

Macroeconomic Models with Financial Intermediation

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Motivation

- (Most) macroeconomic models based on log-linearized Euler equation

$$c_t = \mathbb{E}_t[c_{t+1}] - \sigma(i_t - \mathbb{E}_t[\pi_{t+1}])$$

- **Intertemporal substitution** key mechanism for propagation of shocks and for policy analysis
- No role for risk
- Over the past 10 years, emphasis on time-varying risk/risk aversion
 - Poor empirical performance of log-linearized Euler equation: real rates acyclical. Calls for a different approach to monetary economics (Atkeson and Kehoe, 2008)
 - Difficult to reconcile recessions with very low real rates
 - Need "preference shocks" to fit recent crisis

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Toward a model of “Risk-Averse Recessions”?

“But macro-finance suggests that recessions, such as fall 2008, are not times at which people became thrifty, and they are certainly not times of high real interest rates. **Macro-finance suggests that people consumed and invested less because they were scared to death** - because of risk, risk aversion, high risk premiums, precautionary savings [...].”

John Cochrane (2017)

Models with financial intermediaries promising tools to capture these effects

Macroeconomic models with financial intermediaries

Growing literature. Some common ingredients

- 1 Heterogeneous agents (households and intermediaries)
- 2 Some form of market segmentation
- 3 Financing constraints for the intermediaries

The combination of (1)-(3) leads to

- Time-varying precautionary motives (Brunnermeir and Sannikov, 2014; Bocola, 2016; ...)
- Large and countercyclical risk premia (Aiyagari and Gertler, 1999; He and Krishnamurthy, 2013; ...)
- Different channels through which policy operates (Bianchi and Bigio, 2014; Silva, 2016; Lenel, 2017; ...)

Challenge: difficult to integrate (1)-(3) in quantitative models

Plan for today

- 1 Illustrate main mechanisms in a stylized model of a small open economy with a financial sector (Bocola-Lorenzoni, 2017)
 - Self-fulfilling financial crises due to precautionary motives
 - Constraints on financial policies
- 2 Discuss some challenges for quantitative implementation

Financial Crises and Lending of Last Resort in Open Economies

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June 2017

Motivation

- Key developments in emerging markets over the past 20 years
 - Economies became progressively more open
 - Increase in *depth* of financial sector
 - Large accumulation of foreign currency reserves
- Evidence suggests a financial stability motive for reserve accumulation
 - Reserves accumulated also in countries with floating exchange rates
 - Size of financial sector main predictor (Obstfeld-Shambaugh-Taylor, 2013)
 - Reserve accumulation predicts a lower incidence of financial crises (Obstfeld-Gourinchas, 2012)
- Questions
 - What are the sources of financial instability for open economies?
 - Do foreign reserves help domestic authorities intervene?

Environment

- Small open economy, three periods $t = 0, 1, 2$
- Two goods: tradable (T) and non-tradable (N)
- Two domestic agents: households and bankers
 - Bankers borrow from households/foreigners, accumulate capital
 - Households work and save in domestic and foreign bonds
- Contracts denominated in domestic (pesos) or foreign currency (dollars)

Technology

- Production function of tradables

$$y_t^T = (k_t)^\alpha (l_t)^{1-\alpha}$$

- Adjustment technology (owned by consumers): transform $G(i_t)$ tradable goods into i_t units of new capital in tradable sector,

$$k_{t+1} = k_t + i_t$$

- All capital fully depreciates at $t = 2$
- Endowment of non-tradables

$$e^N$$

Households

- Preferences

$$\mathbb{E} \left[\sum_{t=0}^2 \beta^t U(c_t) \right]$$

where

$$c_t = (c_t^T)^\omega (c_t^N)^{1-\omega}$$

- Supply 1 unit of labor inelastically
- Budget constraint

$$\frac{1}{1+i_t} a_{t+1} + s_t \frac{1}{1+i_t^*} a_{t+1}^* + p_t c_t = w_t + p_t^N e^N + \Pi_t + a_t + s_t a_t^*$$

a_t, a_t^* : positions in pesos and dollars

s_t : exchange rate (pesos per dollar)

