Optimal Macro-Financial Stabilization in a New Keynesian Preferred Habitat Model

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Motivation

Motivation

Bernanke: "QE works in practice but not in theory"

- By now the gap between practice and theory is small
- But what do we mean by *QE works*?
  - Obvious: reduce long-term yields
  - Less obvious: stimulate the economy
  - Even less obvious: improve social welfare
  - Reis: "QE's original sin"
- Especially relevant today now that central banks are implementing QT while increasing short rates
- Question: what is the optimal QE policy, and how does this interact with short rate policy?

Our Model

- This paper: develops a tractable general equilibrium model with market segmentation, nominal frictions, and household heterogeneity
- Arbitrageurs must absorb supply and demand shocks in bond markets
- Clientele investors introduce a degree of market segmentation
  - Bond markets populated by different investor clienteles (pension funds, mutual funds)
  - Arbitrageurs (hedge funds, broker-dealers) partly overcome segmentation
- Households have differentiated access to bond markets
  - Introduces imperfect risk-sharing and consumption dispersion across households
- Formally: embed a Vayanos-Vila model in a New Keynesian model, where households are heterogeneous in their savings vehicles

Findings: Policy Transmission

- Key mechanisms of conventional monetary policy:
  - Policy rate changes are transmitted to households via segmented bond markets
  - Interaction of arbitrageurs and investor clienteles implies portfolio rebalancing
  - Hence, short rate changes lead to variation in risk premia
- Key mechanisms of balance sheet policy:
  - Central bank asset purchases induce portfolio rebalancing and hence reduce risk premia
  - Vice versa for central bank asset sales (QT)
- Thus, short rate and balance sheet policies are substitutes when targeting aggregate borrowing rates
  - A fall in aggregate borrowing rates is stimulative for the usual NK reasons
- However, both policies imply variation in risk premia
  - Excess fluctuations in risk premia implies dispersion in borrowing rates and therefore consumption across households

Findings: Optimal Policy

- Hence, when policy is unconstrained we derive an **optimal separation result**:
  - Conventional policy targets macroeconomic stability
  - Unconventional policy targets financial stability
- However, when policy constraints bind, policy must balance trade-offs:
  - Balance sheet constraints: short rate must be less reactive in order to minimize financial disruptions (at the cost of macroeconomic stability)
  - Short rate constraints: QE must be used to offset macroeconomic shocks (at the cost of financial stability)
- General message: implementation matters for welfare

Related Literature

- Preferred habitat models
  - Vayanos & Vila (2021), Ray, Droste, & Gorodnichenko (2023), Greenwood & Vayanos (2014), Greenwood et al (2016), King (2019, 2021) , ...
- Empirical evidence: QE and preferred habitat
  - Krishnamurthy & Vissing-Jorgensen (2012), D'Amico & King (2013), Li & Wei (2013), Cahill et al. (2013), King (2019), Fieldhouse et al (2018), Di Maggio et al (2020), Gali, Debortoli, & Gambetti (2020) , ...
- Macroeconomic QE models
  - Andres, Lopez-Salido, & Nelson (2004), Gertler & Karadi (2011), Curdia & Woodford (2011), Chen et al (2012), Gertler & Karadi (2013), Sims & Wu (2020), Karadi & Nakov (2020), Iovino and Sergeyev (2023), Carlstrom et al (2017), Ippolito et al (2018) , ...
- Market segmentation, macro-prudential monetary policy
  - Cui & Sterk (2021), Auclert (2016), Collard et al (2017), Kaplan et al (2017), Debortoli & Gali (2017) , ...
- International
  - Itskhoki & Mukhin (2022), Greenwood et al (2023), Gourinchas, Ray, & Vayanos (2022) , ...

Set-Up

Model Set-Up

- Continuous time New Keynesian model with embedded Vayanos-Vila bond markets
- **Agents**:
  - Households: supply labor, consume, save via differentiated habitat bond funds
  - Firms: monopolistic competitors produce using labor, face nominal pricing frictions
  - Habitat funds: buys and sell bonds of a specific maturity
  - Arbitrageurs: imperfect risk-bearing capacity, conduct bond carry trades
  - Central bank: conducts short rate and balance sheet (QE) policy
  - Government: optimal production subsidy, otherwise passive
- **Bond markets**:
  - Continuum of zero coupon bonds with maturity $0 \leq \tau \leq T \leq \infty$
  - Bond price $P_t^{(\tau)}$ with yield to maturity $y_t^{(\tau)} = -\log P_t^{(\tau)}/\tau$
  - Nominal short rate $i_t = \lim_{\tau \to 0} y_t^{(\tau)}$

Households

- Continuum of HHs, differentiated by access to bond markets τ
- There is a mass $\eta(\tau)$ of each τ HH where $\int_0^T \eta(\tau)\,\mathrm{d}\tau = 1$ (but otherwise identical)
- A τ-HH chooses consumption and labor $C_t^{(\tau)}, N_t^{(\tau)}$ in order to solve

$$V_0^{(\tau)} \equiv \max \mathrm{E}_0 \int_0^\infty e^{-\rho t} \left(\frac{\left[C_t^{(\tau)}\right]^{1-\varsigma}}{1-\varsigma} - \frac{\left[N_t^{(\tau)}\right]^{1+\phi}}{1+\phi} \right) \mathrm{d}t$$

$$\text{s.t.} \quad \mathrm{d}A_t^{(\tau)} = \left[\mathcal{W}_t N_t^{(\tau)} - P_t C_t^{(\tau)}\right] \mathrm{d}t + A_t^{(\tau)} \frac{\mathrm{d}P_t^{(\tau)}}{P_t^{(\tau)}} + \mathrm{d}F_t^{(\tau)}$$

- $A^{(\tau)}$ is nominal wealth earning $\frac{\mathrm{d}P_t^{(\tau)}}{P_t^{(\tau)}}$ and $\mathrm{d}F_t^{(\tau)}$ are (flow) nominal transfers
- $\mathcal{W}_t$ is the nominal wage and P_t is the price index (same for all HHs)

Key takeaway: differentiated consumption and labor choices when bond returns not equalized

Firms

- Continuum of intermediate goods $j \in [0,1]$ (and CES final good)
- Linear production in labor $Y_{t,j} = Z_t N_{t,j}$ where $Z_t = \bar{Z}e^{z_t}$ is aggregate technology:

$$\mathrm{d}z_t = -\kappa_z z_t \,\mathrm{d}t + \sigma_z \,\mathrm{d}B_{t,z}$$

- Face Rotemberg costs $\Theta(\pi_{t,j}) = \frac{\theta}{2}\pi_{t,j}^2 P_t Y_t$ when setting prices $\frac{\mathrm{d}P_{t,j}}{P_{t,j}} = \pi_{t,j}\,\mathrm{d}t$
- Nominal profits are given by

$$\mathcal{F}_t(P_{t,j}, Y_{t,j}, \pi_{t,j}) = (1+\tau^*)P_{t,j}Y_{t,j} - W_t N_{t,j} - \Theta(\pi_{t,j}) - \mathcal{T}_t$$

  - τ^* is the (optimal) production subsidy funded by lump-sum taxes $\mathcal{T}_t$
- Firms choose $\pi_{t,j}$ in order to solve

$$U_0 \equiv \max \mathrm{E}_0 \int_0^\infty e^{-\rho t} Q_t \frac{\mathcal{F}_t}{P_t}\,\mathrm{d}t$$

  - Since HHs own firms, profits are discounted by weighted real SDF $Q_t \equiv \int_0^T \eta(\tau) Q_t^{(\tau)}\,\mathrm{d}\tau$

