Leverage Restrictions in a Business Cycle Model

Lawrence J. Christiano
Daisuke Ikeda

March 2014, Bank of Korea Workshop on Macro Prudential Policy.

Background

- Increasing interest in the following sorts of questions:
  - What restrictions should be placed on bank leverage?
  - How should those restrictions be varied over the business cycle?
  - How should monetary policy react to bank leverage, if at all?

What We Do

- Modify a standard medium-sized DSGE model to include a banking sector.

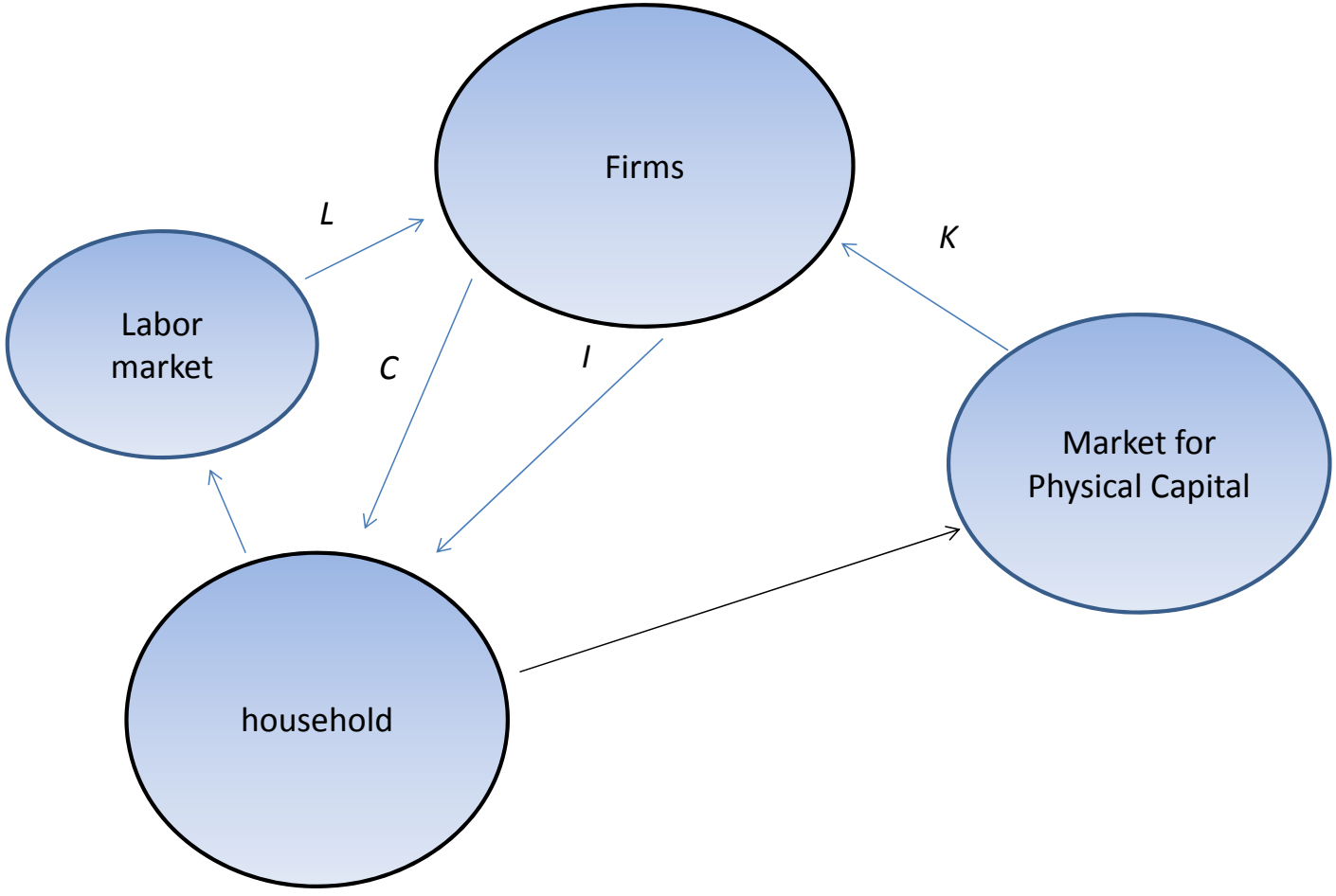
Assets	Liabilities
Loans and other securities	Deposits
	Banker net worth

- Job of bankers is to identify and finance good investment projects.
  - doing this requires exerting costly effort.
- Agency problem between bank and its creditors:
  - banker effort is not observable.
- Consequence: leverage restrictions on banks generate a very substantial welfare gain in steady state.
- Explore some of the dynamic implications of the models.

