

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

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# Motivation

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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 nominal frictions, market segmentation, and household heterogeneity
- **Arbitrageurs** with imperfect risk-bearing capacity absorb supply and demand shocks in bond markets
- **Clientele investors** introduce a degree of **market segmentation**
  - Bonds of different maturities traded by specialized investors (eg pension funds, MMMF)
  - Arbitrageurs (eg hedge funds, broker-dealers) partly overcome segmentation
- **Households** have differentiated access to asset markets
  - Households borrow with bonds of different maturities (eg mortgages)
  - Introduces imperfect risk-sharing, **consumption and labor dispersion** across households
- **Firms** face nominal pricing frictions
- Formally: embed a Vayanos-Vila model in a New Keynesian model, where households are heterogeneous in access to financial markets

## Findings: Policy Transmission

- **Key mechanisms** of conventional monetary policy:
  - Changes in the short rate affect required rates of return of all assets
  - Interaction of arbitrageurs and investor clientele leads to **portfolio rebalancing**
  - Implies **variation in risk premia**, imperfect transmission to households
- **Key mechanisms** of balance sheet policy:
  - Imperfect arbitrage breaks QE neutrality
  - 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

# Findings: Welfare Consequences

- If the policymaker only cares about **macroeconomic stabilization**, conventional and unconventional policies are essentially equivalent
  - **Nominal rigidities**  $\implies$  welfare losses due to inflation volatility
  - Policy stabilizes inflation by keeping aggregate borrowing rates at some “natural” rate
  - **Triumphalist view**: even with short rate constraints, QE is equally effective
- However, both policies imply variation in **risk premia**
  - Excess fluctuations in risk premia lead to dispersion in borrowing rates
- **Social welfare** depends not only on macroeconomic fluctuations:
  - **Imperfect risk sharing**  $\implies$  welfare losses from consumption dispersion
  - **Labor market inefficiencies**  $\implies$  welfare losses from labor dispersion

## 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)
- With full commitment, **forward guidance** is welfare-improving (short rate and QE)
  - Policymaker uses the entire expected path of borrowing rates to minimize macroeconomic volatility
  - But reduces short-run fluctuations to keep risk premia volatility low
  - However, dynamics are complicated and suffer from time-inconsistency
- General message: **implementation matters** for welfare

## Related Literature

- Preferred habitat models
  - Vayanos & Vila (2009, 2021), Ray, Droste, & Gorodnichenko (2024), Greenwood & Vayanos (2014), Greenwood et al (2016), King (2019, 2021) , Kekre, Lenel, & Mainardi (2024), ...
- 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), Dordal & Lee (2024) , ...
- 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

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# 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 differentiated labor, consume, save via bond markets
  - **Arbitrageurs:** imperfect risk-bearing capacity, conduct bond carry trades
  - **Habitat funds:** buys and sell bonds of a specific maturity
- **Policymakers:**
  - **Central bank:** conducts short rate and balance sheet (QE) policy
  - **Government:** optimal subsidies, 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,  $i_t = \lim_{\tau \rightarrow 0} y_t^{(\tau)}$

# Firms

- Continuum of intermediate goods  $j \in [0, 1]$  (and CES final good with elasticity  $\epsilon$ )
- Linear production in differentiated labor  $Y_t(j) = e^{z_t} L_t(j)$ :

$$dZ_t = -\kappa_Z Z_t dt + \sigma_Z dB_{t,Z}, \quad L_t(j) = \left[ \int_{h \in \mathcal{H}} L_t(j, h)^{\frac{\epsilon_W - 1}{\epsilon_W}} dh \right]^{\frac{\epsilon_W}{\epsilon_W - 1}}$$

- Face costs  $\Theta(\pi_t(j)) = \frac{\theta}{2} \pi_t(j)^2 P_t Y_t$  when setting prices  $\frac{dP_t(j)}{P_t(j)} = \pi_t(j) dt$ . Maximizes:

$$U_0 \equiv \max \mathbb{E}_0 \int_0^\infty e^{-\rho t} Q_t^{\mathcal{H}} \frac{\mathcal{F}_t}{P_t} dt$$

s.t.  $\mathcal{F}_t = (1 + \tau^y) P_t(j) Y_t(j) - \mathcal{W}_t L_t(j) - \Theta(\pi_t(j)) - \mathcal{T}_t$

