Strategic complementarities and the two dimensions of systemic risk

How the time-series and cross-section components evolve and interact

Edoardo Gaffeo

Department of Economics and Management
University of Trento

OUTLINE

- Systemic risk and its dimensions
- In search of the financial cycle
- Strategic complementarities in risk-taking
- Leverage and interconnectedness
- Hints for future research

DIMENSIONS OF SYSTEMIC RISK

- Financial stability reflects the ability of the financial system to supply key economic functions (QATs in credit provision, payments systems, risk management, monitoring and information processing) that are needed in the real economy if it is to continue on its growth path.
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DIMENSIONS OF SYSTEMIC RISK

- The failure of a FI generates systemic negative externalities:
  i. Informational contagion
  ii. Net loss of informational capital
  iii. Interconnectedness among FIs
  iv. Liquidity spirals and fire sales during deleveraging
  v. Default cascading of non-financial borrowers

DIMENSIONS OF SYSTEMIC RISK

- Systemic risks to financial stability arise along two dimensions (Borio and Crockett, 2000; BIS, 2010):
  i. the ***cross-sectional dimension***, that captures the risk of spillovers and contagion at one point in time, due to interconnections across entities and sectors.
  ii. the time series dimension, that relates to the rise of financial imbalances over time and the pro-cyclicality of the financial system.

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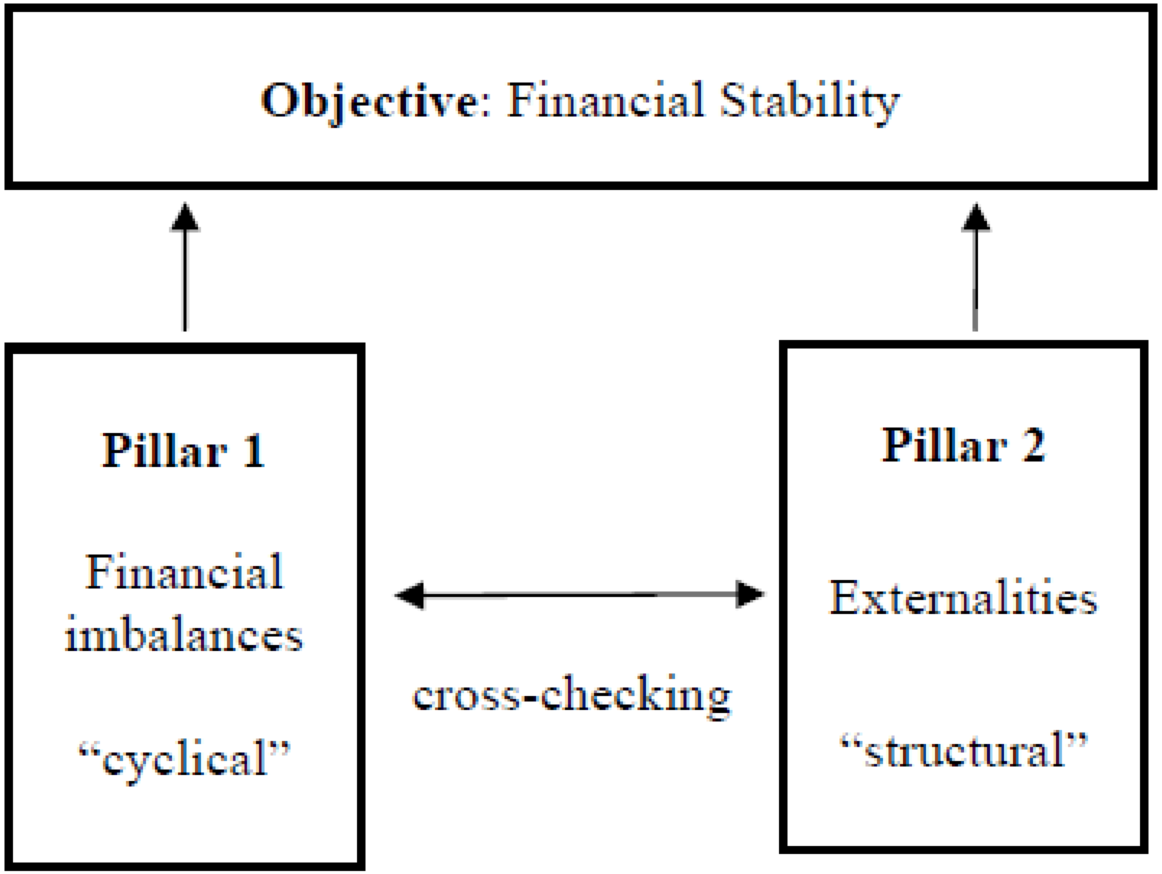
A two-pillar strategy for macroprudential policy?



Source: Schoenmaker and Wierts, 2011

A comparison of aims and tools along the two pillars according to the regulator

	Aim	
	To enhance financial system resilience to shocks	**To moderate the financial cycle**
General approach to achieving aim	Recalibrate micro tools taking into account systemic risk	Use tools dynamically in response to the financial cycle
Key features of instruments	May be macro- or micro-style (ie institution-specific elements in application and calibration)	Tend to be macro-style: broad application, eg across all banks or markets
Frequency of adjustment	Generally less frequent or might be one-off (eg in response to structural changes in the financial system), but frequent review and adjustment also possible	Tend to be periodically reviewed and more frequently adjusted, in response to fluctuations in the financial cycle

Source: BIS, 2010

THE FINANCIAL CYCLE

- Is there a financial cycle as a distinct phenomenon?

