A Framework for Financial Stability Analysis: Contagion and Policy Measures

C.A.E. Goodhart, C. Osorio, D.P. Tsomocos

XIXth European Workshop on General Equilibrium Theory Cracow University of Economics
Special Session: The Current Financial Crisis

June 11, 2010

Features of the 2007-Present Global Crisis

- Financial innovations, an inadequate regulatory framework, and ample liquidity, allowed banks to increases their **leverage** significantly. Hence, when default increased default in the U.S. mortgage market, it spread to the rest of the global nominal sector via securitized products and credit markets; this raised banks' risk aversion, which prevented interbank markets fail to act as a conduit for monetary policy. Consequently, systemically important financial institutions collapse calling for Governments interventions on a scale not seen for decades.

- In the short to medium run, solvent financial insitutions which are temporarily illiquid, due to margin calls (or liquidity requirements), may forced to file for bankruptcy.

Macreconomic models which do not allow for liquidity and endogenous default cannot account for these outcomes

What should (Have) Be(en) done?

- Use the interest rate, instead of the monetary base, as the monetary policy instrument in times of financial distress (See Goodhart, Sunirand and Tsomocos 2009): when the interest rate instrument is used there are no price effects.
- Include an appropriate measure of housing prices in the 'targeted' CPI, in order to reconcile potential trade-offs between **price and financial stability** objectives
- Pursue the (Central Banks') Financial Stability objective through regulatory policies for systemic financial agents, because of their interaction via the interbank market, as well as their contagious relations

What should (Have) Be(en) done?

Countercyclical Regulatory Policies: The New Financial Architecture

- **Capital requirements** reduce leverage in the banking sector, and induce banks to internalize (default) losses without taking a toll on the taxpayer.
- **Margin requirements** prevent excess leverage in the housing and derivatives markets, thus reducing/containing the adverse effects of the housing crisis via lower housing deflation rates
- **Liquidity requirements** reduce banks exposure to risky assets, thereby promoting lending in times of financial distress and stemming house price deflation

Our Framework

Monetary General Equilibrium Model with Commercial Banks, Collateral, Securitisation and Default (**MEBCSD**)

- Non-trivial quantity theory of money
- Term structure of interest rates depends on aggregate liquidity and default risk
- Fisher effect
- Financial fragility is an equilibrium outcome
- Constrained inefficient equilibrium allocations
- Assessment of various policies for crisis management and prevention

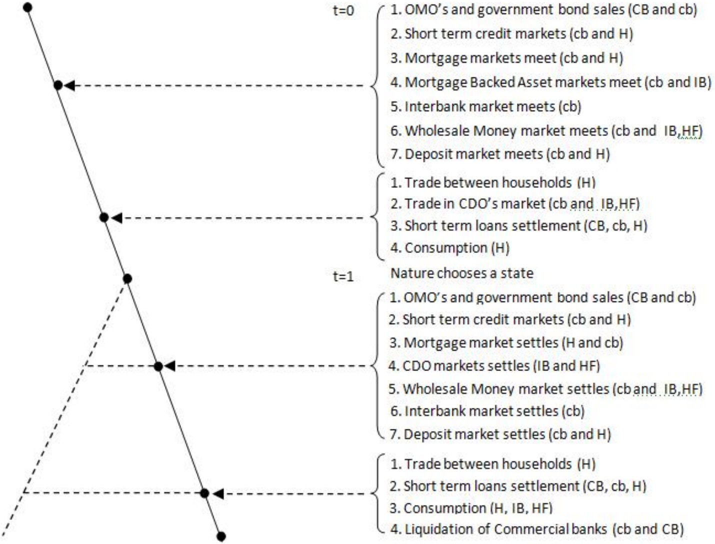
Financial Instability metric: increased aggregate default and lower banking sector profitability

Our Model

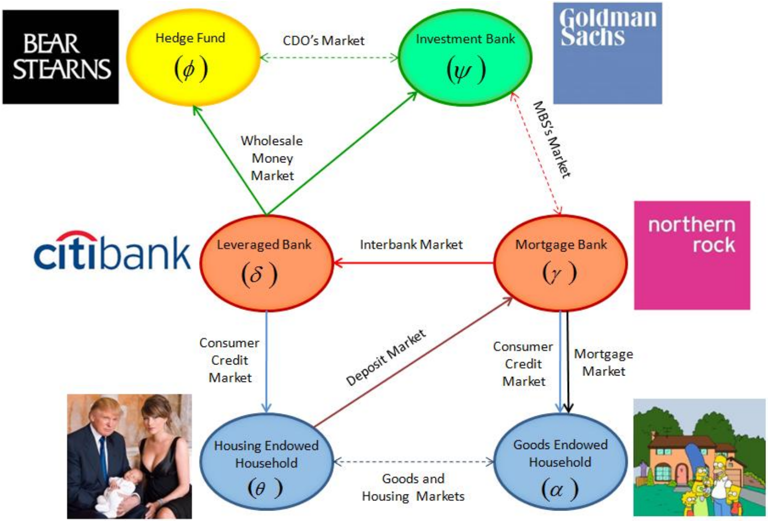
Extend the Goodhart, Sunirand and Tsomocos (2006), and Goodhart, Tsomocos and Vardoulakis (2008), and Tsomocos (2003) model to:

- Introduce non-bank financial institutions (NBFI)
- Separate the interbank from the repo market → Monetary Policy can be properly analyzed
- Model two types of default
  - Discontinuous default in mortgages (Geanakoplos, 2003)
  - Continuous default in credit markets (Shubik and Wilson, 1977 and Dubey et al.,2005)

Time Structure



Nominal Flows of the Economy



The straight lines and their direction represent lending flows. The dashed lines indicate trade.

Money and Collateral

Money

- Introduced by a cash-in-advance (liquidity) transaction technology
- Enters the system as *outside* or *inside* money

Collateral

- Home buyers pledge purchased housing as collateral when he takes out the mortgage
- If they default on the mortgage, the bank seizes the collateral and offers it for sale in the next period (US's 'walk away' option)

Default

Two types of *endogenous* default:

- **Discontinuous** mortgage default. Home buyers default on their mortgage if

$$(\textbf{collateral's worth}) \leq (\textbf{mortgage debt})$$

- **Continuous** default in the interbank and wholesale money markets: agents choose a repayment rate satisfying the *On the Verge Condition*:

marginal utility of default = marginal cost of default (bankruptcy pen

Securitisation

Scarcity of collateral incentivizes agents to strech it by using it many times.

- The investment bank buys the mortgage from a commercial bank at a price p^{α} in the MBS's market
- The investment bank structures a CDO by attaching a Credit Default Swap (CDS) to the MBS
- The hedge fund purchases the CDO at a price $\tilde{q}^{\alpha}$
- CDO's gross returns:

$$R^{CDO} = \begin{bmatrix} \left(1 + \bar{r}^{\gamma\alpha}\right) / \tilde{q}^{\alpha} \\ 1 \end{bmatrix}$$

- The investment bank bears the mortgage and CDS risk

Credit spreads, and the term structure of interest rates

Credit spreads proposition

Since ex-ante interest rates are considered, in the presence of default, borrowing rates have to be at least as high as lending rates to preclude arbitrage opportunities.

Credit spreads, and the term structure of interest rates

Credit spreads proposition

Since ex-ante interest rates are considered, in the presence of default, borrowing rates have to be at least as high as lending rates to preclude arbitrage opportunities.

The term structure of interest rates proposition

The term structure of interest rates is affected by aggregate liquidity and default, because interest rates price-in anticipated default rates (default premium). Aggregate ex-post interest rate payments to commercial banks adjusted by default equal the economy's total amount of outside money

Money Non-Neutrality, the Quantity Theory of Money and the Fisher Effect

Price Wedge Lemma

Since agents must borrow money to purchase goods and interest rates are positive, there is a wedge between selling and purchasing prices.

Money Non-Neutrality, the Quantity Theory of Money and the Fisher Effect

Price Wedge Lemma

Since agents must borrow money to purchase goods and interest rates are positive, there is a wedge between selling and purchasing prices.

Monetary Policy Non-Neutrality Proposition

If nominal interest rates are positive, then monetary policy is non-neutral.

Money Non-Neutrality, the Quantity Theory of Money and the Fisher Effect

Price Wedge Lemma

Since agents must borrow money to purchase goods and interest rates are positive, there is a wedge between selling and purchasing prices.

Monetary Policy Non-Neutrality Proposition

If nominal interest rates are positive, then monetary policy is non-neutral.

Quantity Theory of Money Proposition

If nominal interest rates are positive, the real velocity of money is endogenous and nominal changes affect both prices and quantities.