Bankers

- Risk neutral agents, consume only tradables in final period
- Net worth (in pesos)

$$n_t = (Q_t + r_t)k_t - b_t - s_t b_t^*$$

Q_t : asset price

r_t : rental rate

b_t, b_t^* : debt in pesos and dollars

- Given net worth, borrow from households/bankers to purchase capital

$$Q_t k_{t+1} = n_t + \frac{1}{1+i_t} b_{t+1} + s_t \frac{1}{1+i_t^*} b_{t+1}^*$$

- Bankers face a **collateral constraint**

$$\frac{1}{1+i_t} b_{t+1} + s_t \frac{1}{1+i_t^*} b_{t+1}^* \leq \theta Q_t k_{t+1}$$

Markets and equilibrium

- Domestic and foreign bond markets, prices i_t, i_t^*
 - Market for peso claims clears, $a_t = b_t$
- Capital market, Q_t
- Factor markets, r_t and w_t
- Good markets, p_t^T and p_t^N
- Equilibrium in SOE
 - i_t^* and p_t^{T*} given. Law of one price, $p_t^T = s_t p_t^{T*}$
 - Optimization and market clearing in all other markets
- Shocks: a sunspot ξ realizes at $t = 1$

Unit of account

- Price index is

$$P_t = \xi (p_t^T)^\omega (p_t^N)^{1-\omega}$$

- Monetary authority keeps $P_t = \xi$
- Simple model of flexible exchange rates with inflation targeting
- Nominal exchange rate driven by world nominal shock and by adjustment in real exchange rate,

$$s_t = \frac{1}{p_t^{T*}} \left(\frac{p_t^T}{p_t^N} \right)^{1-\omega}$$

Normalize $p_t^{T*} = 1$ (in paper we consider nominal shocks abroad)

Roadmap

We characterize the equilibria of the model proceeding backward in time

1 Start by describing **continuation equilibria** in the model

- Equilibria from $t = 1$ onward, taking as given $k_1^T, b_1, b_1^*, a_1, a_1^*$

2 Study the determination of asset positions at $t = 0$, and describe how equilibria in the model look like

Consumption and exchange rates

- **Result:** in any continuation equilibrium, (C_t, p_t^N, p_t^T, s_t) are constant

1 From $t = 1$ no uncertainty, consumption given by permanent income

$$c = \frac{1}{1 + \beta} [w_1 + \beta w_2(k_2) + \Pi_1(Q_1) + (1 + \beta)p^N e^N + a_1 + s_1 a_1^*]$$

2 Price of non tradables constant, $(1 - \omega)c = p_t^N e^N$

3 Price of domestic tradable also constant because of price-stability, so s_t

- Given $q_1 = (Q_1/p_t^T)$ and k_2 , we can compute all other objects
- Implicit relation between the real exchange rate and the price of capital,

$$(p_1^N/p_1^T) = \rho(q_1),$$

with $\rho'(q_1) \geq 0$ (Balassa-Samuelson effect)

Bankers' capital demand

Banks' optimization problem determines the demand of capital

1 Unconstrained if

$$\frac{r_2}{Q_1} = 1 + i_1, \quad (1 - \theta)Q_1k_2 \leq n_1$$

2 Constrained if

$$\frac{r_2}{Q_1} > 1 + i_1 \quad (1 - \theta)Q_1k_2 = n_1$$

Bankers' capital demand

- If bankers unconstrained, demand for capital is

$$\frac{\alpha k_2^{\alpha-1}}{q_1} = (1 + i_1) \Rightarrow K_U(q_1) = \left(\frac{\alpha\beta}{q_1} \right)^{\frac{1}{1-\alpha}}$$

downward sloping (because of concavity of production function)

