

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

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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:**
 - **Firms:** monopolistic competitors produce using labor, face nominal pricing frictions
 - **Households:** supply labor, consume, save via differentiated habitat bond funds
 - **Habitat funds:** buys and sell bonds of a specific maturity
 - **Arbitrageurs:** imperfect risk-bearing capacity, conduct bond carry trades
- **Policymakers:**
 - **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: in equilibrium, $i_t = \lim_{\tau \rightarrow 0} y_t^{(\tau)}$

- Mean-variance optimization

$$\begin{aligned} & \max E_t dW_t - \frac{\gamma}{2} \text{Var}_t dW_t \\ \text{s.t. } & dW_t = W_t i_t dt + \int_0^T X_t^{(\tau)} \left(\frac{dP_t^{(\tau)}}{P_t^{(\tau)}} - i_t dt \right) d\tau \end{aligned}$$

- 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

$$d\beta_t = -\kappa_\beta (\beta_t - \bar{\beta}) dt + \sigma_\beta dB_{\beta,t}$$

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

Key takeaway: price movements require portfolio rebalancing

Households

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

$$V_0^{(\tau)} \equiv \max E_0 \int_0^\infty e^{-\rho t} \left(\frac{[C_t^{(\tau)}]^{1-\varsigma}}{1-\varsigma} - \frac{[N_t^{(\tau)}]^{1+\phi}}{1+\phi} \right) dt$$

$$\text{s.t. } dA_t^{(\tau)} = [\mathcal{W}_t N_t^{(\tau)} - P_t C_t^{(\tau)}] dt + A_t^{(\tau)} \frac{dP_t^{(\tau)}}{P_t^{(\tau)}} + dF_t^{(\tau)}$$

- $A^{(\tau)}$ is nominal wealth earning $\frac{dP_t^{(\tau)}}{P_t^{(\tau)}}$ and $dF_t^{(\tau)}$ 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:

$$dz_t = -\kappa_z Z_t dt + \sigma_z dB_{t,z}$$

- Face Rotemberg costs $\Theta(\pi_{t,j}) = \frac{\theta}{2} \pi_{t,j}^2 P_t Y_t$ when setting prices $\frac{dP_{t,j}}{P_{t,j}} = \pi_{t,j} dt$
- 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

$$U_0 \equiv \max E_0 \int_0^\infty e^{-\rho t} Q_t \frac{\mathcal{F}_t}{P_t} dt$$

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

Key takeaway: pricing frictions create deadweight loss

Government

- Central bank chooses the policy rate i_t
- Balance sheet policies: bond holdings $S_t^{(\tau)}$, potentially subject to costs:

$$\frac{1}{2} P_t Y_t \int_0^T \psi(\tau) \left(S_t^{(\tau)} \right)^2 d\tau$$

- Optimal policy: maximize social welfare

$$\max E_0 \int_0^\infty e^{-\rho t} \left(\int_0^T \eta(\tau) u \left(C_t^{(\tau)}, N_t^{(\tau)} \right) d\tau \right) dt$$

- 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” sets transfers such that in equilibrium, wealth is equalized: 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 $\sigma_z, \sigma_\beta \rightarrow 0$ but arbitrageur risk aversion $\gamma \rightarrow \infty$
 - 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:

$$\frac{dP_t^{(\tau)}}{P_t^{(\tau)}} \equiv \mu_t^{(\tau)} dt + \sigma_t^{(\tau)} dB_t$$

- B_t collects innovations to risk factors (technology, noise demand, ...)
- Arbitrageur optimality conditions:

$$\mu_t^{(\tau)} - i_t = \sigma_t^{(\tau)} \Lambda_t$$

$$\Lambda_t = \gamma \int_0^T \chi_t^{(\tau)} [\sigma_t^{(\tau)}]^\top d\tau$$

- Term premia depend on risk aversion γ and equilibrium holdings $\chi_t^{(\tau)}$
 - In our limiting case, $\sigma_t^{(\tau)} \Lambda_t \neq 0$
- Equilibrium: fixed point problem(s)
 - Market clearing: $Z_t^{(\tau)}$ demand depends on $\log P_t^{(\tau)}$
 - Central bank policy reacts to consumption and inflation, which depends on $\mu_t^{(\tau)}$

Aggregation

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

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

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

- Firms, arbitrageurs, and funds transfer profits to HHs. [Bond market clearing](#) implies

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

- [Natural benchmark](#): $\theta \rightarrow 0$ and $\gamma \rightarrow 0$ 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:

$$dc_t^{(\tau)} = \varsigma^{-1} \left(\mu_t^{(\tau)} - \pi_t - \rho \right) dt$$

