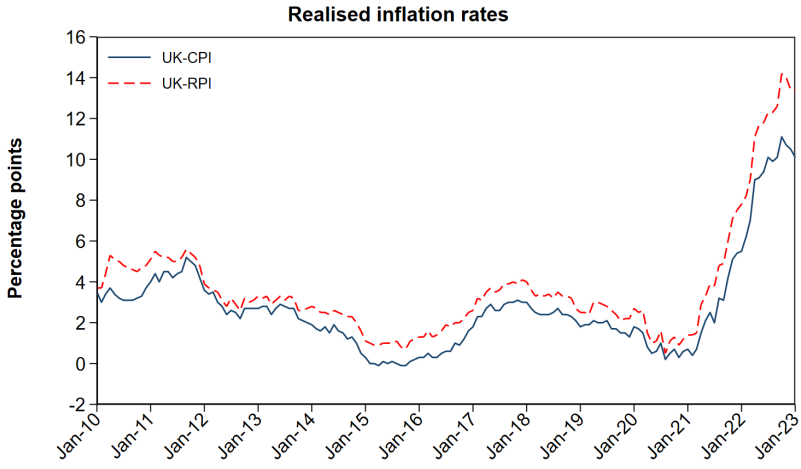
4) Slope of the supply function of dealers is much smaller at long than short horizons.

5) Fundamental shocks drive the long-horizon swap prices, while liquidity shocks drive the short-horizon prices.

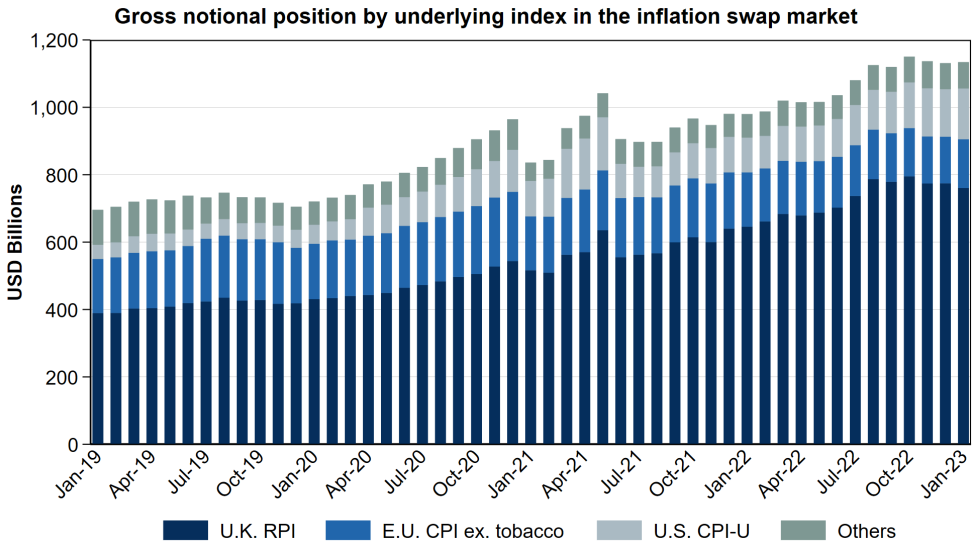
6) New measure of expected inflation at longer horizons cleaned of liquidity frictions.