- Take as given CES demand, wage index, price index,  $\tau^y$  subsidy, taxes  $\mathcal{T}_t$
- Profits are discounted by HH sector real SDF  $Q_t^{\mathcal{H}}$

Key takeaway: inefficiencies due to pricing frictions, differentiated labor

# Households

- Continuum of HH members  $h \in \mathcal{H}$ , differentiated by access to bond markets  $\tau$
- Mass  $\eta(\tau)$  of each  $h = (i, \tau)$  HH where  $\int_0^T \eta(\tau) d\tau = 1$  (otherwise identical)
  - Intuition: HHs **sluggishly rebalance** (our model is limiting case)
- A  $\tau$ -type HH chooses consumption and labor  $C_t(\tau), N_t(\tau)$  in order to solve

$$V_0(\tau) \equiv \max \mathbb{E}_0 \int_0^\infty e^{-\rho t} \left( \frac{C_t(\tau)^{1-\varsigma}}{1-\varsigma} - \frac{N_t(\tau)^{1+\varphi}}{1+\varphi} \right) dt$$

$$\text{s.t. } dA_t(\tau) = [(1 + \tau^w) \mathcal{W}_t(\tau) N_t(\tau) - P_t C_t(\tau)] dt + A_t(\tau) \frac{dP_t^{(\tau)}}{P_t^{(\tau)}} + dF_t(\tau)$$

- $A_t(\tau)$  nominal savings earn  $\frac{dP_t^{(\tau)}}{P_t^{(\tau)}}$ ;  $\mathcal{W}_t(\tau)$  is nominal (differentiated) wage
- Take as given CES labor demand,  $\tau^w$  labor subsidy, transfers  $dF_t(\tau)$

**Key takeaway:** consumption/labor choices differ when bond returns not equalized

# Arbitrageurs

- Mean-variance optimization

$$\begin{aligned} & \max \mathbb{E}_t d\omega_t - \frac{a}{2} \text{Var}_t d\omega_t \\ \text{s.t. } & d\omega_t = \omega_t i_t dt + \int_0^T \chi_t^{(\tau)} \left( \frac{dP_t^{(\tau)}}{P_t^{(\tau)}} - i_t dt \right) d\tau \end{aligned}$$

- Arbitrageurs invest  $\chi_t^{(\tau)}$  in bond carry trade of maturity  $\tau$
- Remainder of wealth  $\omega_t$  invested at the short rate
- Risk-return trade-off governed by  $a$ 
  - Formally: risk aversion coefficient
  - More generally: proxies for any limits to risk-bearing capacity or intermediation frictions
  - Arbitrageurs transfer gains/losses to HHS, so  $a$  represents any frictions which hinder ability to trade on behalf of HHS

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

# Preferred Habitat Funds

- Habitat bond demand (exogenous) for maturity  $\tau$ :

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

- $\alpha(\tau)$ : demand elasticity for  $\tau$  fund
- $\beta_t^{(\tau)}$ : additional time-varying (“noise”) demand factor
  - Noise demand  $\beta_t^{(\tau)} = \theta(\tau)\beta_t$  follows a factor structure across habitat funds, eg

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

- $\theta(\tau)$ : mapping from demand factor  $\beta_t$  to  $\tau$ -habitat demand
- $Z_t^{(\tau)}$  financed at the short rate (zero-cost position)
- Habitat funds also transfer gains/losses to HHs

**Key takeaway:** habitat funds introduce noise; price movements require portfolio rebalancing

# Government

- Central bank chooses policy rate  $i_t$  and bond holdings  $S_t^{(\tau)}$
- Potentially subject to costs:

$$Y_t \Psi_t^S \equiv Y_t \int_0^T \frac{\psi^{(\tau)}}{2} \left( S_t^{(\tau)} \right)^2 d\tau, \quad Y_t \Psi_t^i \equiv Y_t \frac{\psi^i}{2} \left( i_t - \bar{i}_t \right)^2$$

- In the background: fiscal authority chooses production/labor subsidies  $\tau^y, \tau^w$ , balances the budget period by period
- Optimal policy: maximize social welfare

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

Key takeaway: policy attempts to undo frictions:

1. Nominal pricing frictions  $\implies$  deadweight loss
2. Differentiated labor  $\implies$  production inefficiencies
3. Market segmentation  $\implies$  consumption dispersion, imperfect risk-sharing

# Equilibrium

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# Equilibrium Overview

- Equilibrium bond price dynamics and arbitrageur optimality conditions:

$$\frac{dP_t^{(\tau)}}{P_t^{(\tau)}} \equiv \mu_t^{(\tau)} dt + \sigma_t^{(\tau)} dB_t, \quad \mu_t^{(\tau)} - i_t = \sigma_t^{(\tau)} \Lambda_t, \quad \Lambda_t^\top = a \int_0^T \chi_t^{(\tau)} \sigma_t^{(\tau)} d\tau$$

- Term premia** depend on risk aversion  $a$  and equilibrium holdings  $\chi_t^{(\tau)}$
- Approximation** around “small risk, low risk bearing capacity” (nonzero premia)
- The **first-best** allocation obtained when  $\theta = 0$  and  $a = 0$ . Output gap  $X_t \equiv \frac{Y_t}{Y_t^n}$  and inflation evolve according to (linearized)

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

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

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

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

- Up to **first-order**, our model is the same as Ray, Droste, & Gorodnichenko (2024) [details](#)

- Per-period social welfare loss (second-order expansion relative to first-best):

$$\begin{aligned}\mathcal{L}_t \equiv & (\varsigma + \varphi)x_t^2 + \theta\pi_t^2 \\ & + \int_0^T \psi^{(\tau)} \left(S_t^{(\tau)}\right)^2 d\tau + \psi^i \left(i_t - \bar{i}_t\right)^2 \\ & + \frac{\varsigma}{\varphi} \left( \varphi + \varsigma \left[ \frac{\varphi\epsilon_w}{1 + \varphi\epsilon_w} \right]^2 \right) \mathbb{V}\text{ar}_{\tau} c_t(\tau) + \epsilon_w \mathbb{V}\text{ar}_{\tau} w_t(\tau)\end{aligned}$$

- First line: losses from **nominal rigidities** (same as in textbook RANK)
- Next line: losses from policy frictions (when  $\psi^i > 0, \psi^{(\tau)} > 0$ )
- Final line: losses also depends on **consumption and wage dispersion** across HHs

# Aggregate and Welfare Consequences: Simple Policy Rules

- In order to better understand the model, simplify to a version of the model which only includes **natural rate shocks**  $r_t^n$

$$dr_t^n = -\kappa_z r_t^n dt + \sigma_r dB_{z,t}$$

- Consider **policy rules** which implement

$$i_t = \chi_i r_t^n$$
$$S_t^{(\tau)} = \chi_S^{(\tau)} r_t^n$$

- **Simple policy rules**: function of natural state variables only
  - Time-consistent: policymaker seeks to minimize **unconditional** social welfare loss
- We will examine the outcome of these policies in different versions of the model

## Risk Neutral Arbitrageur

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## Benchmark: Risk Neutral Arbitrageur (“Standard Model”)

- Consider the benchmark case of a risk neutral arbitrageur:  $a = 0$
- The **expectations hypothesis** holds:  $\mu_t^{(\tau)} = i_t \implies$  model collapses to **RANK**

$$\mathbb{V}\text{ar}_{\tau} c_t(\tau) = 0, \quad \mathbb{V}\text{ar}_{\tau} w_t(\tau) = 0$$

- 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

$$\chi_i = 1 \implies \mu_t^{(\tau)} = r_t^n \implies x_t = \pi_t = 0$$

- ‘**Woodford-ian**’ **equivalence**: the role of policy on aggregate dynamics and welfare is fully summarized by policy rate  $i_t$

## Imperfect Arbitrage

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# Imperfect Arbitrage

- Now assume  $a > 0$  and the central bank continues to implement  $i_t = r_t^n$

## Proposition (Imperfect Arbitrage and Ad-hoc Policy)

Assume risk aversion  $a > 0$  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  $S_t^{(QE)}$

Aggregate dynamics: output gaps  $x_t$  and inflation  $\pi_t$

- 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 and wage dispersion  $\text{Var}_\tau c_t(\tau) \neq 0, \text{Var}_\tau w_t(\tau) \neq 0$