Key takeaway: pricing frictions create deadweight loss

Arbitrageurs

- Mean-variance optimization

$$\max \mathsf{E}_t \,\mathrm{d}W_t - \frac{\gamma}{2} \mathsf{Var}_t \,\mathrm{d}W_t$$

$$\text{s.t. } \mathrm{d}W_t = W_t i_t \,\mathrm{d}t + \int_0^T X_t^{(\tau)} \left(\frac{\mathrm{d}P_t^{(\tau)}}{P_t^{(\tau)}} - i_t \,\mathrm{d}t \right) \mathrm{d}\tau$$

- Arbitrageurs invest $X_t^{(\tau)}$ in bond carry trade of maturity τ
- Remainder of wealth W_t invested at the short rate
- Risk-return tradeoff governed by γ

Key takeaway: risk averse arbitrageurs' holdings increase with expected return

Preferred Habitat Funds

- Habitat bond demand for maturity τ:

$$Z_t^{(\tau)} = -\alpha(\tau) \log P_t^{(\tau)} - \theta(\tau)\beta_t$$

- $\alpha(\tau)$: demand elasticity for τ fund
- β_t: additional time-varying ("noise") demand factor

$$\mathrm{d}\beta_t = -\kappa_\beta \left(\beta_t - \bar{\beta}\right) \mathrm{d}t + \sigma_\beta \, \mathrm{d}B_{\beta,t}$$

- $\theta(\tau)$: mapping from demand factor to τ-habitat demand

Key takeaway: price movements require portfolio rebalancing

Government

- Central bank chooses the policy rate i_t and bond holdings $S_t^{(\tau)}$
- Optimal policy: maximize social welfare

$$\max \mathrm{E}_0 \int_0^{\infty} e^{-\rho t} \left(\int_0^T \eta(\tau) u \left(C_t^{(\tau)}, N_t^{(\tau)} \right) \right) \mathrm{d}t$$

- In the background: fiscal authority chooses production subsidy τ^*

Key takeaway: policy attempts to undo frictions:

1. Monopolistic competition $\implies$ inefficient production
2. Nominal pricing frictions $\implies$ deadweight loss
3. Market segmentation $\implies$ consumption dispersion

Equilibrium

Simplifying Assumptions

- Tractability assumption: a "head of HH" equalizes wealth: across τ HH groups, $A_t^{(\tau)} \equiv A_t$
  - Pros: clear focus on the role market segmentation plays on consumption dispersion
  - Cons: ignores the impact of market segmentation on wealth inequality
- Approximation: around a limiting case: risk $\sigma_z, \sigma_\beta \to 0$ but arbitrageur risk aversion $\gamma \to \infty$
  - Pros: clear focus on the idea of "imperfect arbitrage"
  - Cons: quantitatively less realistic risk premia
- Allows us to derive simple first-order approximations of dynamics and second-order approximations for welfare and focus on analytical results

Bond Market Equilibrium

- Bond price dynamics:

$$\frac{\mathrm{d}P_t^{(\tau)}}{P_t^{(\tau)}} \equiv \mu_t^{(\tau)}\,\mathrm{d}t + \boldsymbol{\sigma}_t^{(\tau)}\,\mathrm{d}\mathbf{B}_t$$

  - $\mathbf{B}_t$ collects innovations to risk factors (technology, noise demand, ...)
- Arbitrageur optimality conditions:

$$\mu_t^{(\tau)} - i_t = \boldsymbol{\sigma}_t^{(\tau)}\boldsymbol{\Lambda}_t$$

$$\boldsymbol{\Lambda}_t = \gamma \int_0^T X_t^{(\tau)} \left[\boldsymbol{\sigma}_t^{(\tau)}\right]^\top \mathrm{d}\tau$$

- Term premia depend on risk aversion γ and equilibrium holdings $X_t^{(\tau)}$
  - In our limiting case, $\boldsymbol{\sigma}_t^{(\tau)}\boldsymbol{\Lambda}_t \neq 0$

Aggregation

- Symmetric equilibrium: $Y_{t,j} = Y_t, P_{t,j} = P_t, \pi_{t,j} = \pi_t, \frac{\mathrm{d}P_t}{P_t} = \pi_t \, \mathrm{d}t$ and we have

$$Y_t = Z_t N_t \equiv Z_t \int_0^T \eta(\tau) N_t^{(\tau)} \, \mathrm{d}\tau$$

$$C_t \equiv \int_0^T \eta(\tau) C_t^{(\tau)} \, \mathrm{d}\tau = Y_t \left(1 - \frac{\theta}{2}\pi_t^2\right)$$

- Firms, arbitrageurs, and funds transfer profits to HHs. Bond market clearing implies

$$X_t^{(\tau)} + Z_t^{(\tau)} + S_t^{(\tau)} = 0$$

- Natural benchmark: $\theta \to 0$ and $\gamma \to 0$ along with optimal τ^* implies first-best

$$Y_t^n = C_t^n = Z_t^{\frac{1+\phi}{\varsigma+\phi}}, \quad N_t^n = Z_t^{\frac{1-\varsigma}{\varsigma+\phi}}, \quad \frac{\mathcal{W}_t^n}{P_t^n} = Z_t$$

- Output gap $X_t \equiv \frac{Y_t}{Y_t^n}$

details

Household and Firm Optimality Conditions

- Bond price dynamics and household (log-linearized) optimality conditions give:

$$\mathrm{d}c_t^{(\tau)} = \varsigma^{-1}\left(\mu_t^{(\tau)} - \pi_t - \rho\right)\mathrm{d}t$$

- Also gives us a modified dynamic IS curve:

$$\mathrm{d}x_t = \varsigma^{-1}\left(\tilde{\mu}_t - \pi_t - r_t^*\right)\mathrm{d}t$$

- $r_t^* \equiv -\kappa_z z_t$ is the usual natural rate and $\tilde{\mu}_t$ is the effective borrowing rate:

$$\tilde{\mu}_t = \int_0^T \eta(\tau)\mu_t^{(\tau)}\,\mathrm{d}\tau$$

- Firm (log-linearized) optimality conditions give a standard NKPC:

$$\mathrm{d}\pi_t = \left(\rho\pi_t - \delta x_t\right)\mathrm{d}t$$

- $\implies$ to a first-order, our model is essentially the same as Ray, Droste, & Gorodnichenko (2023)

Social Welfare

- A second-order expansion of social welfare relative to the first best gives

$$L_0 \equiv -\frac{1}{2}\,\mathrm{E}_0 \int_0^\infty e^{-\rho t}\left((\varsigma+\phi)x_t^2 + \theta\pi_t^2 + \frac{\varsigma}{\phi}(\varsigma+\phi)\,\mathrm{Var}_\tau\, c_t^{(\tau)}\right)\mathrm{d}t$$