Appendix

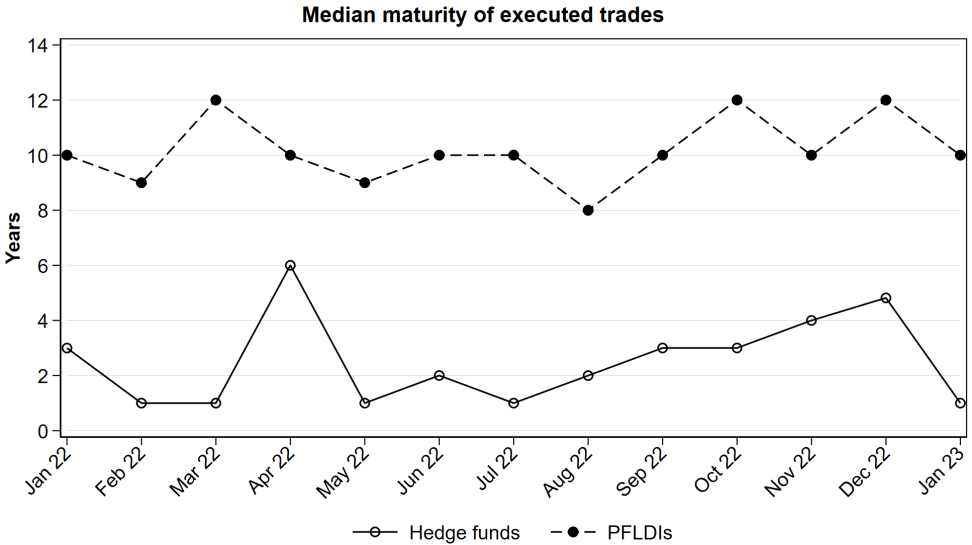
RPI VERSUS CPI



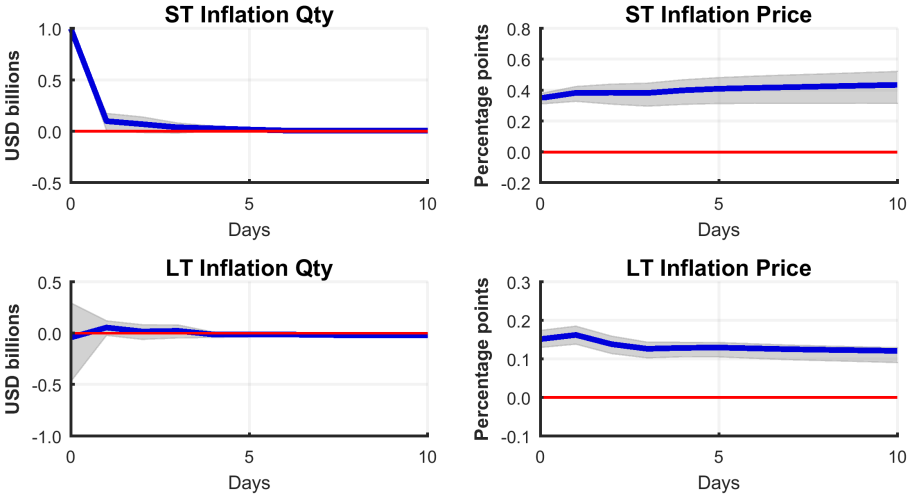
TYPE OF CONTRACT



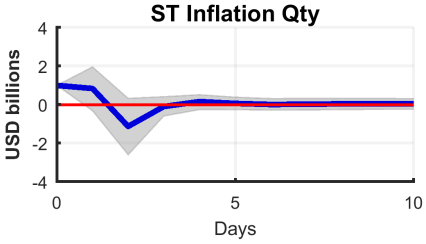
TRADES

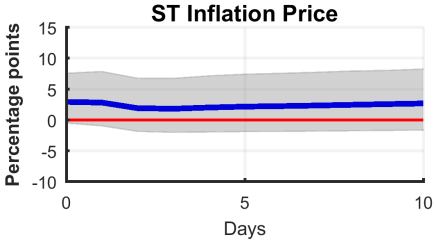

Median maturity of executed trades
Years
14
12
10
8
6
4
2
0
Jan 22
Feb 22
Mar 22
Apr 22
May 22
Jun 22
Jul 22
Aug 22
Sep 22
Oct 22
Nov 22
Dec 22
Jan 23
Hedge funds
PFLDIs

