A Course on DSGE Models with Financial Frictions
Part 4: Monetary and Macroprudential Policy

Stelios Tsiaras

European University Institute

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The GK model in a nutshell

- In the previous lecture we saw in detail the seminal paper by Gertler and Kiyotaki (2010)
- The financial friction is between the households and the banks
- A banker can steal a fraction of her assets and return them back to the household
- An always binding incentive compatibility constraint arises that creates the interest rate spread between the loan and the risk-free rate

Today

- Both BGG, GK and other models of financial frictions introduces wedges in the canonical ”frictionless” RBC model
- We will see how monetary and macroprudential policy can reduce, or eliminate, these frictions
- Return back to the ”optimal” RBC framework
- See common tools used by central banks in the recent financial crises

Today

(1) Gertler and Kiyotaki (2010); Gertler and Karadi (2011) liquidity injections to the banking system

(2) Gertler and Karadi (2013) QE framework

(3) Countercyclical bank capital requirements

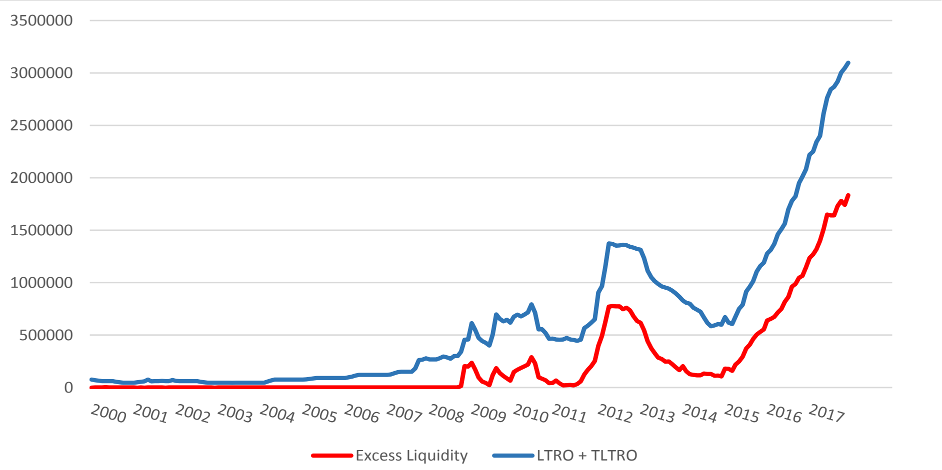
(4) Introducing housing and households borrowing in the models:
Loan to value and Debt service to income ratios Iacoviello (2015), Grodecka (2020)

Today we will go through these extensions

Liquidity Injections

- Large liquidity provision to financial institutions after the 2008 episode in US and Euro Area
- Longer Term Refinancing Operations (LTROs) in the EA (around 450 bn until 2019 + PELTRO)
- Key scope of these direct funding programs was the stabilization of economic activity through a credit expansion

LTRO and Excess Liquidity



Liquidity Injections in a GK Framework

- Consider the GK model we saw in the previous lecture
- Banks used deposits and net worth to fund their credit provision
- Now: Banks' liabilities include also liquidity injection from the central bank - government
- When their incentive constraint binds in bad times, injections loosen the constraint, replacing household deposits
- It is an extension of the Gertler and Kiyotaki (2010), what they call Liquidity Facilities in the paper

Banks: Overview

- The bank j receives deposits D_t from the households and liquidity M_t from the government at time t to provide loans S_t at price Q_t to the firms where
- S_t is the number of claims to one unit of firms' capital, so the asset against which the loans are obtained is end-of-period capital K_t
- Deposits together with her net worth N_t and liquidity M_t finance the loan provision
- Bank's balance sheet therefore is:

$$Q_t S_t = N_t + D_t + M_t$$

Banks: Overview

- Banks receive a gross return from the loans R_t^K, pay back the depositors at the risk-free interest rate R_t and the government at the liquidity rate R_t^M
- Bank's net worth at time t is:

$$N_t = R_t^K Q_{t-1} S_{t-1} - R_t^M M_{t-1} - R_t D_{t-1}$$

- The GK model assumes that an agent can be worker or a banker
- Bankers exit and become workers with probability $(1 - \sigma_B)$ per period
- Workers become banks with the same probability keeping proportions fixed.
- New bankers get a start-up transfer ξ_B similarly to the BGG

The Banker's Objective

- The banker's objective at the end of period t is to maximize expected terminal wealth
$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma_B)\sigma_B^{i-1}\Lambda_{t,t+i}N_{t+i}$$
where $\Lambda_{t,t+i}$ is the $[t, t+i]$ stochastic discount factor corresponding to the consumer's optimization problem.

