A Portfolio Model of Quantitative Easing

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Introduction

- Consensus that QE reduced long-term interest rates

- But the transmission to long rates is not well understood, conceptually and empirically

- Notably, lack of theoretical accounting for role of central bank reserves and commercial banks

- Transmission details matter for how to best design, calibrate, communicate, and exit QE programs

Our Contribution

- We present a portfolio model with a CB, reserve-holding banks, and non-bank financial institutions

- Two financial frictions, imperfect substitutability and segmentation of the market for central bank reserves, lead to two distinct portfolio balance effects:

  - Standard supply induced effects due to a lower available supply of the purchased assets, and

  - Reserve induced portfolio effects, independent of the specific assets purchased

- Application: Impact of leverage constraints on QE transmission

Outline

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Existing PB Models Missing Important Aspects of QE

- Previous PB models of QE one-sided:
  - Seminal paper: Vayanos Vila 2009
  - No role for reserves or banks
  - CB bond purchases modelled as exogenous reduction in supply
  - Price re-equilibrates demand and supply

- What about the other side of the QE transaction? CB reserves
  - Bernanke and Reinhart (2004) argue that an expansion of reserves by itself can have PB effects
  - ...but do not present a model of the mechanism.

We Include Reserves and Banks in a PB Model

Portfolio model of a financial market:

- <u>Three actors</u>: CB, banks and non-bank financial firms

- <u>Four assets</u>: long bonds, short bonds, bank deposits and central bank reserves

- <u>Two central frictions</u> (more can be added):
  - Only banks can hold reserves, and
  - Imperfect asset substitutability

- <u>Central assumption</u>:
  - Banks' bond demand propensity out of new funding is positive, given asset prices

Banks

Assets		Liabilities	
Reserves ⇧↑		Equity	
Short bonds ⇩		Deposits ↑	
Long bonds		Other debt	
Other assets			

Central Bank

Assets		Liabilities	
Short bonds ↑		Equity	
Long bonds		Reserves ↑	
Other assets		Other liabilities	

Non-Bank Financial Firms

Assets		Liabilities
Deposits ↑		Equity
Short bonds ↓		Debt
Long Bonds		
Other assets		

- Example: CB purchases short bonds from banks (green)
- Standard macro: short bonds and money perfect substitutes at ZLB, no effect
- Now consider purchases from non-banks (black arrows)

| Pre-QE Bank Assets | Pre-QE Bank Liabilities | Post-QE Bank Assets | Post-QE Bank Liabilities |

Reserves

Bank loans

Securities

Deposits

Debt issues

Equity

Reserves

Bank loans

Securities

Deposits

Debt issues

Equity
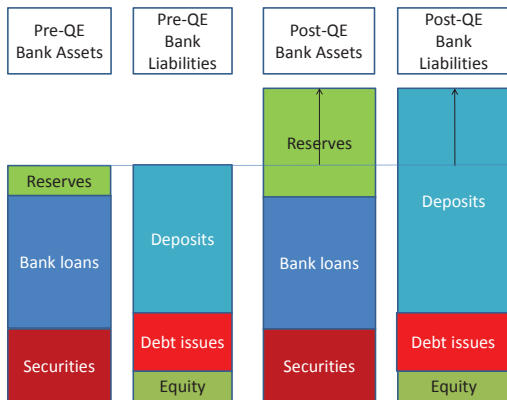
- Initial impact: Bank balance sheets extend, their demand for non-reserve assets increases
- The extra reserves must stay in banks: Hot potato effect....
- ... until longer-duration yields decline enough to make banks content to hold the extra reserves

Banks

Assets	Liabilities
Reserves ⇑ ⬆	Equity
Short bonds	Deposits ⬆
Long bonds ⇓	Other debt
Other assets	

Central Bank

Assets	Liabilities
Short bonds	Equity
Long bonds ⬆	Reserves ⬆
Other assets	Other liabilities

