A Model of Interacting Banks and Money Market Funds

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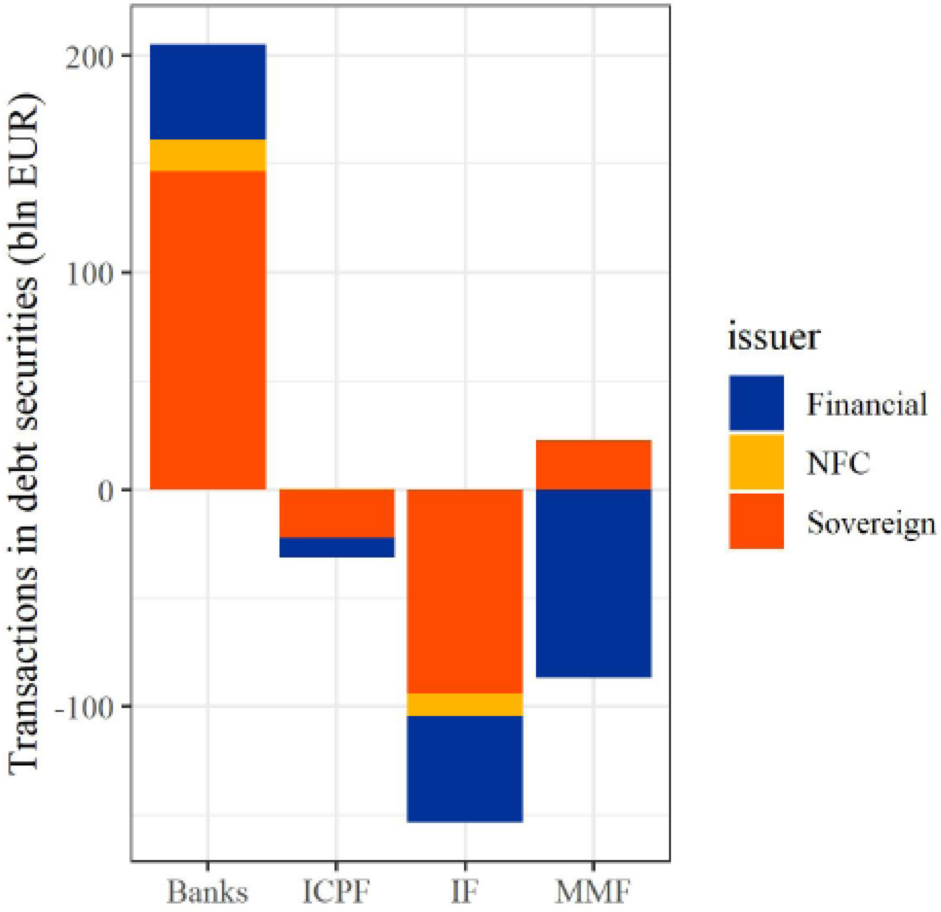
Introduction

- Banks and money market funds (MMFs) [or open-end funds (OEFs) more generally]
  - compete in attracting investors' demand for liquid-looking assets
  - interact in primary and secondary markets for securities
- Despite increasing policy attention, few models have considered banks & OEFs interacting in a market equilibrium setup
- We construct a model where bank deposits and MMFs shares coexist
  - Exploring the rationale for their coexistence
  - Identifying a source of inefficiency: secondary market frictions imply excessive channeling of savings towards MMFs

Empirical motivation

- In March 2020, news about the Covid-19 pandemic triggered a "dash for cash"
- Funds flew from floating value MMFs & corporate debt funds to constant value MMFs & bank deposits
- Sales of securities by MMFs and other OEFs in secondary markets added price pressure
- Several central banks established facilities to directly or indirectly provide liquidity to the OEF sector
- A debate was reignited on the contribution to financial (in)stability of this part of the NBFI sector