- If bankers constrained, demand for capital is

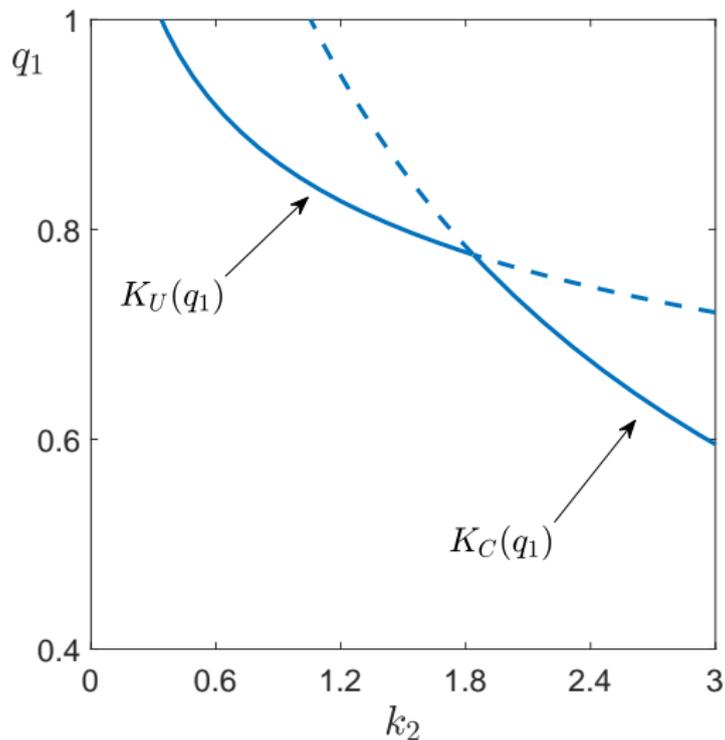
$$K_C(q_1) = \frac{1}{(1-\theta)q_1} [(q_1 + \alpha k_1^{\alpha-1})k_1 - \rho(q_1)^{1-\omega} b_1 - b_1^*]$$

can be upward sloping because of **balance sheet effects**

- The demand for capital is

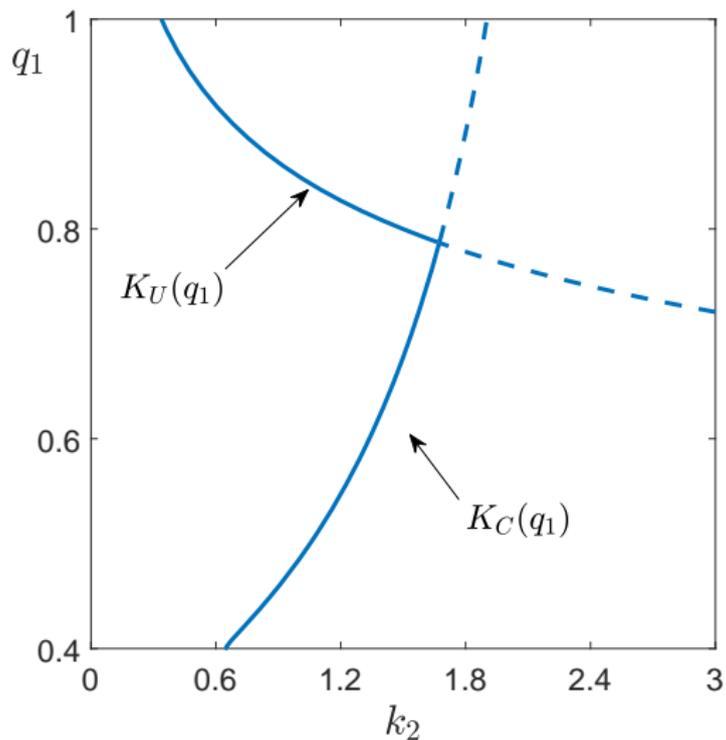
$$K_D(q_1) = \min\{K_U(q_1), K_C(q_1)\}$$