Money Non-Neutrality, the Quantity Theory of Money and the Fisher Effect

Price Wedge Lemma

Since agents must borrow money to purchase goods and interest rates are positive, there is a wedge between selling and purchasing prices.

Monetary Policy Non-Neutrality Proposition

If nominal interest rates are positive, then monetary policy is non-neutral.

Quantity Theory of Money Proposition

If nominal interest rates are positive, the real velocity of money is endogenous and nominal changes affect both prices and quantities.

The Fisher Effect Proposition

Nominal long term interest rates are approximately equal to real interest rates plus expected inflation and a risk premium.

Discussion of the Equilibrium: Assumptions

Parameters determine the structure of the economy, the degree of agent heterogeneity $\Longrightarrow$ the relationships and interconnectedness between the different agents, markets and sectors of the economy.

- Agents believe the probability of a housing and financial crisis is relatively small
- Home buyer is poorer than the owner of housing in monetary endowments at $t = 0$
- Lending banks is more capitalized than the borrowing banks and NBFIs
- Commercial banks are more risk averse than the NBFIs
- Economy experiences an adverse productivity shock: moderate at $s = 1$ and severe at $s = 2$

Discussion of the Equilibrium: Assumptions

Exogenous Variables also describe the action set of authorities: the Central Bank, the Government and the Financial Supervisory Agency.

- Central Bank responds by contracting its monetary policy stance (more in at $s = 2$ than in $s = 1$)
- FSA sets default penalties so as to protect the average consumer (the lendong faces the highest default penalty, and the NBFI is more severely penalized than the borrowing bank)
- At $t = 1$ the Government injects capital to commercial banks as hazardous times prevent them from raising capital in the equity market

Discussion of the Equilibrium: Results

Endogenous Variables

- Housing deflation and goods inflation
  - Negative productivity (supply) shock increases goods prices
  - House prices fall due to home buyer's lower demand for housing
- Relative house prices fall smoothly in $s = 1$ and plummet in $s = 2$, thus
  - At $s = 1$ no mortgage default, hence interbank default rate is low
  - At $s = 2$, α defaults on his mortgage

Discussion of the Equilibrium: Results (continued)

In the bad state ($s = 2$)

- Mortgage's effective return drops
- Significant losses in non-banking financial sector
- CDS contract executed: the borrowing bank delivers collateral to NBFIs in exchange for its initial investment
- NBFIs assume write-off loss
- Collateral sales exacerbate the housing crisis

- Economy becomes *financially unstable* at $s = 2$:
  - Default increases in the mortgage and interbank markets
  - Banks' profits fall

Comparative Statics: Optimal Monetary Policy Instrument

	Increase Money Supply $s=2$	Decrease Repo Rate $s=2$		Increase Money Supply $s=2$	Decrease Repo Rate $s=2$
p_{02}	+	+	$\bar{\mu}^{\psi}$	-	-
p_{22}	+	+	$\bar{v}_2^{\psi}$	+	+
$\bar{r}^{\gamma\alpha}$	-	-	$\bar{\mu}^{\phi}$	-	-
$\bar{r}$	$\approx$	-	$\bar{v}_2^{\phi}$	+	+
$\bar{\rho}$	$\approx$	-	U^{α}	$\approx$	$\approx$
$\bar{r}_d^{\gamma}$	$\approx$	$\approx$	U^{θ}	-	+
$\bar{d}^{\gamma}$	-	+	π_2^{γ}	-	-
$\bar{v}_2^{\delta}$	+	+	π_2^{δ}	-	-

Monetary Base Instrument

- $\downarrow$ Households' welfare (θ credit constrained)
- $\downarrow$ Default in mortgage, $\uparrow \bar{v}_2^{\delta}$, $\uparrow \bar{v}_2^{\psi}$ and $\uparrow \bar{v}_2^{\phi}$
- $\downarrow$ Banks profits
- 'Localized' liquidity trap
- FF improves partially

Interest Rate Instrument

- $\uparrow$ Households' welfare (no credit constraints)
- $\downarrow$ Mortgage default, and $\uparrow \bar{v}_2^{\delta}$, $\uparrow \bar{v}_2^{\psi}$ and $\uparrow \bar{v}_2^{\phi}$
- $\downarrow$ Banks profits (insufficient $\uparrow$lending)
- Undistorted transmission mechanism of M.P.
- FF improves partially

Interest rate instrument is preferable to the monetary base instrument in times of financial distress

Inflation vs. Asset Price Targeting

	Decrease Repo Rate $t = 0$	Decrease Repo Rate $s = 2$		Decrease Repo Rate $t = 0$	Decrease Repo Rate $s = 2$
p_{02}	+	+	$\bar{\mu}^{\psi}$	+	-
p_{22}	-	+	$\bar{v}_2^{\psi}$	-	+
$\bar{r}^{\gamma\alpha}$	-	-	$\bar{\mu}^{\phi}$	+	-
$\bar{r}$	-	-	$\bar{v}_2^{\phi}$	+	+
$\bar{\rho}$	-	-	U^{α}	+	$\approx$
$\bar{r}_d^{\gamma}$	-	$\approx$	U^{θ}	+	+
$\bar{d}^{\gamma}$	+	+	π_2^{γ}	-	-
$\bar{v}_2^{\delta}$	$\approx$	+	π_2^{δ}	$\approx$	-

Expansionary monetary policy at $t = 0$

- Improves households' welfare
- α and ψ default more and $\downarrow \pi_2^{\gamma}$ as $\downarrow (\rho - \bar{r}_d^{\gamma})$
- Mortgage crisis exacerbated
- Leverage procyclicality
- $\uparrow$ Financial Fragility (FF)

Expansionary monetary policy at $s = 2$

- $\uparrow$ Households' welfare (no credit constraints)
- $\downarrow$ Mortgage default, and $\uparrow \bar{v}_2^{\delta}$, $\uparrow \bar{v}_2^{\psi}$ and $\uparrow \bar{v}_2^{\phi}$
- $\downarrow$ Banks profits (insufficient $\uparrow$lending)
- Undistorted transmission mechanism of M.P.
- FF improves partially

Targeting goods inflation alone makes the economy Financially Unstable. The targeted price index should include a measure of house prices

Bankruptcy Code and Prudential Regulation (proxy)

	Tighter NBFI's Default Penalty $s = 2$	Increase γ's Risk Aversion Coefficient		Tighter NFBI's Default Penalty $s = 2$	Increase γ's Risk Aversion Coefficient
p_{02}	+	+	$\bar{\mu}^{\psi}$	-	-
p_{22}	+	+	$\bar{v}_2^{\psi}$	+	+
$\bar{r}^{\gamma\alpha}$	$\approx$	-	$\bar{\mu}^{\phi}$	-	-
$\bar{r}$	-	+	$\bar{v}_2^{\phi}$	+	$\approx$
$\bar{\rho}$	$\approx$	+	U^{α}	$\approx$	+
$\bar{r}_d^{\gamma}$	-	-	U^{θ}	$\approx$	$\approx$
$\bar{d}^{\gamma}$	-	-	π_2^{γ}	+	+
$\bar{v}_2^{\delta}$	$\approx$	+	π_2^{δ}	$\approx$	-

Default Penalties for ψ

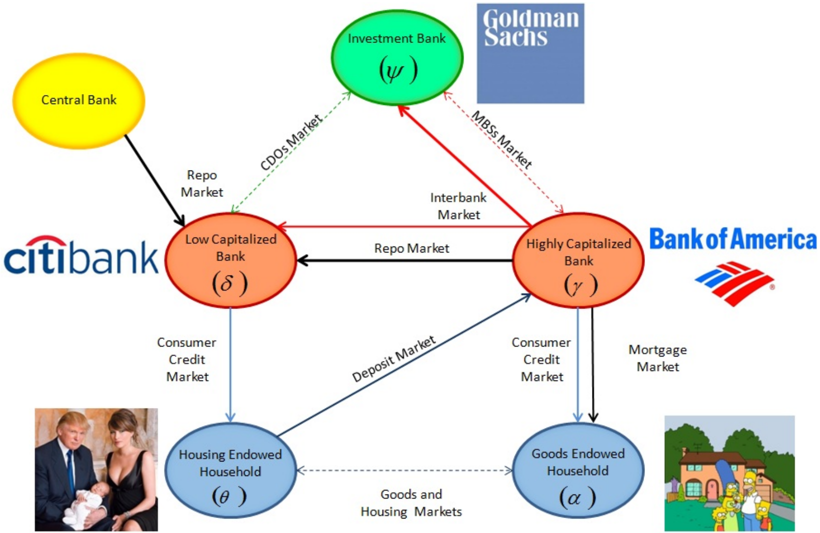
- Weak improvement of households' welfare
- $\downarrow$ Default in mortgage, $\uparrow \bar{v}_2^{\delta}$, $\uparrow \bar{v}_2^{\psi}$ and $\uparrow \bar{v}_2^{\phi}$
- $\uparrow$ Banks profits
- Countercyclical leverage $\downarrow$ FF
- **Pareto improvement**

γ becomes more prudent

- $\uparrow$ Households' welfare (credit conditions ease)
- $\downarrow$ Mortgage default, and $\uparrow \bar{v}_2^{\delta}$, $\uparrow \bar{v}_2^{\psi}$ and $\uparrow \bar{v}_2^{\phi}$
- $\uparrow$ Banks profits as $\uparrow (\rho - \bar{r}_d^{\gamma})$
- Countercyclical leverage and $\downarrow$ FF

Financial Stability objective should be primarily achieved by regulating systemic financial agents

Macroprudential Regulation: simplified model



The straight lines and their direction represent lending flows. The dashed lines indicate trade.