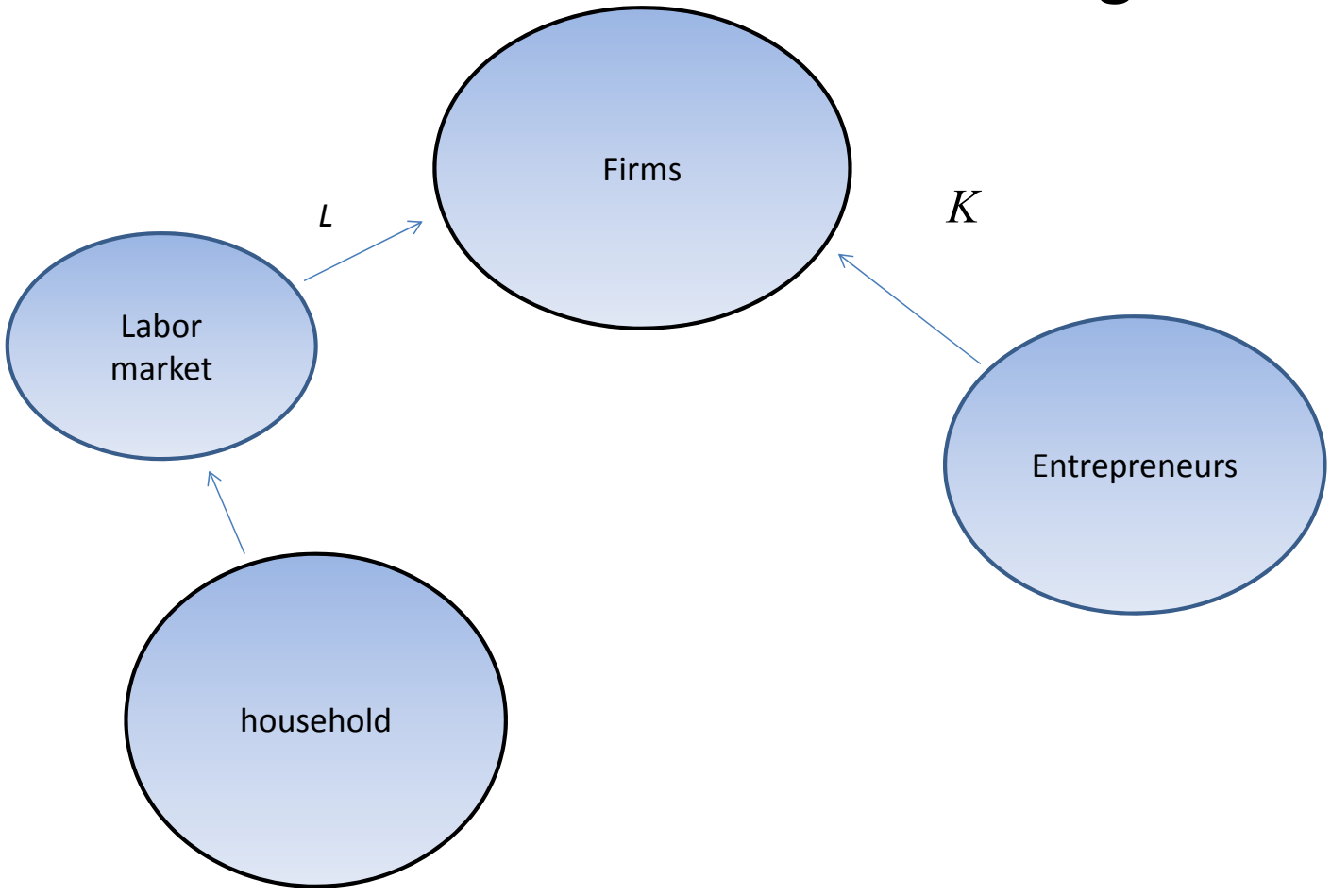
Outline

- Model
  - first, without leverage restriction
    - observable effort benchmark
    - unobservable case
  - then, with leverage restriction
- Steady state properties of leverage restrictions
- Implications for dynamic effects of shocks