The demand of capital



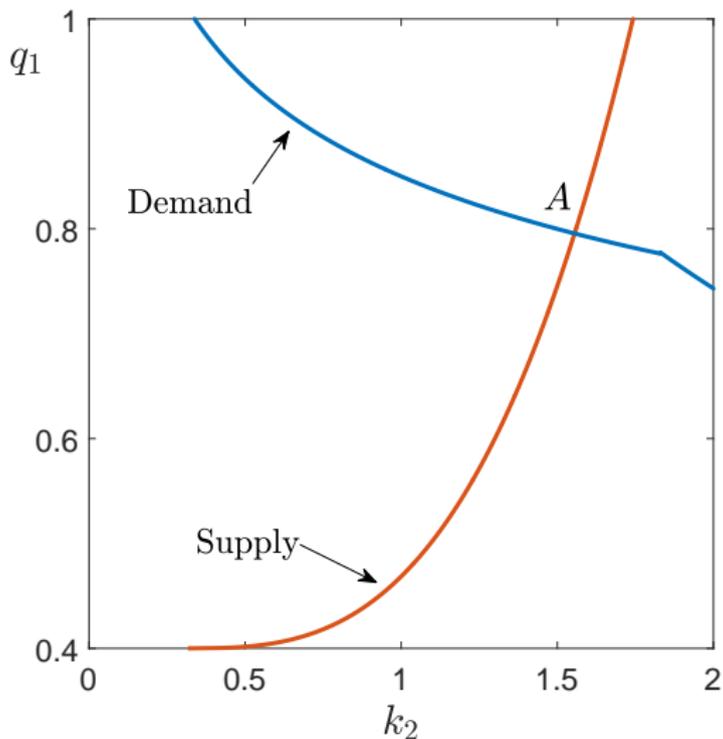
The demand of capital is the minimum between $K_U(q_1)$ and $K_C(q_1)$

The demand of capital



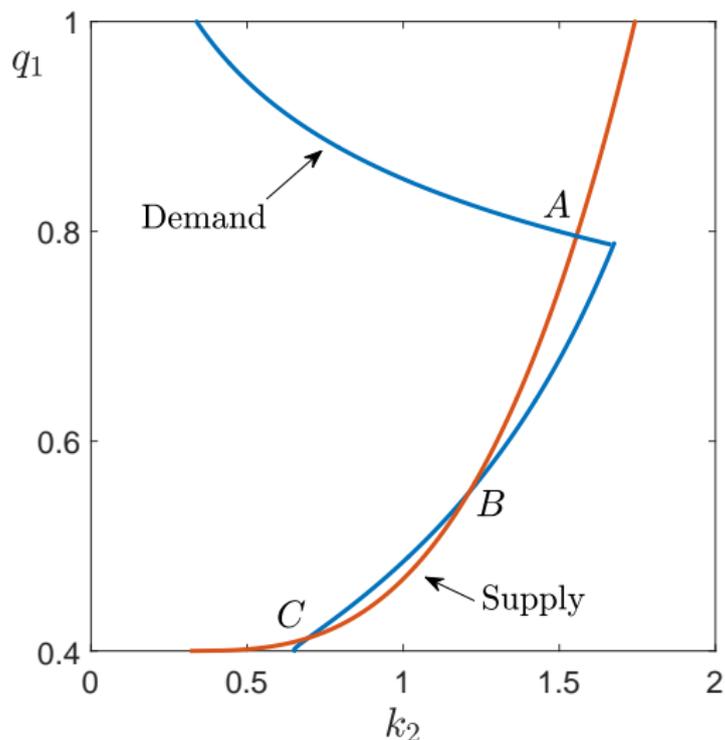
In this case upward sloping in some region

The supply of capital



Supply of capital upward sloping (convex adjustment costs). In this example, unique continuation equilibrium

Multiple equilibria in the capital market



In this example, multiple continuation equilibria: a “good” (unconstrained) equilibrium, and two “bad” (constrained) equilibria

Twin crises

Result: In the bad equilibrium

- Asset prices and investment are lower
- Consumption lower (depressed wages)
- The exchange rate (real and nominal) is permanently depreciated
- Current account balance is larger (*sudden stop*)
- Both consumers and bankers are worse off