The Banker Constraint

- The banks manager may divert a fraction θ of her assets back to her family
- In the original formulation of the incentive compatibility (IC) constraint we had

$$\underbrace{V_t}_{\text{Value of the bank}} \geq \underbrace{\theta(Q_t S_t)}_{\text{Gain from diverting}}$$

- Taking account the liquidity injections and the central banks advantage in retrieving assets, the IC constraint becomes

$$V_t \geq \theta\{Q_t S_t - \omega M_t\}$$

- M_t is essentially a central bank's asset, so the banker cannot divert the full of this; only a fraction ω

The Banker's Problem

- The banker's decision problem is to maximize discounted future earnings

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma_B)\sigma_B^{i-1} \Lambda_{t,t+i} N_{t+i}$$

subject to

- Balance sheet $Q_t S_t = N_t + D_t + M_t$
- Net worth $N_t = R_t^K Q_{t-1} S_{t-1} - R_t^M M_{t-1} - R_t D_{t-1}$
- Incentive constraint $V_t \geq \theta\{Q_t S_t - \omega M_t\}$ where we assume that it is always binding

Banker's Problem Solution

- To solve the problem we follow exact the same procedure as in the original formulation

- Make a guess that a value function has the following linear form:

$$V_t(s_t, m_t, d_t) = \nu_{s,t} S_t - \nu_{d,t} D_t - \nu_{m,t} M_t \tag{1}$$

  where $\nu_{s,t}$ is the marginal value from credit for the bank, $\nu_{d,t}$ the marginal cost of deposits and $\nu_{m,t}$ the marginal cost of liquidity

- Using the balance sheet constraint we can eliminate d_t from the value function, this yields

$$V_t(s_t, d_t) = \nu_{s,t} S_t - \nu_{m,t} M_t - \nu_{d,t}(Q_t S_t - N_t - M_t)$$

  and

$$V_t = Q_t S_t (\frac{\nu_{s,t}}{Q_t} - \nu_{d,t}) - M_t(\nu_{m,t} - \nu_{d,t}) + \nu_{d,t} N_t$$

Banker's Problem Solution

- Let $\mathcal{L}$ be the Lagrangian of the maximization problem and λ_t the Lagrange multiplier.

$$\mathcal{L} = V_t + \lambda_t[V_t - \theta(Q_t S_t - \omega M_t)] = (1+\lambda_t)V_t - \lambda_t \theta(Q_t S_t - \omega M_t)$$

- The first order and Kuhn-Tucker conditions for the maximization problem are:

$$\frac{\theta \mathcal{L}}{\theta S_t} : (1+\lambda_t)(\frac{\nu_{s,t}}{Q_t} - \nu_{d,t}) = \lambda_t \theta$$
$$\frac{\theta \mathcal{L}}{\theta M_t} : (1+\lambda_t)(\nu_{m,t} - \nu_{d,t}) = \lambda_t \theta \omega$$

$$KT : \lambda_t[(\frac{\nu_{s,j,t}}{Q_t} - \nu_{d,t})Q_{j,t}s_{j,t} - (\nu_{m,t} - \nu_{d,t})M_t + \nu_{d,j,t}N_{j,t} - \theta(Q_{j,t}S_{j,t} - \omega M_t)] = 0$$