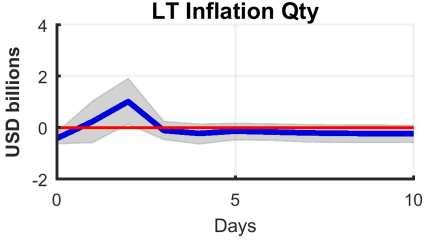
IRF TO FUNDAMENTAL WITH GIV

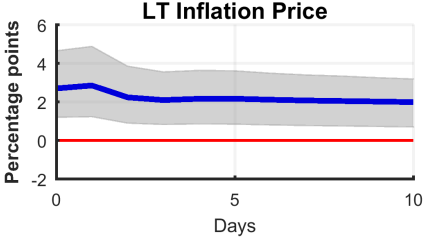


IRF TO FUNDAMENTAL WITH HETEROSKEDASTICITY

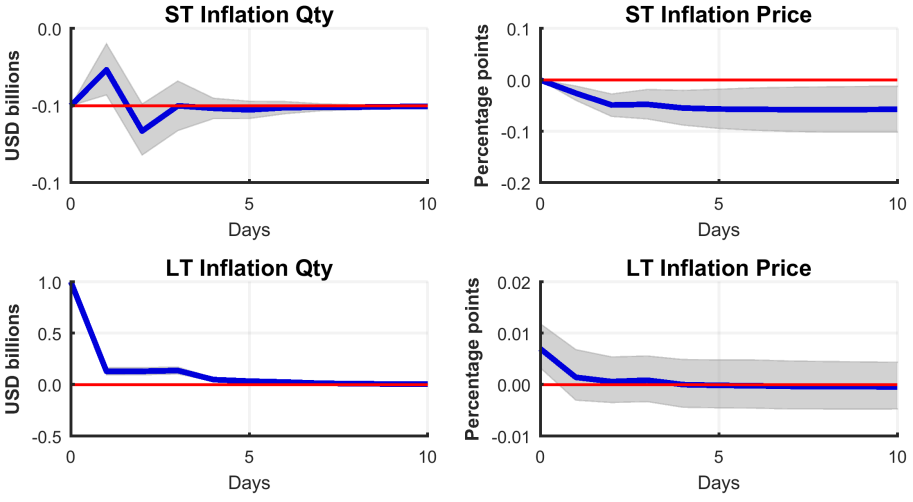




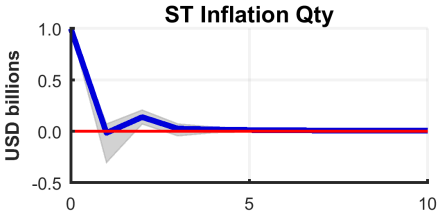


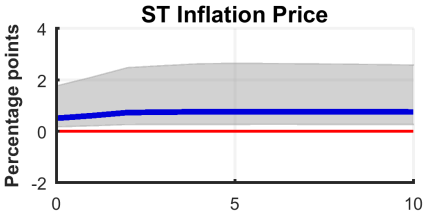


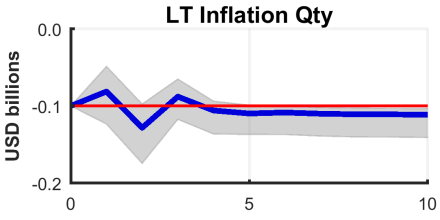
RESPONSE TO LIQUIDITY SHOCK TO PENSION FUNDS

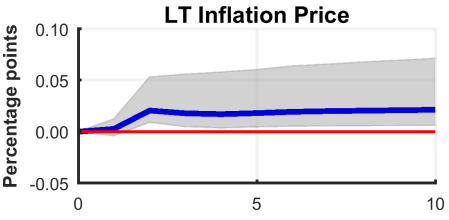


RESPONSE TO LIQUIDITY SHOCK TO HEDGE FUNDS









REPRESENTATIVENESS OF DATA

Comparison of Solvency II insurance holdings and EMIR TR data