- Also gives us a **modified dynamic IS curve**:

$$dx_t = \varsigma^{-1} (\tilde{\mu}_t - \pi_t - r_t^*) dt$$

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

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

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

$$d\pi_t = (\rho\pi_t - \delta x_t) dt$$

- \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 social loss

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

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

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

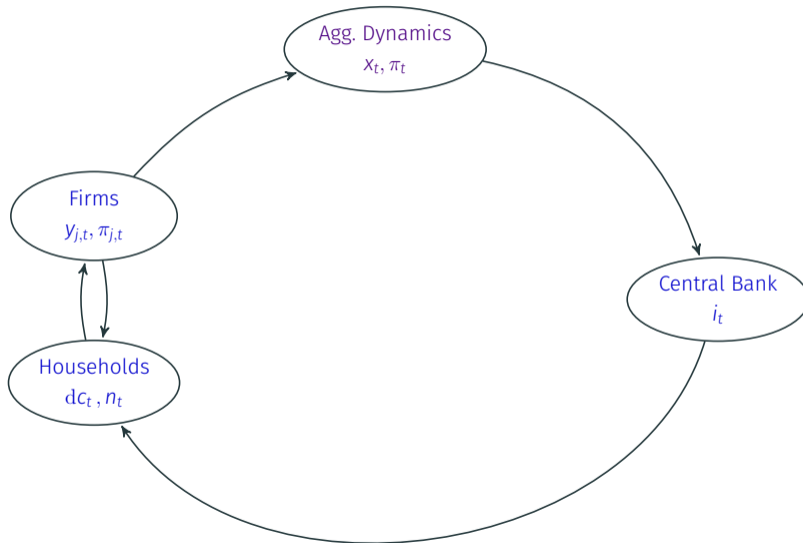
- Also losses from central bank balance sheet policies when costs $\psi(\tau) > 0$

$$\Psi_t \equiv \int_0^T \psi(\tau) \left(S_t^{(\tau)} \right)^2 d\tau$$

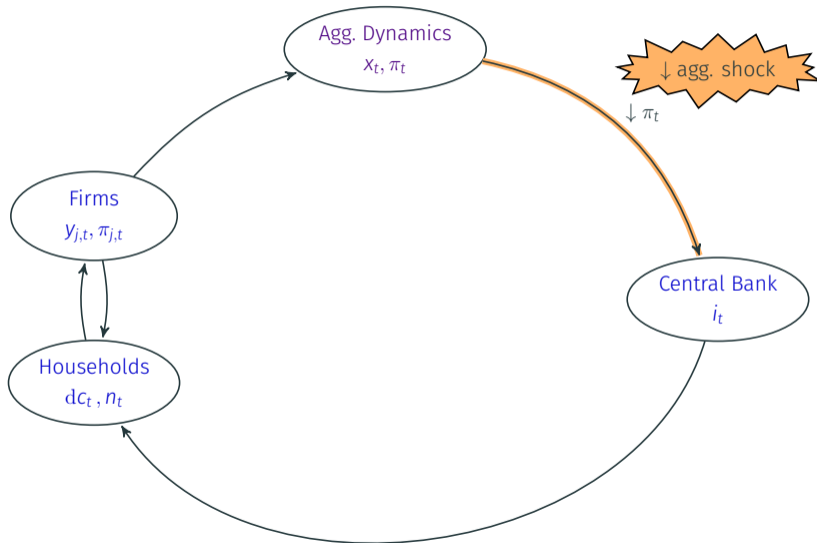
- Increased **consumption dispersion** across HHs implies welfare losses

details

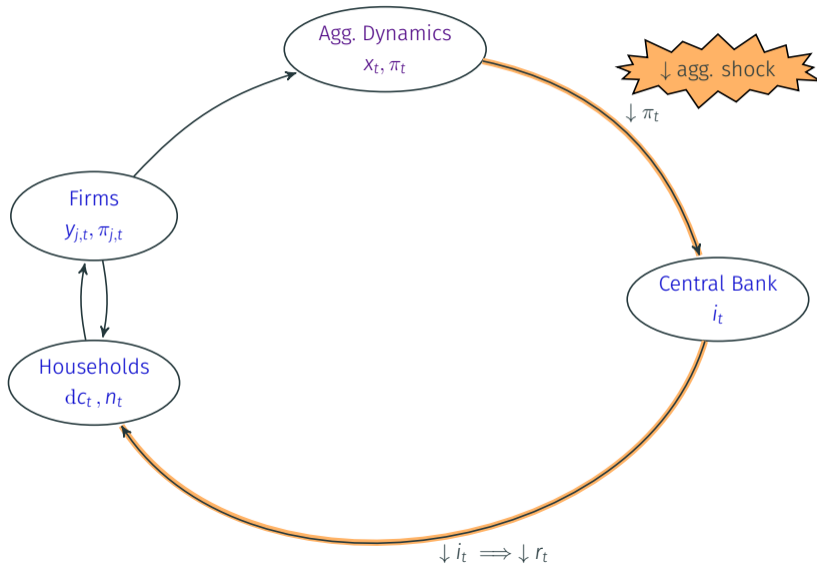
Equilibrium and Welfare Illustration: Standard Model