Sudden stop driven by two motives

- Collateral constraint binds, less borrowing (Mendoza, 2010)
- Households anticipate low wage growth, consume less (Aguiar and Gopinath, 2007)

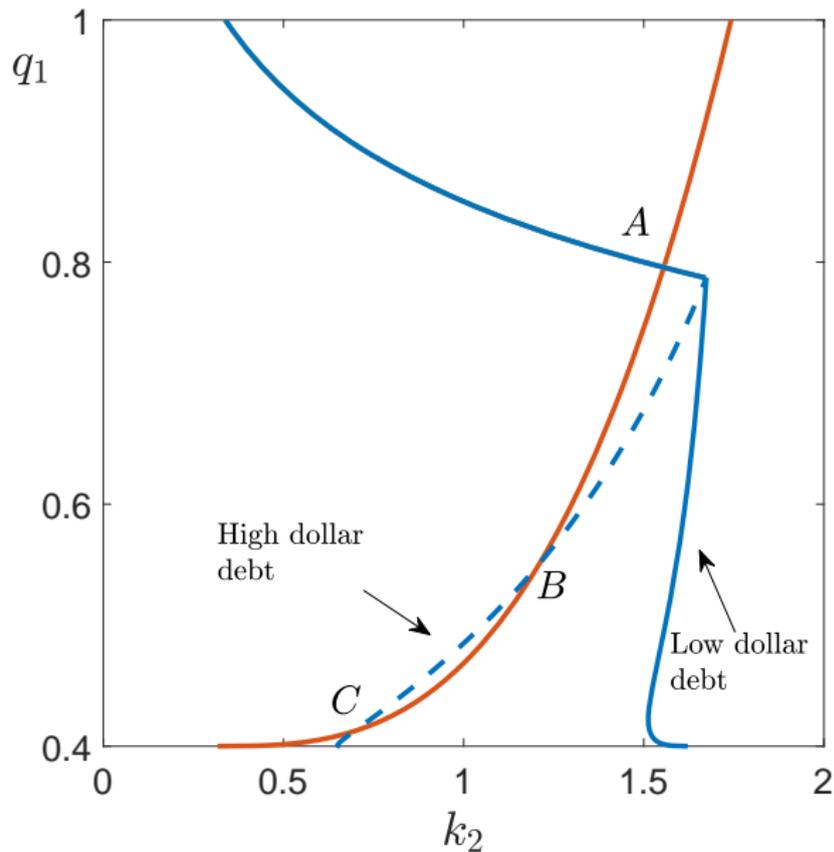
Sources of financial fragility

Possibility of multiple equilibria depends on the slope of $K_C(q_1)$. What factors expose the economy to bad equilibria?

$$K'_C(q_1) = \frac{b_1 \rho(q_1)^{1-\omega} + b_1^* - \alpha k_1^\alpha}{(1-\theta)q_1^2} - (1-\omega) \frac{b_1 \rho'(q_1) \rho(q_1)^{-\omega}}{(1-\theta)q_1}$$

- **Leverage:** Set $b_1 = 0$. An increase in b_1^* holding k_1 constant raises the slope of the constrained demand curve
 - Similar to closed economy financial accelerator model (Lorenzoni, 2008; Gertler and Kiyotaki, 2015)
- **Dollar debt:** locally increasing b_1^* and reducing b_1 , keeping total debt unchanged, increases the slope of $K_C(q_1)$
 - Because of state-contingency of real exchange rate, peso debt helps bankers

Dollar debt and self-fulfilling crises



Back to time 0

- Crisis can arise in continuation equilibrium
 - If economy exposed to multiple equilibria, the sunspot selects which equilibrium is played
- Whether economy is exposed to multiple equilibria at $t = 1$ depends on the assets positions chosen at $t = 0$
- Crisis at $t = 1$ more likely if these positions involve dollar debt for banks
- Will agents choose positions that expose the economy to a crisis?