- Choice of variables?
  i. Credit - leverage
  ii. Asset prices
  iii. Risk measures

- Methods to detect cycles
  i. Turning point analysis (ex., Bry-Boschan algorithm)
  ii. Frequence-based methods – filters (ex., HP, BK or CF filters)

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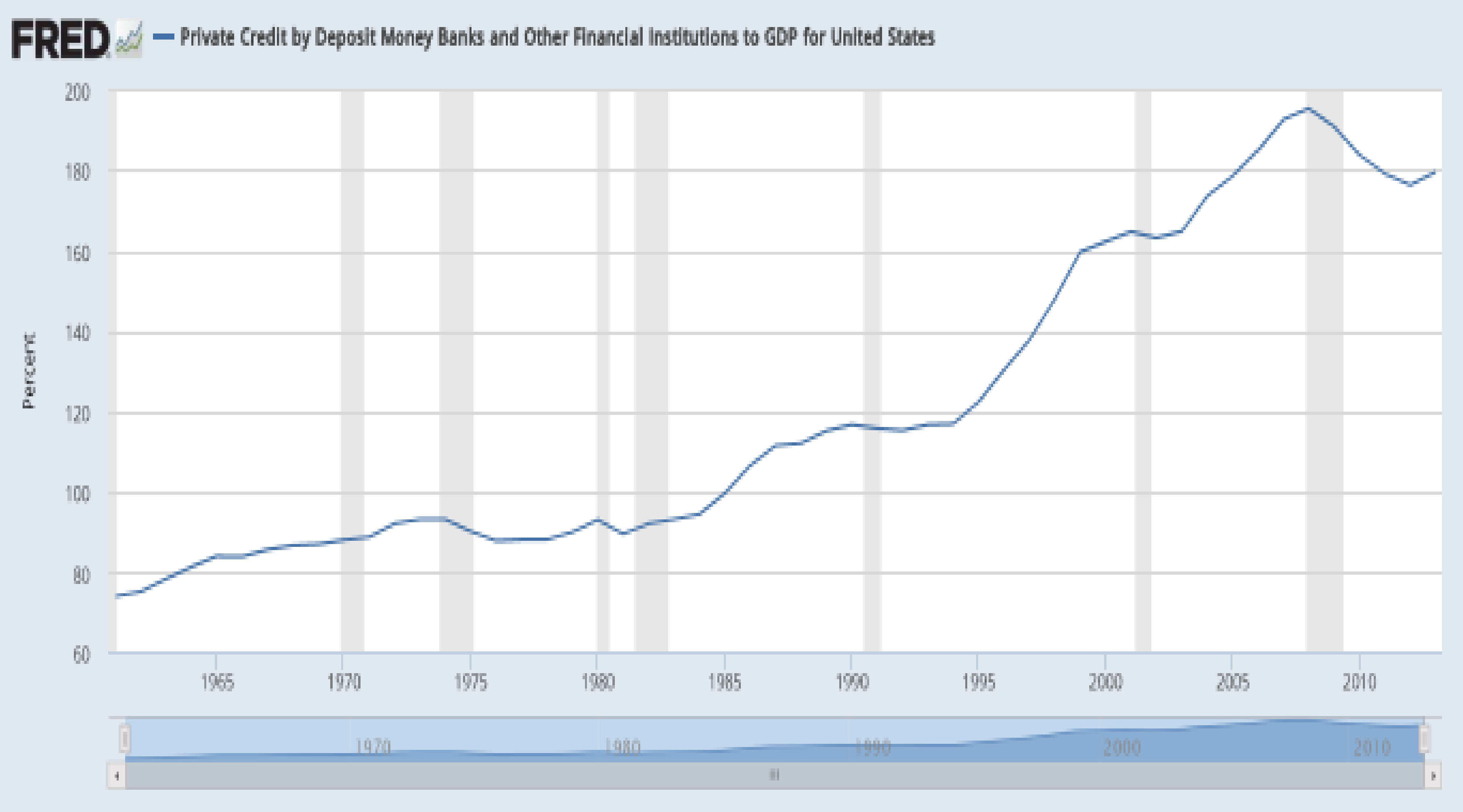
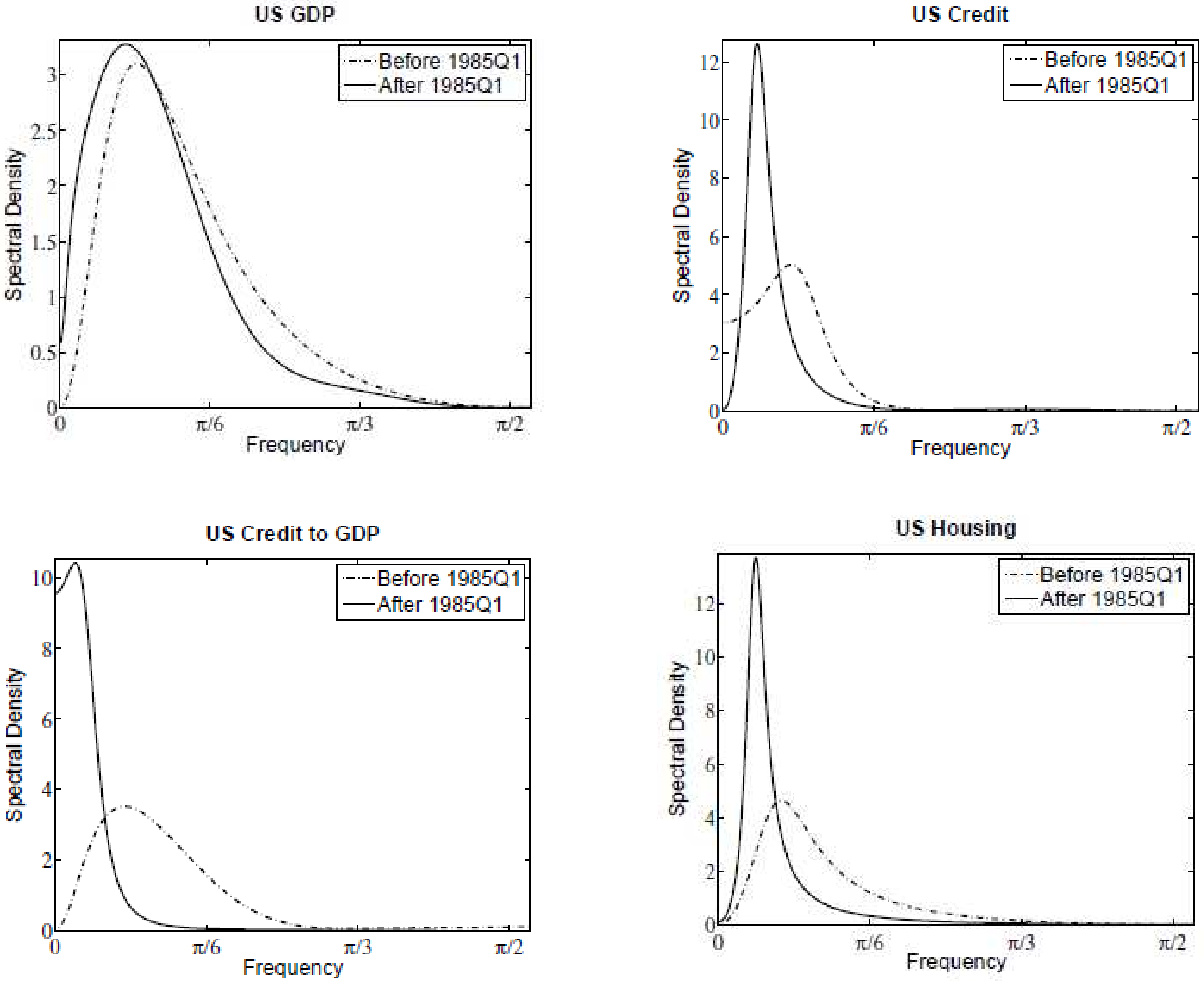
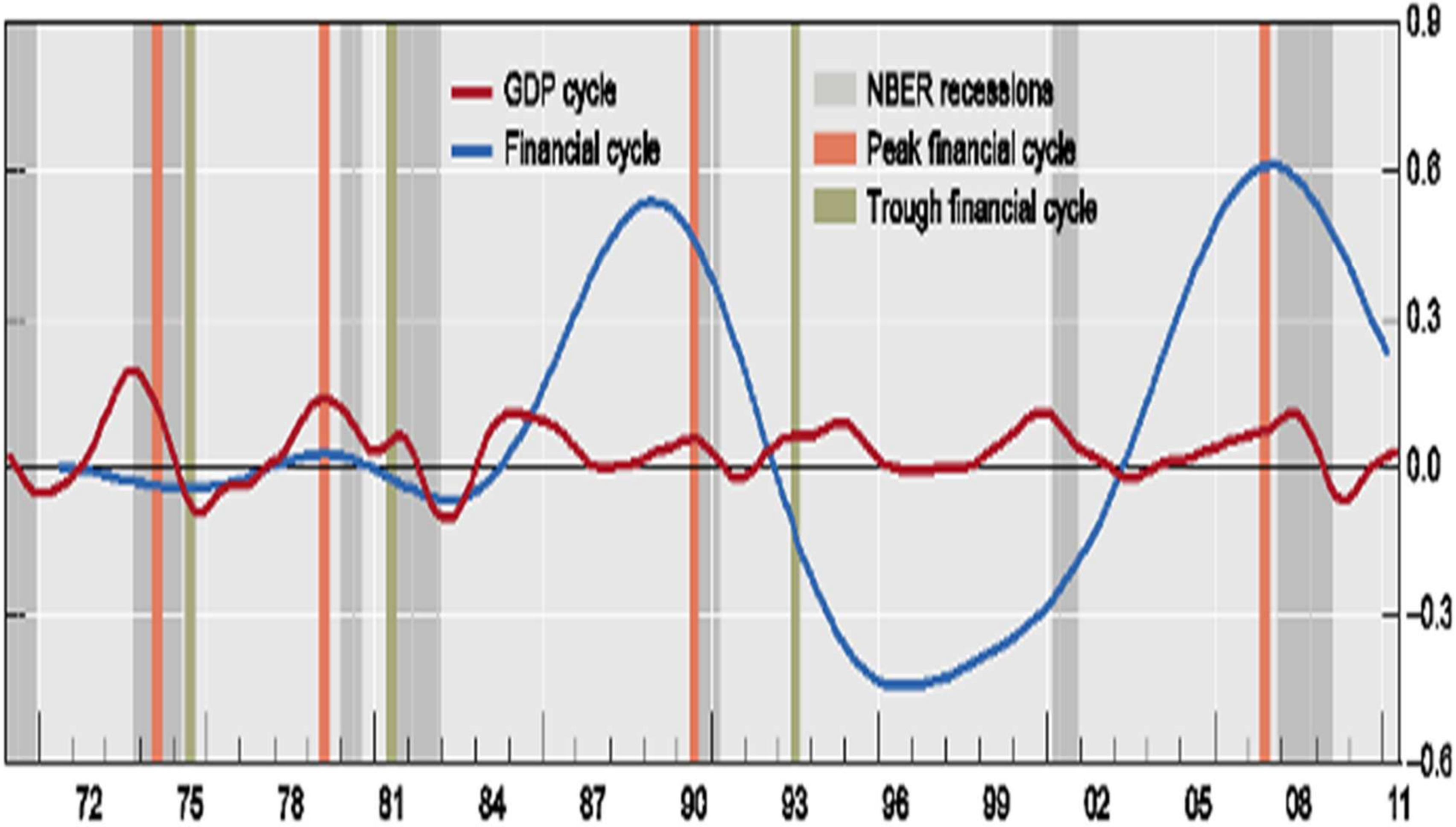