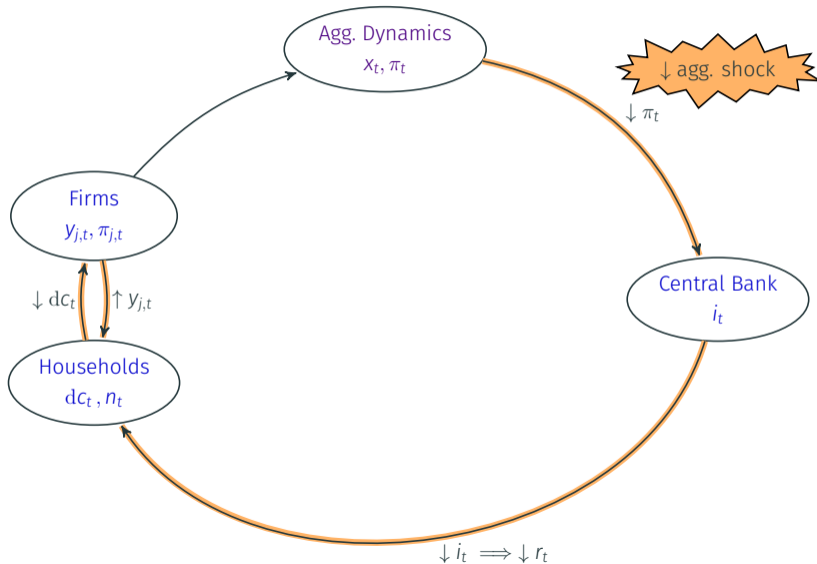
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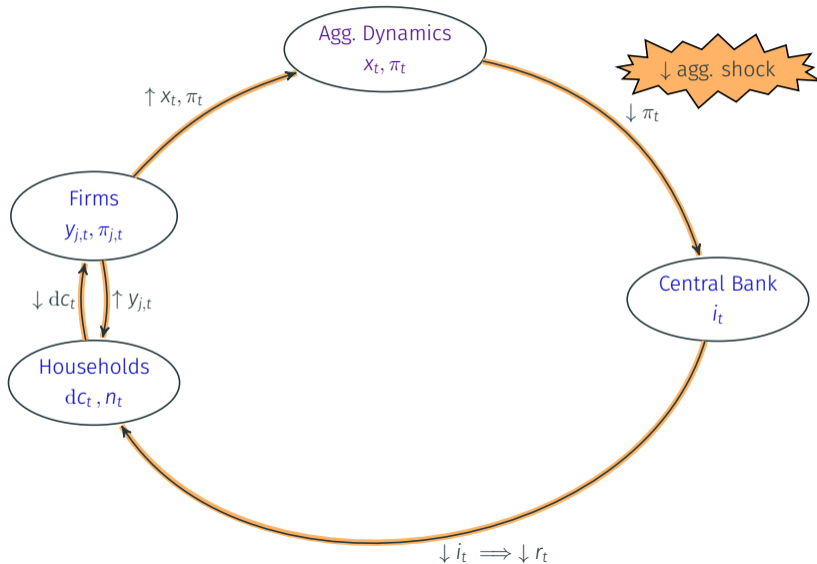
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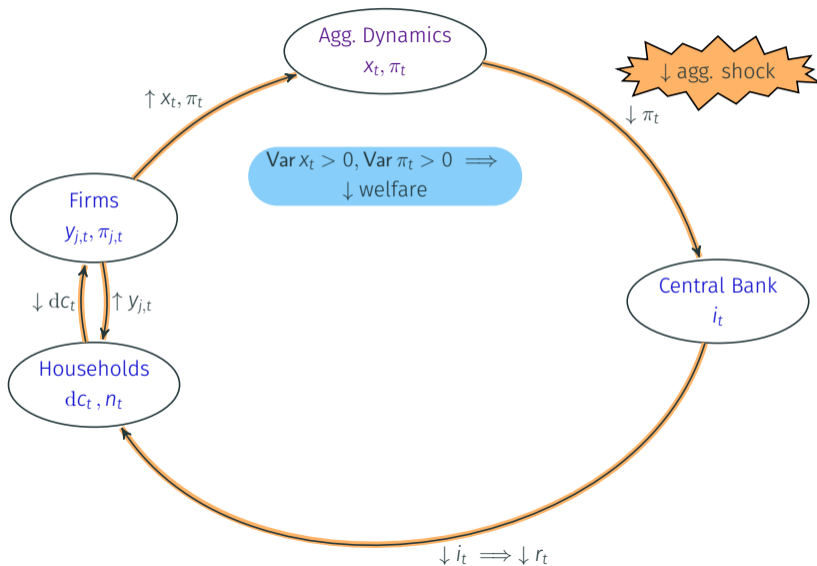
Equilibrium and Welfare Illustration: Standard Model