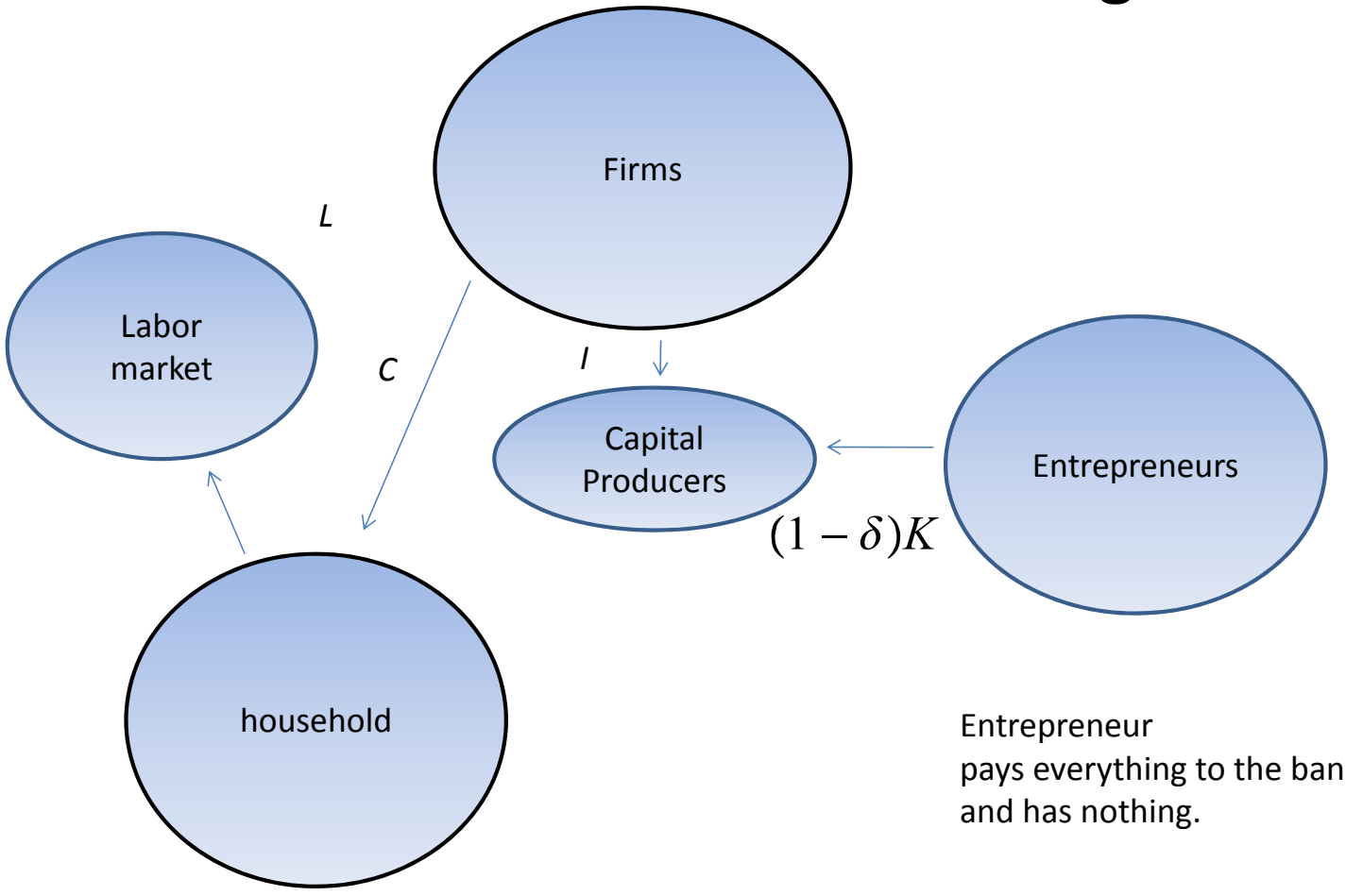
Standard Model



Standard Model with Banking

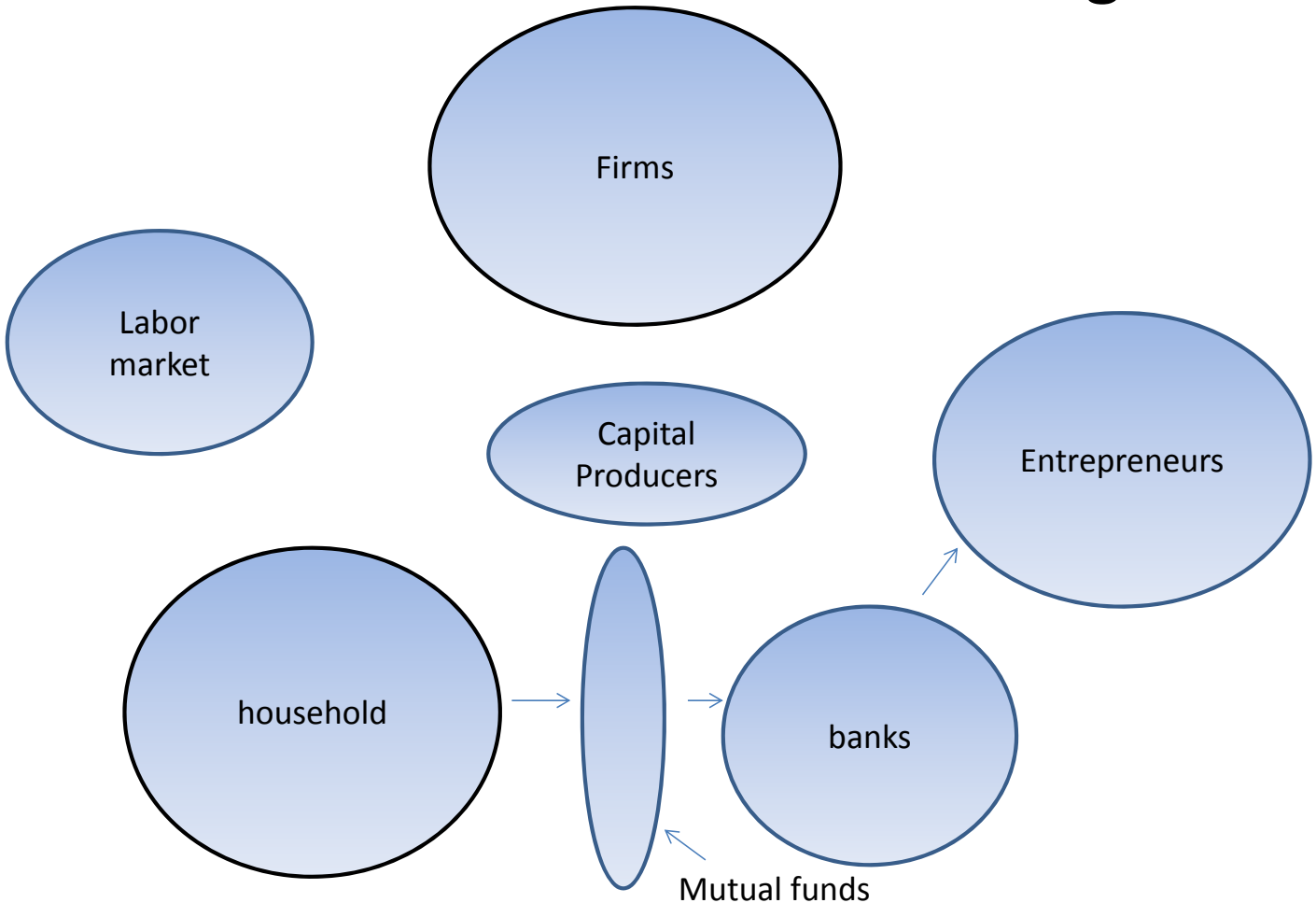


Standard Model with Banking



Entrepreneur
pays everything to the bank
and has nothing.