# 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
  - $\implies c_t(\tau) \neq c_t(\tau'), n_t^{(\tau)} \neq n_t(\tau')$  and therefore  $\text{Var}_\tau c_t(\tau) \neq 0, \text{Var}_\tau w_t(\tau) \neq 0$

## Optimal Policy

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# 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:

$$\exists \chi_i^n > 1 : i_t = \chi_i^n r_t^n \implies \tilde{\mu}_t = r_t^n$$

- However, this does not achieve first-best since  $\text{Var}_\tau c_t(\tau) \neq 0, \text{Var}_\tau w_t(\tau) \neq 0$
- In fact, relative to the policy  $i_t = r_t^n$ , in general we have  $\uparrow \text{Var}_\tau c_t(\tau), \uparrow \text{Var}_\tau w_t(\tau)$ 
  - 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/labor dispersion
- **Optimal short rate policy**: if  $\psi^{(\tau)} \rightarrow \infty$ , then optimal policy implements

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

# 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  $a > 0$  and price elasticities  $\alpha(\tau) > 0$ , and policy costs  $\psi^i = \psi^{(\tau)} = 0$ . Suppose the central bank implements short rate and balance sheet policy according to

$$\begin{aligned}i_t &= r_t^n \\ S_t^{(\tau)} &= \alpha(\tau) \log P_t^{(\tau)}\end{aligned}$$

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 and wage equalization:**  $\text{Var}_\tau c_t(\tau) = 0, \text{Var}_\tau w_t(\tau) = 0 \ \forall t$

# 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  $i_t = r_t^n$  is optimal

**Separation principle** for optimal policy:

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

# Separation Principle with Balance Sheet Constraints

- When the central bank faces **balance sheet constraints** ( $\Psi^{(\tau)} > 0$ ), policy can no longer achieve first-best
- However, as long as  $\Psi^{(\tau)} < \infty$ , optimal policy implies the central bank still uses balance sheet tools
- Let  $\Psi^{(\tau)} = a \cdot \sigma^{(\tau)} [\sigma^{(\tau)}]^\top$ 
  - $\implies$  same friction  $a$  as arbitrageurs, except policymaker **cannot net out** positions
- Even with “large” balance sheet costs, the central bank still uses QE to (partially) stabilize term premia
- **Intuition:**
  - The central bank faces holding costs which imply it is **worse than private arbitrageurs** at financial intermediation
  - But the central bank **internalizes the social benefits** of minimizing fluctuations in term premia
  - Nevertheless, non-negligible balance sheet costs imply that optimal policy is less reactive

# Financial Stabilization Policy with Short Rate Constraints

- Suppose that **short rate policy is constrained**, and implements

$$i_t = \tilde{\chi}_i r_t^n, \quad 0 < \tilde{\chi}_i < 1$$

- Formally: assume costs  $\psi^i (i_t - \tilde{\chi}_i r_t^n)$  and take  $\psi^i \rightarrow \infty$
- 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,  $\tilde{\mu}_t \neq r_t^n$  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:

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

$$\lambda_t \equiv a \int_0^T \left[ \alpha(\tau) \log P_t^{(\tau)} - S_t^{(\tau)} \right] \sigma_t^{(\tau)} d\tau$$

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

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

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

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



# 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**  $\{s_t^{(\tau)}\}$ , in practice it can **only manipulate**  $\lambda_t$
- Related to **localization results** in Vayanos & Vila (2021) and Ray, Droste, & Gorodnichenko (2024)
  - 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 Overview

- “Noise” Demand Shocks details
  - Optimal separation principle still holds with stochastic habitat demand  $\beta_t^{(\tau)}$ , but QE must be more reactive
  - **Additional result**: if noise demand dynamics are such that  $\uparrow\uparrow \beta_t^{(\tau)}$  in response to  $\uparrow r_t^n$ , then it is optimal to **expand** the balance sheet  $\uparrow S_t^{(\tau)}$  while hiking rates  $\uparrow i_t$
- Cost-Push Shocks details
  - Adding shocks to NKPC (eg, wage rigidity in labor markets) breaks divine coincidence but unfortunately, our separation principle still holds
  - Despite multiple policy instruments, (un)conventional policy only affects aggregate outcomes through changes in **effective borrowing rate**  $\tilde{\mu}_t$
  - *Work-in-progress*: financial segmentation for firms  $\implies$  *endogenous* cost-push shocks
- Nonzero First-Best Term Premia details
  - When **first-best** BCT returns are  $\nu^{(\tau)} \neq 0$
  - Our results hold when  $\nu^{(\tau)}$  is achievable but optimal short rate policy is a function of  $\nu^{(\tau)}$