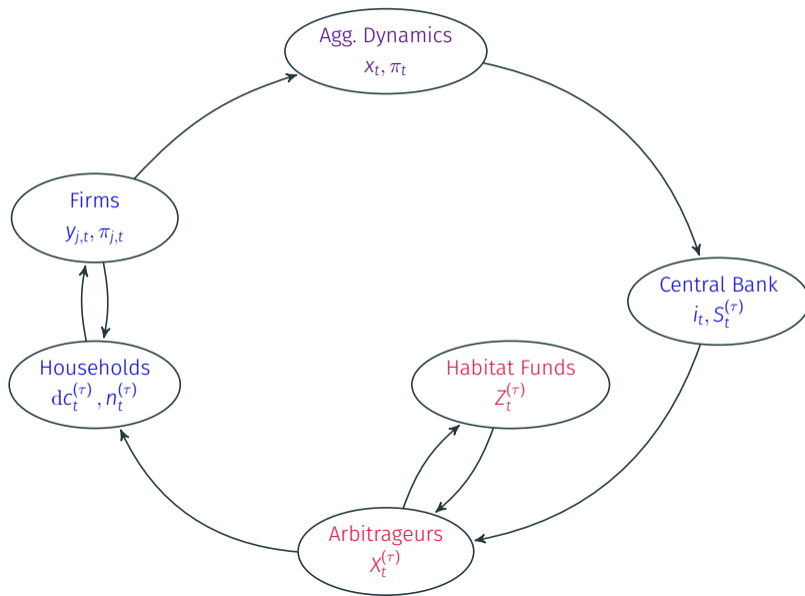
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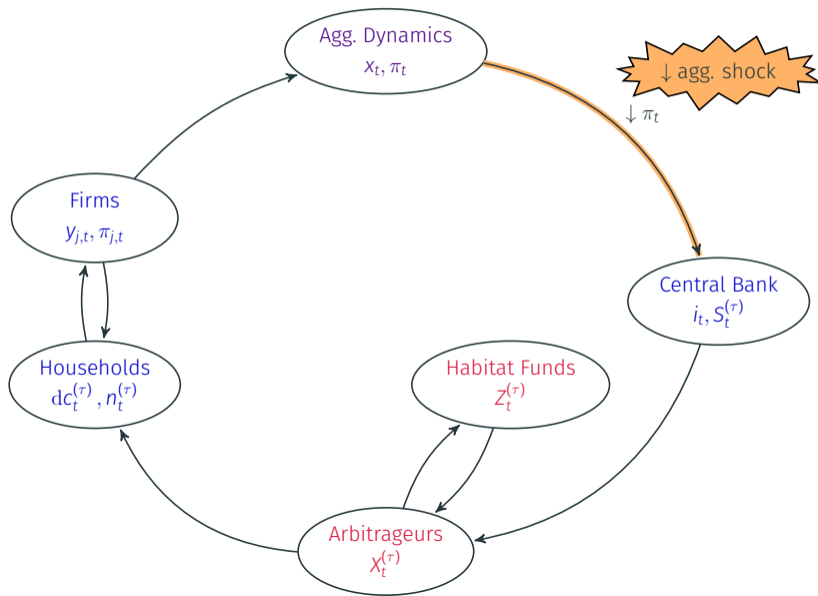
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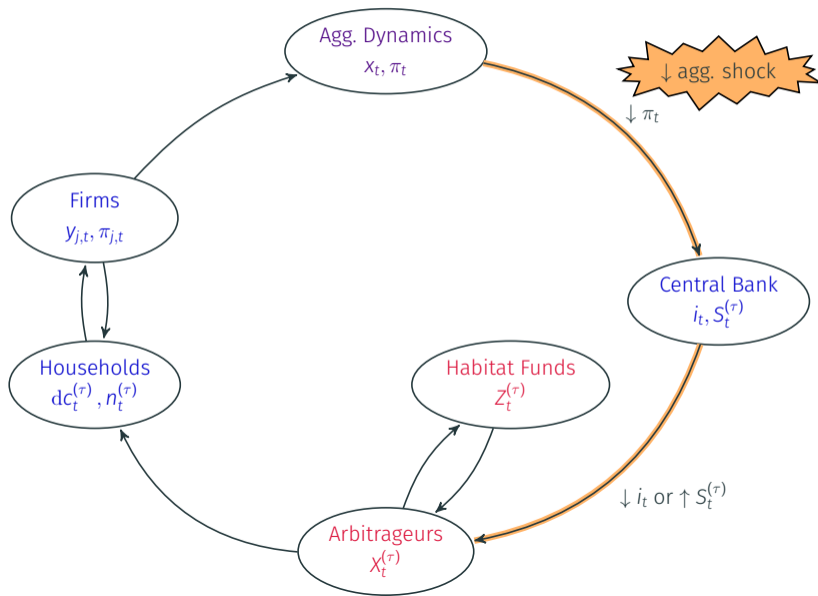
Equilibrium and Welfare Illustration: Imperfect Arbitrage