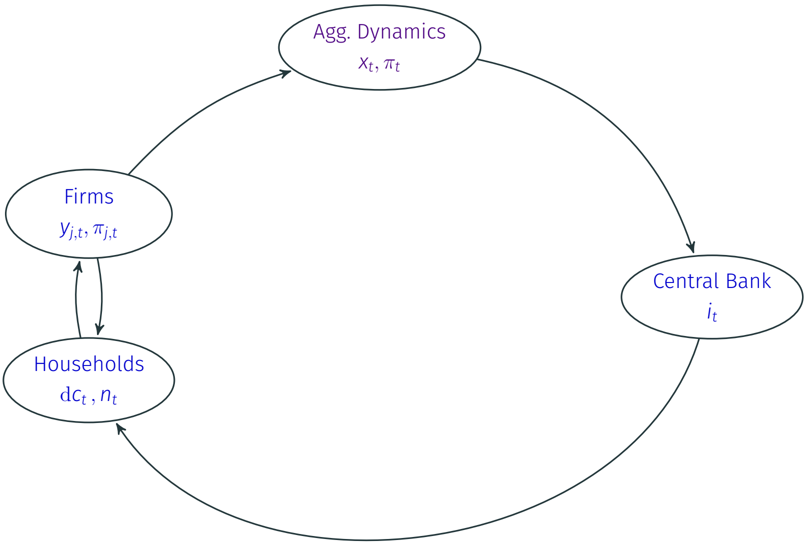
- Compared to a standard RANK model, there is the addition of the term $\mathrm{Var}_\tau\, c_t^{(\tau)}$

$$\mathrm{Var}_\tau\, c_t^{(\tau)} \equiv \int \eta(\tau)\left(c_t^{(\tau)}\right)^2 \mathrm{d}\tau - \left[\int \eta(\tau) c_t^{(\tau)}\,\mathrm{d}\tau\right]^2$$

- Increased consumption dispersion across HHs implies welfare losses

details

Equilibrium and Welfare Illustration: Standard Model



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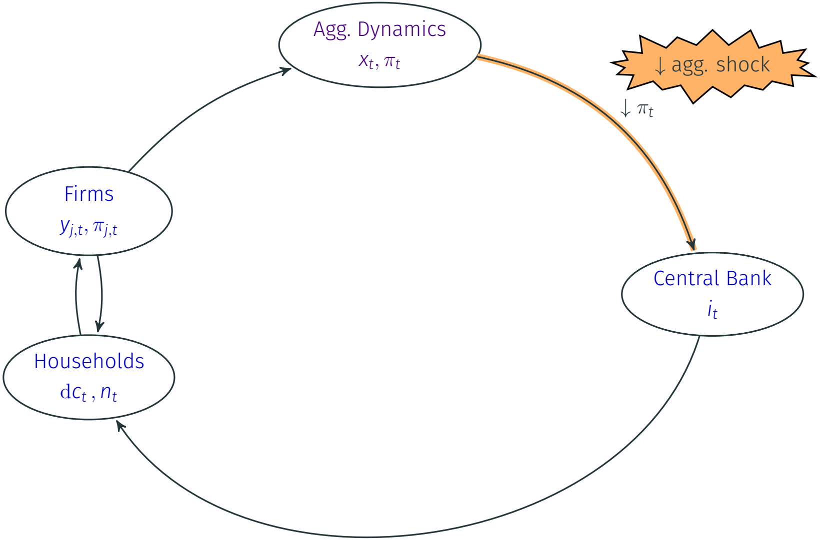

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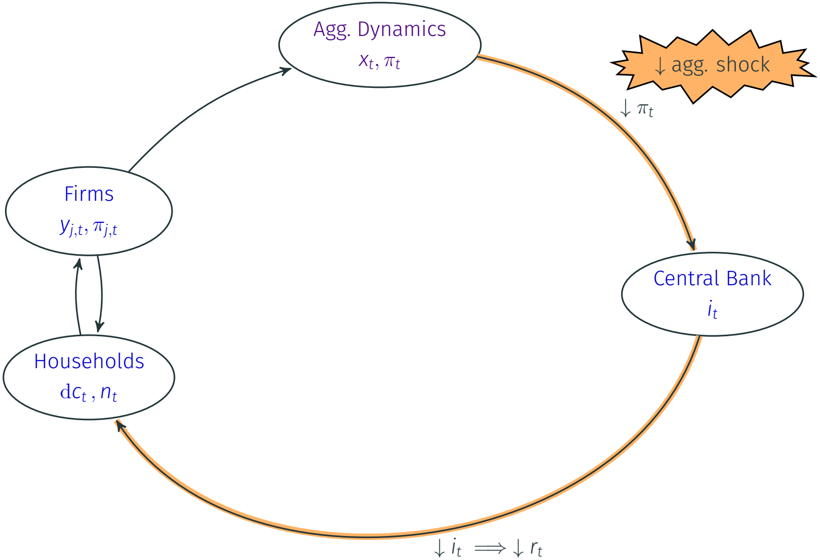

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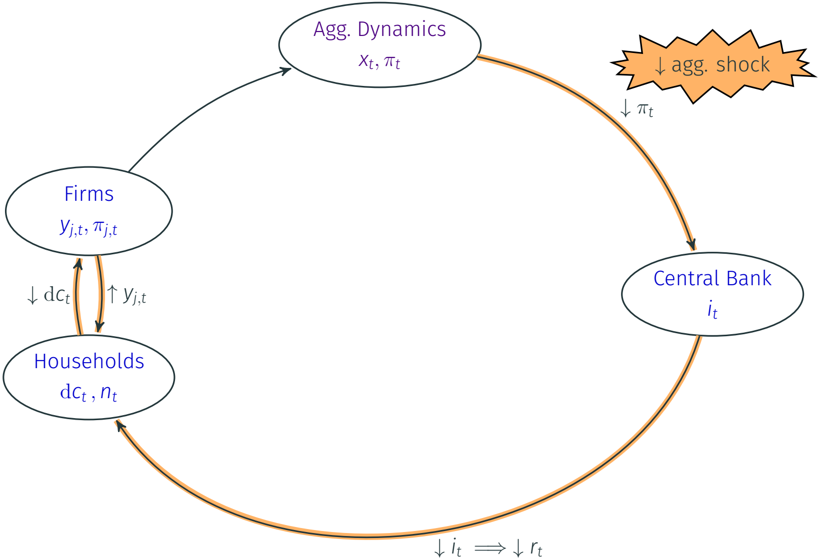

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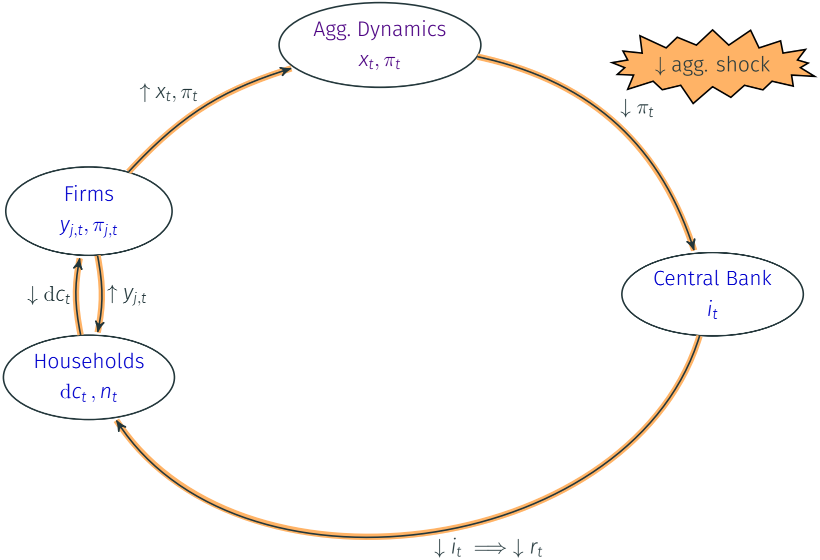