## History-Dependent Policy

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# Monetary Policy with Commitment

- When policy frictions bind, simple policy rules fail to achieve first-best
- Instead suppose the policymaker chooses policy tools  $\mathbf{u}_t$  as a function of **entire history** of predetermined and nonpredetermined variables  $\mathbf{Y}_t \equiv \begin{bmatrix} \mathbf{y}_t^\top & \mathbf{x}_t^\top \end{bmatrix}^\top$
- Minimizes conditional social loss

$$\begin{aligned}\mathcal{W}_0 &= \frac{1}{2} \mathbb{E}_0 \int_0^\infty e^{-\rho t} \mathcal{L}_t dt \\ &= \frac{1}{2} \mathbb{E}_0 \int_0^\infty e^{-\rho t} (\mathbf{Y}_t^\top \mathbf{R} \mathbf{Y}_t + \mathbf{u}_t^\top \mathbf{Q} \mathbf{u}_t) dt, \quad \mathbf{y}_0 \text{ given}\end{aligned}$$

- By setting policy in a history-dependent manner, full commitment policies can improve on simple policy rules

# Characterizing Optimal Policy with Commitment

## Theorem (Optimal Policy with Commitment)

Given  $\mathbf{y}_0$ , the policymaker minimizes  $\mathcal{W}_0$  by choosing  $\mathbf{u}_t = \mathbf{F}\mathbf{Y}_t$ , which induce equilibrium dynamics  $d\mathbf{Y}_t = -\mathbf{\Upsilon}(\mathbf{F})\mathbf{Y}_t dt + \mathbf{S}(\mathbf{F}) d\mathbf{B}_t$ . Necessary conditions are given by

$$\mathbf{y}_0^\top \left( \partial_i \mathbf{P}_{11} - \partial_i \mathbf{P}_{12} \mathbf{P}_{22}^{-1} \mathbf{P}_{21} - \mathbf{P}_{12} \mathbf{P}_{22}^{-1} \partial_i \mathbf{P}_{21} + \mathbf{P}_{12} \left( \mathbf{P}_{22}^{-1} \partial_i \mathbf{P}_{22} \mathbf{P}_{22}^{-1} \right) \mathbf{P}_{21} \right) \mathbf{y}_0 = 0$$

where  $\rho \mathbf{P} = \mathbf{R} + \mathbf{F}^\top \mathbf{Q} \mathbf{F} - \mathbf{P} \mathbf{\Upsilon} - \mathbf{\Upsilon}^\top \mathbf{P}$ . Dynamics are given by  $\mathbf{q}_0 = \begin{bmatrix} \mathbf{y}_0 & \mathbf{0} \end{bmatrix}^\top$  and

$$d\mathbf{q}_t = - \begin{bmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{P}_{21} & \mathbf{P}_{22} \end{bmatrix} \mathbf{\Upsilon} \begin{bmatrix} \mathbf{I} & \mathbf{0} \\ -\mathbf{P}_{22}^{-1} \mathbf{P}_{21} & \mathbf{P}_{22}^{-1} \end{bmatrix} \mathbf{q}_t dt + \begin{bmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{P}_{21} & \mathbf{P}_{22} \end{bmatrix} \mathbf{S} d\mathbf{B}_t \equiv -\mathbf{\Gamma} \mathbf{q}_t dt + \mathbf{\sigma} d\mathbf{B}_t$$

Bond prices are affine in  $\mathbf{A}(\tau)^\top \mathbf{q}_t$  with  $\mathbf{A}(\tau) = [\mathbf{I} - e^{-\mathbf{M}\tau}] \mathbf{M}^{-1} \mathbf{e}_i$  and

$$\mathbf{e}_i^\top \mathbf{q}_t = i_t, \quad \mathbf{M} = \mathbf{\Gamma}^\top - \int_0^T [-\alpha(\tau) \mathbf{A}(\tau) + \mathbf{\Theta}(\tau)] \mathbf{A}(\tau)^\top d\tau \tilde{\mathbf{\Sigma}}$$