Non-Bank Financial Firms

Assets	Liabilities
Deposits ⬆	Equity
Short bonds	Debt
Long Bonds ⬇	
Other assets	

- Reserve-induced effects arise when assets are purchased from non-banks, and are independent of the assets
- Long bonds can have both reserve and supply effects

Outline

Modelling Approach and Versions

- One period model of asset market equilibrium with smallest number of features to illustrate that reserves matter

- Long-term bond demand assumptions:
  - Imperfect substitutability: $-\infty < \frac{\partial f_j}{\partial P_L} < 0$
  - Banks' bond demand propensity out of new funding: $0 < \frac{\partial f_B}{\partial D_B^l} < 1$

- Different model versions:
  - Benchmark model with one traded security (the long bond, L): simple, tractable, captures all effects
  - Two traded securities version (long and short bonds): confirms findings of one-security version

Solution in One-Security Model Version

- The equilibrium bond price ensures aggregate demand for bonds in banks and non-banks equals total supply of bonds net of central bank holdings

- Comparative statics. Change in equilibrium bond price associated with a QE transaction:

$$\frac{dP_L}{dL_{CB}} = \frac{-1}{\frac{\partial f_{NB}}{\partial P_L} + \frac{\partial f_B}{\partial P_L} - P_L \frac{\partial f_{NB}}{\partial P_L} \frac{\partial f_B}{\partial D_B}}$$

- First two terms in denominator are supply induced effects. Third term is reserve induced effect

- Price impact depends on price sensitivity of bond demand, and banks' bond demand propensity from new funding

Outline

Are Reserve-Induced Effects Empirically Relevant?

- To identify reserve effects, we need QE-style CB reserve expansions without long-term bond purchases

- The Swiss reserve expansion program of August 2011:
  - Akin to natural experiment of QE in short-term bonds
  - Christensen and Krogstrup (FRBSF WP 2016) find support for reserve induced effects

- Event studies of US and UK QE cannot identify, but:
  - Exit may provide insights: Bonds roll off - reserves effect?
  - Studies indicate non-bank counterparties and bank balance sheet expansions associated with parts of QE (Joyce et al. 2011, Ennis and Wollman 2015, Carpenter et al. 2013)

Empirical Relevance of Reserve-Induced Effects

- Data on bank total liabilities suggest the conditions were there for reserve induced effects during QE2 and QE3:
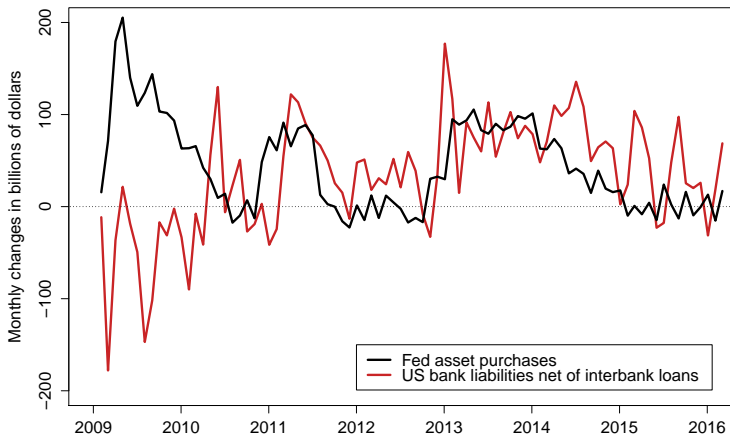
Outline

Conclusion

We develop a portfolio model of QE transmission to asset prices that includes central bank reserves and banks

- **Main finding**: PB effects come in two variants
  - Supply induced PB effect
  - Reserve induced PB effects

- **The distinction matters**. Reserve effects are different:
  - Independent of the assets that central bank is purchasing
  - Depend on features of market and banking system (preferences and constraints)

- **Empirically relevant**. Effects shown for Swiss reserve expansions. Likely to have played a role BoE and Fed QE

Some Tentative Policy Implications

Implications for the design and transmission of QE programs:

- **Which assets to buy**? Not necessary to buy long-dated securities to affect long-term yields

- **Financial institutional structure matters**. Who has access to reserves, and preferred habitat investors

- **Role of bank regulation** in transmission: bank leverage constraints and portfolio risk management models of non-banks matter

- **Transmission and Exit**: Rolling off of bonds akin to sales of short bonds. Reverse reserve effects?