Banker's Problem Solution

- Define the excess value of bank's financial claim holdings as

$$\mu_t = \frac{\nu_{s,t}}{Q_t} - \nu_{d,t}$$

and of the liquidity

$$\mu_t^M = \nu_{m,t} - \nu_{d,t}$$

- From the FOCs we have

$$\mu_t^M = \omega \mu_t$$

- If you do the math as in the original case you end up at :

$$Q_t S_t = \phi_t N_t + \omega M_t$$

where $\phi_t = \frac{\nu_{d,t}}{\theta - \mu_t}$

- As long as $\omega > 0$ CB liquidity can expand the total level of assets intermediated by banks

Banker's Problem Solution

- Using the method of undetermined coefficients we have the final solutions for the coefficients:

$$
\begin{aligned}
\nu_{s,t} &= E_t \Lambda_{t,t+1} \Omega_{t+1} Q_t R_{k,t+1} \\
\nu_{d,t} &= E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1} \\
\nu_{m,t} &= E_t \Lambda_{t,t+1} \Omega_{t+1} R^M_{t+1} \\
\mu_t &= E_t \Lambda_{t,t+1} \Omega_{t+1} [R^K_{t+1} - R_{t+1}] \\
\mu^M_t &= E_t \Lambda_{t,t+1} \Omega_{t+1} [R^M_{t+1} - R_{t+1}] = \omega E_t \Lambda_{t,t+1} \Omega_{t+1} [R^K_{t+1} - R_{t+1}]
\end{aligned}
$$

and

$$
\phi_t = \frac{\mathbb{E}_t[\Omega_{t+1} \Lambda_{t,t+1} R_{t+1}]}{\Theta - \mathbb{E}_t[\Omega_{t+1} \Lambda_{t,t+1} (R_{k,t+1} - R_{t+1})]}
$$

Aggregation

- Given K_t, aggregate net worth accumulates according to

$$N_t = (\sigma_B + \xi_B) R_t^K Q_{t-1} S_{t-1} - \sigma_B (R_t D_{t-1} + R_t^M M_{t-1})$$

  where $D_t = Q_t S_t - N_t - M_t$

- Remember that the asset against which the loans S_t are obtained is end-of-period capital K_t. Therefore, $S_t = K_t$

Liquidity Injections

- The fraction of the total bank assets financed through liquidity

$$\chi_{m,t} = \frac{M_t}{Q_t S_t}$$

- The credit policy

$$\chi_{m,t} = \chi_m + \kappa_m \big(\underbrace{E(R^K_{t+1}) - R_{t+1}}_{\text{spread}} - \underbrace{(R^K - R)}_{\text{st.st. spread}} \big)$$

- The government budget constraint

$$G + M_t = T_t + R_{m,t} M_{t-1}$$

Summary of Equilibrium

$$
\begin{aligned}
Q_t S_t &= \phi_t N_t + \omega M_t \\
\phi_t &= \frac{\Omega_{t+1}\mathbb{E}_t[\Lambda_{t,t+1}R_{t+1}]}{\theta - \Omega_{t+1}\mathbb{E}_t\Lambda_{t,t+1}[R_{k,t+1} - R_{t+1}]} \\
\Omega_t &= 1 - \sigma_B + \sigma_B \theta \phi_t \\
N_t &= (\sigma_B + \xi_B) R_t^K Q_{t-1} S_{t-1} - \sigma_B (R_t D_{t-1} + R_t^M M_{t-1}) \\
D_t &= Q_t S_t - M_t - N_t \\
\chi_{m,t} &= \frac{M_t}{Q_t S_t} \\
E_t \Lambda_{t,t+1} \Omega_{t+1} [R_{t+1}^M - R_{t+1}] &= \omega E_t \Lambda_{t,t+1} \Omega_{t+1} [R_{t+1}^K - R_{t+1}]
\end{aligned}
$$

Steady State Solution Strategy

- Very similar to the original GK solution
- Only difference is that now we have an extra asset M_t and an extra interest rate R_t^M
- Solve for the financial sector
- Then go to the real sector and find all the variables as shares of capital

Steady State Solution Strategy

- $\chi_{m,t}$ in SS is equal just to its SS value (an exogenous parameter)
- Then $M^{ss} = \chi_m Q^{ss} S^{ss} = \chi_m S^{ss}$
- From the arbitrage condition between the two spreads