Higher Capital Requirements

Households Welfare		Banking Sector Profits		Repayment Rates	
U^{α}	-	π^{γ}	-	$\bar{v}_2^{\alpha}$	-
U^{θ}	+	π^{δ}	-	$\bar{v}_2^{\delta}$	+
U_2^{α}	+	π_2^{γ}	-	$\bar{v}_2^{\psi}$	-
U_2^{θ}	-	π_2^{δ}	-	$\bar{v}_2$	-

- Banks finance their portfolios with less debt
- Lower deposit rate induces savers to anticipate consumption $\rightarrow\uparrow p_{02}$
- $\uparrow p_{02} \rightarrow$ higher mortgage default rates $\rightarrow\uparrow$ default rates in the NBFI, but not the BFI sector
- Consumers' welfare improves: households smooth consumption efficiently (household α via default)

Commercial banks internalize (default) losses without taking a toll on the taxpayer

Tighter Margin Requirements

Households Welfare		Banking Sector Profits		Repayment Rates		Housing Prices	
U^{α}	+	π^{γ}	+	$\bar{v}_2^{\alpha}$	+	p_{02}	+
U^{θ}	-	π^{δ}	+	$\bar{v}_2^{\delta}$	+	p_{22}	+
U_2^{α}	+	π_2^{γ}	+	$\bar{v}_2^{\psi}$	+	(p_{22}/p_{02})	+
U_2^{θ}	-	π_2^{δ}	-			$\bar{r}_2^{\gamma\alpha}$	+
						$\bar{r}^{\gamma\alpha}$	-

- Lower LTV and haircut constraints induce home buyers and NBFIs to leverage less
- Lower demand for mortgages $\downarrow \bar{r}^{\gamma\alpha} \rightarrow$ reduces derivatives demand $\rightarrow$ commercial banks $\downarrow$ debt-to-equity ratios
- Lower house deflation an mortgage rates $\rightarrow\uparrow$ collateral value $\rightarrow\downarrow$ mortgage default
- Thus, interbank repayment rates rise $\rightarrow\uparrow$ lending to households at $s = 2 \rightarrow\downarrow$ house deflation

Margin requirements improve home buyers' welfare as well as financial stability via lower BFI, NBFI and household leverage

Higher Liquidity Ratios

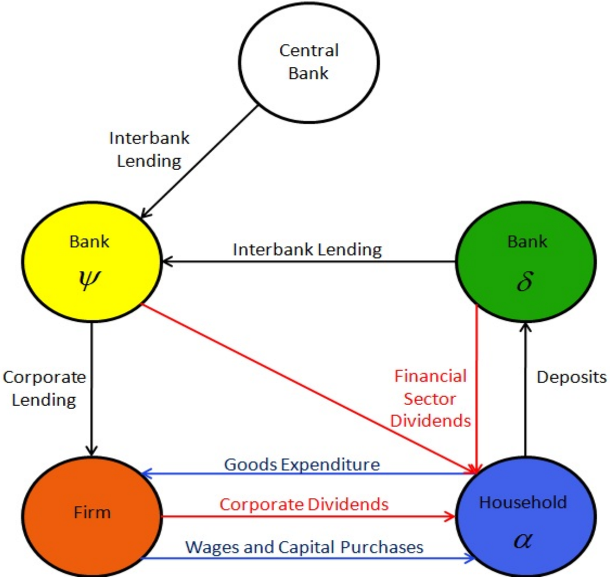
Households Welfare		Banking Sector Profits		Repayment Rates		Housing Prices		Lending at $s = 2$	
U^{α}	+	π^{γ}	+	$\bar{v}_2^{\alpha}$	+	(p_{22}/p_{02})	+	m_2^{γ}	+
U^{θ}	-	π^{δ}	+	$\bar{v}_2^{\delta}$	+	$\bar{r}_2^{\gamma\alpha}$	+	m_2^{δ}	+
U_2^{α}	+	π_2^{γ}	+	$\bar{v}_2^{\psi}$	+	$\bar{r}^{\gamma\alpha}$	+		
U_2^{θ}	-	π_2^{δ}	-						

- Commercial banks make fewer (more) credit extensions in the interbank and mortgage (short term consumer) markets
- NBFI reduces its leverage and bank δ makes smaller CDO investments
- As commercial banks reduce their exposure to derivatives $\rightarrow\uparrow$ beginning of $t = 1$ revenue $\rightarrow\uparrow$ lending to households at $s = 2$
- Higher demand by home buyers at $s = 2$ stems collapse of housing prices and $\uparrow$ value of collateral
- Hence, default rates in the mortgage and interbank markets decrease

Liquidity requirements improve home buyers' welfare as well as financial stability by reducing credit exposure of the banking sector

Nominal Flows of the Economy

s



Simulations

- Objectives
  - Describe how the endogenous variables of the model respond to several shocks
  - Assess the impact of introducing agent heterogeneity, liquidity and default into a DSGE model

- Therefore, we analyze the effects of monetary and fiscal policy shocks in three different models:
  - New Keynesian
  - Our model in the absence of default frictions (MGE)
  - The complete version of our model

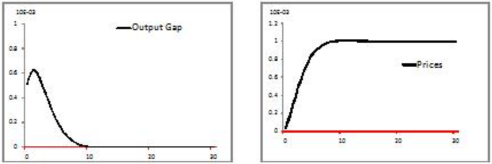
- Regulatory policy has non-trivial effects only in the presence of default frictions

Expansionary Monetary Policy in NKM and MGE

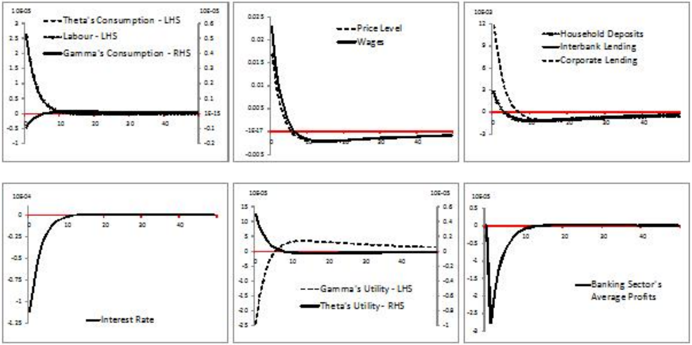
- In the NKM model
  - Monetary Policy is neutral in the long run
  - In the short run monetary policy has real effects due to sluggishly adjusting prices (Calvo pricing)
- In the MGE model
  - $\downarrow$ interest rates (equally)
  - $\uparrow$ borrowing, spending, trade, and prices
  - $\downarrow$ Banking sector profits due to $\downarrow$ interest rates
  - Variables converge gradually to steady state as shock disappears

Impulse Response Functions

New Keynesian Model



Monetary General Equilibrium Model without Default

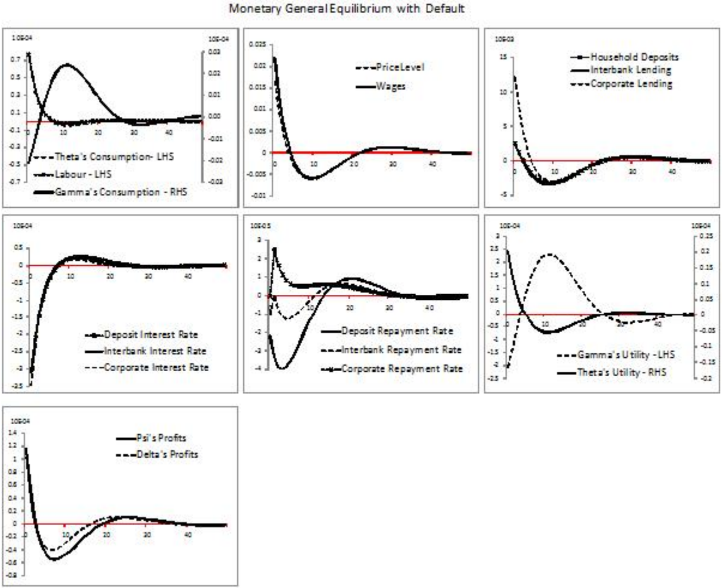


Expansionary Monetary Policy in the presence of Default

- $\downarrow$ interest rates
- $\uparrow$ borrowing, spending, trade, and prices
- $\downarrow v^d, v^{IB}$ due to lower credit costs
- $\uparrow v^F$ due to higher sales revenues
- $\uparrow$ Banking sector profits due to wider credit spreads and $\uparrow$ lending
- Due to $\downarrow E_t \left\{ v^d_{t+s} \right\}$ in the first few periods after the shock $\rightarrow \uparrow r^d$ $\rightarrow \uparrow r^{IB}, r^F$: 'Built-in stabilizer' $\equiv$ medium run destabilizer
- Variables oscillate around the steady state as shock disappears