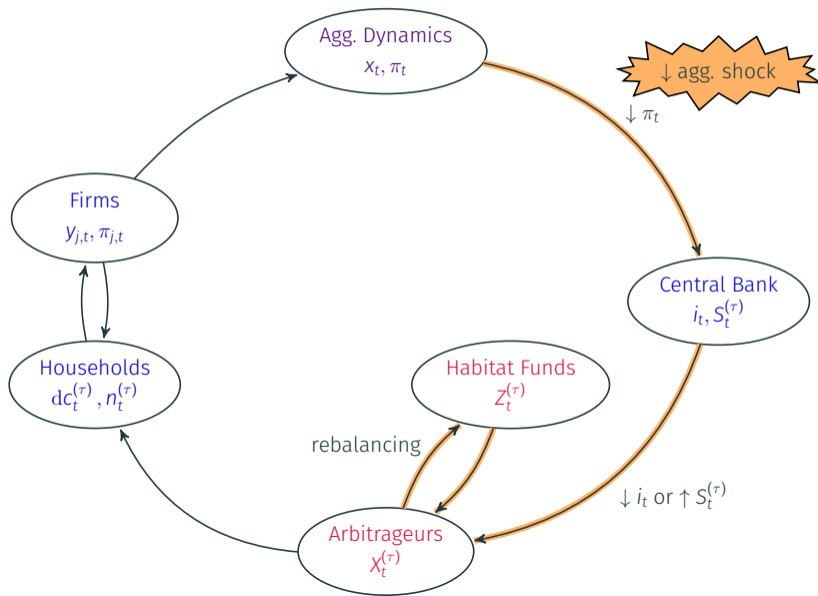
Equilibrium and Welfare Illustration: Imperfect Arbitrage



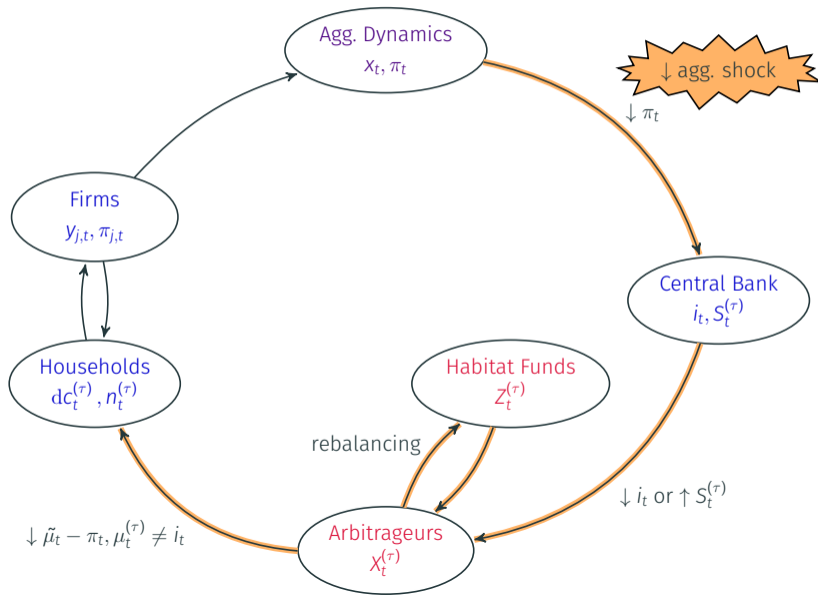
Equilibrium and Welfare Illustration: Imperfect Arbitrage