Standard Model with Banking



Entrepreneurs

- After goods production in period t : Purchase raw capital from capital producers, for price $P_{k',t}$.
  - entrepreneurs have no resources of their own and must obtain financing from banks.
- Entrepreneurs convert raw capital into effective capital.
  - Some are good at it and some are bad.
- In period $t+1$:
  - entrepreneurs rent capital to goods-producers in competitive markets, at rental rate, r_{t+1}.
  - after production, sell undepreciated capital back to capital producers at price, $P_{k',t+1}$.
  - entrepreneurs pay all earnings to bank at end of $t+1$, keeping nothing.
  - no agency problems between entrepreneurs and banks.

Earnings of Entrepreneurs

- there are good entrepreneurs and bad entrepreneurs.
- bad: 1 unit, raw capital $\longrightarrow e^{b_t}$ units, effective capital
- good: 1 unit, raw capital $\longrightarrow e^{g_t}$ units, effective capital

- return to capital enjoyed by entrepreneurs:

$$R^g_{t+1} = e^{g_t} R^k_{t+1},\ R^b_{t+1} = e^{b_t} R^k_{t+1}$$

$$R^k_{t+1} \equiv \frac{r^k_{t+1} P_{t+1} + (1-\delta) P_{k,t+1}}{P_{k't}}$$

- In effect, entrepreneurs operate linear investment technologies,

$$R^g_{t+1} > R^b_{t+1}$$

Bankers

- each has net worth, N_t.
- a banker can only invest in one entrepreneur (asset side of banker balance sheet is risky).
- by exerting effort, e_t, a banker finds a good entrepreneur with probability p :

$$p\left(e_t\right) = \bar{a} + \bar{b}e_t$$

- in t, bankers seek to optimize:

$$E_t\lambda_{t+1}\{p\left(e_t\right)\left[R^g_{t+1}\left(N_t + d_t\right) - R^d_{g,t+1}d_t\right]$$
$$+\left(1 - p\left(e_t\right)\right)\left[R^b_{t+1}\left(N_t + d_t\right) - R^d_{b,t+1}d_t\right]\} - \frac{1}{2}e_t^2$$

- Bankers have a cash constraint:

$$R^b_{t+1}\left(N_t + d_t\right) \geq R^d_{b,t+1}d_t$$

Bankers and their Creditors

- Bankers and Mutual Funds interact in competitive markets for loan contracts:

$$\left(d_t, e_t, R^d_{g,t+1}, R^d_{b,t+1}\right)$$

- Free entry and competition among mutual funds implies:

$$p\left(e_t\right) R^d_{g,t+1} + \left(1 - p\left(e_t\right)\right) R^d_{b,t+1} = R_t$$

- Two scenarios:
  - banker effort, e_t, is observed by mutual fund
  - banker effort, e_t, is unobserved.

Unobserved Effort

- In this case, banker always sets e_t to its privately optimal level, whatever e_t is specified in the loan contract:

$$\text{incentive} \quad : \quad e_t = E_t \lambda_{t+1} p_t' (e_t) \left[\left(R_{t+1}^g - R_{t+1}^b \right) (N_t + d_t) - \left(R_{g,t+1}^d - R_{b,t+1}^d \right) d_t \right].$$

- Set of contracts available to bankers is the $\left(d_t, e_t, R_{g,t+1}^d, R_{b,t+1}^d \right)$'s that satisfy 'incentive' in addition to:

$$\text{MF zero profits} \quad : \quad p(e_t) R_{g,t+1}^d + (1 - p(e_t)) R_{b,t+1}^d = R_t,$$

$$\text{cash constraint} \quad : \quad R_{t+1}^b (N_t + d_t) \geq R_{b,t+1}^d d_t$$

- One factor that can make e_t inefficiently low:
  - $R_{g,t+1}^d > R_{b,t+1}^d$.

Law of Motion of Net Worth

- Bankers live in a large representative household, with workers (as in Gertler-Karadi, Gertler-Kiyotaki).
  - Bankers pool their net worth at the end of each period (we avoid worrying about banker heterogeneity)
- Law of motion of banker net worth

$$N_{t+1} = \gamma_{t+1}\{p(e_t)\overbrace{\left[R^g_{t+1}(N_t+d_t) - R^d_{g,t+1}d_t\right]}^{\text{profits when bank assets good}} + (1-p(e_t))\overbrace{\left[R^b_{t+1}(N_t+d_t) - R^d_{b,t+1}d_t\right]}^{\text{profits when bank assets are bad}}\} + \overbrace{T_{t+1}}^{\text{lump sum transfer, households to their bankers}}$$