Economy becomes financially unstable in the medium run

Impulse Response Functions



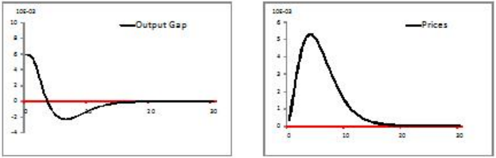
Expansionary Fiscal Policy in NKM and MGE

- In the NKM model
  - $\uparrow$ aggregate demand $\rightarrow$ positive output gap $\rightarrow$ prices *start* rising
  - $\uparrow$ prices $\rightarrow \downarrow$ real money balances $\rightarrow \downarrow$ output gap: 'Built-in stabilizer'
  - Economy experiences a short recession in the medium run (prices remain high after shock disappears)
  - Aggregate demand = consumption demand $\rightarrow$ no crowding-out effect unlike the IS-LM model

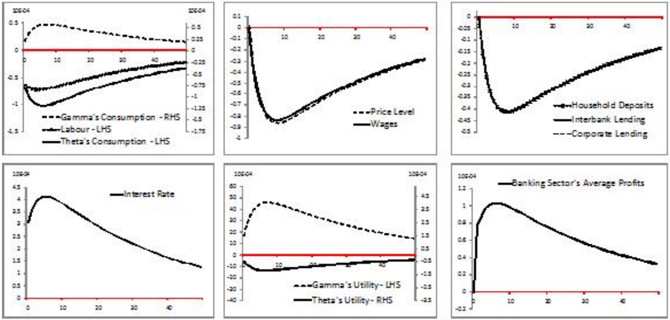
- In the MGE model
  - $\uparrow$ agents capacity to make interest payments $\rightarrow \uparrow$ demand for credit and bids interest rates up (equally)
  - Firm sells fewer goods $\rightarrow \downarrow$ labour, trade and wages, but $\uparrow$ prices
  - These effects remain for a few periods as credit conditions remain tight (despite prices starting to fall)
  - Household θ is worst-off
  - $\uparrow$ Banking sector profits due to $\uparrow$ interest rates
  - Variables converge gradually to steady state as shock disappears

Impulse Response Functions

New Keynesian Model



Monetary General Equilibrium Model without Default

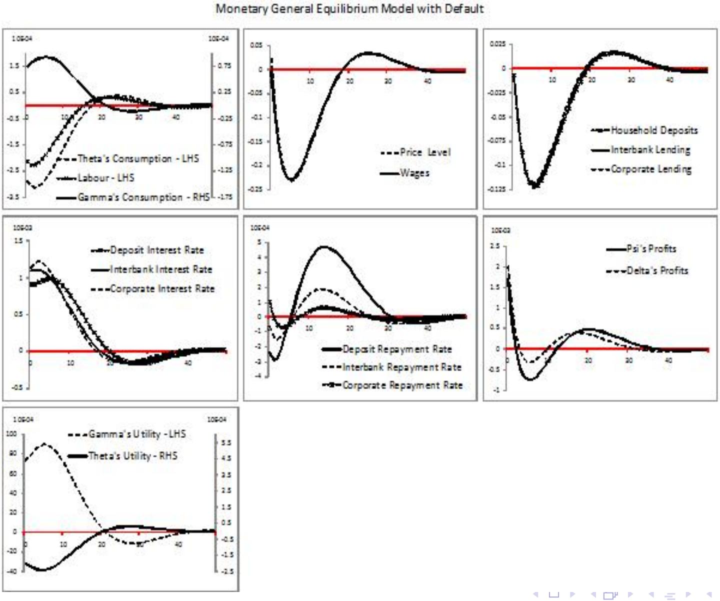


Expansionary Fiscal Policy in the presence of Default

- $\uparrow$ agents capacity to make interest payments $\rightarrow \uparrow$ demand for credit and bids interest rates up
- Higher monetary endowments allow agents to afford more credit costs $\rightarrow \uparrow$ (SR) Expected Default $\rightarrow \uparrow$ interest rates more than in default-free case
- $\uparrow$ profits in banking sector due to significant $\uparrow$ interest rates
- Sharp $\uparrow$ interest rates $\rightarrow \downarrow$ default a few periods after the shock: 'Built-in stabilizer' $\equiv$ medium run destabilizer
- Variables oscillate to steady state as shock disappears

Economy becomes financially unstable in the short to medium run

Impulse Response Functions

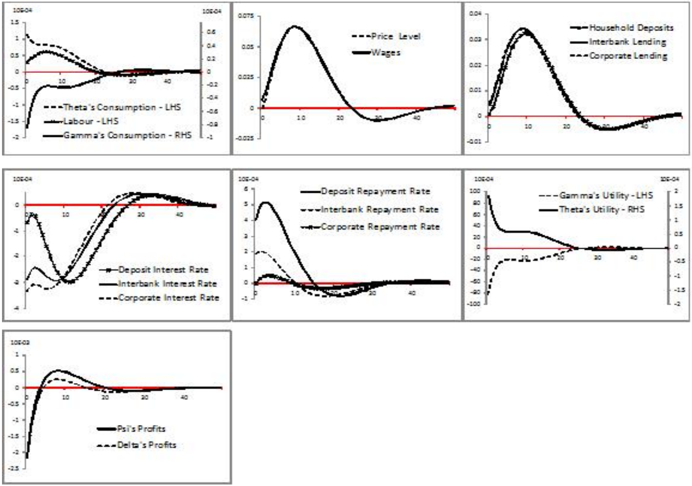


Regulatory Policy

- Proportional Increase of all Default Penalties
  - $\uparrow$ credit costs $\rightarrow$ $\uparrow$ repayment rates in all markets
  - Thus, $\downarrow$ interest rates $\rightarrow$ $\uparrow$ credit demand, spending, trade, prices and wages
  - Proportionate increase of default penalties $\rightarrow$ more pronounced effects in more regulated markets $\rightarrow$ credit spreads narrow and $\downarrow$ banking sector profits
  - Changes in interest rates affect credit costs such that, repayment rates oscillate as shock disappears
  - This policy promotes financial stability in the medium run

Impulse Response Functions

Monetary General Equilibrium with Default



Concluding Remarks

- We propose finite and infinite horizon models to analyze Financial Stability, which (should) include:
  - Heterogeneous agents
  - Endogenous Default
  - An essential role for money
  - Heterogeneous and active banks
- In our finite horizon model, we introduced frictions such as collateral and securitisation, to examine and obtain an equilibrium outcome consistent with the global 2007-2009/10 crisis
- Our infinite horizon model reveals the importance of allowing for *endogenous default* for the economy's short to medium run dynamics and its impact on financial stability

Concluding Remarks

Our comparative statics and simulations suggest that:

- In times of crisis, monetary policy conducted by means of the interest rate instrument is a more effective than using the monetary base instrument.
- CPI should include an appropriate measure of housing prices
- Optimal regulatory policies should target systemic financial agents and induce them to behave more prudently
- Capital requirements on their own do not promote financial stability
- Macro-prudential regulation should be concerned with margin and liquidity ratios as well
- Margin requirements reduce banks' leverage, whereas liquidity requirements lower their risk exposure

THANK YOU

The Economy

Endowment economy

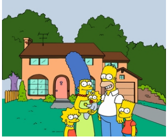
- 2 periods ($t \in T = \{0, 1\}$)
  - First period: a single state
  - Second period: S possible states
  - $S^* = \{0\} \cup S = \{0, 1, 2\}$
- 2 goods:
  - Consumption goods basket (1)
  - Housing (2): a durable good, but infinitely divisible
- Agents
  - Households: $h \in H = \{\alpha, \theta\}$, CRRA preferences
  - Commercial Banks: $j \in J = \{\gamma, \delta\}$, quadratic preferences
  - Investment Banks: ψ, risk neutral
  - Hedge Fund: ϕ, risk neutral
  - The Central Bank/Government/FSA: strategic dummies