Shaded areas indicate US recessions (/help-faq/#graph_recessions) Source: World Bank fred.stlouisfed.org

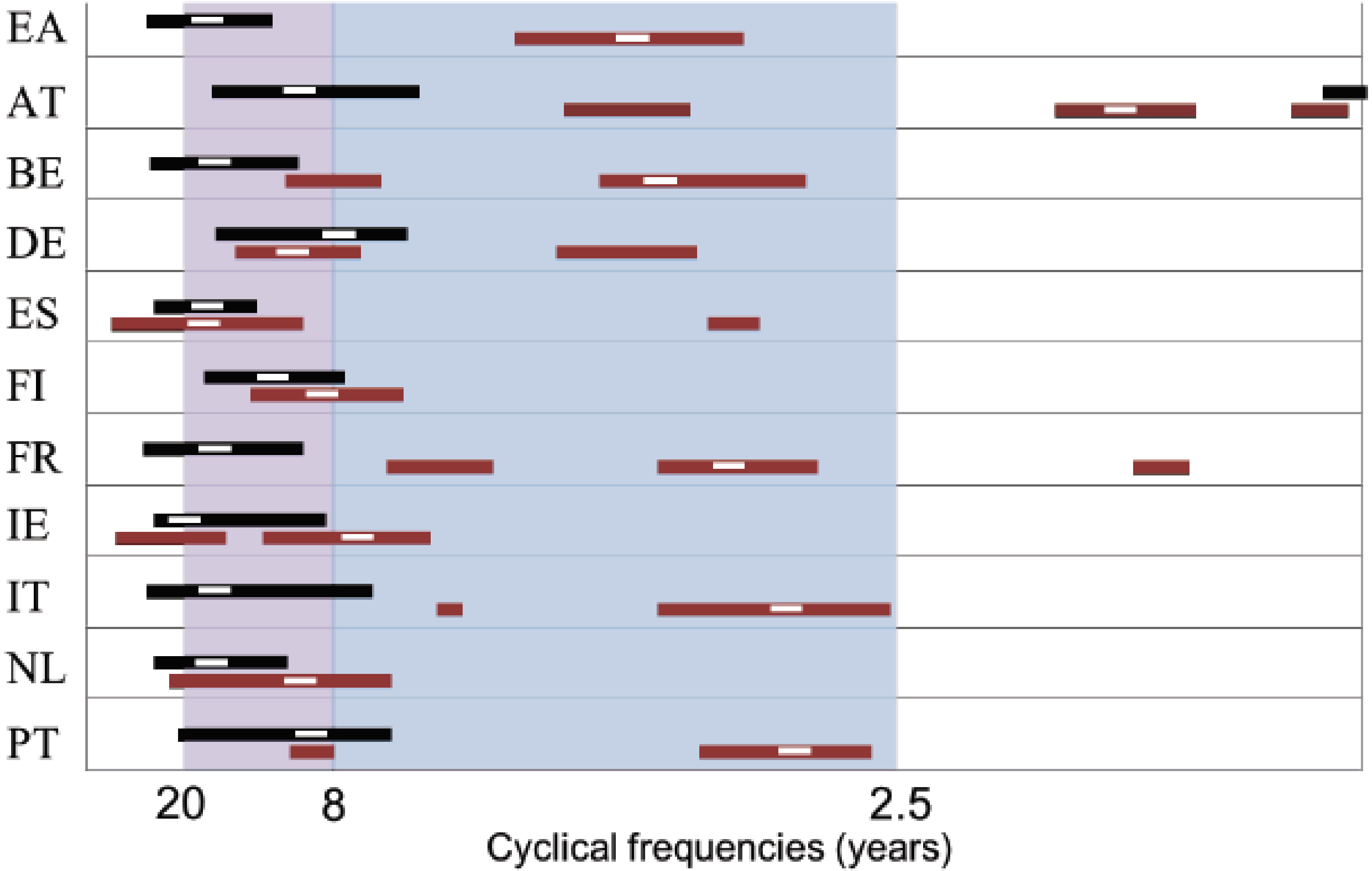
THE FINANCIAL CYCLE



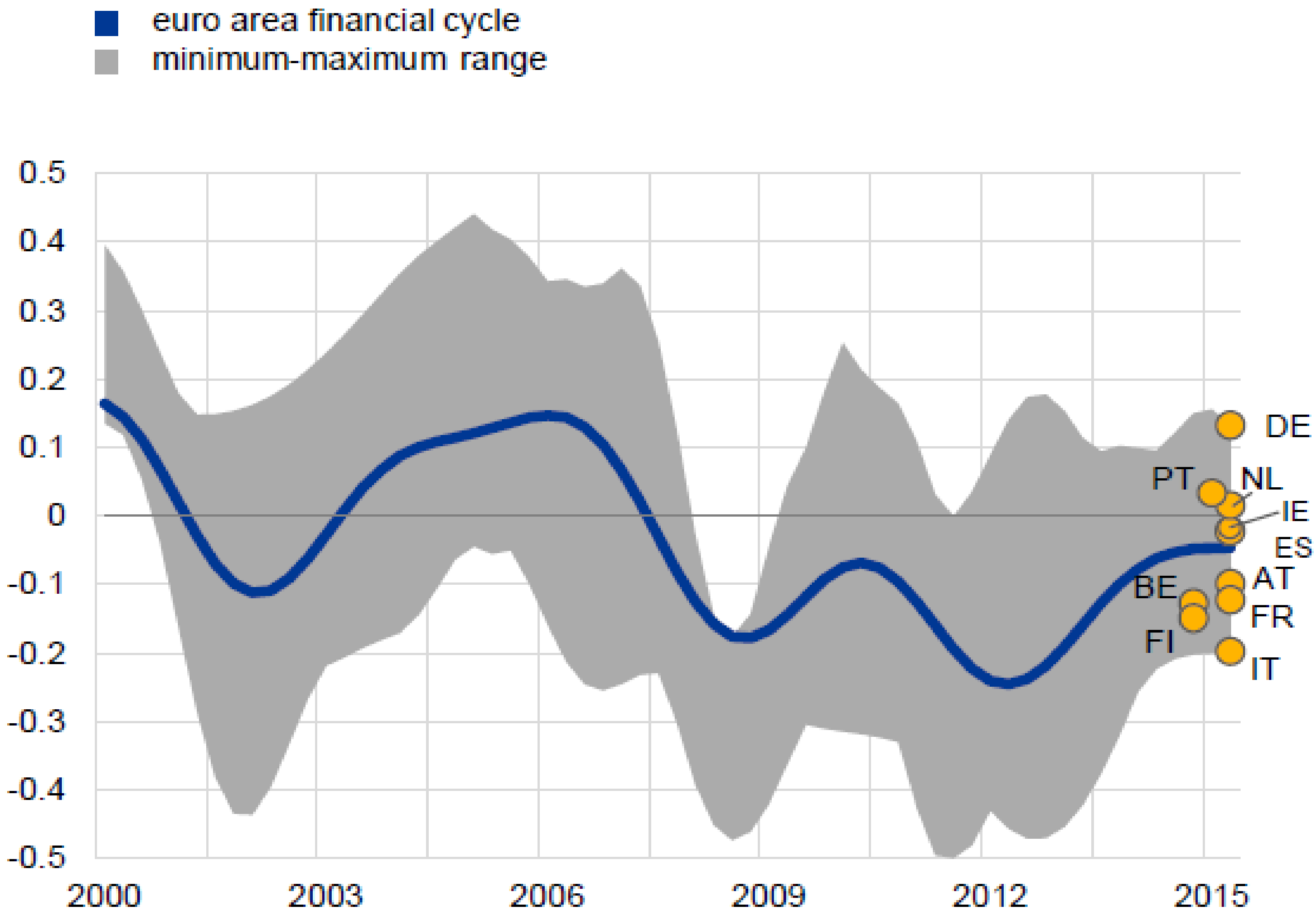
The financial cycle in the USA …



… and in the EU (1970-2014)
(black: financial cycle; red: business cycle)

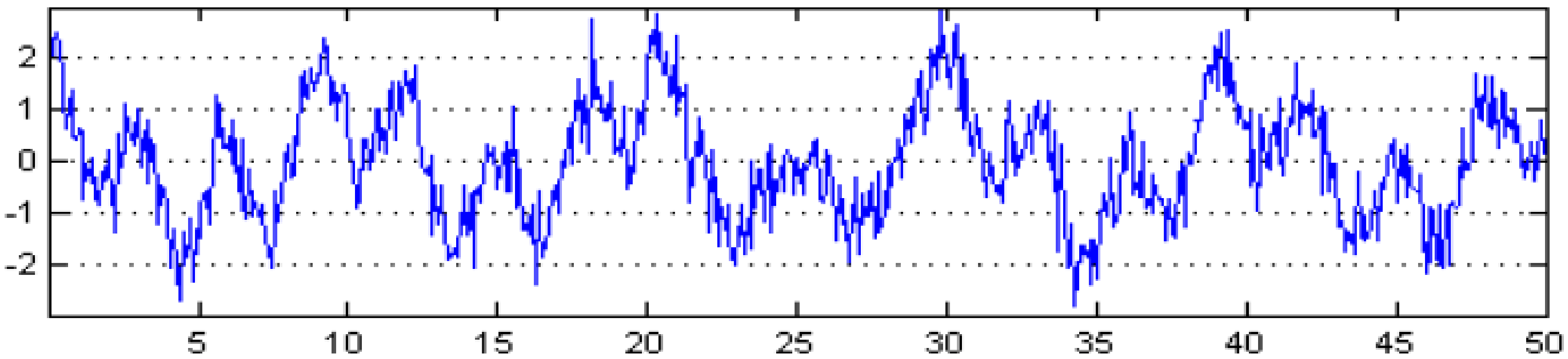


Heterogeneity in country financial cycles



- Wavelets are mathematical functions that allows the decomposition of a signal into its different frequency components and to study the dynamics of each of these components over time.
- The continuous wavelet transform maps the original time series, which is a function of just one variable – time – into a function of two variables – time and frequency.
- Particularly useful in tracing transitional changes across time.
- Can be used also for non-stationary time series.