Law of Motion of Net Worth

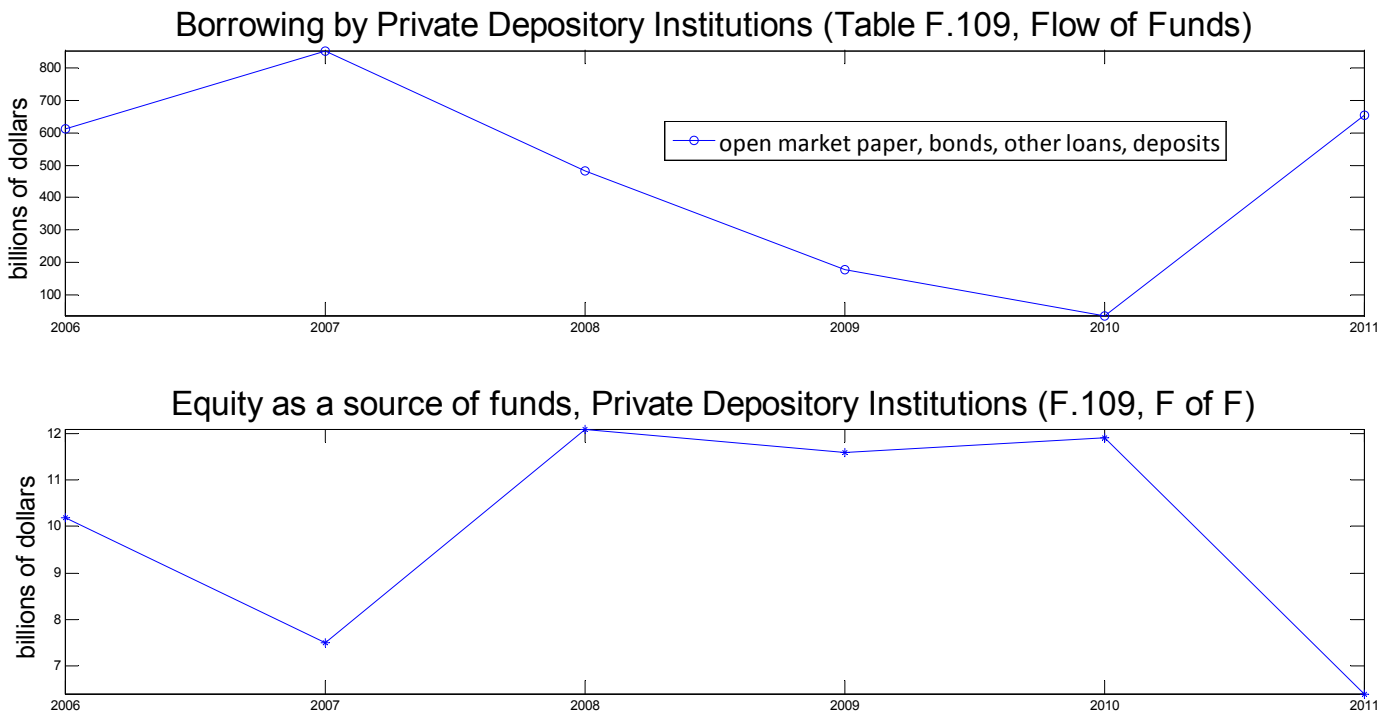
- Bankers live in a large representative household, with workers (as in Gertler-Karadi, Gertler-Kiyotaki).
  - Bankers pool their net worth at the end of each period (we avoid worrying about banker heterogeneity)
- Law of motion of banker net worth

$$N_{t+1} = \gamma_{t+1}\{p(e_t)\overbrace{\left[R^g_{t+1}(N_t+d_t) - R^d_{g,t+1}d_t\right]}^{\text{profits when bank assets good}} + (1-p(e_t))\overbrace{\left[R^b_{t+1}(N_t+d_t) - R^d_{b,t+1}d_t\right]}^{\text{profits when bank assets are bad}}\} + \overbrace{T_{t+1}}^{\text{lump sum transfer, households to their bankers}}$$

Model Assumption that Banks Don't Systematically Rely on Equity Issues to Finance Assets

- Adrian and Shin, 'Procyclical Leverage and Value-at-Risk'
  - Changes in financial firm equity not systematically related to their assets.
  - Changes in financial firm debt moves one-for-one with changes in assets.

- The model assumes that when bankers want funds, issuing equity is not an option.



'Crisis'

- Suppose something makes banker net worth, N_t, drop.
- For given d_t, bank cash constraint gets tighter:

$$R^b_{t+1}\left(N_t + d_t\right) \geq R^d_{b,t+1} d_t.$$

- So, $R^d_{b,t+1}$ has to be low
  - when N_t is low, banks with bad assets cannot cover their own losses and creditors must share in losses.
  - then, creditors require $R^d_{g,t+1}$ high
- So, interest rate spread, $R^d_{g,t+1} - R_t$, high, banker effort low.
- Banks get riskier (cross sectional mean return down, standard deviation up).

Leverage Restrictions

- Banks face the following restriction:

$$L_t \geq \frac{N_t + d_t}{N_t}.$$

- What is the consequence of this restriction?
  - With less d_t, banks with bad assets more able to cover losses
    - interest rate spread, $R_b^d - R$, falls, so banker effort rises.
  - Second effect of leverage restriction,
    - leverage restriction in effect implements collusion among bankers
    - allows them to behave as monopsonists
    - make profits on demand deposits....lots of profits:

$$\left[p\left(e_t\right)\left(R_{t+1}^g - R_{g,t+1}^d\right) + \left(1 - p\left(e_t\right)\right)\left(R_{t+1}^b - R_{b,t+1}^d\right)\right] \overbrace{\frac{d_t}{N_t}}^{\text{big}}$$

    - makes N_t grow, offseting incentive effects of decline in d_t.