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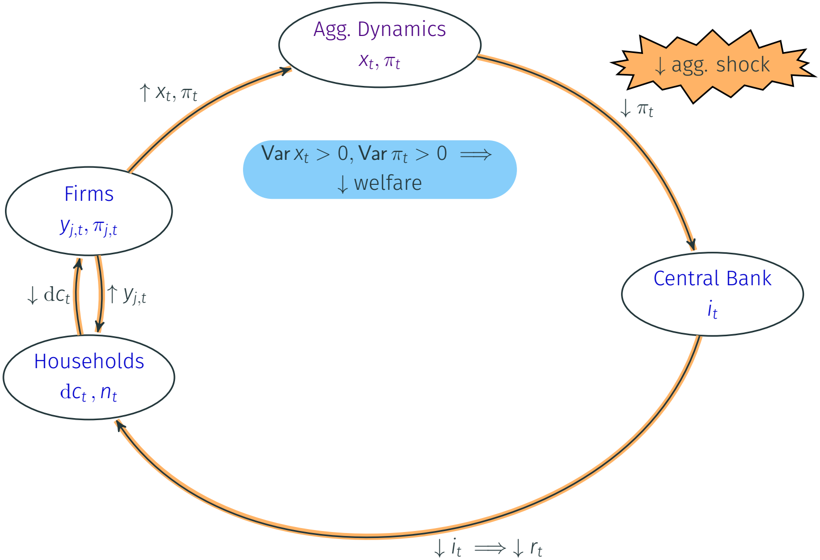
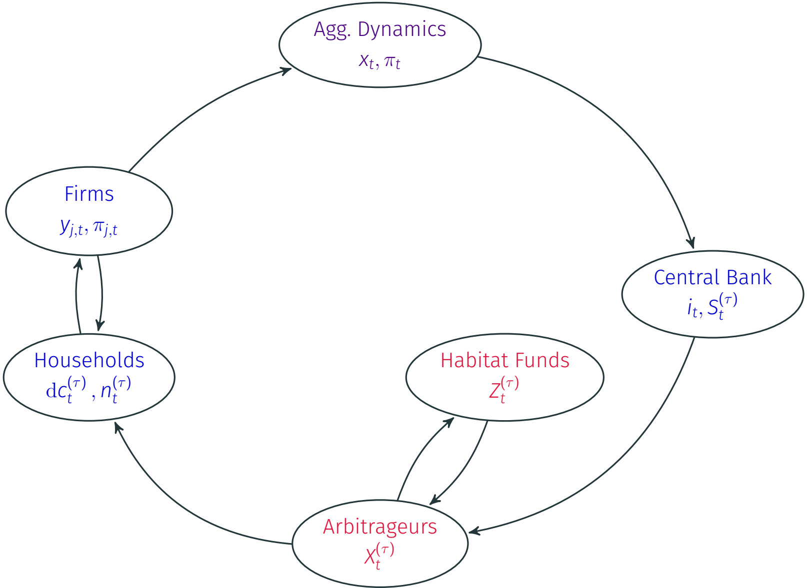


Equilibrium and Welfare Illustration: Imperfect Arbitrage



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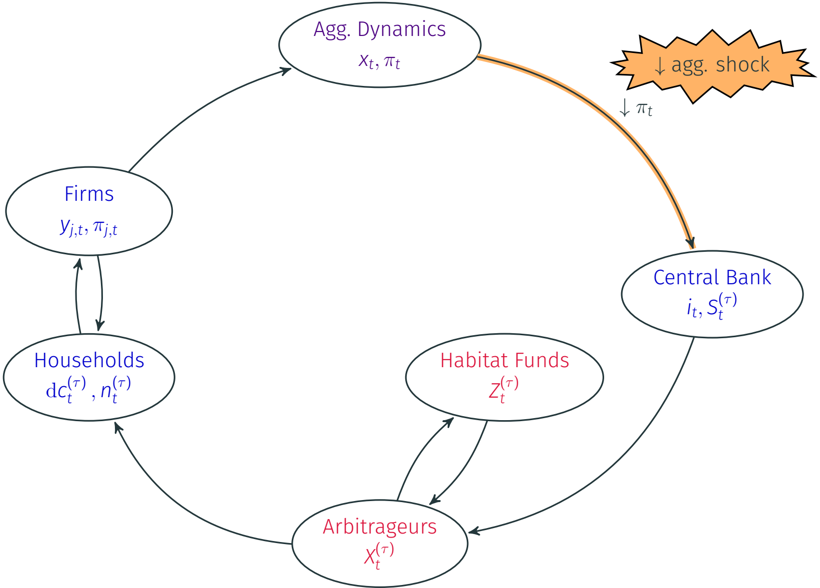

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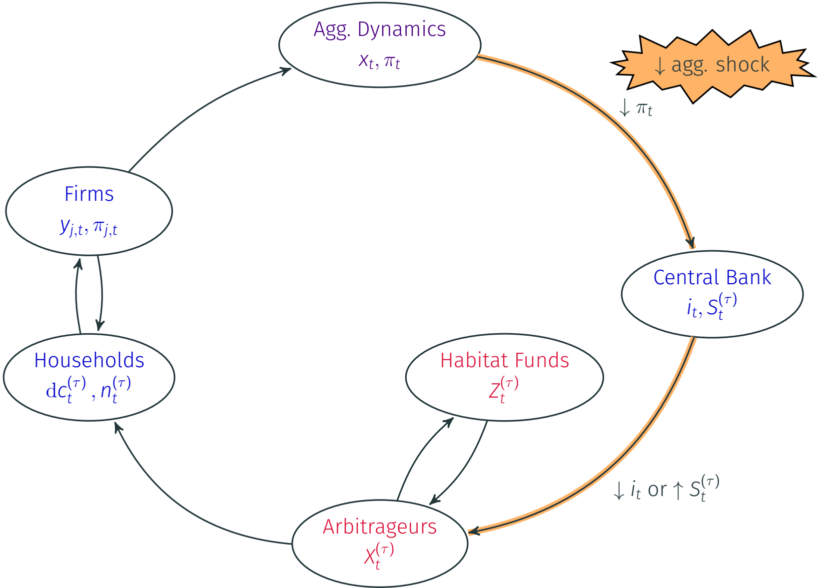

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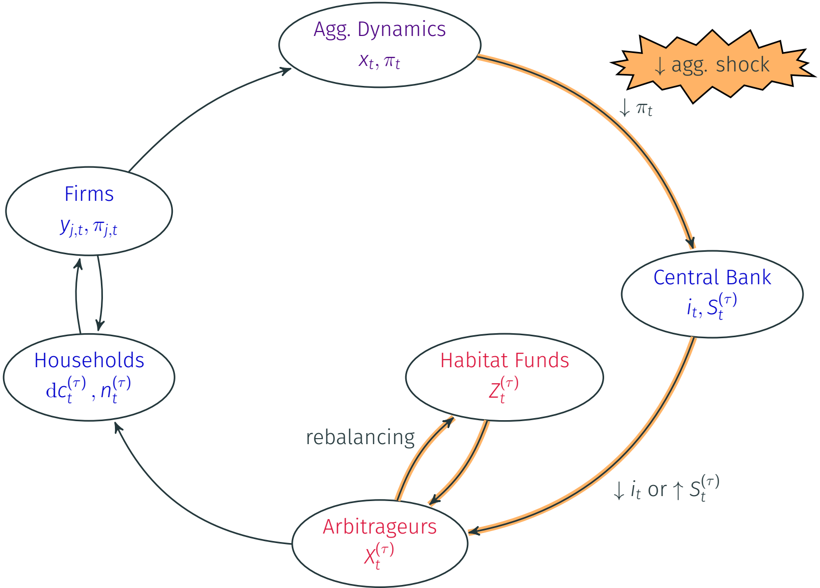