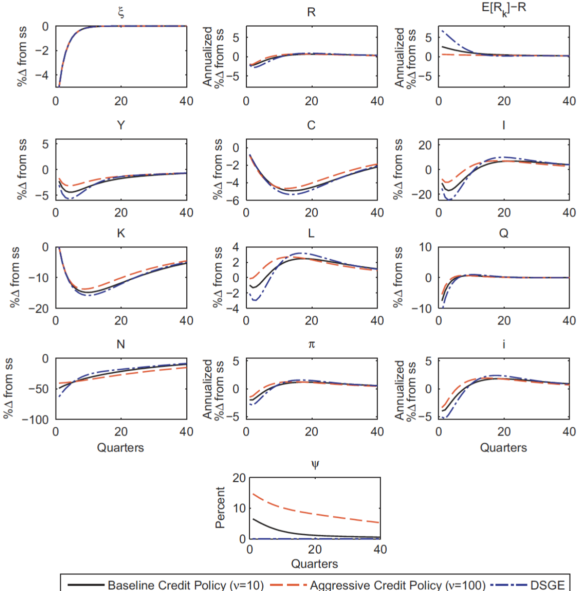
$$R^M = \omega R^K + (1-\omega)R$$

- Therefore $R^M = f(R^K, \omega)$

Steady State Solution Strategy

- Follow the same strategy as in the original GK
- Find two equations with only unknowns the bank leverage (ϕ) and the return on capital (R^K)
- Additional step, express all R^M in terms of R^K

Capital Quality Shock and Liquidity Policy



Quantitative Easing

- The next unconventional MP tool that we will see how we can incorporate it in our framework is the quantitative easing
- Essentially bonds purchases by the central bank in exchange for risk free assets (i.e. cash; reserves)
- We will go through an extension of GK to this direction, namely the Gertler and Karadi (2013)

Quantitative Easing in a GK Framework

- Consider the GK model
- In the original model, banks hold only capital claims (i.e. loans)
- Now: Banks' assets include also government bonds
- When their incentive constraint binds in bad times, government purchases of bonds loosen the constraint and making the banks extend more lending

Banks: Overview

- The bank j receives deposits D_t from the households at time t to provide loans S_t at price Q_t to the firms and buy bonds B_t at price q_t
- B_t is the number of bonds
- Deposits together with her net worth N_t finance the loan provision and the bond purchases
- Bank's balance sheet therefore is:

$$Q_t S_t + q_t B_t = N_t + D_t$$

Banks: Overview

- Banks receive a gross return from the loans R_t^K, and bonds R_t^B and pay back the depositors at the risk-free interest rate R_t
- Bank's net worth at time t is:

$$N_t = R_t^K Q_{t-1} S_{t-1} + R_t^B 1_{t-1} B_{t-1} - R_t D_{t-1}$$

The Banker Constraint

- The banks manager may divert a fraction of her assets back to her family
- Taking account the banker's bond holdings and the central banks advantage in retrieving assets, the IC constraint becomes

$$V_t \geq \theta\{Q_t S_t + \Delta q_t B_t\}$$

- It is easier for the bank to divert funds from its holdings of private loans than from its holding of government bonds
- It can divert the fraction θ of its private loan portfolio and the fraction $\Delta\theta$ with $\Delta \in (0, 1)$ from its government bonds

The Banker's Problem

- The banker's decision problem is to maximize discounted future earnings

$$V_t = E_t \sum_{i=1}^{\infty} (1 - \sigma_B) \sigma_B^{i-1} \Lambda_{t,t+i} N_{t+i}$$

  subject to

- Balance sheet $Q_t S_t + q_t B_t = N_t + D_t$
- Net worth $N_t = R_t^K Q_{t-1} S_{t-1} + R_t^B q_{t-1} B_{t-1} - R_t D_{t-1}$
- Incentive constraint $V_t \geq \theta \{Q_t S_t + \Delta q_t B_t\}$ where we assume that it is always binding

Banker's Problem Solution

- Make a guess that a value function has the following linear form:

$$V_t(s_t, b_t, d_t) = \nu_{s,t} S_t + \nu_{b,t} B_t - \nu_{d,t} D_t \tag{2}$$

- Let $\mathcal{L}$ be the Lagrangian of the maximization problem and λ_t the Lagrange multiplier.