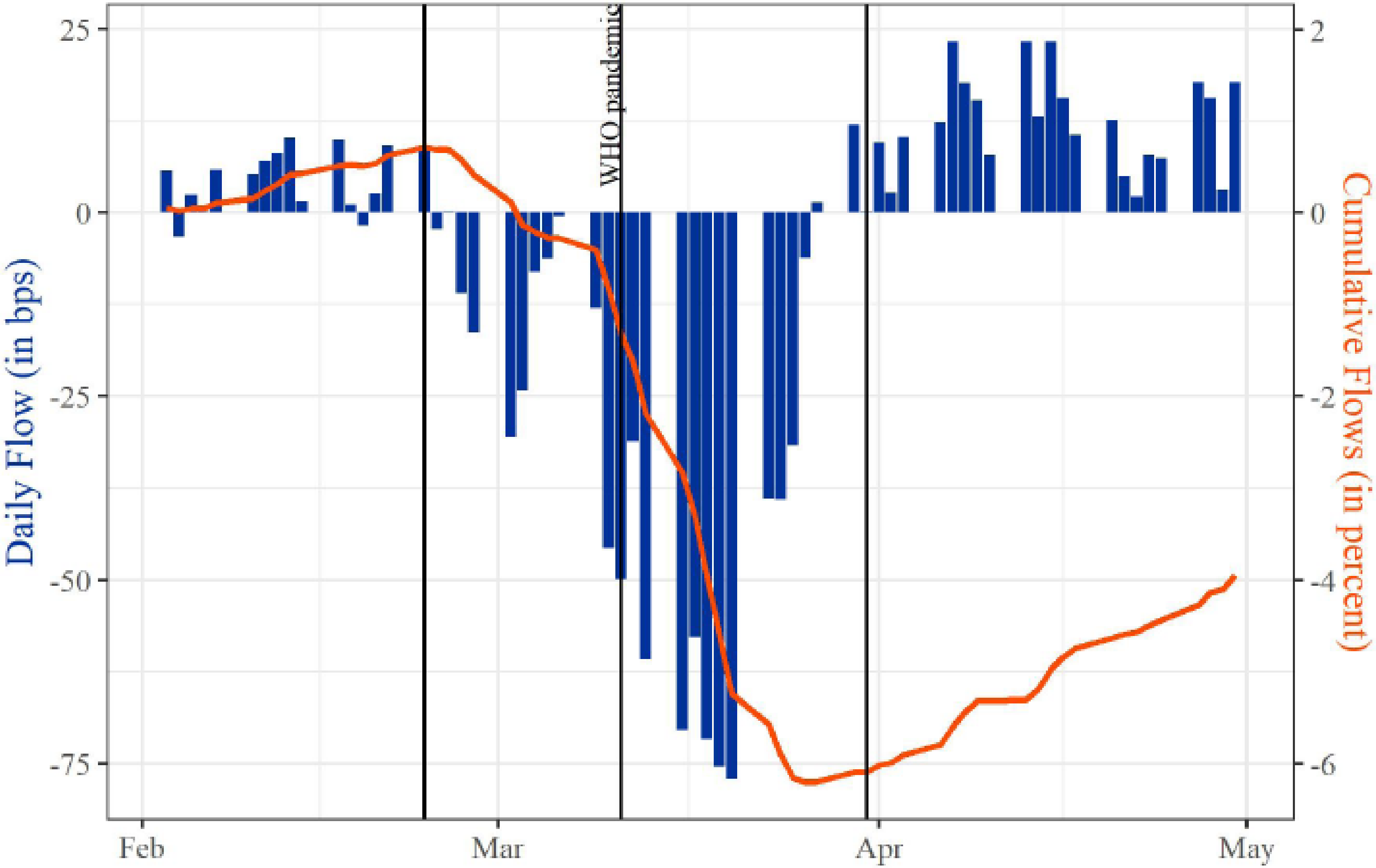
Figure 1: Transactions in debt securities during 2020Q1.



Notes: This figure shows aggregate transactions in debt securities by euro area investors broken down by investor type during the first quarter of 2020. We distinguish between Banks, Insurance Companies and Pension Funds (ICPF), Investment Funds (IF), and Money Market Funds (MMF). We also distinguish between debt issued by financial companies (Financial), non-financial corporations (NFC), and governments (Sovereign). Source: Securities Holdings Statistics.

Source: Dekker, Molestina Vivar, Wedow, Weistroffer (2023), "Liquidity buffers and open-end investment funds: containing outflows and reducing fire sales," ECB WP 2825, June.

Figure 3: Fund flows between February and April 2020.



(a) Open-end corporate bond mutual funds.

Source: Dekker, Molestina Vivar, Wedow, Weistroffer (2023), "Liquidity buffers and open-end investment funds: containing outflows and reducing fire sales," ECB WP 2825, June.