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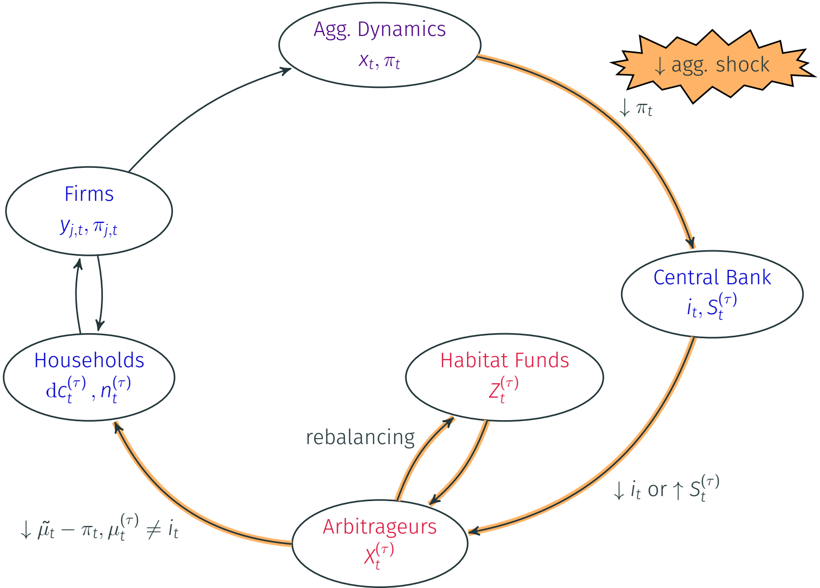

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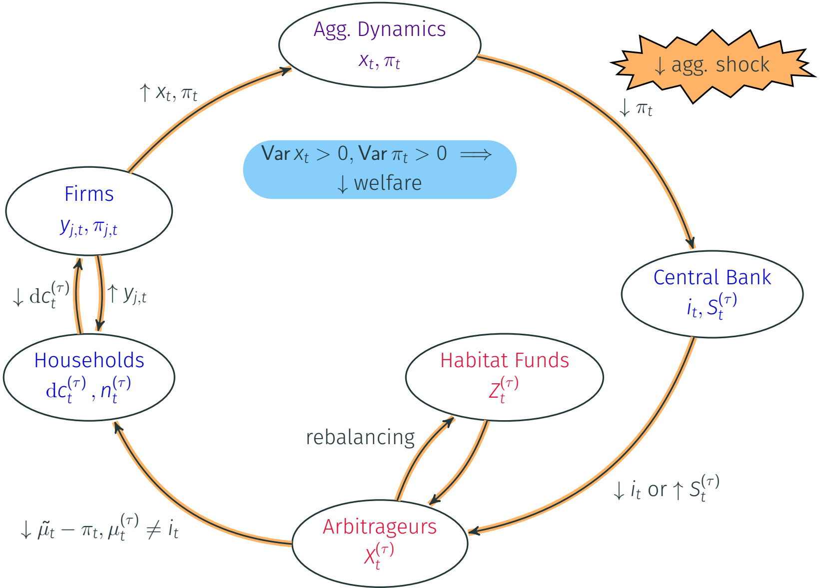

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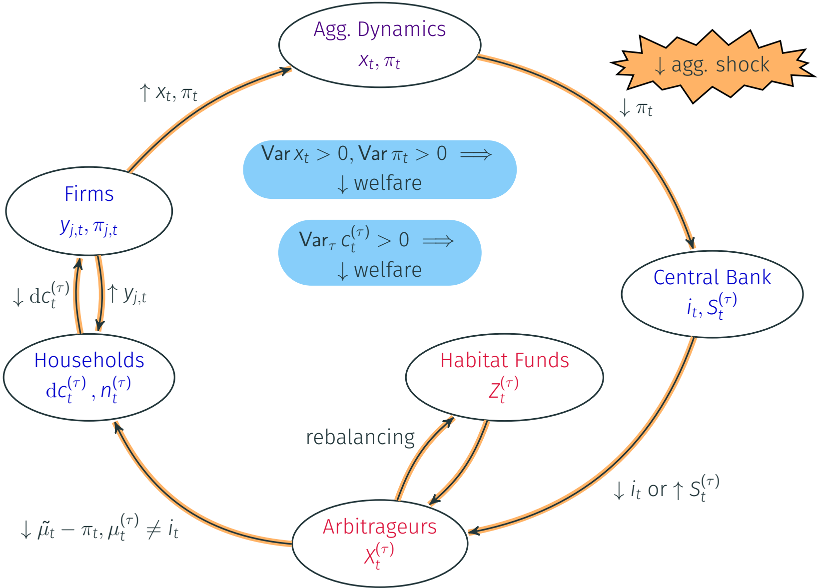


Ad-hoc Policy Rule

- In order to better understand the model, simplify to a version of the model which only includes natural rate shocks r_t^*
- Consider a policy rule which implements

$$i_t = r_t^*$$

- Also consider an ad-hoc QE shock:

$$S_t^{(\tau)} \equiv \zeta(\tau)\beta_t^{(QE)}$$
$$\mathrm{d}\beta_t^{(QE)} = -\kappa_{QE}\beta_t^{(QE)}\,\mathrm{d}t$$

- We will examine the outcome of these policies in different versions of the model

Risk Neutral Arbitrageur

Benchmark: Risk Neutral Arbitrageur ("Standard Model")

- Consider the benchmark case of a risk neutral arbitrageur: $\gamma = 0$
- The expectations hypothesis holds:

$$\mu_t^{(\tau)} = i_t = r_t^*$$

- $\implies$ model collapses to a standard RANK model and so

$$\mathrm{Var}_\tau \, c_t^{(\tau)} = 0$$

- Recover the standard QE neutrality result: balance sheet policies do not affect bond prices (and therefore have no aggregate effects)
- Divine coincidence holds: conventional policy can achieve first-best $x_t = \pi_t = 0$
  - With the addition of cost-push shocks, instead face an output-inflation trade-off
- 'Woodford-ian' equivalence: the role of policy on aggregate dynamics and welfare is fully summarized by policy rate i_t

Imperfect Arbitrage

Imperfect Arbitrage

- Now assume $\gamma > 0$ and the central bank continues to implement $i_t = r_t^*$

Proposition (Imperfect Arbitrage and Ad-hoc Policy)

Assume risk aversion $\gamma > 0$ and price elasticities $\alpha(\tau) > 0$

Bond markets: bond carry trade return $\mu_t^{(\tau)} - i_t$

- Decreases with the short rate i_t
- Decreases with QE shocks $\beta_t^{(QE)}$

Aggregate dynamics: output gaps x_t and inflation π_t

- Not identically zero: $\mathbf{Var}\, x_t \neq 0$ and inflation $\mathbf{Var}\, \pi_t \neq 0$;
- QE increases the output gap and inflation

Dispersion: consumption dispersion $\mathbf{Var}_\tau\, c_t^{(\tau)} \neq 0$

Imperfect Arbitrage Intuition: Policy Pass-Through

- Consider a fall in the natural rate inducing a cut in the policy rate:
  - When $\downarrow i_t$, bond arbitrageurs want to invest more in the BCT
  - $\implies$ bond prices increase $\uparrow P_t^{(\tau)}$
  - As $\uparrow P_t^{(\tau)}$, price-elastic habitat bond investors ($\alpha(\tau) > 0$) reduce their holdings: $\downarrow Z_t^{(\tau)}$
  - Bond arbitrageurs increase their holdings $\uparrow X_t^{(\tau)}$, which requires a larger BCT return
- Now consider a QE shock
  - QE purchases: $\uparrow S_t^{(\tau)}$
  - Bond arbitrageurs reduce holdings $\downarrow X_t^{(\tau)}$, reducing risk exposure and pushing down yields