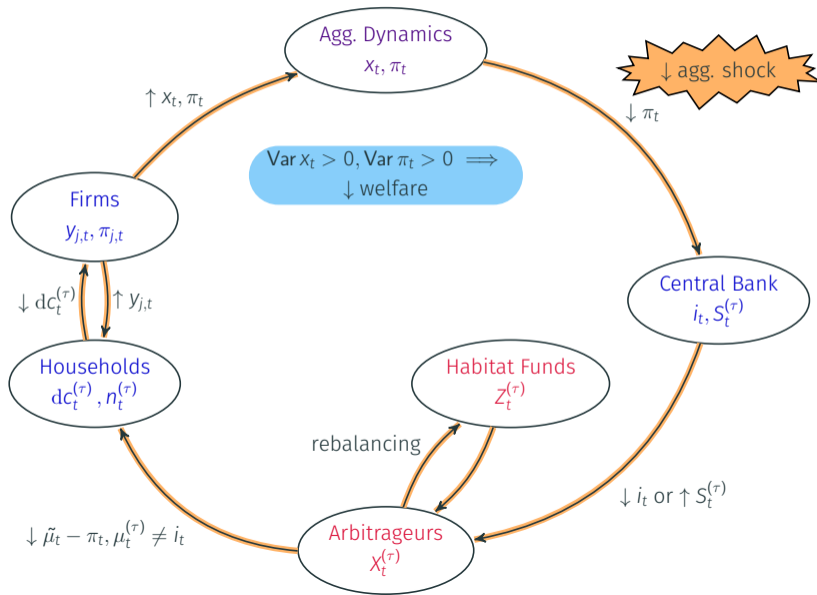
Equilibrium and Welfare Illustration: Imperfect Arbitrage



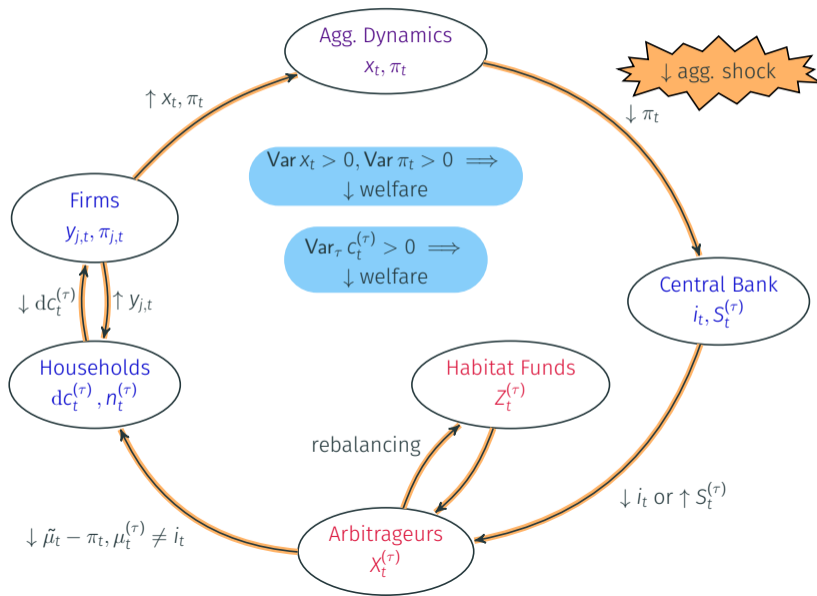
Equilibrium and Welfare Illustration: Imperfect Arbitrage



Equilibrium and Welfare Illustration: Imperfect Arbitrage



Equilibrium and Welfare Illustration: Imperfect Arbitrage



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

$$\dot{i}_t = r_t^*$$

- Also consider an ad-hoc **QE shock**:

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

- 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

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

- 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: $\text{Var } x_t \neq 0$ and inflation $\text{Var } \pi_t \neq 0$;
- QE increases the output gap and inflation

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

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 $\text{Var}_\tau c_t^{(\tau)} \neq 0$

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:

$$i_t = \hat{\chi}_i r_t^*, \quad \hat{\chi}_i > 1$$

- The parameter $\hat{\chi}_i$ is 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
- **Optimal short rate policy**: if $\psi(\tau) \rightarrow \infty$, then optimal policy implements

$$i_t = \chi_i^* r_t^*, \quad \chi_i^* < \hat{\chi}_i \implies \frac{\partial \tilde{\mu}_t}{\partial r_t^*} < 1$$