$$\mathcal{L} = V_t + \lambda_t [V_t - \theta(Q_t S_t + \Delta q_t B_t)] = (1 + \lambda_t) V_t - \lambda_t \theta (Q_t S_t + \Delta q_t B_t)$$

- The first order and Kuhn-Tucker conditions for the maximization problem are:

$$\frac{\theta \mathcal{L}}{\theta S_t} : (1 + \lambda_t)(\frac{\nu_{s,t}}{Q_t} - \nu_{d,t}) = \lambda_t \theta$$
$$\frac{\theta \mathcal{L}}{\theta B_t} : (1 + \lambda_t)(\frac{\nu_{b,t}}{q_t} - \nu_{d,t}) = \lambda_t \theta \Delta$$

Banker's Problem Solution

- If you do the math as in the original case you end up at :

$$Q_t S_t + \Delta q_t B_t \leq \phi_t N_t$$

  where $\phi_t = \frac{\nu_{d,t}}{\theta - \mu_t}$

- When CB acquires bonds the constraint loosens and more capital is available for new loans $Q_t S_t^B$

- Easier credit conditions stimulate aggregate demand, $\uparrow$ asset prices, $\downarrow$ spreads, $\uparrow$ bank's NW

Banker's Problem Solution

- Using the method of undetermined coefficients we have the final solutions for the coefficients:

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} [R^K_{t+1} - R_{t+1}]$$
$$E_t \Lambda_{t,t+1} \Omega_{t+1} [R^B_{t+1} - R_{t+1}] = \Delta E_t \Lambda_{t,t+1} \Omega_{t+1} [R^K_{t+1} - R_{t+1}]$$

and

$$\phi_t = \frac{\mathbb{E}_t[\Omega_{t+1} \Lambda_{t,t+1} R_{t+1}]}{\Theta - \mathbb{E}_t[\Omega_{t+1} \Lambda_{t,t+1} (R_{k,t+1} - R_{t+1})]}$$

Aggregation

- Given K_t, aggregate net worth accumulates according to

$$N_t = (\sigma_B + \xi_B)(R_t^K Q_{t-1} S_{t-1} + R_t^B q_{t-1} B_{t-1}) - \sigma_B (R_t D_{t-1})$$

where $D_t = Q_t S_t + q_t B_t - N_t$

Central Bank Asset Purchases

- The total quantity of bonds can be decomposed as:

$$B_t^{total} = B_t + B_t^g$$

  where B_t^g is the amount held by the government

- The central bank to finance its bond purchases issues riskless short-term debt $D_{g,t}$ that pays the safe market interest rate R_t

$$q_t B_t^g = D_{g,t}$$

- The leverage constraint now is

$$Q_t S_t \leq \phi_t N_t + \Delta q_t (B_t^g - B_t^{total})$$

- As B_t^g increases the constraint loosens

Central Bank Asset Purchases

- The central bank purchases the fraction phi_t^B of the outstanding stock of long-term government bonds

$$B_t^g = \phi_{b,t} B^{total}$$

where $\phi_{b,t}$ obey a second-order stationary stochastic process

- The government budget constraint

$$G - T_t + \bar{B}(R_{b,t} - 1) + \underbrace{q_{t-1} B_{t-1}^g + = N_t^G + D_{g,t}}_{\text{Asset Purchases}}$$

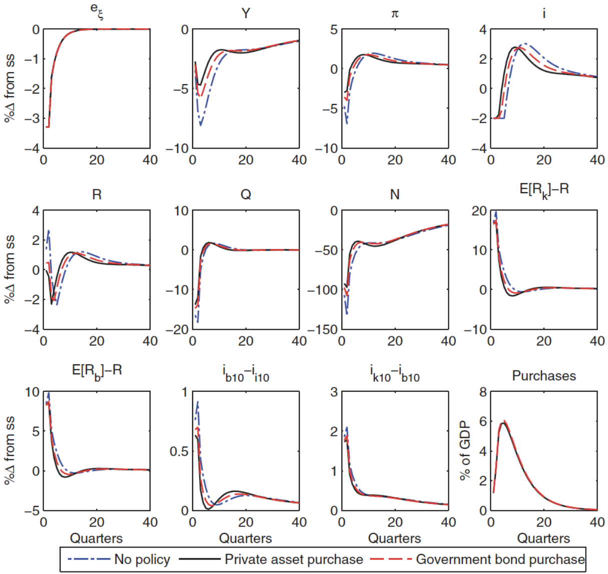
where the government's net worth evolution is