Macro Model

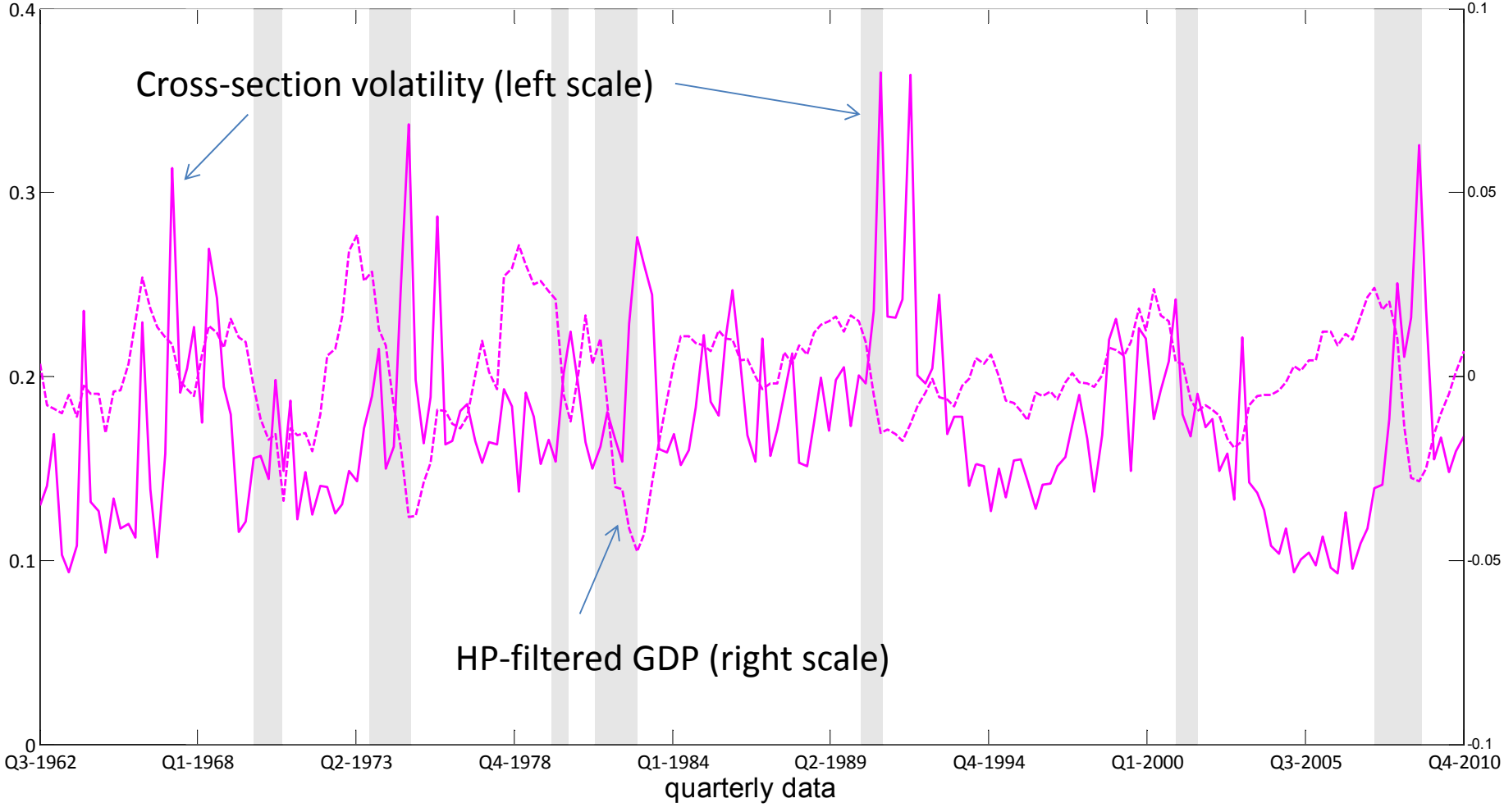
- Sticky wages and prices
- Investment adjustment costs
- Habit persistence in consumption
- Monetary policy rule

Calibration targets

Table 2: Steady state calibration targets for baseline model		
Variable meaning	variable name	magnitude
Cross-sectional standard deviation of quarterly non-financial firm equity returns	s^b	0.20
Fnancial firm interest rate spreads (APR)	$400(R_g^d - R)$	0.60
Financial firm leverage	L	20.00
Allocative efficiency of the banking system	$p(e)e^g + (1 - p(e))e^b$	1

Data behind calibration targets

Figure 1: Cross-section standard deviation financial firm quarterly return on equity, HP-filtered US real GDP