Imperfect Arbitrage and Macro-Financial Stabilization

- With access to frictionless **balance sheet policies**, we obtain the following

Proposition (Optimal Policy Separation Principle)

Assume risk aversion $\gamma > 0$ and price elasticities $\alpha(\tau) > 0$, and holding costs $\psi(\tau) = 0$. Suppose the central bank implements short rate and balance sheet policy according to

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

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 $\text{Var}_{\tau} c_t^{(\tau)} = 0 \ \forall t$

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:

$$S_t^{(\tau)} = -Z_t^{(\tau)} \implies \sigma_t^{(\tau)} \Lambda_t = 0$$

- 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 difficult
 - 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:

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

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

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

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

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

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

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 market price of risk and term premia across maturities
- Hence, while in principle the central bank has a **continuum of policy tools** $\{s_t^{(\tau)}\}$, 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

Imperfect Balance Sheet Policies

- When facing balance sheet costs $0 < \psi(\tau) < \infty$, optimal policy is a mix of the examples described above
- In this case, optimal policy implies

$$\frac{\partial \tilde{\mu}_t}{\partial r_t^*} < 1, \quad \frac{\partial \mu_t^{(\tau)} - i_t}{\partial i_t} < 0$$

- Hence, first-best is not achieved: $x_t \neq 0, \pi_t \neq 0$ and $\text{Var}_\tau c_t^{(\tau)} \neq 0$
- **Counter-intuitive result:** suppose $\exists \tau'$ such that $0 < \psi(\tau') < \psi(\tau), \alpha(\tau') > \alpha(\tau)$
- Optimal policy may still imply central bank takes largest positions in $\tau^* \neq \tau'$ bonds
- **Intuition:** other bonds may be more effective at repricing market risk (also related to localization results from previous example)

Extensions

Extensions: “Noise” Demand Shocks

- We obtain identical results when allowing for shocks to habitat demand $\beta_t^{(\tau)}$
- Optimal separation principle still holds with $\psi(\tau) = 0$, but 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:**

$$d\pi_t = (\rho\pi_t - \delta x_t - u_t) dt$$

- 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 $\{\tilde{i}_t, \tilde{S}_t^{(\tau)}\}_t$
 - Can also be achieved with $i_t = \tilde{\mu}_t, S_t^{(\tau)} = \alpha(\tau) \log P_t^{(\tau)} + \beta_t^{(\tau)}$
 - This guarantees $\text{Var}_\tau c_t^{(\tau)} = 0$ and hence strictly dominates

Extensions: Non-Zero First-Best Carry Trade Returns

- Our approximation approach implies that in the first-best, expected carry trade returns 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 $\nu^{(\tau)}$
- **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 $\tilde{\mu}_t = i_t + \int_0^T \eta(\tau) \nu^{(\tau)} d\tau \equiv i_t + \tilde{\nu}$
 - Thus, optimal short rate policy implements $i_t = r_t^* - \tilde{\nu}$
 - Note: if first-best BCT returns 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:

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

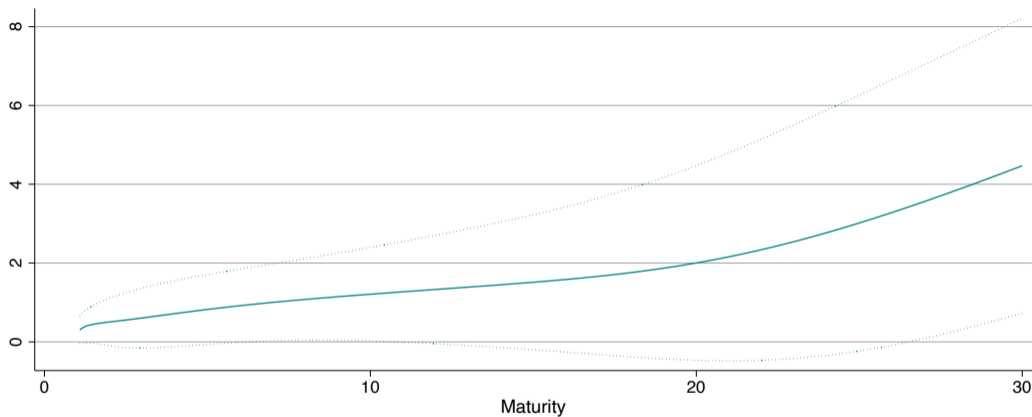
- If balance sheet policy is pursuing **financial stabilization**:

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

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

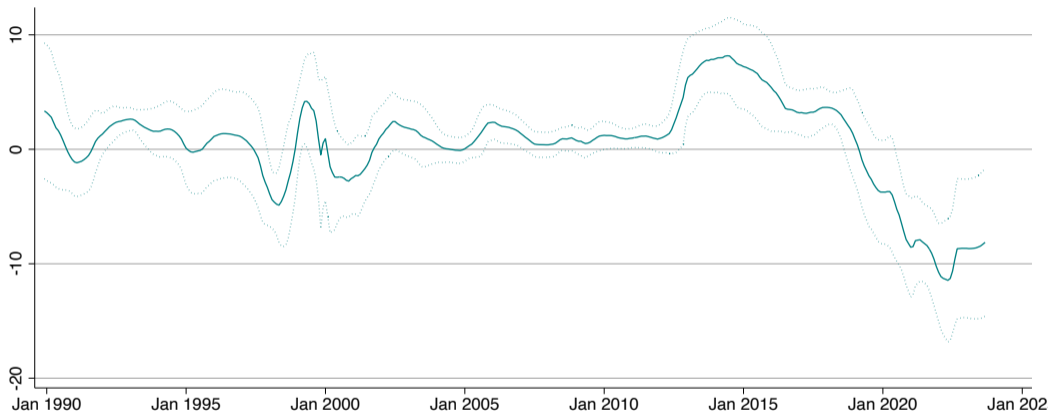
$$b_{FB}^{(\tau)} > \bar{b}_{FB}^{(\tau)}$$

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:

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

- Hence, aggregate HH real wealth evolves:

$$da = [wN - C] dt + a \left(\int \eta(\tau) \frac{dP^{(\tau)}}{P^{(\tau)}} d\tau - \pi dt \right) + \frac{1}{P} dF$$

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

$$dW^{(\tau)} = Z^{(\tau)} \frac{dP^{(\tau)}}{P^{(\tau)}} + \left[W^{(\tau)} - Z^{(\tau)} + \eta(\tau) A^{(\tau)} \right] i dt - \eta(\tau) A^{(\tau)} \frac{dP^{(\tau)}}{P^{(\tau)}}$$

- Flow budget constraint for the central bank:

$$dW^{(CB)} = W^{CB} i dt + \int S^{(\tau)} \left(\frac{dP^{(\tau)}}{P^{(\tau)}} - i dt \right) d\tau$$

Aggregation Details II

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

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

- Follows from market clearing $\int X^{(\tau)} + Z^{(\tau)} + S^{(\tau)} d\tau = 0$
- 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:

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

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

$$dF = [PC - WN] dt - A \int \eta(\tau) \frac{dP(\tau)}{P(\tau)} d\tau$$
$$\implies dA = 0, \quad da = -a\pi dt = 0 \quad (\text{if } A = 0)$$

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

$$dF = [PC - \mathcal{W}N] dt$$

- Wealth of a τ member in equilibrium is given by

$$dA^{(\tau)} = [\mathcal{W}N^{(\tau)} - PC^{(\tau)}] + dF^{(\tau)}$$

- Hence, the head of HH redistributes wealth according to

$$\begin{aligned} dF^{(\tau)} &= [PC^{(\tau)} - \mathcal{W}N^{(\tau)}] dt \\ \implies dF &= \int \eta(\tau) dF^{(\tau)} d\tau \end{aligned}$$

- 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

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

$$d\mathbf{Y}_t = -\boldsymbol{\Upsilon} (\mathbf{Y}_t - \bar{\mathbf{Y}}) dt + \mathbf{S} d\mathbf{B}_t$$
$$\implies d\mathbf{y}_t = -\boldsymbol{\Gamma} (\mathbf{y}_t - \bar{\mathbf{y}}) dt + \boldsymbol{\sigma} d\mathbf{B}_t$$
$$\mathbf{x}_t - \bar{\mathbf{x}} = \boldsymbol{\Omega} (\mathbf{y}_t - \bar{\mathbf{y}})$$

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

Equilibrium General Characterization II

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

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

- Affine coefficients solve the following fixed point

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

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

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

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

$$\begin{aligned}\hat{\mathbf{A}}(\tau) &= \mathbf{A}'(\tau) + \boldsymbol{\Gamma}^\top \mathbf{A}(\tau) \\ &= \boldsymbol{\chi}_i + (\boldsymbol{\Gamma}^\top - \mathbf{M})\mathbf{A}(\tau)\end{aligned}$$

Equilibrium General Characterization III

- In general, welfare loss can be written

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

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

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