$$N_t^G = R_t^B q_t B_t^g - R_t D_{g,t-1}$$

Central Bank Asset Purchases

- Gertler and Karadi (2013) assume that the central bank can also purchase private assets (S_t) from the banks, in the same way it purchases bonds
- Therefore
$$S_t^{total} = S_t + S_t^g$$
  and
$$S_t^g = \phi_{s,t} S^{total}$$
  where $\phi_{s,t}$ obey a second-order stationary stochastic process
- Because private assets have a higher coefficient in the IC (i.e. 1), the purchase of private assets will have a much higher impact since $1 > \Delta$

Capital Quality Shock and Quantitative Easing Policy



Counter-Cyclical Capital Buffer

- Macroprudential policy tries to provide greater capacity for the banks to be resilient in a potential crisis
- A macroprudential policy tool of interest for the banking sector is the countercyclical capital requirements
- Bank's capital moves according to changes in the credit gap (i.e. the difference between credit to GDP and its long term trend)

Counter-Cyclical Capital Buffer

- Remember the IC of the bankers in the case of GK model with bonds

$$V_t \geq \theta\{Q_t S_t + \Delta q_t B_t\}$$

- You can interpret θ as the fraction of assets the bank needs to hold (minimum capital requirements) and 1 and Δ as the risk weights for the assets: 1 for loans, Δ for bonds
- In a scenario bank's capital can move according to changes in the credit gap (i.e. the difference between credit to GDP and its long term trend)
- Consider a rule which relates the minimum capital requirement faced by banks, θ, to the credit gap for loans for capital to firms $gap_{k,t}$

Counter-Cyclical Capital Buffer

- This will make θ time-varying according to the credit gap and also an exogenous value (the minimum capital requirement) θ^* :

$$\theta_t = \theta^* + \psi_k gap_{k,t}$$

where the definition of the credit gap following the recommendation of the ESRB is:

$$gap_{k,t} = \frac{Q_t S_t}{Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3}} - \frac{QS}{4Y}$$

Model with Loan to Value Constraints

- Loan to value (LTV) constraints are similar to collateral constraints
- Households can borrow up to a fraction of their expected discounted undepreciated housing value

$$M_t \leq \mathbb{E}_t \, \theta^{LTV} \frac{q_{t+1} H_t^b (1 - \delta_h)}{R_{t+1}^m}$$

where q_t is the price of housing and H_t^b the quantity. R_t^m is the borrowing rate

- Iacoviello (2015) was the seminal paper on this where he estimated a DSGE model with two agents and borrowing against collateral

Models with Loan to Value Constraints

- There are two household types
- One patient with a high discount factor and one impatient type
- The patient is the lender in the model and the impatient is the borrower
- Both hold housing, but the impatient borrows in order to buy housing
- There is no financial intermediary in this model

Households

- Two types of households $j \in \{s, b\}$: savers (s) and borrowers (b)
- Savers: patient households, Borrowers impatient: $\beta^b < \beta^s \rightarrow$ Guarantees that the borrowing constraint will always bind in and around the steady state neighbourhood. A household's j utility is:

$$U^j = \log\left(C_t^j - \chi C_{t-1}^j\right) + \phi \log H_t^j - \psi \frac{(L_t^j)^{1+\eta}}{1+\eta}.$$

Savers (s)