# Monetary Policy with Commitment: Intuition

- Policymaker chooses tools  $i_t, \{S_t^{(\tau)}\}$  which:
  - Directly affect optimality conditions of arbitrageurs
  - Indirectly affect HHs through changes in equilibrium borrowing rates
  - Indirectly affect firms through changes in marginal costs
- **Trade-off**: more aggressive policy reactions to shocks:
  - Greater pass-through to HHs
  - Larger and more volatile term premia
- Commitment partially relaxes this link:
  - HH decisions depend on entire expected path of borrowing rates  $\int_0^\infty \mu_t^{(\tau)} d\tau$
  - Arbitrageur risk compensation depends on volatility of short-run fluctuations  $di_t, dS_t^{(\tau)}$
- Characterizing dynamics of optimal policy with commitment is difficult
  - Ongoing work studies optimal policy numerically
  - Suffers from time inconsistency; simple rules may be more practical

# 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:

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

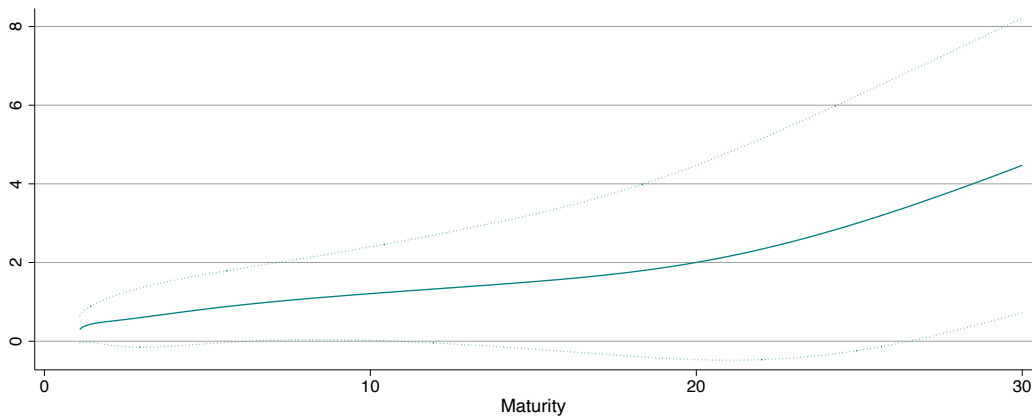
- If balance sheet policy is pursuing **financial stabilization**:

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

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

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

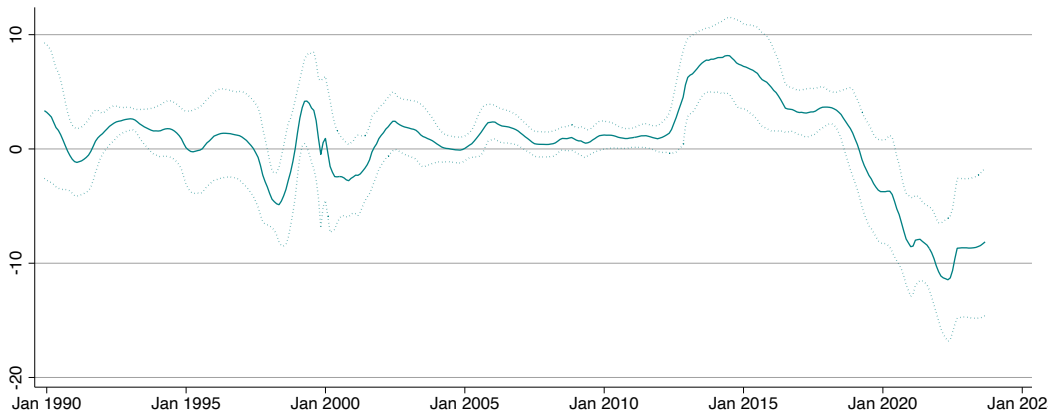
## Fama-Bliss Coefficients: Treasuries, Full Sample



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!