Imperfect Arbitrage Intuition: Aggregate Effects

- Therefore, a shock to the natural rate does not fully pass through to the effective borrowing rate $\tilde{\mu}_t \neq i_t$
  - Thus aggregate borrowing demand changes, and hence $x_t \neq 0$
  - Through the NKPC, $\pi_t \neq 0$
- On the other hand, a QE shock stimulates the economy
  - QE reduces borrowing rates $\downarrow \tilde{\mu}_t$ and therefore stimulates aggregate consumption $\uparrow x_t$
  - Through the NKPC, inflation $\uparrow \pi_t$
- Additionally, in general $\mu_t^{(\tau)} \neq \mu_t^{(\tau')}$
  - Hence individual Euler equations differ
  - $\implies c_t^{(\tau)} \neq c_t^{(\tau')}$ and therefore $\mathbf{Var}_\tau\, c_t^{(\tau)} \neq 0$

Optimal Policy

Imperfect Arbitrage and Macroeconomic Stabilization

- Can conventional policy alone close the output gap?
- Yes but the short rate must react more than one-for-one with the natural rate:

$$i_t = \chi_i r_t^*, \quad \chi_i > 1$$

- The parameter χ_i can be chosen so that

$$\tilde{\mu}_t = r_t^*$$

- However, this does not achieve first-best since $\text{Var}_\tau \, c_t^{(\tau)} \neq 0$
- In fact, relative to the policy $i_t = r_t^*$, in general we have $\uparrow \text{Var}_\tau \, c_t^{(\tau)}$
    - Short rate is more volatile, hence $\uparrow$ term premia volatility
    - This implies higher dispersion across borrowing rates $\mu_t^{(\tau)}$ and therefore an increase in consumption dispersion

- If the central bank also utilizes balance sheet policies, we obtain the following

Proposition (Optimal Policy Separation Principle)

Assume risk aversion $\gamma > 0$ and price elasticities $\alpha(\tau) > 0$

Suppose the central bank implements short rate and balance sheet policy according to

$$i_t = r_t^*$$
$$S_t^{(\tau)} = \alpha(\tau) \log P_t^{(\tau)} + \theta(\tau)\bar{\beta}$$

Then first-best is achieved:

- Macroeconomic stabilization: $x_t = \pi_t = 0 \ \forall t$
- Financial stabilization: $\mu_t^{(\tau)} = \tilde{\mu}_t \ \forall \tau$
- Consumption equalization: $c_t^{(\tau)} = c_t^{(\tau')} \ \forall \tau, \tau'$ and hence $\mathbf{Var}_\tau \, c_t^{(\tau)} = 0 \ \forall t$

Optimal Policy Separation Principle: Intuition

- The results follow naturally from our findings regarding ad-hoc policy
- QE policy stabilizes shocks to bond markets by offsetting all habitat portfolio rebalancing shocks:

$$S_t^{(\tau)} = -Z_t^{(\tau)} \implies \boldsymbol{\sigma}_t^{(\tau)} \boldsymbol{\Lambda}_t = 0$$

- This equalizes borrowing rates across HHs: $\mu_t^{(\tau)} = \tilde{\mu}_t$
- Hence the model collapses to a standard RANK model, in which case divine coincidence implies $i_t = r_t^*$ is optimal

Separation principle for optimal policy:

- Optimal balance sheet policy stabilizes financial markets
- Optimal short rate policy stabilizes macroeconomic aggregates

Constrained Optimal Policy

Financial Stabilization Policy with Short Rate Constraints

- Suppose that short rate policy is constrained and so cannot implement the policy derived above
  - Note: we do not model an explicit ZLB as the non-linearities make solving for equilibrium in bond markets much more tedious
  - Instead, assume that the short rate in equilibrium evolves according to

$$i_t = \chi_i r_t^*, \quad 0 < \chi_i < 1$$

- If the central bank continues to implement the balance sheet policy derived above, then borrowing rates are still equalized $\mu_t^{(\tau)} = \tilde{\mu}_t$
- However, $\tilde{\mu}_t \neq r_t^*$ and hence this policy does not achieve macroeconomic stabilization

$$x_t \neq 0, \pi_t \neq 0$$

Macroeconomic Stabilization with Short Rate Constraints

- Can balance sheet policy alone close the output gap?
- Yes but must sacrifice equalizing borrowing rates:

$$\mu_t^{(\tau)} = i_t + \sigma_t^{(\tau)} \lambda_t$$

$$\lambda_t \equiv \gamma \int_0^T \left[\alpha(\tau) \log P_t^{(\tau)} + \theta(\tau)\bar{\beta} - S_t^{(\tau)} \right] \sigma_t^{(\tau)} \, \mathrm{d}\tau$$

- Hence, can always choose $\left\{ S_t^{(\tau)} \right\}$ such that

$$\lambda_t^* = \frac{r_t^* - i_t}{\int_0^T \eta(\tau)\sigma_t^{(\tau)} \, \mathrm{d}\tau} \implies \tilde{\mu}_t = r_t^*$$

- However, because $\frac{\sigma_t^{(\tau)}}{\sigma_t^{(\tau')}} \neq 1$ this necessitates

$$\mu_t^{(\tau)} = i_t + \sigma_t^{(\tau)} \left(\frac{r_t^* - i_t}{\int_0^T \eta(\tau')\sigma_t^{(\tau')} \, \mathrm{d}\tau'} \right) \neq r_t^* \qquad \text{(unless } i_t = r_t^*\text{)}$$

Stabilization with Short Rate Constraints: Intuition

- Balance sheet policy works by affecting term premia through changes in the market price of risk
- Although arbitrage is imperfect in this model, arbitrageurs still enforce tight restrictions between between market price of risk and term premia across maturities
- Hence, while in principle the central bank has a continuum of policy tools $\left\{S_t^{(\tau)}\right\}$, in practice it can only manipulate λ_t
- Related to localization results in Vayanos & Vila (2021) and Ray, Droste, & Gorodnichenko (2023)
    - In the one-factor model considered here, the effects of QE are fully global
    - Even with more complicated risk structure, localization is not strong enough to allow balance sheet policy alone to achieve first-best

Extensions

Extensions: "Noise" Demand Shocks

- We obtain identical results when allowing for shocks to habitat demand $\beta_t^{(\tau)}$
- Optimal separation principle still holds, but optimal QE must be more reactive:

$$S_t^{(\tau)} = \alpha(\tau) \log P_t^{(\tau)} + \beta_t^{(\tau)}$$

- Optimal short rate policy still implements $i_t = r_t^*$
- Additional result: if noise demand dynamics are such that $\uparrow\uparrow \beta_t^{(\tau)}$ in response to $\uparrow r_t^*$, then it is optimal to expand the balance sheet $\uparrow S_t^{(\tau)}$ while hiking rates $\uparrow i_t$
- Intuition:
    - Suppose during a hiking cycle and in the absence of QE we have an increase in term premia
    - Then the optimal balance sheet policy is to conduct additional QE purchases in order to offset spike in term premia
    - $\implies$ conventional and unconventional policy seem to be at odds with one another
    - Otherwise, short rate policy and balance sheet policy tend to be reinforcing