- Maximize their utility subject to

$$C_t^s + D_t + q_t^h(H_t^s - (1-\delta_h)H_{t-1}^s) + T_t = D_{t-1}R_t + W_t^s L_t^s + \Pi_t,$$

with respect to C_t^s

$$\lambda_t^s = \frac{1}{C_t^s - \chi C_{t-1}^s} - \beta^s \chi \frac{1}{C_{t+1}^s - \chi C_t^s}.$$

with respect to D_t

$$\lambda_t^s = \beta^s \, \mathbb{E}_t \, \lambda_{t+1}^s R_{t+1}.$$

with respect to L_t^s

$$W_t^s = -\frac{U_{l,t}^s}{\lambda_t^s} \rightarrow \psi(L_t^s)^\eta = \lambda_t^s W_t^s.$$

with respect to H_t^s

$$\frac{\phi}{H_t^s} + \beta^s \, \mathbb{E}_t \, \lambda_{t+1}^s q_{t+1}^h (1-\delta_h) = \lambda_t^s q_t^h.$$

Borrowers (b)

- Maximize their utility subject to

$$C_t^b + R_t^m M_{t-1} + q_t^h (H_t^b - (1-\delta_h) H_{t-1}^b) = M_t + W_t^b L_t^b$$

- Impatient households are also subject to a borrowing constraint that limits their liabilities to a fraction of the value of their un-depreciated housing:

$$R_{t+1}^m M_t \leq \mathbb{E}_t \, \theta^{LTV} q_{t+1} H_t^b (1-\delta_h)$$

Borrowers (b)

- The first order conditions for this problem yield
  with respect to C_t^b

$$\lambda_t^b = \frac{1}{C_t^b - \chi C_{t-1}^b} - \beta^b \chi \frac{1}{C_{t+1}^b - \chi C_t^b}.$$

with respect to L_t^b

$$W_t^b = -\frac{U_{l,t}^b}{\lambda_t^b} \to \psi (L_t^b)^\eta = \lambda_t^b W_t^b.$$

with respect to M_t

$$\lambda_t^b = \beta^b \, \mathbb{E}_t \, \lambda_{t+1}^b R_{t+1}^m + \mathbb{E}_t \, \mu_t R_{t+1}^m$$

where μ_t is the Lagrange multiplier associated with the LTV constraint. With respect to H_t^b

$$\frac{\phi}{H_t^b} + \beta^b \, \mathbb{E}_t \, \lambda_{t+1}^s q_{t+1}^h (1 - \delta_h) + \mu_t \theta^{LTV} \, \mathbb{E}_t \, q_{t+1} (1 - \delta_h) = \lambda_t^s q_t^h.$$

Homework I

- Consider the model of GK with the liquidity injections
- Use the code of the steady state for the original GK and extend this to include the liquidity injections
- Solve for the SS by pen and paper
- Express M and R^M as function of variables you know
- $M^{ss} = \chi_m S^{ss}$ and $R^M = f(R^K)$
- End up to the 2 equations for 2 unknowns (ϕ, R^K) as we did in the previous lecture

Homework I

- You don't have to work with the `.mod` file and the `steady_state.m` file
- Create a new Matlab file just for the SS. Copy paste the old GK SS file, delete the preamble and the ending that connects it with Dynare
- Make the adjustments in the %% **Banker Solution (GK)** section
- Set $\chi_m = 0.001$ and $\omega = 0.5$
- Extend the `myfun_GK1` with the new components
- Find ϕ, R^K, R^M in steady state and report those values

Homework II

- Consider the original model of GK

- Turn the θ parameter into a time varying parameter (actually a variable in `Dynare` wording) that follows the countercyclical buffer equation as

$$\theta_t = \theta^* + \psi_k gap_{k,t}$$

where $\theta^* = 0.383$, $\psi_k = 0.5$ and the definition of the credit gap follows

$$gap_{k,t} = \frac{Q_t S_t}{Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3}} - \frac{Q^{ss} S^{ss}}{4Y^{ss}}$$

- Plot the impulse responses for $Y, C, I, N, \phi, spread$ after a capital quality shock of `std=1` for the cases of
  - $\theta_t = \theta^*$ (original GK)
  - $\theta_t = \theta^* + \psi_k gap_{k,t}$

- Essentially you turn $\psi_k = 0$ to $\psi_k = 0.5$

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