The Economy

10 Markets

- Real sector
  - goods
  - housing
- Short-term (Default-free) credit markets
  - Repo
  - Consumer
- Long-term credit markets
  - deposit (Default-free)
  - mortgage (Default)
  - interbank (Default)
  - wholesale money markets (Default)
- Derivatives markets
  - Mortgage Backed Securities (MBSs)
  - Credit Debt Obligations (CDOs)

Household α's Optimisation Problem



$$\max_{q^{\alpha}_{s*1},\, b^{\alpha}_{s*2},\, \mu^{\alpha}_{s*},\, \bar{\mu}^{\alpha}} U^{\alpha} = u\left(e^{\alpha}_{01} - q^{\alpha}_{01}\right) + u\left(\frac{b^{\alpha}_{02}}{p_{02}}\right) + \sum_{s \in S} \omega_s u\left(e^{\alpha}_{s1} - q^{\alpha}_{s1}\right) + \sum_{s \in S^{\alpha}_{1}} \omega_s u\left(\frac{b^{\alpha}_{02}}{p_{02}} + \frac{b^{\alpha}_{s2}}{p_{s2}}\right) + \sum_{s \notin S^{\alpha}_{1}} \omega_s u\left(\frac{b^{\alpha}_{s2}}{p_{s2}}\right)$$

$s.t.$

$$b^{\alpha}_{02} \leq \frac{\bar{\mu}^{\alpha}}{(1+\bar{r}^{\gamma\alpha})} + \frac{\mu^{\alpha}_{0}}{(1+r^{\gamma}_{0})} + e^{\alpha}_{m,0}$$

i.e. housing expenditure at t=0 $\leq$ mortgage loan + short-term borrowing + private monetary endowments at t=0

$$\mu^{\alpha}_{0} \leq p_{01} q^{\alpha}_{01}$$

i.e. short term loan repayment at t=0 $\leq$ goods sales revenues at t=0

Household α's Optimisation Problem

$$b^{\alpha}_{s2} + \bar{\mu}^{\alpha} \leq \frac{\mu^{\alpha}_{s}}{(1 + r^{\gamma}_{s})} + e^{\alpha}_{m,s} \qquad \text{for} \quad s \in S^{\alpha}_{1}$$

i.e. housing expenditure at $s \in S^{\alpha}_{1}$ + mortgage repayment $\leq$ short-term borrowing+private monetary endowments at $s \in S^{\alpha}_{1}$

$$b^{\alpha}_{s2} \leq \frac{\mu^{\alpha}_{s}}{(1 + r^{\gamma}_{s})} + e^{\alpha}_{m,s} \qquad \text{for} \quad s \notin S^{\alpha}_{1}$$

i.e. housing expenditure at $s \notin S^{\alpha}_{1}$ $\leq$ short-term borrowing+private monetary endowments at $s \notin S^{\alpha}_{1}$

$$\mu^{\alpha}_{s} \leq p_{s1} q^{\alpha}_{s1}$$

i.e. short term loan repayment$\leq$ goods sales revenues at t=0

$$q^{\alpha}_{s^*1} \leq e^{\alpha}_{s^*1}$$

i.e. quantity of goods sold at $s \in S^*$ $\leq$ goods endowments at $s \in S^*$

Household θ's Optimisation Problem

$$\max_{q^{\theta}_{s*2}, b^{\theta}_{s*1}, \mu^{\theta}_{s*}, \bar{d}^{\theta}} U^{\theta} = u\left(\frac{b^{\theta}_{01}}{p_{01}}\right) + u\left(e^{\theta}_{02} - q^{\theta}_{02}\right) + \sum_{s \in S} \omega_s u\left(\frac{b^{\theta}_{02}}{p_{02}}\right) + \sum_{s \in S} \omega_s u\left(e^{\theta}_{02} - q^{\theta}_{s0} - q^{\theta}_{s2}\right)$$

s.t.

$$b^{\theta}_{01} + \bar{d}^{\theta} \leq \frac{\mu^{\theta}_{0}}{1 + r^{\delta}_{0}} + e^{\theta}_{m,0}$$

i.e. goods expenditure at t=0 + inter-period deposits ≤ short-term borrowing + private monetary endowments at t=0

$$\mu^{\theta}_{0} \leq p_{02} q^{\theta}_{02}$$

(i.e. short term loan repayment at t=0 ≤ housing sales revenues at t=0)

Household θ's Optimisation Problem

$$b_{s1}^{\theta} \leq \frac{\mu_s^{\theta}}{1+r_s^{\delta}} + \bar{d}^{\theta}\left(1+\bar{r}_d^{\gamma}\right) + e_{m,s}^{\theta} \qquad \text{for} \quad s \in S$$

i.e. goods expenditure at $s \in S \leq$ short-term borrowing + deposits and interest payment+private monetary endowments at $s \in S$

$$\mu_s^{\theta} \leq p_{s2} q_{s2}^{\theta}$$

i.e. short term loan repayment at $s \in S \leq$ housing sales revenues at $s \in S$

$$q_{s*2}^{\theta} \leq e_{s2}^{\theta} - q_{02}^{\theta}$$

i.e. number of housing units sold at $s \in S \leq$endowment of housing at t=0 - units of housing sold at $s \in S$

Bank γ's Optimisation Problem

$$\max_{m^{\gamma}_{s*2},\bar{m}^{\alpha},d^{G\gamma}_{s*},\bar{d}^{\gamma},\pi^{\gamma}_{s}} \Pi^{\gamma} = \sum_{s\in S} \omega_s \left(\pi^{\gamma}_{s} - c^{\gamma}\left(\pi^{\gamma}_{s}\right)^2\right)$$

$s.t.$

$$d^{G\gamma}_{0} + m^{\gamma}_{0} + \bar{m}^{\alpha} + \bar{d}^{\gamma} \leq e^{\gamma}_{0} + (\bar{\mu}^{\gamma}_{d}/1 + \bar{r}^{\gamma}_{d})$$

i.e. deposits in the repo market + short-term lending +mortgage extension + interbank lending $\leq$ capital endowment at t=0 + consumer deposits

Bank γ's Optimisation Problem

$d_s^{G\gamma} + m_s^{\gamma} + \bar{\mu}_d^{\gamma} + \leq e_s^{\gamma} + \pi_0^{\gamma} + \bar{R}_s^{\delta} \bar{d}^{\gamma} (1 + \bar{\rho})$

i.e. short-term lending + deposits in the repo market at $s \in S$ + deposits repayment $\leq$ capital endowment at $s \in S$ + accumulated profits + interbank loan repayments at $s \in S$

$\pi_0^{\gamma} = m_0^{\gamma} (1 + r_0^{\gamma}) + d_0^{G\gamma} \left(1 + \rho_0^{CB}\right) + p^{\alpha} \bar{m}^{\alpha}$

i.e. profits at (t=0) = short term loan repayment + repo deposits and interest payment at t=0 + MBS's sales revenues

$\pi_s^{\gamma} = m_s^{\gamma} (1 + r_s^{\gamma}) + d_s^{G\gamma} \left(1 + \rho_s^{CB}\right)$

i.e. profits at $s \in S$ = short term loan repayment + repo deposits and interest payment at $s \in S$

Bank δ's Optimisation Problem

$$\max_{m^{\delta}_{s*2},\bar{m},\mu^{G\delta}_{s*},\bar{\mu}^{\delta},\mu^{\delta}_{s*},\bar{v}^{\delta}_{s},\pi^{\gamma}_{s}} \Pi^{\delta} = \sum_{s\in S}\omega_s\left(\pi^{\delta}_s - c^{\delta}\left(\pi^{\delta}_s\right)^2\right) - \sum_{s\in S}\omega_s\bar{\tau}^{\delta}_s\left[\bar{D}^{\delta}_s\right]^+$$

$s.t.$

$$m^{\delta}_0 + \bar{m} \leq e^{\delta}_0 + \frac{\mu^{G\delta}_0}{1+\rho^{CB}_0} + \frac{\bar{\mu}^{\delta}}{1+\bar{\rho}}$$

i.e. short-term lending at t=0 + wholesale money market credit extension $\leq$ capital endowment + short-term borrowing in the repo market at t=0 + interbank borrowing