Bankers' portfolio problem

At $t = 0$, bankers' Euler equations are

$$(\lambda_0 + \mu_0) = (1 + i_0)\mathbb{E}_0[\lambda_1], \quad (\lambda_0 + \mu_0)s_0 = (1 + i_0^*)\mathbb{E}_0[s_1\lambda_1],$$

where λ_1 is the marginal value of net worth at $t = 1$. Combining the two,

$$(1 + i_0) = \frac{(1 + i_0^*)\mathbb{E}_0[s_1]}{s_0} + \text{Cov}_0 \left[\frac{(1 + i_0^*)s_1}{s_0}, \frac{\lambda_1}{\mathbb{E}_0[\lambda_1]} \right]$$

- If banks expect no multiplicity at $t = 1$, they act as risk neutral (UIP)
- If they expect multiple equilibria at $t = 1$, they act as "risk averse"
 - Incentives to borrow in peso (willing to pay higher rates in pesos)
 - Incentives to delever

Households' portfolio problem

At $t = 0$, bankers' Euler equations are

$$U'(c_0) = \beta(1 + i_0)\mathbb{E}_0[U'(c_1)] \quad U'(c_0)s_0 = \beta(1 + i_0^*)\mathbb{E}_0[s_1 U'(c_1)],$$

Combining the two,

$$(1 + i_0) = \frac{(1 + i_0^*)\mathbb{E}_0[s_1]}{s_0} + \text{Cov}_0 \left[\frac{(1 + i_0^*)s_1}{s_0}, \beta \frac{U'(c_1)}{U'(c_0)} \right]$$

- If households expect no multiplicity, they act as risk neutral
- If they expect multiple equilibria, they act as "risk averse"
 - Incentives to save in dollars (willing to accept lower rates in dollars)

Self-fulfilling risk

For a set of initial conditions, the economy features two types of equilibria

- **Non-dollarized equilibrium:**

- Households do not expect future crises, and are happy to save in pesos
- Financial sector not dollarized and not exposed to equilibrium multiplicity in the future
- No risk in equilibrium

- **Dollarized equilibrium:**

- Households expect *risk*, save in pesos **and** in dollars
- Financial sector exposed to equilibrium multiplicity in the future
- Risk in equilibrium

Numerical illustration: non-dollarized equilibria

	Non-dollarized	Dollarized
a_1, b_1	0.703	0.050
a_1^*	0.000	0.710
b_1^*	-0.280	0.360
Stdev(\tilde{w}_1)	0.000	0.043
Corr(\tilde{w}_1, \tilde{s}_1)	0.000	-0.969
Stdev(\tilde{c}_1)	0.000	0.015
$\mathbb{E}[(1 + i_0^*)(s_1/s_0)]$	1.000	0.941
$(1 + i_0)$	1.000	1.034

- Households save only in pesos
- Banks' debt all in pesos. Unique unconstrained equilibrium from $t = 1$
- Households non-financial income constant

Numerical illustration: dollarized equilibria

	Non-dollarized	Dollarized
a_1, b_1	0.703	0.050
a_1^*	0.000	0.710
b_1^*	-0.280	0.360
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$\mathbb{E}[(1 + i_0^*)(s_1/s_0)]$	1.000	0.941
$(1 + i_0)$	1.000	1.034

- Households save mostly in dollars
- Banks' debt mostly in dollars. Multiple equilibria from $t = 1$
- Households non-financial income risky: dollar assets provide insurance

Taking Stock

We have seen an example of two main mechanisms

- Financial accelerator
- Ex-ante effects due to anticipation of binding financial constraints (risk premia, deleveraging, dollarization)

Researchers trying to incorporate these mechanisms into quantitative models

Gertler and Karadi (2011) is becoming a benchmark

- NK model with financial intermediaries
- Simple structure of financial intermediation (boils down to a leverage constraint)

Challenges: numerical approximation

Analytical solutions not available. Need numerical approximation

1 Perturbation (Gertler and Karadi, 2011; ...)

- Pros: fast, easy to code. Captures the financial accelerator
- Cons: assume that the constraint is always binding. Misses ex-ante effects