Extensions: Cost-Push Shocks

- What if divine coincidence does not hold? Cost-push shocks:

$$\mathrm{d}\pi_t = (\rho\pi_t - \delta x_t - v_t)\,\mathrm{d}t$$

- Unfortunately, our separation principle still holds:
  - Optimal QE stabilizes term premia
  - Short rate policy must contend with the output gap/inflation trade-offs
- Intuition: despite multiple policy instruments, (un)conventional policy only affects aggregate outcomes through changes in effective borrowing rate $\tilde{\mu}_t$
  - Take any feasible path $\{x_t, \pi_t, \tilde{\mu}_t\}_t$ from an implementation implying policies $\left\{\tilde{i}_t, \tilde{S}_t^{(\tau)}\right\}_t$
  - Can also be achieved with $i_t = \tilde{\mu}_t, S_t^{(\tau)} = \alpha(\tau)\log P_t^{(\tau)} + \beta_t^{(\tau)}$
  - This guarantees $\mathrm{Var}_\tau\, c_t^{(\tau)} = 0$ and hence strictly dominates

Extensions: Non-Zero First-Best Term Premia

- Our approximation approach implies that in the first-best, term premia are zero
- This simplifies our analytical results but of course is an extreme assumption
- Suppose instead that first-best BCT returns are $\nu^{(\tau)} \neq 0$
- Our separation principle still holds when $\nu^{(\tau)}$ is achievable but optimal short rate policy is a function of first-best term premia
- Intuition: combination of previous results
  - Aggregate outcomes through changes in effective borrowing rate $\tilde{\mu}_t$ (as before)
  - Optimal QE policy guarantees $\mu_t^{(\tau)} - i_t \equiv \nu^{(\tau)}$ and hence $\tilde{\mu}_t = i_t + \int_0^T \eta(\tau)\nu^{(\tau)}\,\mathrm{d}\tau \equiv i_t + \tilde{\nu}$
  - Thus, optimal short rate policy implements $i_t = r_t^* - \tilde{\nu}$
  - Note: if first-best term premia are not achievable, optimal policy is more complicated

Measuring Balance Sheet Objectives: Return Predictability

- Fama-Bliss regression:

$$\frac{1}{\Delta\tau}\log\left(\frac{P_{t+\Delta\tau}^{(\tau-\Delta\tau)}}{P_t^{(\tau)}}\right) - y_t^{(\Delta\tau)} = a_{FB}^{(\tau)} + b_{FB}^{(\tau)}\left(f_t^{(\tau-\Delta\tau,\tau)} - y_t^{(\Delta\tau)}\right) + \varepsilon_{t+\Delta\tau}$$

- Measures how the slope of the term structure predicts excess returns
- In our model, when the central bank does not use balance sheet policies:

$$\bar{b}_{FB}^{(\tau)} > 0$$

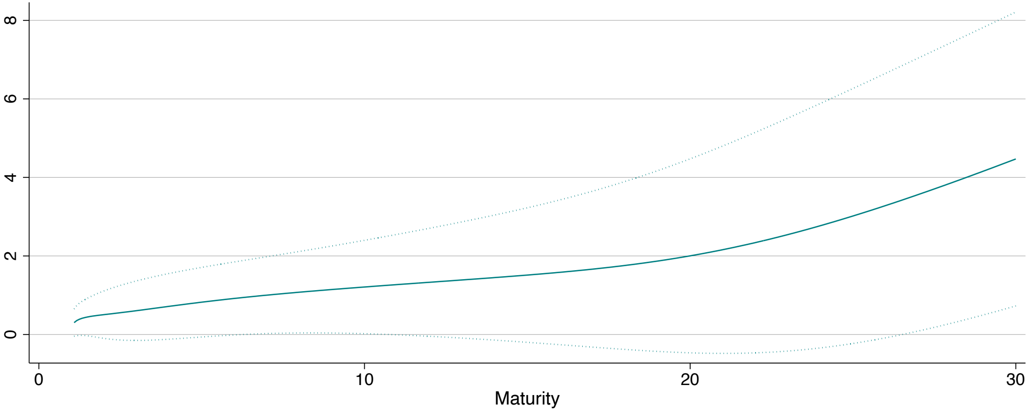
- If balance sheet policy is pursuing financial stabilization:

$$\bar{b}_{FB}^{(\tau)} > b_{FB}^{(\tau)} \to 0$$

- Instead, if balance sheet policy is pursuing macroeconomic stabilization:

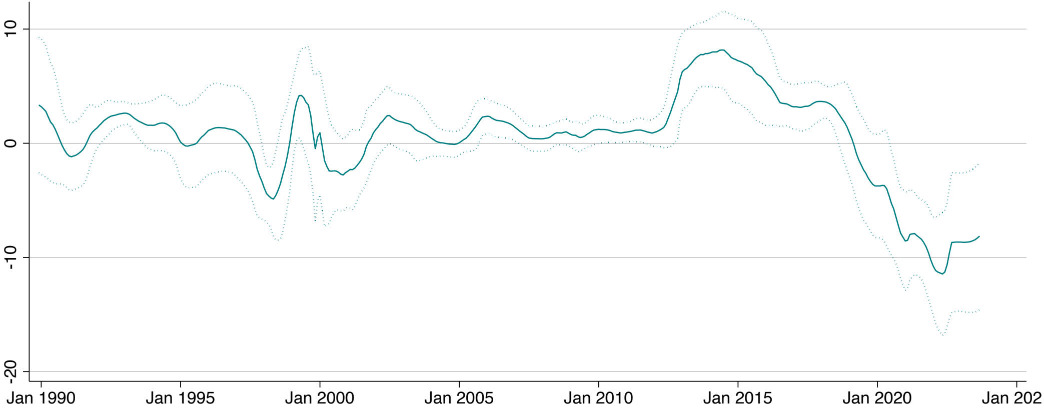
$$b_{FB}^{(\tau)} > \bar{b}_{FB}^{(\tau)}$$

Fama-Bliss Coefficients: Treasuries, Full Sample



FB coefficients are non-zero (and increasing across maturities)

Fama-Bliss Coefficients: 10-year Treasuries, Rolling Sample



FB coefficients increase during initial QE regime, but have fallen and even become negative in recent years

Concluding Remarks

- This paper develops a tractable general equilibrium model with market segmentation, nominal frictions, and household heterogeneity
- We find that optimal short rate and balance sheet policy is characterized by a sharp **optimal separation result**:
  - Conventional policy targets macroeconomic stability
  - Unconventional policy targets financial stability
- Optimal policy removes excess volatility of risk premia and hence improves risk-sharing across households, while reducing excess macroeconomic volatility
  - Policy constraints on either the short rate or balance sheets imply trade-offs between these two policy objectives
- When considering social welfare, cannot abstract from the policy tools used to conduct monetary policy

Thank You!