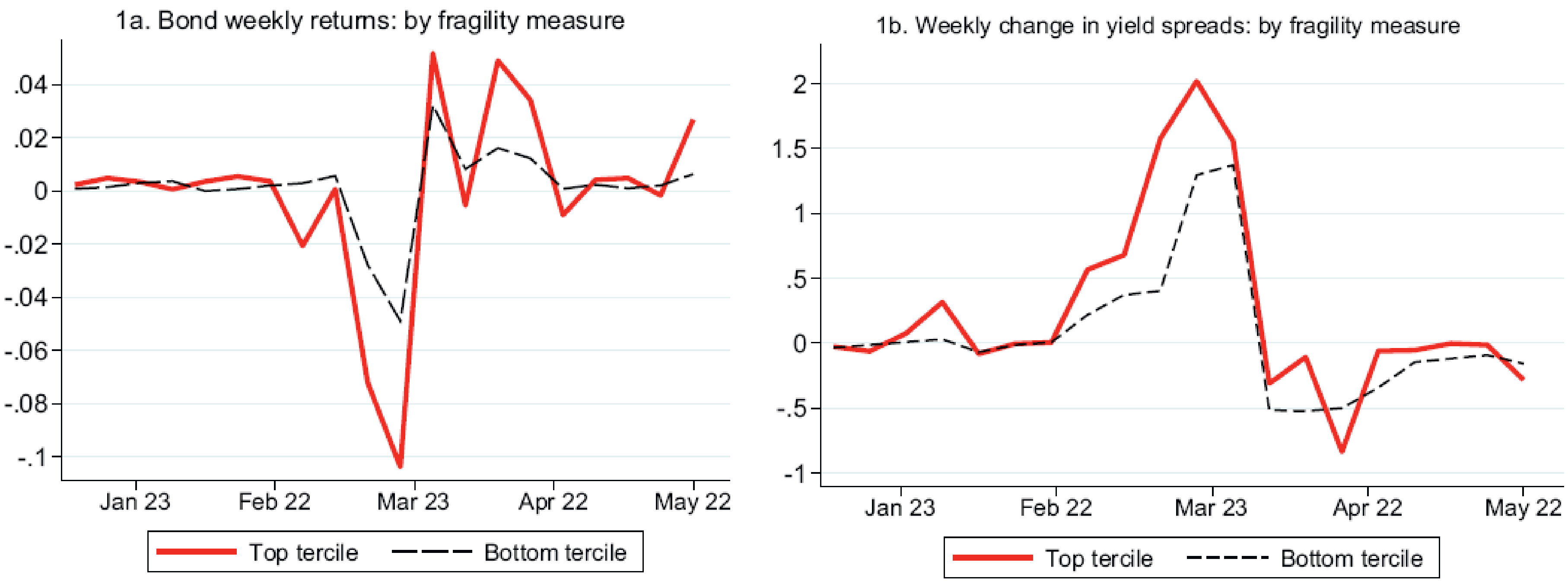


Fig. 1. Corporate bond returns and yield spreads during the COVID-19 crisis. This figure shows the dynamics of corporate bond returns and yield spreads during the COVID-19 crisis in March 2020, with the Federal Reserve announcing SMCCF on March 23. Bonds are sorted into terciles based on their end-of-2019 fragility measures, which are calculated based on the illiquidity levels of the bonds' mutual fund holders. Panel A shows the average weekly returns (not annualized, in decimals), weighted by amount outstanding. Panel B shows the average weekly change in yield spreads, weighted by amount outstanding.

Source: Jiang, Li, Sun, Wang (2022), "Does mutual fund illiquidity introduce fragility into asset prices? Evidence from the corporate bond market" Journal of Financial Economics 143, 277–302.

Our analytical setup

- Taking a step back, this paper constructs a simple 3-date model in which
  - At t=0, banks and MMFs compete to attract the savings of firms that wish to hold liquid-looking assets for precautionary reasons
    - Deposits promise fixed conversion value
    - MMF shares are redeemable at (potentially fluctuating) market value
  - At t=1,
    - idiosyncratic shocks make some deposits unaccessible & some firms get the opportunity to undertake profitable investment opportunities
    - an aggregate liquidity shock may push savings away from MMFs and into bank deposits
  - At t=2, final payoffs accrue to agents

Main insights from the analysis

- Portfolio rebalancing at $t=1$ is accommodated with trade of securities in frictional secondary market (due diligence costs, congestion,...)

  redemptions $\Rightarrow$ asset sales $\Rightarrow$ price declines

- Firms optimize aware of risk of fluctuations in redemption values but neglect pecuniary externality (via secondary market frictions)

  $\uparrow$ holdings of MMF shares $\rightarrow$ $\uparrow$ asset sales $\rightarrow$ $\uparrow$ price declines
  (in bad states)

- Even without 1st mover advantages, competitive equilibrium features inefficiency: excessive channeling of savings to MMFs

- Pigouvian tax on investment in MMFs can restore constrained efficiency

  [But problem is not MMFs per se but frictional secondary market]

Related literature ($\times$)

- Banks & non-banks: Plantin'15; Gertler-Kiyotaki-Prestipino'16; Moreira-Savov'17; Begenau-Landvoigt'18; Bengui-Bianchi'18; Ordoñez'18; Martinez-Miera & Repullo'19; Jeanne-Korinek'20 [here: not just in parallel but closely interacting]
- Non-bank provision of safe assets: Gennaioli-Shleifer-Vishny'13; Ferrante'18; Segura-Villacorta'20 [here: traditional precautionary preference for cash-like features]
- Financial fragility in the mutual fund sector: Chen-Goldstein-Jiang'10; Cipriani-Martin-McCabe-Parigi'14; Goldstein-Jiang-Ng'17; Cipriani-La Spada'20; Voellmy'21; Jin-Kacperczyk-Kahraman-Suntheim'22; policy papers [here: ex ante & ex post stages + no 1st-mover advantages]
- Other: pecuniary externalities (Lorenzoni'08, Dávila-Korinek'17); effects of bank regulation on liquidity provision (Cimon-Garriott'19; Saar-Sun-Yang-Zhu'20; d'Avernas-Vandeweyer'20; Breckenfelder-Ivashina'21); trading restrictions & deposit optimality (Jacklin'87); CB interventions (Falato-Goldstein-Hortacsu'21; Breckenfelder-Hoerova'23)

Outline of the presentation

- Some model details
- Equilibrium prices
- Equilibrium quantities
- Efficiency properties
- Conclusions and way forward

Some model details Three dates $t = 0, 1, 2$

- Measure-one continua of risk-neutral firms, banks & MMFs
- Firms and banks are competitive expected terminal net worth maximizers

Firms invest initial net worth e_0^f in deposits d_0^f & MMFs m_0^f

Firms	
Deposits $p_0^D d_0^f$	Net worth e_0^f
MMFs shares m_0^f	

At t=1, they receive:

- w/ idiosyncratic pr. π, scalable opportunity to invest w/ returns $A > 1 + r_1$
- w/ aggregate pr. γ, need to hold liquid deposits$\geq \theta e_0^f$ until t=2

Firms' uses & sources of funds at t=1:

Firm i

Illiquid deposits εd_0^f	Illiquid deposits εd_0^f
Deposits $p_1^D(\omega) d_1^f(s_i^f)$	Past liquid deposits $(1-\varepsilon)\, d_0^f$
MMFs shares $q_1(\omega) m_1^f(s_i^f)$	Past MMFs shares $q_1(\omega) m_0^f$
Investment in project $k_1^f(s_i^f)$	

Banks Indexed by j, aim to maximize expected terminal value

- Issue at discount one-period deposits d_0^b & two-period CP cp_0^b to invest at safe short-term rate r_0

Banks

Bank assets a_0^b	Deposits $p_0^D d_0^b$
	Commercial paper $p_0^{CP} cp_0^b$

- At $t{=}1$, illiquid banks ($\delta_j{=}1$, fraction ϵ) roll-over positions, while liquid banks ($\delta_j{=}0$) rebalance assets & liabilities

Liquid bank j (uses and sources of funds)

Assets $a_1^b(s_j^b)$ (with return r_1)	Past assets $(1+r_0)\,a_0^b$
CP $p_1^{CP}(\omega)\,(1+\lambda\,(\omega))\,t_1^b(s_j^b)$	Net deposit funding $p_1^D(\omega) d_1^b(s_j^b) - d_0^b$

- Buying in frictional secondary market involves unit cost

$$\lambda(\omega) = \frac{v}{e_0^f} \int t_1^b(s_j^b)\,dj \tag{1}$$

MMFs

- Invest m_0^f in bank CP:

MMFs

Commercial paper $\quad p_0^{CP} cp_0^m$	Shares m_0^f [w/ price normalized to q_0^m=1]

- At t =1 accommodate redemptions $m_0^f - \int m_1^f(s_i^f)di$ with CP sales:

MMFs (uses and sources of funds)

CP $\quad p_1^{CP}(\omega)\left(cp_0^m - t_1^m(\omega)\right)$	Shares $\quad q_1(\omega) \int m_1^f(s_i^f)di$

- Floating NAV avoids 1st mover advantage:

$$q_1(\omega) = \frac{\text{floating NAV}}{m_0^f} = \frac{p_1^{CP}(\omega)}{p_0^{CP}} \quad \Rightarrow \quad q_2(\omega) = \frac{\text{value of residual CP}}{\text{outstanding shares}} = \frac{1}{p_0^{CP}}$$

[declining with redemptions] [independent of redemptions]

Links between agents' balance sheets at t=0

Banks

Bank assets a_0^b	Deposits $p_0^D d_0^b$
	Commercial paper $p_0^{CP} cp_0^b$

Firms

Deposits $p_0^D d_0^f$	Net worth e_0^f
MMFs shares m_0^f	

MMFs

Commercial paper $p_0^{CP} cp_0^m$	Shares m_0^f

[At t=1, in an aggregate illiquidity state ω=1 (w. pr. γ) all firms need a minimum of liquid deposits up to terminal date (*dash for cash*)]

Agents' uses & sources of funds (or balance sheets) at t=1

Firm i (uses & sources of funds)

Illiquid deposits εd_0^f	Illiquid deposits εd_0^f
Deposits $p_1^D(\omega) d_1^f(s_i^f)$	Past liquid deposits $(1-\varepsilon)\, d_0^f$
MMFs shares $q_1(\omega) m_1^f(s_i^f)$	Past MMFs shares $q_1(\omega) m_0^f$
Investment in project $k_1^f(s_i^f)$	

Liquid bank j (uses & sources of funds)

Assets $a_1^b(s_j^b)$	Past assets $(1+r_0)\, a_0^b$
CP $p_1^{CP}(\omega)\,(1+\lambda(\omega))\, t_1^b(s_j^b)$	Net deposit funding $p_1^D(\omega) d_1^b(s_j^b) - d_0^b$

MMFs

CP $p_1^{CP}(\omega)\,(cp_0^m - t_1^m(\omega))$	Shares $q_1(\omega) \int m_1^f(s_i^f) di$

[Secondary trade in commercial paper is $t_1^m(\omega) = \int t_1^b(s_j^b) dj$]

Issues to discuss

- Characterization of interior competitive equilibrium
- Efficiency properties
- Pigouvian implementation of constrained efficient allocation

Equilibrium prices

- Model is very linear, except for aggregate friction in secondary market
- Firms' interior savings allocation at t=0 is characterized by an indifference condition which requires having $\lambda(1) = \lambda^*$ defined by

$$\epsilon \left\{\pi[A\text{–}(1+r_1)] + (1\text{–}\pi)\gamma\lambda^*(1+r_1)\right\} = \gamma \left\{\pi \frac{\lambda^* A}{1+\lambda^*} + (1\text{–}\pi)\lambda^*(1+r_1)\right\}$$

[E(losses due to deposit illiquidity)=E(losses due to MMF price decline if ω=1)]

- This builds on a "guess and verify" strategy (conjecturing no frictions in the liquid state, $\lambda(0) = 0$)
- Other prices are trivially connected to short-term rates r_0 & r_1

[Formal details in **L1**-**L4**]