- Let's use an example. The following time series …



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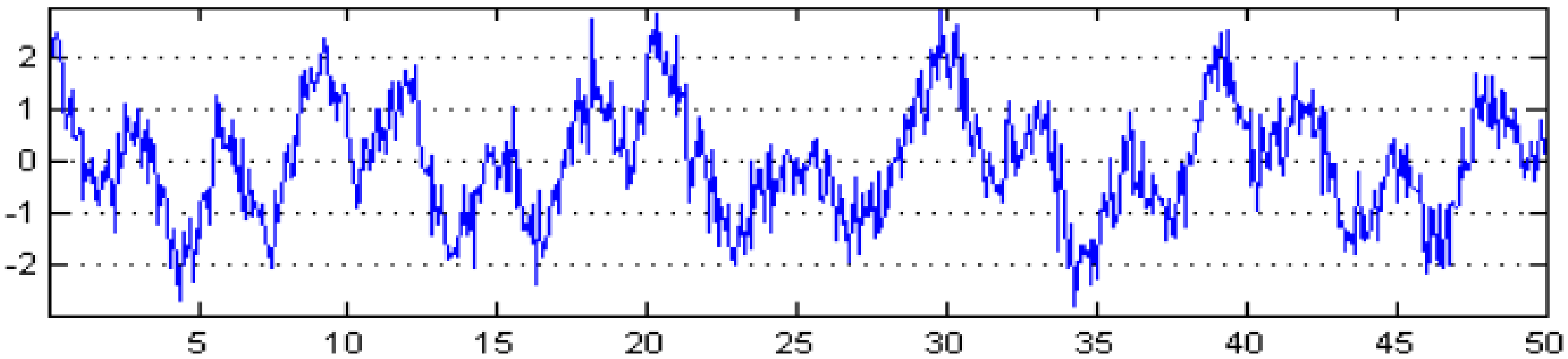
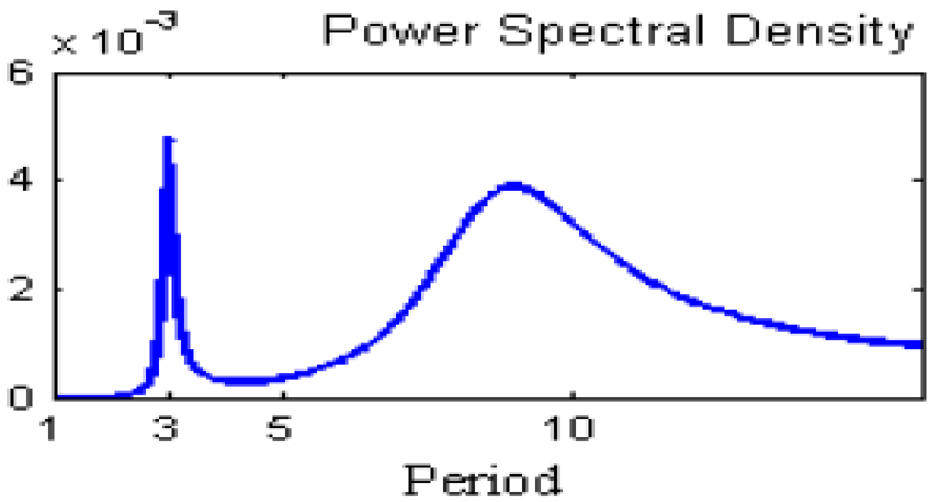


- … admits the following spectral representation



- Actually, the DGP for the series is

$$y_t = \cos\left(\frac{2\pi}{p_1}t\right) + \cos\left(\frac{2\pi}{p_2}t\right) + \varepsilon_t, \qquad t = \frac{1}{12}, \frac{2}{12}, \dots, 50$$

where

$$p_1 = 10$$

$$p_2 = \begin{cases} 5 & if \quad 20 \le t \le 30 \\ 3 & otherwise \end{cases}$$