Parameter Values

Table 1: Baseline Model Parameter Values		
Meaning	Name	Value
Panel A: financial parameters		
return parameter, bad entrepreneur	b	-0.09
return parameter, good entrepreneur	g	0.00
constant, effort function	$\bar{a}$	0.83
slope, effort function	$\bar{b}$	0.30
lump-sum transfer from households to bankers	$\tilde{T}$	0.38
fraction of banker net worth that stays with bankers	γ	0.85
Panel B: Parameters that do not affect steady state		
steady state inflation (APR)	$400(\pi - 1)$	2.40
Taylor rule weight on inflation	α_π	1.50
Taylor rule weight on output growth	$\alpha_{\Delta y}$	0.50
smoothing parameter in Taylor rule	ρ_p	0.80
curvature on investment adjustment costs	S''	5.00
Calvo sticky price parameter	ξ_p	0.75
Calvo sticky wage parameter	ξ_w	0.75
Panel C: Nonfinancial parameters		
steady state gdp growth (APR)	μ_{z^*}	1.65
steady state rate of decline in investment good price (APR)	Υ	1.69
capital depreciation rate	δ	0.03
production fixed cost	Φ	0.89
capital share	α	0.40
steady state markup, intermediate good producers	λ_f	1.20
habit parameter	b_u	0.74
household discount rate	$100(\beta^{-4} - 1)$	0.52
steady state markup, workers	λ_w	1.05
Frisch labor supply elasticity	$1/\sigma_L$	1.00
weight on labor disutility	ψ_L	1.00
steady state scaled government spending	$\tilde{g}$	0.89

Steady State Calculations

- Next study steady state impact of leverage
  - Quantify role of hidden effort in the analysis (*essential!*)

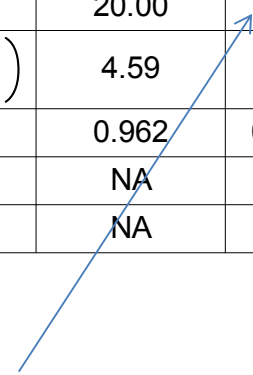
Table 3: Steady State Properties of the Model					
Variable meaning	Variable name	Unobserved Effort		Observed Effort	
		Leverage Restriction		Leverage Restriction	
		non-binding	binding	non-binding	binding
Spread	$400(R_g^d - R)$	0.600		NA	
scaled consumption	c	1.84		2.01	
labor	h	1.18		1.15	
scaled capital stock	k	51.52		59.75	
bank assets	$N + d$	51.52		59.55	
bank net worth	N	2.58		2.58	
bank deposits	d	48.94		56.98	
bank leverage	$(N + d)/N$	20.00		23.12	
bank return on equity (APR)	$400\left(\frac{\left[p(e_t)R_{t+1}^g + (1-p(e_t))R_{t+1}^b\right](N_t+d_t) - R_t d_t}{N_t} - 1\right)$	4.59		4.59	
fraction of firms with good balance sheets	$p(e)$	0.962		1.000	
Benefit of leverage (in c units)	100χ	NA		NA	
Benefit of making effort observable (in c units)	100χ	NA		6.11	

Making effort observable makes things *a lot* better, equivalent to a 6% permanent jump in consumption!

Table 3: Steady State Properties of the Model					
Variable meaning	Variable name	Unobserved Effort		Observed Effort	
		Leverage Restriction		Leverage Restriction	
		non-binding	binding	non-binding	binding
Spread	$400(R_g^d - R)$	0.600		NA	
scaled consumption	c	1.84		2.01	
labor	h	1.18		1.15	
scaled capital stock	k	51.52		59.75	
bank assets	$N+d$	51.52		59.55	
bank net worth	N	2.58		2.58	
bank deposits	d	48.94		56.98	
bank leverage	$(N+d)/N$	20.00		23.12	
bank return on equity (APR)	$400\left(\frac{\left[p(e_t)R_{t+1}^g+(1-p(e_t))R_{t+1}^b\right](N_t+d_t)-R_t d_t}{N_t}-1\right)$	4.59		4.59	
fraction of firms with good balance sheets	$p(e)$	0.962		1.000	
Benefit of leverage (in c units)	100χ	NA		NA	
Benefit of making effort observable (in c units)	100χ	NA		6.11	

Interestingly, leverage goes up.

Table 3: Steady State Properties of the Model					
Variable meaning	Variable name	Unobserved Effort		Observed Effort	
		Leverage Restriction		Leverage Restriction	
		non-binding	binding	non-binding	binding
Spread	$400(R_g^d - R)$	0.600	0.211	NA	
scaled consumption	c	1.84	1.88	2.01	
labor	h	1.18	1.16	1.15	
scaled capital stock	k	51.52	51.40	59.75	
bank assets	$N + d$	51.52	51.31	59.55	
bank net worth	N	2.58	3.02	2.58	
bank deposits	d	48.94	48.29	56.98	
bank leverage	$(N + d)/N$	20.00	17.00	23.12	
bank return on equity (APR)	$400\left(\frac{\left[p(e_t)R_{t+1}^g + (1-p(e_t))R_{t+1}^b\right](N_t+d_t) - R_t d_t}{N_t} - 1\right)$	4.59	14.96	4.59	
fraction of firms with good balance sheets	$p(e)$	0.962	0.982	1.000	
Benefit of leverage (in c units)	100χ	NA	1.19	NA	
Benefit of making effort observable (in c units)	100χ	NA	NA	6.11	



Cut in leverage in the unobserved effort economy moves things towards observed effort.