Additional details $(\times)$

P1 Determinants of the price discount in $\omega{=}1$

$$\lambda^* = L(\underset{+}{\pi},\ \underset{+}{A},\ \underset{+}{\epsilon},\ \underset{-}{\gamma},\ \underset{0}{\theta},\ \underset{0}{r_0},\ \underset{-}{r_1},\ \underset{0}{v},\ \underset{0}{e_0^f})$$

(Demand-side determined λ^*; increases with parameters that make deposits comparatively less attractive; most surprising one: probability and attractiveness of investment projects increase $\lambda^* \rightarrow$ "procyclical" attractiveness of MMFs)

Equilibrium quantities

Firms' equilibrium portfolio decisions at $t{=}0$ are those compatible w/ market clearing at $t{=}1$ under the prices derived before

- Let $x_0^f \equiv m_0^f / e_0^f \in [0,1]$
- Market clearing with $\lambda(0)\mathbf{=}0$ **requires** $t_1^m(0){=}0 \Leftrightarrow x_0^f \leq \bar{x}_0^f$ **(L5)**
- Market clearing with $\lambda(1)\mathbf{=}\lambda^*$ **requires** $\Lambda(\underset{+}{x_0^f}) = \lambda^* \Rightarrow$ unique x^*:

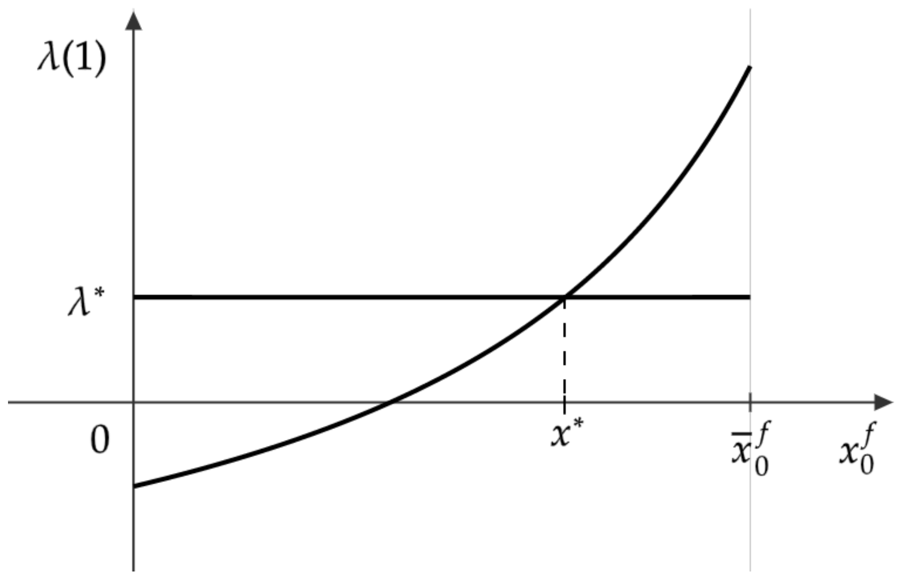


Fig. 2

[**P2** sets cond. for $x^* \in (0, \bar{x}_0^f]$

Additional results ($\times$)

P3 Determinants of x^*

	π	A	ϵ	γ	θ	r_0	r_1	v	e_0^f
Direct effect on x^*	–	0	–	0	-	+	+	–	0
Indirect effect via λ^*	+	+	+	-	0	0	-	0	0
Overall effect on x^*	?	+	?	–	–	+	?	–	0

[+ eff. A; – eff. illiquidity pr γ, liquidity needs θ & trading frictions v]

Efficiency analysis

Frictions in the model:

i) Markets incompleteness ($\rightarrow$ self-insurance)

ii) Friction affecting convertibility of deposits at interim date

iii) Secondary market frictions (growing in aggregate selling pressure)

Narrow notion of constrained efficiency [as in, e.g., Davila-Korinek'17]:

- How would a social planner decide x_0^f ($\rightarrow x^{SP}$)?

  [Maximizing firms' value subject to all frictions; letting agents & markets operate freely otherwise]

- Assume firms' decisions at $t{=}1$ are qualitatively as in competitive equilibrium $\Rightarrow$ pricing, except for $\lambda(1)$, is as in competitive equilibrium

Constrained inefficiency of the unregulated equilibrium

Social planner decides $x_0^f = x^{SP}$ aware of $\lambda(1) = \Lambda(x_0^f)$ & equlibrium pricing

$$\begin{aligned} \max_{x_0^f \in [0,1]} \quad & \mathbb{E}_0 \left[V_1^f \left((1 - x_0^f) e_0^f / p_0^D, x_0^f e_0^f; s_i^f \right) \right] \\ \text{s.t.:} \quad & \lambda(1) = \Lambda(x_0^f) + \text{equilibrium pricing} \end{aligned} \tag{2}$$

$$\text{FOC: } \frac{\partial \mathbb{E}_0 \left[V_1^f \left((1-x_0^f) e_0^f / p_0^D, x_0^f e_0^f; s_i^f \right) \right]}{\partial x_0^f} + \frac{\partial \mathbb{E}_0 \left[V_1^f \left((1-x_0^f) e_0^f / p_0^D, x_0^f e_0^f; s_i^f \right) \right]}{\partial \lambda(1)} \Lambda'(x_0^f) = 0 \tag{3}$$

[Evaluated at $x_0^f = x^*$, 1st term =0 (envelop theorem) & second term <0]