End of Slides

Thank you!

Model With One Traded Security

One period model of asset market equilibrium

- Three types of actors:

    - A central bank (*CB*)

    - An infinity of reserve holding commercial banks (*B*)

    - An infinity of non-bank financial firms (*NB*)

- Three types of assets (simplest case):

    - Long bonds, L, with the price of P_L and $TP = 1 - P_L$

    - Central bank reserves, R, with the price of one (numeraire)

    - Bank deposits, D with the price of one

The Model (2)

The central bank balance sheet:

- $P_L L_{CB} = E_{CB} + R$

  - L_{CB}: is the central bank's holdings L
  - E_{CB} is the value of the central bank's initial equity
  - R is outstanding reserves

Policy tool is bond purchases, $P_L dL_{CB}$, paid for by reserves, dR, and equity is residually determined by bond price changes:

- $dE_{CB} = dP_L L_{CB} + P_L dL_{CB} - dR$

The Model (3)

The non-bank financial firm j balance sheet:

- $P_L L_{NB}^{j} + D_{NB}^{j} = E_{NB}^{j}$

  - L_{NB}^{j} is firm j's holdings of bonds
  - D_{NB}^{j} holdings of bank deposits
  - E_{NB}^{j} initial equity value

Non-banks obtain deposits by selling bonds and vise versa, equity is residually determined by price changes:

- $dE_{NB}^{j} = dP_L L_{NB}^{j} + P_L dL_{NB}^{j} + dD_{NB}^{j}$

The Model (4)

Non-bank financial firms balance their liquid portfolio between deposits and bonds, demanding positive amounts of both:

- $L_{NB}^j = f_{NB}(P_L, E_{NB}^j)$

- $\frac{\partial f_{NB}}{\partial P_L} < 0$ Normal downward sloping demand Substitutability

- $\frac{\partial f_{NB}}{\partial E_{NB}} = 0$ No real-time reaction to changes in equity value. Allows more tractability, not central for results

The demand for deposits is determined as a residual:

- $D_{NB}^j = E_{NB}^j - P_L f_{NB}(P_L, E_{NB}^j)$

The Model (5)

Depository bank i balance sheet:

- $R^i + P_L L_B^i = E_B^i + D_B^i$

  - L_B^i is bank i's holdings of bonds
  - R^i is its holdings of central bank reserves
  - D_B^i is the bank's deposit funding
  - E_B^i initial equity value

Banks can obtain reserves by selling bonds. Reserves fluctuate autonomously when bank costumers trade bonds for deposits:

- $dR^i = dD_B^i - P_L dL_B^i$

Bank equity is residually determined by bond-price changes:

- $dE_B^i = dP_L L_B^i$

The Model (6)

Depository banks' demand for bonds and reserves:

- $L_B^i = f_B(P_L, E_B^i + D_B^i)$

Central assumptions:

- $\frac{\partial f_B}{\partial P_L} < 0$ Normal good, imperfect substitutability
- $0 < \frac{\partial f_B}{\partial D_B^i} < 1$ Bank "maturity transformation" assumption

The demand for reserves is determined as a residual:

- $R_B^i = E_B^i + D_B^i - P_L f_B(P_L, E_B^i + D_B^i)$

Model Equilibrium

- Assume no market power of individual financial institutions:
  Continuum of identical banks and nonbanks, normalized to 1:
  Drop equation subscripts

- The equilibrium bond price ensures aggregate demand for
  bonds in banks and non-banks equals total supply of bonds
  net of central bank holdings

- Comparative statics: We analyze the change in equilibrium
  bond price associated with a QE transaction:

- $-dL_{CB} = dL_B + dL_{NB}$