Table 3: Steady State Properties of the Model					
Variable meaning	Variable name	Unobserved Effort		Observed Effort	
		Leverage Restriction		Leverage Restriction	
		non-binding	binding	non-binding	binding
Spread	$400(R_g^d - R)$			NA	NA
scaled consumption	c			2.01	1.95
labor	h			1.15	1.14
scaled capital stock	k			59.75	53.86
bank assets	$N + d$			59.55	53.68
bank net worth	N			2.58	3.16
bank deposits	d			56.98	50.52
bank leverage	$(N + d)/N$			23.12	17.00
bank return on equity (APR)	$400\left(\frac{\left[p(e_t)R_{t+1}^g+(1-p(e_t))R_{t+1}^b\right](N_t+d_t)-R_t d_t}{N_t} - 1\right)$			4.59	17.63
fraction of firms with good balance sheets	$p(e)$			1.000	1.000
Benefit of leverage (in c units)	100χ			NA	-2.70
Benefit of making effort observable (in c units)	100χ			6.11	2.03

Hidden effort assumption is *essential*. Otherwise, leverage restriction *reduces* utility.

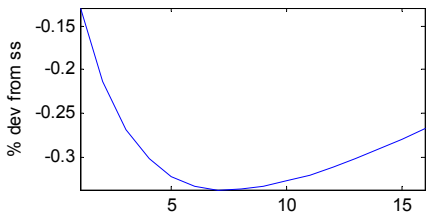
Dynamics

- Here, we consider the dynamic effects of two shocks
  - shock to monetary policy
  - lump sum shock to net worth

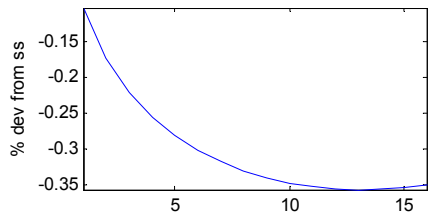
$$R_t = 0.80R_{t-1} + (1-0.80)[1.5\pi_{t+1} + 0.5g_{y,t}] + \varepsilon_t^p$$

$$\varepsilon_0^p = +25 \text{ annual basis points}$$

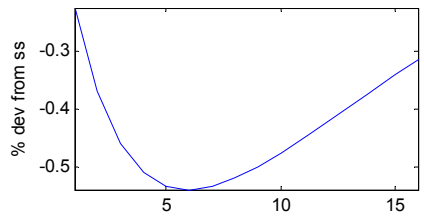
GDP



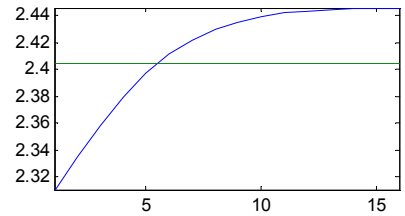
Consumption



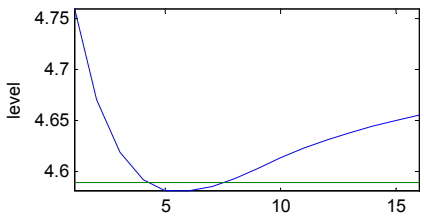
Investment



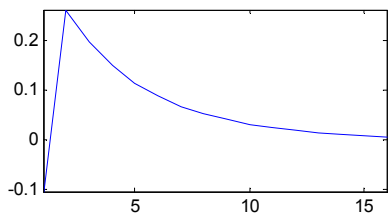
Inflation (APR)



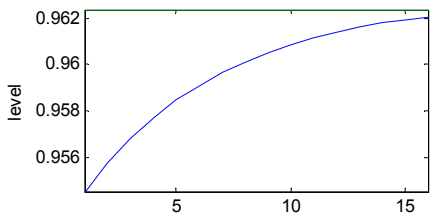
Risk free rate (APR)



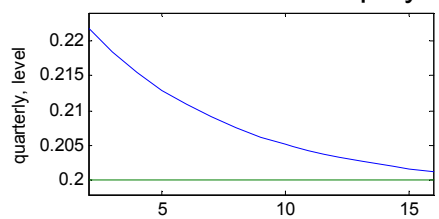
Interest rate spread (APR)



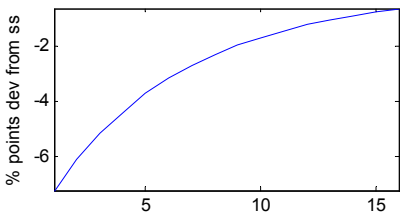
Prob of success



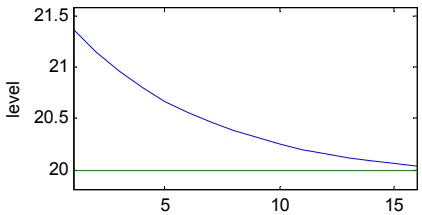
Cross-section std dev, Bank return on equity



Bank net worth (N)



Leverage (N+d)/N



Contractionary M policy shock:

fall in:

c, i, y,

bank net worth, *N*,

inflation

Rise in:

leverage

cross-sectional dispersion of bank performance

Conclusion

- Described a model in which there is a problem that is mitigated by the introduction of leverage restrictions.
- Described some loose tests of the model by looking at its dynamic implications.
- Studied steady state implications of leverage.
- Currently exploring what are the optimal dynamic properties of leverage.Conjecture:
  - leverage restrictions useful in a boom, so banks to build up a lot of net worth then.
  - so, when a recession occurs, banks have enough net worth to shield depositors from losses on bank balance sheets.