P4 Competitive equilibrium is not constrained efficient ($x^* \neq x^{SP}$); welfare can be increased by lowering the investment in MMFs $x_0^f < x^*$

Implementation of x^{SP} with a Pigouvian tax

Consider taxing m_0^f at rate τ & rebating revenue to firms at $t = 0$ with lump-sum transfer $L = \tau m_0^f$:

P5 Constrained efficient allocation w/ $x^{SP} < x^*$ can be implemented w/ some $\tau = \tau^{SP} > 0$

The optimal tax:

- induces firms to internalize social MgC of aggravating secondary market frictions via investment in MMFs
- reduces portfolio share x_0^f while reducing liquidity discosunt $\lambda(1)$ in state ω=1

Conclusions and way forward

- Preliminary model with interacting banks & MMFs / OEFs
- Even without 1st mover advantages, investment in OEFs is excessive due to pecuniary externality related to secondary market frictions
- Model is just a 1st step along several dimensions:
  - reduced-form nature of frictions affecting bank deposits
  - no microfoundations for secondary market frictions
  - banks are not (explicitly) involved in maturity transformation
- Way forward:
  - allowing banks to invest in long-term assets
  - relating the frictions to the quality of (bank) assets
  - allowing MMFs / OEFs to invest in more liquid assets (or to have access to central bank liquidity)

THANK YOU!

SUPPLEMENTARY MATERIAL

Balance sheets at t=2

Firm i

Illiquid deposits $\varepsilon d_0^f / p_1^D(\omega)$	Net worth
Liquid deposits $d_1^f(s_i^f)$	
MMFs shares $q_2(\omega) m_1^f(s_i^f)$	
Real assets $A k_1^f(s_i^f)$	

Liquid bank j

Assets $(1+r_1)\, a_1^b(s_j^b)$	Deposits $d_1^b(s_j^b)$
CP $t_1^b(s_j^b)$	CP cp_0^b
	Net worth (=0)

MMFs

CP $cp_0^m - t_1^m(\omega)$	Shares $q_2(\omega) \int m_1^f(s_i^f) di$

Definition of competitive equilibrium

- Allocation

$$\Big\{ \{d_0^f, m_0^f, d_0^b, cp_0^b, a_0^b, cp_0^m\}$$
$$\{d_1^f(s^f), m_1^f(s^f), k_1^f(s^f)\}_{s^f}, \{d_1^b(s^b), t_1^b(s^b), a_1^b(s^b)\}_{s^b}, \{t_1^m(\omega)\}_{\omega=0,1} \Big\}$$

- Prices

$$\{p_0^D, p_0^{CP}, \{p_1^D(\omega), p_1^{CP}(\omega)\}_{\omega=0,1}\}$$

such that agents optimize and markets clear

[We derive equilibrium conditions by backward induction; with conjectured firm behavior that is confirmed as optimal under equilibrium prices]

Backward induction analysis:

Firms at t=2

Firm terminal net worth:

$$V_2^f(s_i^f) = \varepsilon \frac{d_0^f}{p_1^D(\omega)} + d_1^f(s_i^f) + q_2\,(\omega)\, m_1^f(s_i^f) + \psi_i A k_1^f(s_i^f) \tag{4}$$

Bank terminal net worth (trivial):

$$V_2^b(s_j^b) = (1 + r_1)\, a_1^b(s_j^b) + t_1^b(s_j^b) - d_1^b(s_j^b) - cp_0^b \tag{5}$$

MMFs' balance sheet (trivial):

$$q_2(\omega) \int m_1^f(s_i)di = cp_0^m - t_1^m(\omega) \tag{6}$$

Firms at t=1

Continuation value results from maximization of expected final net worth

$$V_1^f(d_0^f, m_0^f; s_i^f) = \max_{\left\{d_1^f(s_i^f), m_1^f(s_i^f), k_1^f(s_i^f)\right\}} \left\{\frac{\varepsilon d_0^f}{p_1^D(\omega)} + d_1^f(s_i^f) + q_2(\omega)\, m_1^f(s_i^f) + \psi_i A k_1^f(s_i^f)\right\} \tag{7}$$

s.t.: $$p_1^D(\omega)\, d_1^f(s_i^f) + k_1^f(s_i^f) = (1-\varepsilon)\, d_0^f + q_1(\omega)\,(m_0^f - m_1^f(s_i^f)) \tag{8}$$

$$d_1^f(s_i^f) \geq \omega\theta e_0^f \tag{9}$$

$$m_1^f(s_i^f), k_1^f(s_i^f) \geq 0 \tag{10}$$

[budget constraint; liquid deposits requirement in ω=1; non-negativity constraints]

Guess & verify optimal firm behavior at t=1

1. Firms **with an investment project** choose maximum project scale given frozen deposits & minimal liquid deposits in ω=1:

$$d_1^f(s_i^f) = \omega\theta e_0^f, \quad m_1^f(s_i^f) = 0 \tag{11}$$

$$k_1^f(s_i^f) = (1-\varepsilon)\, d_0^f + q(\omega) m_0^f - p_1^D(\omega)\, \omega\theta e_0^f \geq 0 \tag{12}$$

$$\text{Optimality requires } A \geq \max\left\{\frac{1}{p_1^D(0)}, \frac{1}{p_1^D(1)}, \frac{q_2(0)}{q_1(0)}, \frac{q_2(1)}{q_1(1)}\right\} \tag{13}$$