Bank δ's Optimisation Problem

$$\mu_0^{G\delta} \leq m_0^{\delta}\left(1 + r_0^{\delta}\right)$$

i.e. repo loan repayment at t=0 $\leq$ short-term loan repayment at t=0

$$m_s^{\delta} + \bar{v}_s^{\delta}\bar{\mu}^{\delta} \leq e_s^{\delta} + \frac{\mu_s^{G\delta}}{1 + \rho_s^{CB}} + \bar{R}_s\bar{m}\left(1 + \bar{r}\right)$$

i.e. short-term lending + interbank loan repayment at $s \in S \leq$ capital endowment + wholesale money market loan repayment short-term loan repayment at $s \in S$

$$\pi_s^{\delta} = m_s^{\delta}\left(1 + r_s^{\delta}\right) - \mu_s^{G\delta}$$

i.e. profits at $s \in S$ = short term loan repayment - repo loan repayment at $s \in S$

Investment Bank (ψ)'s Optimisation Problem

Goldman Sachs

$$\max_{\tilde{m}^{\alpha}, \bar{\mu}^{\psi}, \bar{v}_s^{\psi},} \Pi^{\psi} = \sum_{s \in S} \omega_s \pi_s^{\psi} - \sum_{s \in S} \omega_s \bar{\tau}_s^{\psi} \left[\bar{D}_s^{\psi} \right]^{+}$$

$s.t.$

$$\tilde{m}^{\alpha} \leq e_0^{\psi} + \frac{\bar{\mu}^{\psi}}{1 + \bar{r}}$$

i.e. expenditure in MBS's $\leq$ capital endowments at t=0 + wholesale money market borrowing

$$\bar{v}_s^{\psi} \bar{\mu}^{\psi} \leq \frac{\tilde{m}^{\alpha}}{p^{\alpha}} \tilde{q}^{\alpha} \quad \text{for} \quad s \in S_1^{\alpha}$$

i.e. whole sale money market loan repayment at $s \in S_1^{\alpha}$ $\leq$ CDO's sales revenues + capital endowments at $s \in S_1^{\alpha}$

$$\bar{v}_s^{\psi} \bar{\mu}^{\psi} \leq e_s^{\psi} + \left(\frac{b_{02}^{\alpha} p_{22}}{\bar{m}^{\alpha} p_{02}} \right) \frac{\tilde{m}^{\alpha}}{p^{\alpha}} \quad \text{for} \quad s \notin S_1^{\alpha}$$

i.e. CDS settlement payment + wholesale money market loan repayment at $s \notin S_1^{\alpha}$ $\leq$ capital endowment at $s \notin S_1^{\alpha}$ + CDO's sales revenues + collateral sales revenues

Hedge Fund (ϕ)'s Optimisation Problem

$$\max_{\bar{\mu}^{\phi}, \hat{m}^{\alpha}, \bar{v}^{\phi}_{s*}} \Pi^{\phi} = \sum_{s \in S} \omega_s \pi^{\phi}_s - \sum_{s \in S} \omega_s \bar{\tau}^{\phi}_s \left[\bar{D}^{\phi}_s \right]^{+}$$

s.t.

$$\hat{m}^{\alpha} \leq \frac{\bar{\mu}^{\phi}}{1+\bar{r}}$$

i.e. expenditure in the CDO's market $\leq$ wholesale money market borrowing

$$\bar{v}^{\phi}_s \bar{\mu}^{\psi} \leq \frac{\hat{m}^{\alpha}}{\tilde{q}^{\alpha}} \left(1 + \bar{r}^{\gamma\alpha}\right) \quad \text{for} \quad s \in S^{\alpha}_1$$

i.e. wholesale money market loan repayment $\leq$ CDO's payoffs at $s \in S^{\alpha}_1$

$$\bar{v}^{\phi}_s \bar{\mu}^{\psi} \leq \hat{m}^{\alpha} \quad \text{for} \quad s \notin S^{\alpha}_1$$

i.e. wholesale money market loan repayment $\leq$ CDO's payoffs at $s \notin S^{\alpha}_1$

Market Clearing Conditions

Goods Market

$$p_{01} = \frac{b_{01}^{\theta}}{q_{01}^{\alpha}}$$

$$p_{s1} = \frac{b_{s1}^{\theta}}{q_{s1}^{\alpha}} \quad \text{for} \quad s \in S$$

Housing Market

$$p_{02} = \frac{b_{02}^{\alpha}}{q_{02}^{\theta}}$$

$$p_{s2} = \frac{b_{s2}^{\alpha}}{q_{s2}^{\theta}} \quad \text{for} \quad s \in S_1^{\alpha}$$

$$p_{s2} = \frac{b_{s2}^{\alpha}}{q_{s2}^{\theta} + b_{02}^{\alpha}/p_{02}} \quad \text{for} \quad s \notin S_1^{\alpha}$$

Market Clearing Conditions

Mortgage Market

$$(1 + \bar{r}^{\gamma\alpha}) = \frac{\bar{\mu}^{\alpha}}{\bar{m}^{\alpha}}$$

Clearing conditions for effective returns on mortgages

$$(1 + \bar{r}_s^{\gamma\alpha}) = \begin{cases} (1 + \bar{r}^{\gamma\alpha}) & \text{for} \quad s \in S_1^{\alpha} \\ \left(\frac{p_{22} b_{02}^{\alpha}}{p_{02}}\right)\left(\frac{\bar{\mu}^{\alpha}}{1 + \bar{r}^{\gamma\alpha}}\right)^{-1} & \text{for} \quad s \notin S_1^{\alpha} \end{cases}$$

Short-term Consumer Markets

$$(1 + r_{s*}^{\gamma}) = \frac{\mu_{s*}^{\alpha}}{m_{s*}^{\gamma}}$$

$$(1 + r_{s*}^{\delta}) = \frac{\mu_{s*}^{\theta}}{m_{s*}^{\delta}}$$

Market Clearing Conditions

Consumer Deposit Market

$$(1+\bar{r}_d^{\gamma}) = \frac{\bar{\mu}_d^{\gamma}}{\bar{d}^{\theta}}$$

Wholesale Money Market

$$(1+\bar{r}) = \frac{\bar{\mu}^{\psi}+\bar{\mu}^{\phi}}{\bar{m}}$$

Repo Market

$$(1+\rho_{s*}^{CB}) = \frac{\mu_{s*}^{G\delta}}{M_{s*}^{CB}+d_{s*}^{G\gamma}}$$

Interbank Market

$$(1+\bar{\rho}) = \frac{\bar{\mu}^{\delta}}{\bar{d}^{\gamma}}$$

MBS's Market

$$p^{\alpha} = \frac{\tilde{m}^{\alpha}}{\bar{m}^{\alpha}}$$

CDO's Market

$$\tilde{q}^{\alpha} = \frac{\hat{m}^{\alpha}}{\tilde{m}^{\alpha}}$$

Conditions on Expected Delivery Rates (Rational Expectations)

Wholesale Money Market

$$\bar{R}_s = \begin{cases} \dfrac{\bar{v}_s^{\psi}\bar{\mu}^{\psi} + \bar{v}_s^{\phi}\bar{\mu}^{\phi}}{\bar{\mu}^{\psi} + \bar{\mu}^{\phi}} & \text{if} \quad \bar{\mu}^{\psi} + \bar{\mu}^{\phi} > 0 \\ \text{arbitrary} & \text{if} \quad \bar{\mu}^{\psi} + \bar{\mu}^{\phi} = 0 \end{cases} \qquad \forall s \in S$$

Interbank Market

$$\bar{R}_s^{\delta} = \begin{cases} \dfrac{\bar{v}_s^{\delta}\bar{\mu}^{\delta}}{\bar{\mu}^{\delta}} = \bar{v}_s^{\delta} & \text{if} \quad \bar{\mu}^{\delta} > 0 \\ \text{arbitrary} & \text{if} \quad \bar{\mu}^{\delta} = 0 \end{cases} \qquad \forall s \in S$$

Exogenous Variables

Risk Aversion Coefficients		Goods Endowments		Housing Endowments		Monetary Endowments		Default Penalties		Others	
c^{α}	1.30	e^{α}_{01}	30	e^{θ}_{02}	20	$e^{\alpha}_{m,0}$	10	$\bar{\tau}^{\delta}_{1}$	1.00	M^{CB}_{0}	25
c^{θ}	1.30	e^{α}_{11}	20			$e^{\alpha}_{m,1}$	1	$\bar{\tau}^{\delta}_{2}$	0.05	M^{CB}_{1}	28
c^{γ}	0.03	e^{α}_{21}	4			$e^{\alpha}_{m,2}$	1	$\bar{\tau}^{\psi}_{1}$	2.00	M^{CB}_{2}	0.1
c^{δ}	0.03					$e^{\theta}_{m,0}$	60	$\bar{\tau}^{\psi}_{2}$	0.00001	ω_1	0.85
						$e^{\theta}_{m,1}$	1	$\bar{\tau}^{\phi}_{1}$	0.1	ω_2	0.15
						$e^{\theta}_{m,2}$	1	$\bar{\tau}^{\phi}_{2}$	0.00005		
						e^{γ}_{0}	60				
						e^{γ}_{1}	1.0				
						e^{γ}_{2}	1.0				
						e^{δ}_{0}	1.0				
						e^{δ}_{1}	0.1				
						e^{δ}_{2}	0.1				
						e^{ψ}_{0}	0.00001				
						e^{ψ}_{1}	0.00001				
						e^{ψ}_{2}	0.00001				