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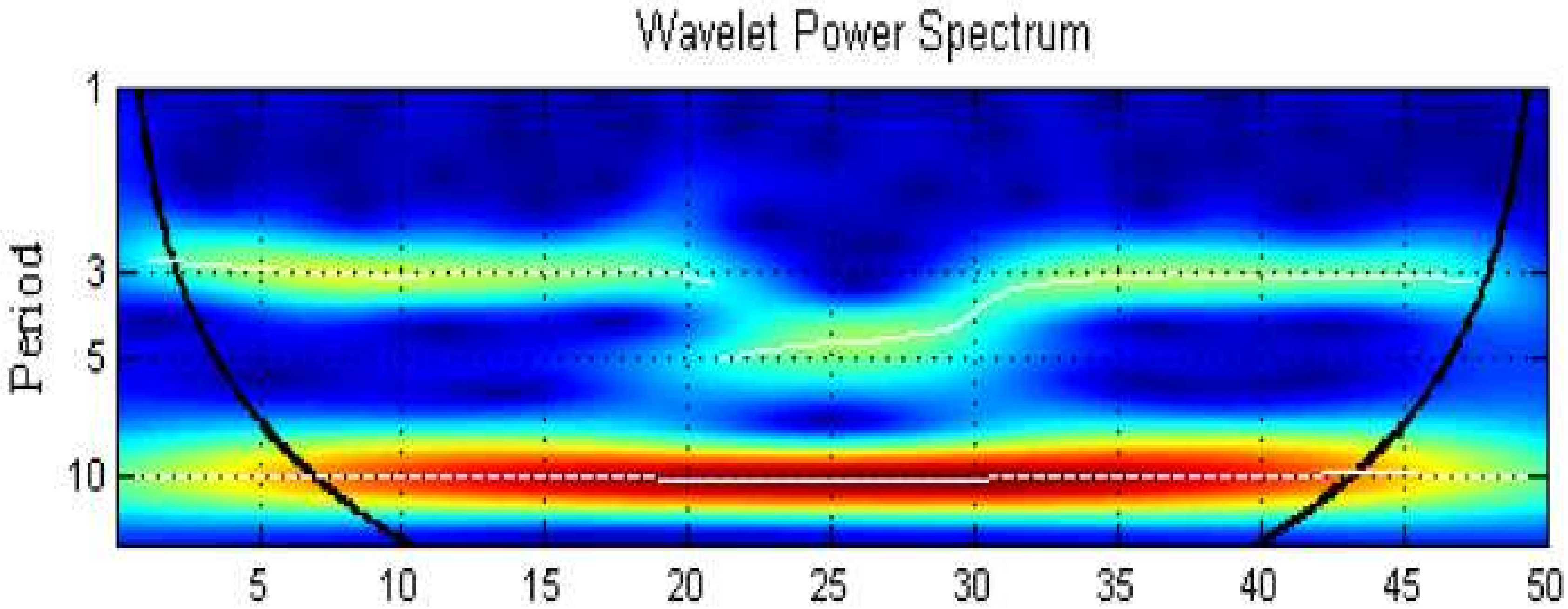
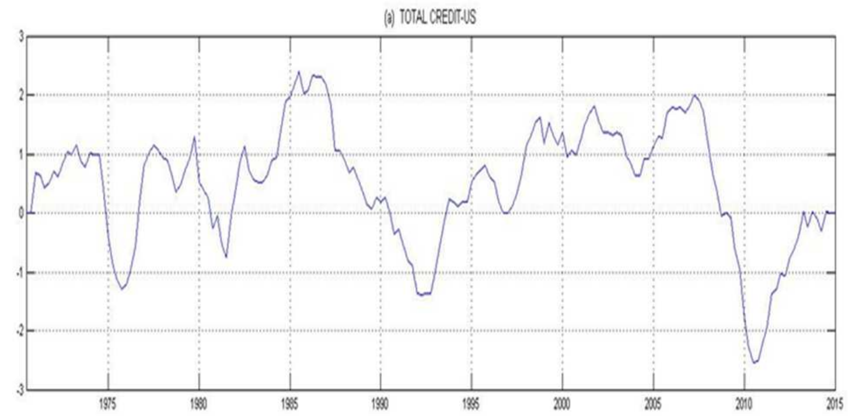
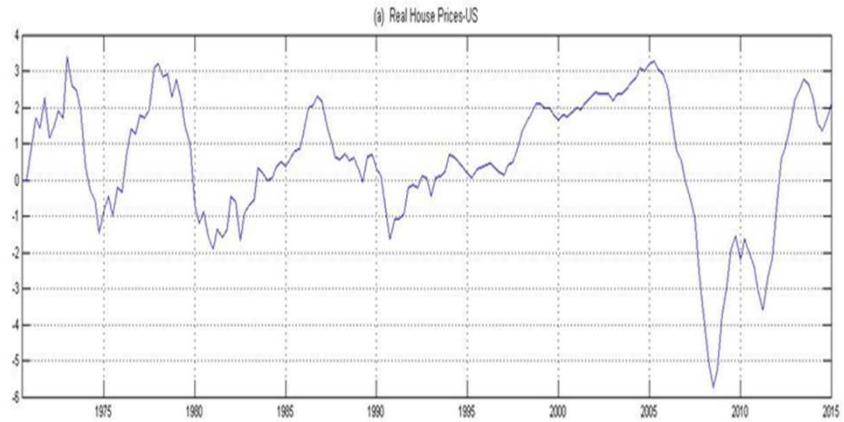


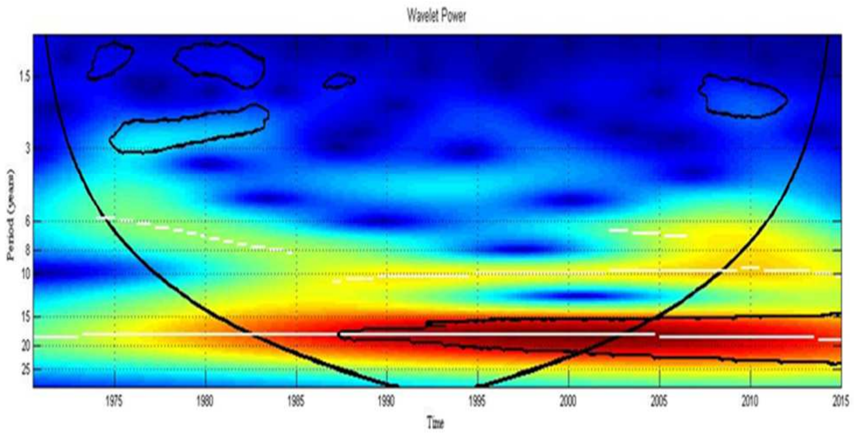
The wavelet-based financial cycle in the USA