Aggregation Details I

- Aggregating across HH members:

$$C = \int \eta(\tau) C^{(\tau)} \,\mathrm{d}\tau\,, \quad N = \int \eta(\tau) N^{(\tau)} \,\mathrm{d}\tau\,, \quad A = \int \eta(\tau) A^{(\tau)} \,\mathrm{d}\tau\,, \quad a = \int \eta(\tau) a^{(\tau)} \,\mathrm{d}\tau$$

- Hence, aggregate HH real wealth evolves:

$$\mathrm{d}a = [wN - C]\,\mathrm{d}t + a \left(\int \eta(\tau) \frac{\mathrm{d}P^{(\tau)}}{P^{(\tau)}} \,\mathrm{d}\tau - \pi \,\mathrm{d}t \right) + \frac{1}{P} \,\mathrm{d}F$$

- Formally, τ HHs borrow through the relevent τ-habitat fund $\implies$ budget constraint

$$\mathrm{d}W^{(\tau)} = Z^{(\tau)} \frac{\mathrm{d}P^{(\tau)}}{P^{(\tau)}} + \left[W^{(\tau)} - Z^{(\tau)} + \eta(\tau) A^{(\tau)} \right] i \,\mathrm{d}t - \eta(\tau) A^{(\tau)} \frac{\mathrm{d}P^{(\tau)}}{P^{(\tau)}}$$

- Flow budget constraint for the central bank:

$$\mathrm{d}W^{(CB)} = W^{CB} i \,\mathrm{d}t + \int S^{(\tau)} \left(\frac{\mathrm{d}P^{(\tau)}}{P^{(\tau)}} - i \,\mathrm{d}t \right) \mathrm{d}\tau$$

back

Aggregation Details II

- Total transfers from arbitrageurs, central bank, and habitat funds to HHs:

$$\mathrm{d}W + \int \mathrm{d}W^{(\tau)}\,\mathrm{d}\tau + \mathrm{d}W^{(CB)} = \left[W + W^{(CB)} + \int W^{(\tau)}\,\mathrm{d}\tau + A\right] i\,\mathrm{d}t - A\int \eta(\tau)\frac{\mathrm{d}P^{(\tau)}}{P^{(\tau)}}\,\mathrm{d}\tau$$

  - Follows from market clearing $\int X^{(\tau)} + Z^{(\tau)} + S^{(\tau)}\,\mathrm{d}\tau = 0$
  - Term in brackets is aggregate demand for short-term bonds (reserves): $B = 0$ in equilibrium
- Output and goods market clearing gives nominal firm profits transferred to HHs:

$$\int_0^1 \mathcal{F}_j\,\mathrm{d}j = PY\left(1 - \frac{W}{Z} - \frac{\theta}{2}\pi^2\right) = PC - \mathcal{W}\frac{Y}{Z} = PC - \mathcal{W}N$$

- Hence, aggregate nominal transfers to the HH sector are given by

$$\mathrm{d}F = [PC - WN]\,\mathrm{d}t - A\int \eta(\tau)\frac{\mathrm{d}P^{(\tau)}}{P^{(\tau)}}\,\mathrm{d}\tau$$

$$\Longrightarrow \mathrm{d}A = 0,\quad \mathrm{d}a = -a\pi\,\mathrm{d}t = 0 \qquad (\text{if } A = 0)$$

back

Aggregation Details III

- Finally, the "head of HH" ensures that each member has identical wealth $A^{(\tau)} \equiv A$
- With $A^{(\tau)} = A = 0$, we have that aggregate HH transfers are given by

$$\mathrm{d}F = [PC - \mathcal{W}N]\,\mathrm{d}t$$

- Wealth of a τ member in equilibrium is given by

$$\mathrm{d}A^{(\tau)} = \left[\mathcal{W}N^{(\tau)} - PC^{(\tau)}\right] + \mathrm{d}F^{(\tau)}$$

- Hence, the head of HH redistributes wealth according to

$$\mathrm{d}F^{(\tau)} = \left[PC^{(\tau)} - \mathcal{W}N^{(\tau)}\right]\mathrm{d}t$$

$$\implies \mathrm{d}F = \int \eta(\tau)\,\mathrm{d}F^{(\tau)}\,\mathrm{d}\tau$$

- Note: recall that there is a mass $\eta(\tau)$ of each τ-HH type; while transfers depend on τ, each τ member takes these as given

back

Equilibrium General Characterization I

- Collect all state variables $\mathbf{y}_t$ and jump variables $\mathbf{x}_t$ into a vector $\mathbf{Y}_t$
- Assume the central bank implements policy which in equilibrium satisfies

$$i_t = \boldsymbol{\chi}_i^\top \mathbf{y}_t$$
$$S_t^{(\tau)} = \boldsymbol{\zeta}(\tau)^\top \mathbf{y}_t$$

- Then (assuming determinacy conditions hold), the first-order approximation described above implies the unique REE

$$\mathrm{d}\mathbf{Y}_t = -\boldsymbol{\Upsilon}\left(\mathbf{Y}_t - \bar{\mathbf{Y}}\right)\mathrm{d}t + \mathbf{S}\,\mathrm{d}\mathbf{B}_t$$
$$\Longrightarrow \quad \mathrm{d}\mathbf{y}_t = -\boldsymbol{\Gamma}\left(\mathbf{y}_t - \bar{\mathbf{y}}\right)\mathrm{d}t + \boldsymbol{\sigma}\,\mathrm{d}\mathbf{B}_t$$
$$\mathbf{x}_t - \bar{\mathbf{x}} = \boldsymbol{\Omega}\left(\mathbf{y}_t - \bar{\mathbf{y}}\right)$$

- $\boldsymbol{\Gamma}, \boldsymbol{\Omega}$ are functions of the eigen-decomposition of $\boldsymbol{\Upsilon}$, which depends endogenously on sensitivity of bond prices to state

back

Equilibrium General Characterization II

- Bond prices are (log) affine functions of the state

$$-\log P_t^{(\tau)} = \mathsf{A}(\tau)^\top (\mathsf{y}_t - \bar{\mathsf{y}}) + C(\tau)$$

- Affine coefficients solve the following fixed point

$$\mathsf{A}(\tau) = \int_0^\tau e^{-\mathsf{M}s}\,\mathrm{d}s\,\boldsymbol{\chi}_i$$

$$\mathsf{M} = \boldsymbol{\Gamma}^\top - \int_0^T \left[-\alpha(\tau)\mathsf{A}(\tau) + \boldsymbol{\Theta}(\tau) - \boldsymbol{\zeta}(\tau)\right]\mathsf{A}(\tau)^\top\,\mathrm{d}\tau\,\overline{\gamma\boldsymbol{\Sigma}}$$

  - Note: $\overline{\gamma\boldsymbol{\Sigma}} \neq \mathbf{0}$ in the limiting case described above
- Bond returns are given by

$$\mu_t^{(\tau)} = \hat{\mathsf{A}}(\tau)^\top (\mathsf{y}_t - \bar{\mathsf{y}}) + C'(\tau)$$

$$\hat{\mathsf{A}}(\tau) = \mathsf{A}'(\tau) + \boldsymbol{\Gamma}^\top \mathsf{A}(\tau)$$

$$= \boldsymbol{\chi}_i + (\boldsymbol{\Gamma}^\top - \mathsf{M})\mathsf{A}(\tau)$$

back

Equilibrium General Characterization III

- In general, welfare loss can be written

$$
\begin{aligned}
L_0 &\equiv -\frac{1}{2}\,\mathsf{E}_0 \int_0^T \eta(\tau)\mathsf{B}(\tau)^\top \left[\int_0^\infty e^{-\rho t}\left(\mathsf{y}_t - \bar{\mathsf{y}}\right)\left(\mathsf{y}_t - \bar{\mathsf{y}}\right)^\top \mathrm{d}t\right] \mathsf{B}(\tau)\,\mathrm{d}\tau \\
&= -\frac{1}{2}\int_0^T \eta(\tau)\mathsf{B}(\tau)^\top \tilde{\boldsymbol{\Sigma}}^\infty \mathsf{B}(\tau)\,\mathrm{d}\tau
\end{aligned}
$$

- Both the vector functions $\mathsf{B}(\tau)$ and the long-run discounted variance $\tilde{\boldsymbol{\Sigma}}^\infty$ terms may depend on policy choices

back