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## Equilibrium Details

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# Aggregation

- Firms, arbitrageurs, and funds transfer profits equally to HHs
- **Symmetric firm equilibrium**  $Y_t(j) = Y_t, P_t(j) = P_t, \pi_t(j) = \pi_t, \frac{dP_t}{P_t} = \pi_t dt$
- Clearing in production and goods markets:

$$Y_t = Z_t L_t \equiv Z_t \left[ \int_0^T \eta(\tau) N_t(\tau)^{\frac{\epsilon_W - 1}{\epsilon_W}} d\tau \right]^{\frac{\epsilon_W}{\epsilon_W - 1}}$$
$$C_t \equiv \int_0^T \eta(\tau) C_t(\tau) d\tau = Y_t \left( 1 - \frac{\theta}{2} \pi_t^2 - \Psi_t^S - \Psi_t^i \right)$$

- **Bond market clearing** implies

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

# Optimality Conditions

- 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:

$$\mu_t^{(\tau)} - i_t = \sigma_t^{(\tau)} \Lambda_t, \quad \Lambda_t^\top = a \int_0^T \chi_t^{(\tau)} \sigma_t^{(\tau)} d\tau$$

- Term premia depend on risk aversion  $a$  and equilibrium holdings  $\chi_t^{(\tau)}$
- HH optimality conditions (log-linearized) :

$$w_t = \varsigma c_t(\tau) + \phi n_t(\tau) + \frac{1}{\epsilon_w} (n_t(\tau) - \ell_t), \quad \mathbb{E}_t dc_t(\tau) = \varsigma^{-1} \left( \mu_t^{(\tau)} - \pi_t - \rho \right) dt$$

- Firm optimality conditions (log-linearized):

$$\mathbb{E}_t d\pi_t = (\rho\pi_t - \delta_w w_t) dt$$

# Simplifying Assumptions

- **Tractability assumption:** a “head of HH” sets transfers such that in equilibrium, wealth is equalized: across  $\tau$  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  $\hat{\sigma}_t^{(\tau)} \equiv \hat{h}^{\frac{1}{2}} \cdot \sigma_t^{(\tau)} \rightarrow \mathbf{0}$  but arbitrageur risk aversion  $\hat{a} \equiv a/\hat{h} \rightarrow \infty$  such that  $\hat{a}^{\frac{1}{2}} \cdot \hat{\sigma}_t^{(\tau)} \equiv a^{\frac{1}{2}} \cdot \sigma_t^{(\tau)}$  remains non-zero and bounded
  - Pros: clear focus on the idea of “imperfect arbitrage”
  - Cons: less realistic risk premia (particularly in first-best)
- Allows us to derive simple first-order approximations of dynamics and second-order approximations for welfare

# Aggregate Dynamics

- The **first-best** (natural) allocation obtained when  $\theta = 0$  and  $a = 0$ . Output gap:

$$\chi_t \equiv \frac{Y_t}{Y_t^n}$$

- Output gap evolves according to **modified aggregate Euler equation**:

$$d\chi_t = \varsigma^{-1} (\tilde{\mu}_t - \pi_t - r_t^n) dt$$

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

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

- We recover a **standard NKPC**:

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



## Extensions

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## 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  $i_t = r_t^n$
- **Additional result:** if noise demand dynamics are such that  $\uparrow\uparrow \beta_t^{(\tau)}$  in response to  $\uparrow r_t^n$ , 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 back

## Extensions: Cost-Push Shocks

- What if divine coincidence does not hold? Eg, wage rigidity in labor markets
- More generally, introduce exogenous **cost-push shocks**  $u_t$  in NKPC:

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

- 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  $\{\hat{i}_t, \hat{S}_t^{(\tau)}\}_t$
  - Can also be achieved with  $i_t = \tilde{\mu}_t, S_t^{(\tau)} = \alpha(\tau) \log P_t^{(\tau)} + \beta_t^{(\tau)}$
  - This guarantees  $\mathbb{V}\text{ar}_\tau c_t(\tau) = \mathbb{V}\text{ar}_\tau w_t(\tau) = 0$  and hence strictly dominates
- However, room for policy improvement with **endogenous** cost-push shocks (eg, working capital channel) [back](#)

## 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  $i_t = r_t^n - \tilde{\nu}$  [back](#)