2. Firms **w/o investment project in ω=1** choose minimal liquid deposits (implying minimal MMFs redemption at aggregate level):

$$d_1^f(s_i^f) = \theta e_0^f, \quad k_1^f(s_i^f) = 0 \tag{14}$$

$$m_1^f(s_i^f) = \frac{q_1(1)\, m_0^f + (1-\varepsilon)\, d_0^f - p_1^D(1)\, \theta e_0^f}{q_1(1)} \geq 0 \tag{15}$$

Optimality requires $\frac{q_2(1)}{q_1(1)} \geq \frac{1}{p_1^D(1)}$

3. Firms **w/o investment project in ω=0** choose any combination $\left(d_1^f(s_i^f), m_1^f(s_i^f)\right)$ satisfying:

$$p_1^D(0)\, d_1^f(s_i^f) = (1-\varepsilon)\, d_0^f + q_1(0) \left(m_0^f - m_1^f(s_i^f)\right) \tag{16}$$

(allowing accommodation of liquidity shock w/o sales of CP)

$$\text{Optimality requires } \frac{q_2(0)}{q_1(0)} = \frac{1}{p_1^D(0)} \tag{17}$$

Liquid banks at t=1

- Maximize continuation value:

$$V_1^b\left(d_0^b, cp_0^b; s_j^b\right) = \max_{\left\{a_1^b(s_j^b), d_1^b(s_j^b), t_1^b(s_j^b)\right\}} \left\{(1+r_1)\, a_1^b(s_j^b) + t_1^b(s_j^b) - d_1^b(s_j^b) - cp_0^b\right\} \quad (18)$$

subject to

$$a_1^b(s_j^b) + p_1^{CP}(\omega)\,(1+\lambda(\omega))\, t_1^b(s_j^b) = (1+r_0)\,(p_0^D d_0^b + p_0^{CP} cp_0^b) + (p_1^D(\omega)\, d_1^b(s_j^b) - d_0^b) \quad (19)$$

$$d_1^b(s_j^b) \geq 0 \quad (20)$$

- Having interior optimal $d_1^b(s_j^b)$ & $t_1^b(s_j^b)$ requires:

$$p_1^D(\omega) = \frac{1}{1+r_1} \quad (21)$$

$$p_1^{CP}(\omega) = \frac{1}{(1+r_1)(1+\lambda(\omega))} \quad (22)$$

[perfectly elastic supply of deposits + willingness to buy commercial paper]

MMFs at t=1

- Sell commercial paper $t_1^m(\omega)$ to accommodate net redemptions
- Under non-diluting pricing this implies

$$t_1^m(\omega) = \left(1 - \frac{\int m_1^f(s_i^f)\,di}{m_0^f}\right) cp_0^m \tag{23}$$

Market clearing at $t = 1$

Clearing markets for deposits and commercial paper requires

$$\int d_1^b(s_j^b)\,dj - \epsilon \frac{d_0^f}{p_1^D(\omega)} \;=\; \int d_1^f(s_i^f)\,di \tag{24}$$

$$\int t_1^b(s_j^b)\,dj \;=\; t_1^m(\omega) \tag{25}$$

Firms at t=0 Allocate initial funds across deposits & MMFs shares

$$\max_{\{d_0^f, m_0^f\}} \quad \mathbb{E}_0 \left[V_1^f \left(d_0^f, m_0^f; s_i^f \right) \right] \qquad \text{[linear objective]} \tag{26}$$

s.t.:

$$p_0^D d_0^f + m_0^f = e_0^f \tag{27}$$

$$d_0^f, m_0^f \geq 0 \qquad \text{[linear constraints]} \tag{28}$$

L1 Firms' **indifference** at t=0 requires

$$\frac{1}{p_0^D} \left\{ (1-\epsilon) \left[\pi A + (1-\pi) \left(\tfrac{1-\gamma}{p_1^D(0)} + \tfrac{\gamma q_2(1)}{q_1(1)} \right) \right] + \epsilon \left(\tfrac{1-\gamma}{p_1^D(0)} + \tfrac{\gamma}{p_1^D(1)} \right) \right\} =$$

$$\pi A \left[(1-\gamma)\, q_1(0) + \gamma q_1(1) \right] + (1-\pi) \left[(1-\gamma) q_2(0) + \gamma q_2(1) \right] \tag{29}$$

[E(R_bank deposits) = E(R_MMFs shares); notice elements in $q_t(\omega)$]

Banks at t=0 (trivial)

Building on expression for continuation value in (18)-(20), the bank solves

$$\max_{\{d_0^b, cp^b\}} \quad \mathbb{E}_0 \left[V_1^b \left(d_0^b, cp_0^b; s_j^b \right) \right] \tag{30}$$

$$\text{s.t.:} \qquad d_0^b, cp_0^b \geq 0 \tag{31}$$

Interior solutions require

$$p_0^D = \frac{1}{1+r_0} \text{ and} \tag{32}$$

$$p_0^{CP} = \frac{1}{(1+r_0)(1+r_1)} \tag{33}$$

[supply of deposits & CP are perfectly elastic at these prices]