2 Occbin (Guerrieri and Iacoviello, 2015)

- Pros: fast, easy to code. Captures some nonlinearities (endogenous variables more responsive to shocks when constraint binds)
- Cons: misses ex-ante effects

3 Global methods (Bianchi and Mendoza, 2015; Bocola, 2016; ...)

- Pros: captures all economic effects
- Cons: algorithm needs to be tailored. Curse of dimensionality

Challenges: bringing models to data

- Models very stylized, hard to directly map to observables
 - Ex: “stealing parameter” in Gertler and Karadi (2011)
- Recent research shows that financial intermediaries matter for asset prices (Adrian, Etula and Muir, 2015)
- It makes sense to fit these models to asset prices
- Few examples of macroeconomic models with financial intermediaries that match quantities and prices

Conclusions

- Macroeconomic models with financial intermediaries promising
 - Allow us to incorporate risk, risk aversion, precautionary motives
 - Allow us to think about policy
- Still challenging to incorporate these frictions into benchmark quantitative macroeconomic models
 - Need tractable numerical solutions
 - Need models that account for prices and quantities
- This is good news for you!

Additional Material

Introducing a Lender of Last Resort

- Benevolent government (maximizes households' welfare)
- At $t = 1$, government extends a credit line \bar{b}_2^{*g} to banks and guarantees private sector debt up to $\theta q_1 k_2$
- It finances these operations by borrowing, taxing, or using reserves

$$s_1 \frac{1}{1 + i_1^*} (b_2^{*g} - A_2^*) = \tau_1 w_1 l_1 + A_1 + s_1 A_1^*$$

At $t = 2$, government receive payments \hat{b}_2 from banks

$$T_2 = \tau_2 w_2 l_2 + s_2 (\hat{b}_2 + A_2^*)$$

- To make problem interesting, introduce labor/leisure choices

Timing

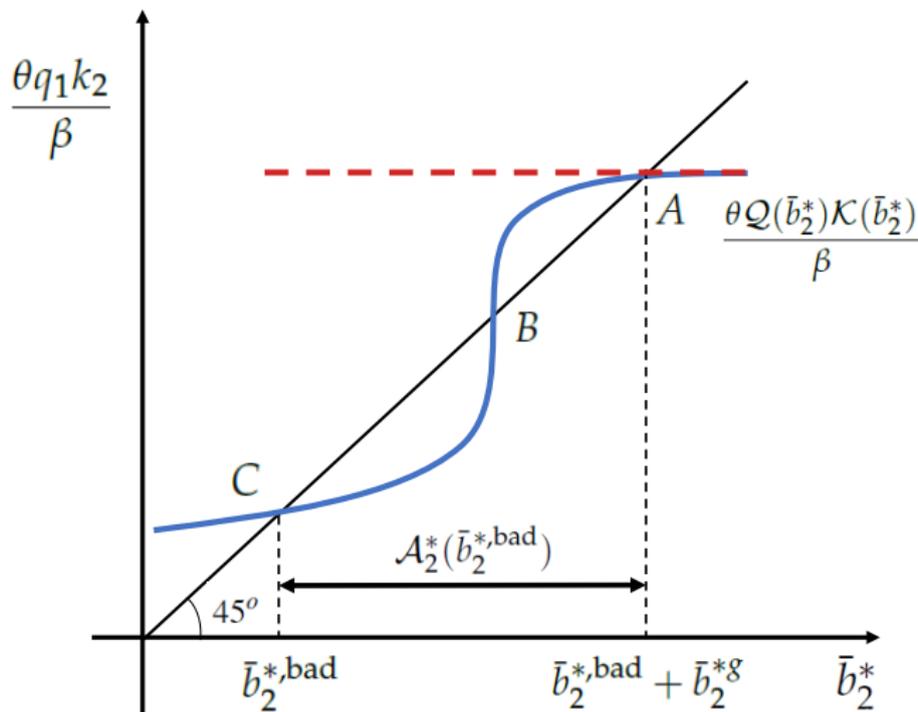
Need to refine the timing in order to introduce a notion of credibility