Equilibrium

Prices		*Households* Lending Borrowing		*Financial Sector* Lending Borrowing		Repayment Rates		*Trade and Spending* Goods		Housing		Derivatives	
p_{01}	3.23	μ_0^α	53.43	$d_0^{G\gamma}$	14.62	$\bar{v}_1^\alpha$	100%	q_{01}^α	16.53	q_{02}^θ	4.47	$\tilde{m}^\alpha$	14.10
p_{11}	11.46	μ_1^α	106.46	$d_1^{G\gamma}$	8.18	$\bar{v}_2^\alpha$	85.3%	q_{11}^α	9.29	q_{12}^θ	4.34	$\hat{m}^\alpha$	31.51
p_{21}	53.59	μ_2^α	85.70	$d_2^{G\gamma}$	7.64	$\bar{v}_1^\delta$	98.5%	q_{21}^α	1.60	q_{22}^θ	4.30		
p_{02}	12.75	$\bar{\mu}^\alpha$	34.07	m_0^γ	37.16	$\bar{v}_2^\delta$	58.6%	b_{01}^θ	53.43	b_{02}^α	56.96		
p_{12}	11.53	μ_0^θ	56.96	m_1^γ	83.09	$\bar{v}_1^\psi$	100%	b_{11}^θ	106.46	b_{12}^α	50.02		
p_{22}	6.50	μ_1^θ	50.02	m_2^γ	56.02	$\bar{v}_2^\psi$	88.8%	b_{21}^θ	85.70	b_{22}^α	57.02		
r_0^γ	0.44	μ_2^θ	27.96	$\bar{m}^\alpha$	9.81	$\bar{v}_1^\phi$	100%						
r_1^γ	0.28	$\bar{d}^\theta$	46.19	$\bar{\mu}_d^\gamma$	66.42	$\bar{v}_2^\phi$	64.3%						
r_2^γ	0.53			$\bar{d}^\gamma$	44.61								
r_0^δ	0.44			$\mu_0^{G\delta}$	56.96								
r_1^δ	0.28			$\mu_1^{G\delta}$	46.36								
r_2^δ	0.53			$\mu_2^{G\delta}$	11.84								
$\bar{r}_d^\gamma$	0.44			m_0^δ	39.62								
$\bar{r}^{\gamma\alpha}$	2.47			m_1^δ	39.04								
ρ_0^{CB}	0.44			m_2^δ	18.28								
ρ_1^{CB}	0.28			$\bar{m}$	45.61								
ρ_2^{CB}	0.53			$\bar{\mu}^\delta$	69.17								
$\bar{\rho}$	0.55			$\bar{\mu}^\psi$	21.92								
$\bar{r}$	0.56			$\bar{\mu}^\phi$	48.98								
p^α	1.44												
$\tilde{q}^\alpha$	2.23												

Extensions: Macro-Prudential Regulation

Are Capital Adequacy Requirements welfare improving?

$$k_s^{\gamma} = \frac{e_s^{\gamma} + \pi_0^{\gamma}}{\xi_1 \left(m_s^{\gamma} \left(1 + r_s^{\gamma}\right) + d_s^{G\gamma} \left(1 + \rho_s^{CB}\right) \right) + \xi_2 \;\; \bar{R}_s^{\delta} \bar{d}^{\gamma} \left(1 + \bar{\rho}\right)} \quad , \qquad \xi_1 \leq \xi_2$$

$$k_s^{\delta} = \frac{e_s^{\delta}}{\xi_1 m_s^{\delta} \left(1 + r_s^{\delta}\right) + \xi_3 \;\; \bar{R}_s \bar{m} \left(1 + \bar{r}\right)} \quad , \qquad \xi_1 \leq \xi_3$$

Extensions: Macro-Prudential Regulation

Are Margin Requirements welfare improving?

$$\frac{\bar{\mu}^{\alpha}}{1+\bar{r}^{\gamma\alpha}} \leq \chi^{LTV} b_{02}^{\alpha} \quad , \qquad 0 \leq \chi^{LTV} \leq 1$$

(i.e. mortgage lending $\leq$ Loan-to-value $\times$ housing's worth at t=0)

$$\frac{\bar{\mu}^{\psi}}{(1+\bar{r})} \leq (1-\chi^{MG,\psi}) \frac{b_{02}^{\alpha} p_{22}}{p_{02}} \quad , \quad 0 \leq \chi^{MG,\psi} \leq 1$$

(i.e. borrowing by $\psi \leq$ (1- margin ratio)$\times$ housing collateral at $s \notin S_1^{\alpha}$)

$$\frac{\bar{\mu}^{\phi}}{(1+\bar{r})} \leq (1-\chi^{MG,\phi}) \hat{m}^{\alpha}$$

(i.e. borrowing by $\phi \leq$ (1- margin ratio)$\times$ CDO's repayment at $s \notin S_1^{\alpha}$)

The Economy

- Infinite horizon ($t \in T = \{0, 1, 2, ..., t-1, t, t+1, ...\}$)
- 1 consumption good
- CRS Production Function
    - Two factors of production: labour and capital
    - No technological progress
- Agents
    - Household α; consumes, rents out capital, works and saves
    - Firm: hires labour, rents capital, and produces and sells goods final goods
    - Commercial Banks: $j \in J = \{\delta, \psi\}$, risk averse
    - The Central Bank/Government/FSA: strategic dummies
- 6 Markets: goods, labour, capital, consumer deposit, interbank, and corporate credit markets.

Financial Frictions

Default

- Agents are allowed to default partially: they choose the fraction of outstanding debt they repay
- Default choice trade-offs the benefit of defaulting (more consumption) and its **pecuniary** cost (bankruptcy costs).

Money

- Introduced by a cash-in-advance (liquidity) transaction technology
- Enters the system as *outside* or *inside* money

Outside Money: Money-financed Fiscal Transfers

- Aggregate outside money (G_t) enters the system free and clear of any offsetting obligation $\rightarrow$ is accumulated (stock)
- Thus, following Schorfheide (2000) and Nason and Cogley (1994), we stationarize the model with respect to G_{t-1}
- An outside money shock is a perturbation to its growth rate

$$g_{G,t} = \frac{G_t}{G_{t-1}}$$

$$\ln(g_{G,t}) = \rho^G \ln(\bar{g_G}) + \left(1 - \rho^G\right) \ln(g_{G,t-1}) + e_{G,t}; \quad e_{G,t} \tilde{} N\left(0, \sigma_G^2\right)$$

- We assume that outside money is always distributed to agents on the same 'pro-rata' basis

$$G_t = m_t^\theta + m_t^\gamma + m_t^\psi + m_t^\delta$$

$$m_t^i = \omega_i G_t \quad \text{, where} \quad \sum_i \omega_i = 1 \quad , \quad \omega_i > 0 \qquad \forall i \in I = \{\theta, \gamma, \psi, \delta\}$$

Inside Money: Open Market Operations

- Inside money represents the interventions of the Central Bank in the interbank market every period
- These liquidity injections exit the system when borrowing commercial banks repay their obligations
- An inside money shock is a perturbation to the inside to outside money (interest to non-interest bearing money) ratio; i.e. **Open Market Operations**.

$$\hat{M}_t = \eta_t^{CB} \bar{\hat{M}}$$

$$\ln\left(\eta_t^{CB}\right) = \rho^{CB} \ln\left(\bar{\eta^{CB}}\right) + \left(1 - \rho^{CB}\right) \ln\left(\eta_{t-1}^{CB}\right) + e_{CB,t}; \quad e_{CB,t} \sim N\left(0, \sigma_{CB}^2\right)$$

Household θ's Optimisation Problem

$$\max_{\left\{d_t^\theta\right\},\left\{L_t^\theta\right\},\left\{b_t^\theta\right\}} E_0 \sum_{t=0}^{\infty} \beta^t \ \ln\left(\frac{b_t^\theta}{p_t}\right) + \ \ln\left(N^\theta - L_t^\theta\right)$$

s.t.

$$b_t^\theta + d_t^\theta \leq m_t^\theta + w_t^\theta L_t^\theta + R_t^d d_{t-1}^\theta \left(1 + r_{t-1}^d\right) + \pi_t^\psi + \pi_t^\delta, \quad \forall t \in T \tag{1}$$

i.e. goods expenditures + deposits at time t $\leq$ private monetary endowments + labour income at time t + deposits repayment + banks dividend payments