MMFs at t=0 (trivial)

Balance sheet constraint:

$$m_0^f = p_0^{CP} cp_0^m \tag{34}$$

Market clearing at t=0 (trivial)

Clearing of deposit and commercial paper markets

$$d_0^b = d_0^f \tag{35}$$

$$cp_0^b = cp_0^m \tag{36}$$

Equilibrium analysis

Banks' optimization & MMFs pricing rules determine most prices; indifference condition in L1 determines unique candidate value of $\lambda(1)$

L2+L3 Conjectured equilibrium involves

$$p_1^{CP}(1) = \frac{1}{(1+r_1)(1+\lambda(1))}, \quad q_1(1) = \frac{1+r_0}{1+\lambda(1)}; \tag{37}$$

and $\lambda(1) = \lambda^*$ defined by

$$\epsilon \{\pi[A-(1+r_1)] + (1-\pi)\gamma\lambda^*(1+r_1)\} = \gamma \left\{\pi \frac{\lambda^* A}{1+\lambda^*} + (1-\pi)\lambda^*(1+r_1)\right\} \tag{38}$$

[E(losses due to deposit illiquidity)=E(losses due to MMF price decline if ω=1)]

Other prices are trivially connected to short-term rates r_0 & r_1

L4 Remaining necessary and sufficient condition for optimality of firms' conjectured behavior under the prices obtained in L2 & L3:

$$\gamma \geq \frac{\pi\epsilon}{\pi\epsilon + (1-\epsilon)} \tag{39}$$

$[\mathrm{Pr}($illiquid state$) \geq F($pr. receiving project, pr. deposit illiquidity$)]$

Equilibrium quantities

Firms' portfolio decisions at $t{=}0$ are determined as those compatible w/ market clearing at $t{=}1$ under the prices derived before

- Let $x_0^f \equiv m_0^f / e_0^f \in [0,1]$
- Market clearing under $\lambda(0)\mathbf{=}0$ **requires** $t_1^m(0){=}0 \Leftrightarrow x_0^f \leq \bar{x}_0^f$ **(L5)**
- Market clearing under $\lambda(1)\mathbf{=}\lambda^*$ **requires** $\underset{+}{\Lambda(x_0^f)} = \lambda^* \Rightarrow$ unique x^*:

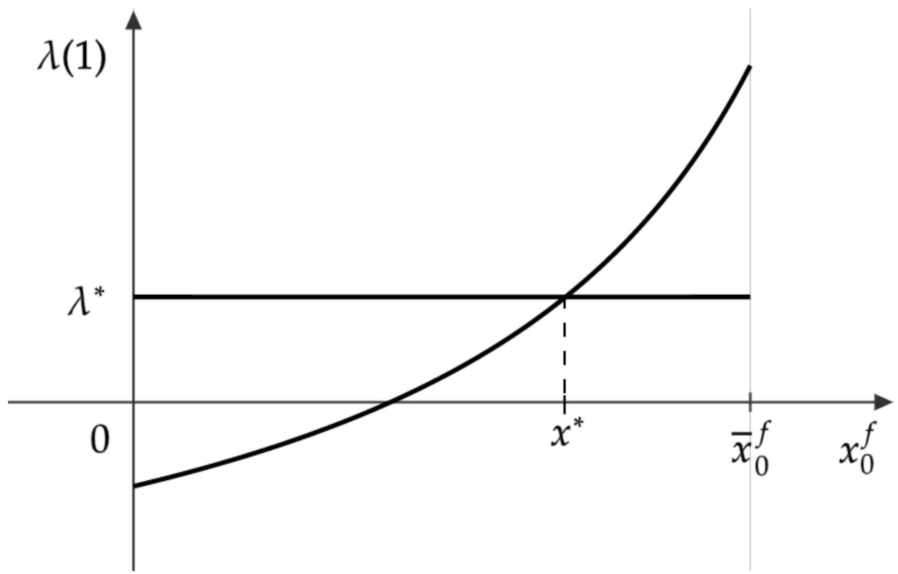


Fig. 2
[**P2** sets cond. for $x^* \in (0, \bar{x}_0^f]$

P2 Under (39), the necessary and sufficient condition for $x^* \in (0, \bar{x}_0^f]$ is

$$\frac{\lambda^*}{1+\lambda^*}\frac{[\pi+(1-\pi)(1-\varepsilon)]+v(1-\pi)(1-\epsilon)(1+r_0)(1+r_1)\pi}{v(1-\pi)[\pi+(1-\pi)(1-\varepsilon)]} \leq \theta < (1-\epsilon)(1+r_0)(1+r_1) \quad (40)$$

Further discussion on policy issues

- Richer policy interventions (w/ taxes & subsidies not only at t=0) might improve on the constrained efficient allocation

  [But characterizing interventions bringing outcomes closer to 1st best is beyond our scope]

- We could examine specific policy proposals put forward after March 2020 (e.g. redemption fees or liquidity requirements)

  $\longrightarrow$ Some of these might help while being generally inferior to taxing m_0^f

  - $*$ Investment in MMFs is ex ante discouraged
  - $*$ But at cost of worsening MMFs' "liquidity insurance" function

  [If taxes are not viable, liquidity requirements at t =0 might be superior to interventions aimed to discourage x_0^f by penalizing redemptions]