- At the beginning of $t = 1$, savers decide credit limits \bar{b}_2^* and \bar{A}_2^* forming expectations about the collateral values $\theta q_1 k_2$ and future tax revenues
- Government decides $(\bar{b}^g, -A_2^*, \tau_1, \tau_2, T_2)$. Banks decide how much to borrow (b_2^*, b_2^{*g}) to finance purchases of capital.
- Banks renegotiate their debt if $\theta q_1 k_2 < b_2^* + b_2^{*g}$

In a Nash equilibrium

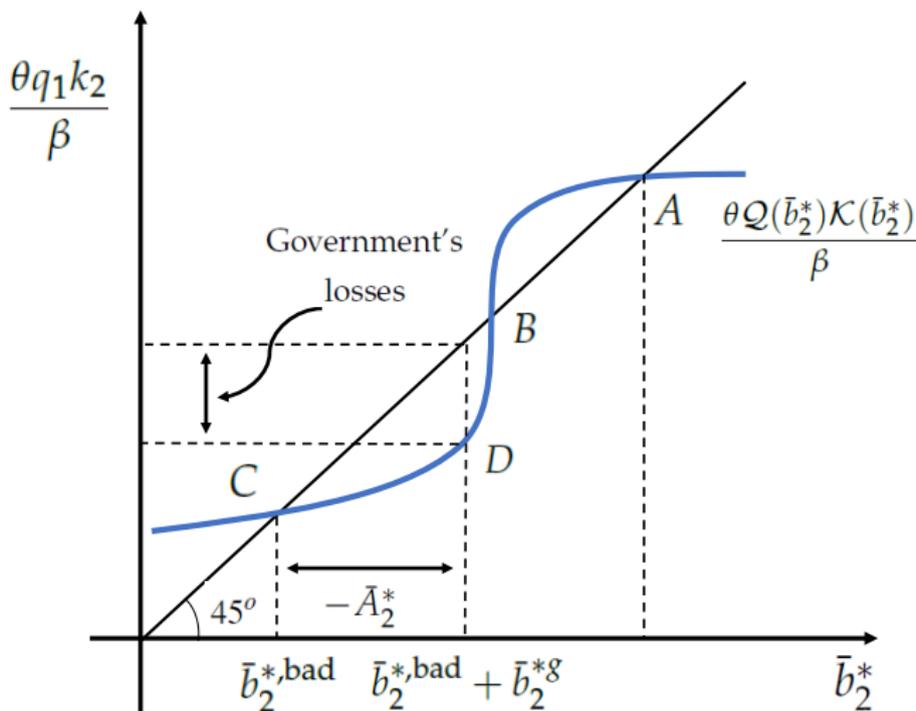
- 1 Gov't maximizes households' welfare, taking credit limits as given
- 2 Banks optimize
- 3 Savers hold rational expectation

Government's optimality with loose credit constraints



If no credit constraints, Government is able to eliminate bad equilibrium

Government's optimality with tight credit constraints



If Government faces credit constraints, trade-off between LOLR and distortionary taxation

The role of reserves

Result: Suppose that

$$\frac{A_1}{s_1^{\text{bad}}} + A_1^* \geq \beta \left[\frac{\theta}{\beta} (q_1^{\text{good}} k_2^{\text{good}} - q_1^{\text{bad}} k_2^{\text{bad}}) + \Xi (k_2^{\text{bad}})^{\alpha \frac{1+\phi}{\alpha+\phi}} \right].$$

Then, the government can credibly eliminate the bad equilibrium

1 Role for ex-ante accumulation of dollar reserves

- Allow government to intervene more when expectations are pessimistic

2 They have a “catalytic” effect on the private sector

- If LOLR successful, only “non-dollarized” equilibria survive

3 Hard to establish whether reserves are “excessive”