Household θ's FOCs

$\left[b_t^\theta\right]$:

$$g_{G,t}U'\left(c_t^\theta\right) = \beta E_t\left\{\frac{\left(1+r_t^d\right)R_{t+1}^d}{\hat{p}_{t+1}/\hat{p}_t}U'\left(c_{t+1}^\theta\right)\right\} \quad (2)$$

$\left[L_t^\theta\right]$:

$$\frac{\hat{w}_t}{\hat{p}_t} = \frac{U'\left(N^\theta - L_t^\theta\right)}{U'\left(c_t^\theta\right)} \quad (3)$$

The budget constraint binds because:

- Money is fiat and agents do not derive utility from holding it $\rightarrow$ agents do not hold idle cash, they lend it out

Yeoman Farmer γ's Optimisation Problem

$$\max_{\{b^{\gamma}_{L,t}\},\{q^{\gamma}_t\},\{\mu^{\gamma}_t\},\{v^F_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \ln\left(Y^{\gamma}_t - q^{\gamma}_t\right)$$

$s.t.$

$$Y^{\gamma}_t = A_t \left(\frac{b^{\gamma}_{L,t}}{w_t}\right)^{\alpha} \qquad \forall t \in T$$

$$v^F_t \mu^{\gamma}_{t-1} \leq m^{\gamma}_t + p_{t-1} q^{\gamma}_{t-1} \qquad \forall t \in T \quad \text{with} \quad v^F_0 = \mu^{\gamma}_{-1} = 0 \tag{4}$$

i.e. corporate loan repayment at time t $\leq$ private monetary endowments at time t + sales revenues carried forward from period (t-1)

$$b^{\gamma}_{L,t} \leq \frac{\mu^{\gamma}_t}{(1+r^F_t)} - \tau^{\gamma}_t \left(1 - v^F_t\right) \mu^{\gamma}_{t-1} \qquad \forall t \in T \quad \text{with} \quad v^F_0 = \mu^{\gamma}_{-1} = 0 \tag{5}$$

i.e. payroll payment at time t $\leq$ corporate borrowing at time t - credit costs on outstanding corporate debt

$$\ln(A_t) = \rho^A \ln(\bar{A}) + \left(1 - \rho^A\right) \ln(A_{t-1}) + e_{A,t}; \quad e_{A,t} \,\tilde{}\, N\left(0, \sigma^2_A\right)$$

$$\ln\left(\tau^{\gamma}_t\right) = \rho^{\gamma} \ln(\bar{\tau^{\gamma}}) + (1 - \rho^{\gamma}) \ln\left(\tau^{\gamma}_{t-1}\right) + e_{\gamma,t}; \quad e_{\gamma,t} \,\tilde{}\, N\left(0, \sigma^2_{\gamma}\right)$$

Yeoman Farmer γ's FOCs

$\left[b^{\gamma}_{L,t}\right]$:

$$g_{G,t}U'\left(c^{\gamma}_{t}\right) = \beta E_t \left\{ \frac{\left(1 + r^{F}_{t}\right) \tau^{\gamma}_{t}}{\hat{w}_{t+1}/\hat{w}_t} U'\left(c^{\gamma}_{t+1}\right) \right\} \tag{6}$$

$[q^{\gamma}_{t}]$:

$$\frac{\hat{w}_t\left(1 + r^{F}_{t}\right)}{\hat{p}_t} = \frac{U'\left(L^{\theta}_{t}\right)}{U'\left(q^{\gamma}_{t}\right)} \tag{7}$$

Budget constraints bind

Commercial Bank ψ's Optimisation Problem

$$\max_{\{\mu_t^d\},\{d_t^{IB}\},\{v_t^d\},\{\pi_t^\psi\}} E_0 \sum_{t=0}^{\infty} \hat{\beta}^t \ \ln\left(\pi_t^\psi\right)$$

s.t.

$$\pi_t^\psi = R_t^{IB}\left(1 + r_{t-1}^{IB}\right) d_{t-1}^{IB} - v_t^d \mu_{t-1}^d \qquad \forall t \in T \quad \text{with} \quad v_0^d = \mu_{-1}^d = d_{-1}^{IB} = 0 \tag{8}$$

$$d_t^{IB} \leq m_t^\psi + \frac{\mu_t^d}{(1 + r_t^d)} - \tau_t^\psi\left(1 - v_t^d\right)\mu_{t-1}^d \qquad \forall t \in T \quad \text{with} \quad v_0^d = \mu_{-1}^d = d_{-1}^{IB} = 0 \tag{9}$$

i.e. interbank credit extensions at time t $\leq$ monetary endowments + household deposits - credit costs on outstanding debt with households at time t

$$\ln\left(\tau_t^\psi\right) = \rho^\psi \ln\left(\bar{\tau^\psi}\right) + \left(1 - \rho^\psi\right)\ln\left(\tau_{t-1}^\psi\right) + e_{\psi,t}; \quad e_{\psi,t} \sim N\left(0, \sigma_\psi^2\right)$$

Commercial Bank ψ's FOCs

$\left[\mu_t^d\right]$:

$$g_{G,t}\Pi'\left(\hat{\pi}_t^{\psi}\right) = \beta\left(1+r_t^d\right)E_t\left\{\tau_{t+1}^{\psi}\Pi'\left(\hat{\pi}_{t+1}^{\psi}\right)\right\} \tag{10}$$

$\left[d_t^{IB}\right]$:

$$g_{G,t}\Pi'\left(\hat{\pi}_t^{\psi}\right) = \beta\left(1+r_t^{IB}\right)E_t\left\{R_{t+1}^{IB}\tau_{t+1}^{\psi}\Pi'\left(\hat{\pi}_{t+1}^{\psi}\right)\right\} \tag{11}$$

From equations (10) and (11)

$$\Rightarrow \left(1+r_t^d\right) = \left(1+r_t^{IB}\right)E_t\left\{R_{t+1}^{IB}\right\} \Rightarrow r_t^{IB} \geq r_t^d$$

Commercial Bank δ's Optimisation Problem

$$\max_{\{d_t^F\},\{\mu_t^{IB}\},\{v_t^{IB}\},\{\pi_t^{\delta}\}} E_0 \sum_{t=0}^{\infty} \hat{\beta}^t \ \ln\left(\pi_t^{\delta}\right)$$

$s.t.$

$$\pi_t^{\delta} = R_t^F \left(1 + r_{t-1}^F\right) d_{t-1}^F - v_t^{IB} \mu_{t-1}^{IB} \qquad \forall t \in T \quad \text{with} \quad v_0^{IB} = \mu_{-1}^{IB} = d_{-1}^F = 0 \tag{12}$$

$$d_t^F \leq m_t^{\delta} + \frac{\mu_t^{IB}}{\left(1 + r_t^{IB}\right)} - \tau_t^{\delta}\left(1 - v_t^{IB}\right)\mu_{t-1}^{IB} \qquad \forall t \in T \quad \text{with} \quad v_0^{IB} = \mu_{-1}^{IB} = d_{-1}^F = 0 \tag{13}$$

(i.e. corporate credit extensions at time t $\leq$ monetary endowments + interbank borrowing - credit costs on outstanding interbank debt at time t)

$$\ln\left(\tau_t^{\delta}\right) = \rho^{\delta} \ln\left(\bar{\tau}^{\delta}\right) + \left(1 - \rho^{\delta}\right) \ln\left(\tau_{t-1}^{\delta}\right) + e_{\delta,t}; \quad e_{\delta,t} \sim N\left(0, \sigma_{\delta}^2\right)$$

Commercial Bank δ's FOCs

$\left[\mu_t^{IB}\right]$:

$$g_{G,t}\Pi'\left(\hat{\pi}_t^{\delta}\right) = \beta\left(1 + r_t^{IB}\right) E_t\left\{\tau_{t+1}^{\delta}\Pi'\left(\hat{\pi}_{t+1}^{\delta}\right)\right\} \tag{14}$$

$\left[d_t^F\right]$:

$$g_{G,t}\Pi'\left(\pi_t^{\delta}\right) = \beta\left(1 + r_t^{F}\right) E_t\left\{R_{t+1}^{F}\tau_{t+1}^{\delta}\Pi'\left(\pi_{t+1}^{\delta}\right)\right\} \tag{15}$$

From equations (14) and (15)

$$\Rightarrow \left(1 + r_t^{IB}\right) = \left(1 + r_t^{F}\right) E_t\left\{R_{t+1}^{F}\right\} \Rightarrow r_t^F \geq r_t^{IB}$$