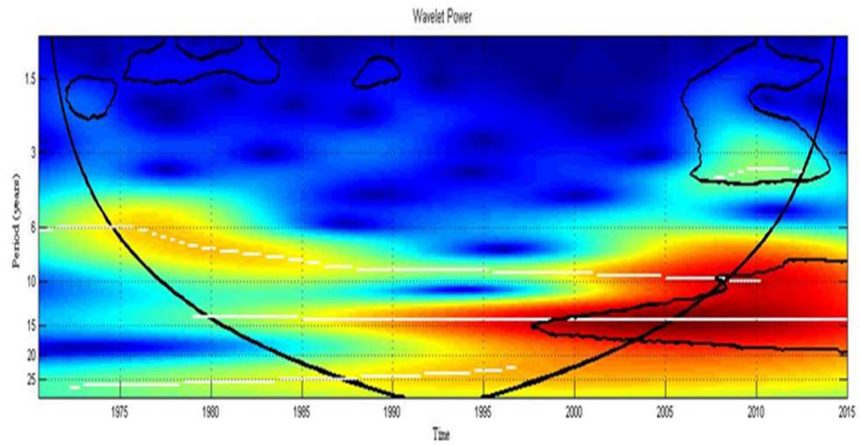
Total credit

Real house prices

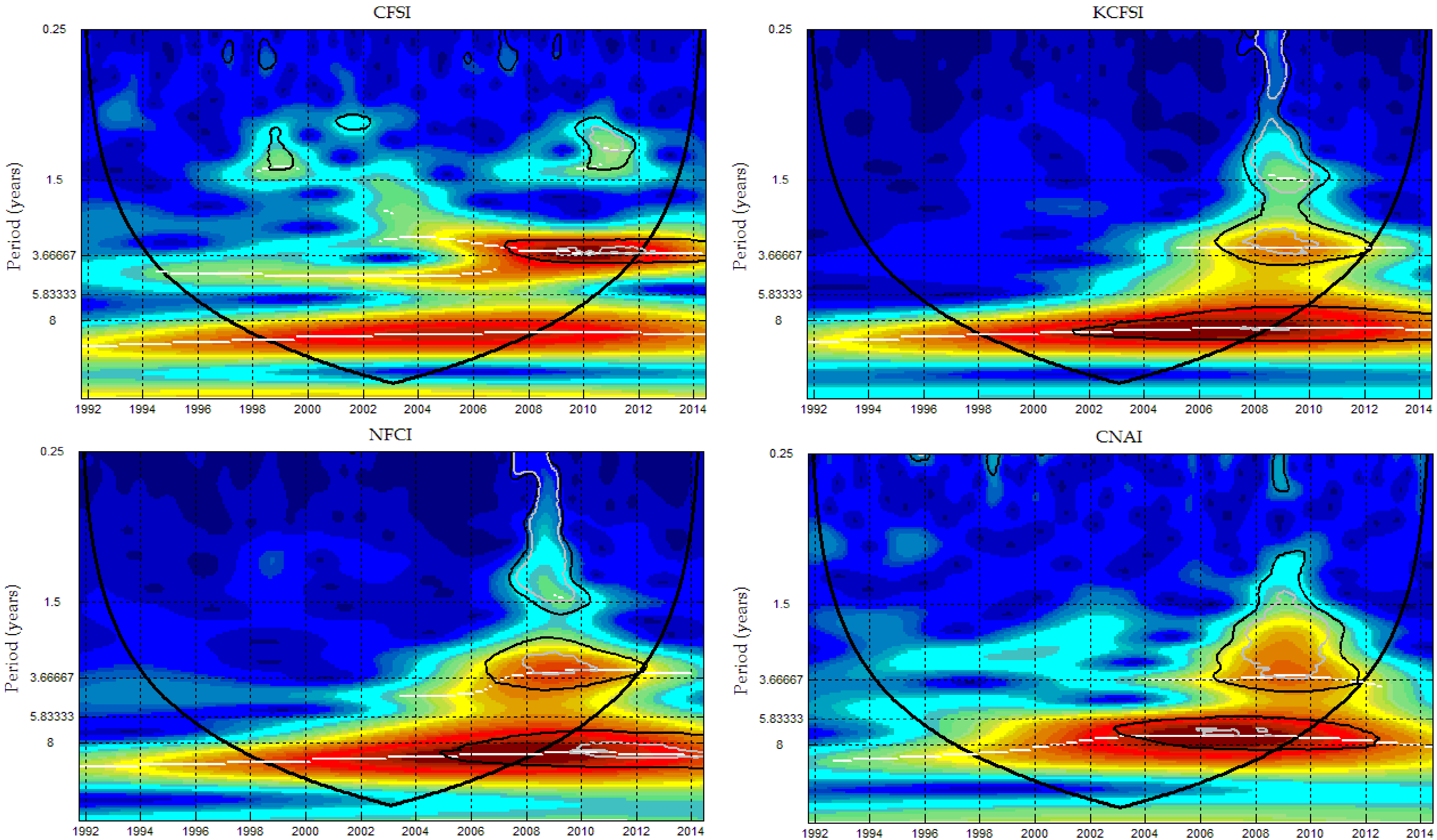






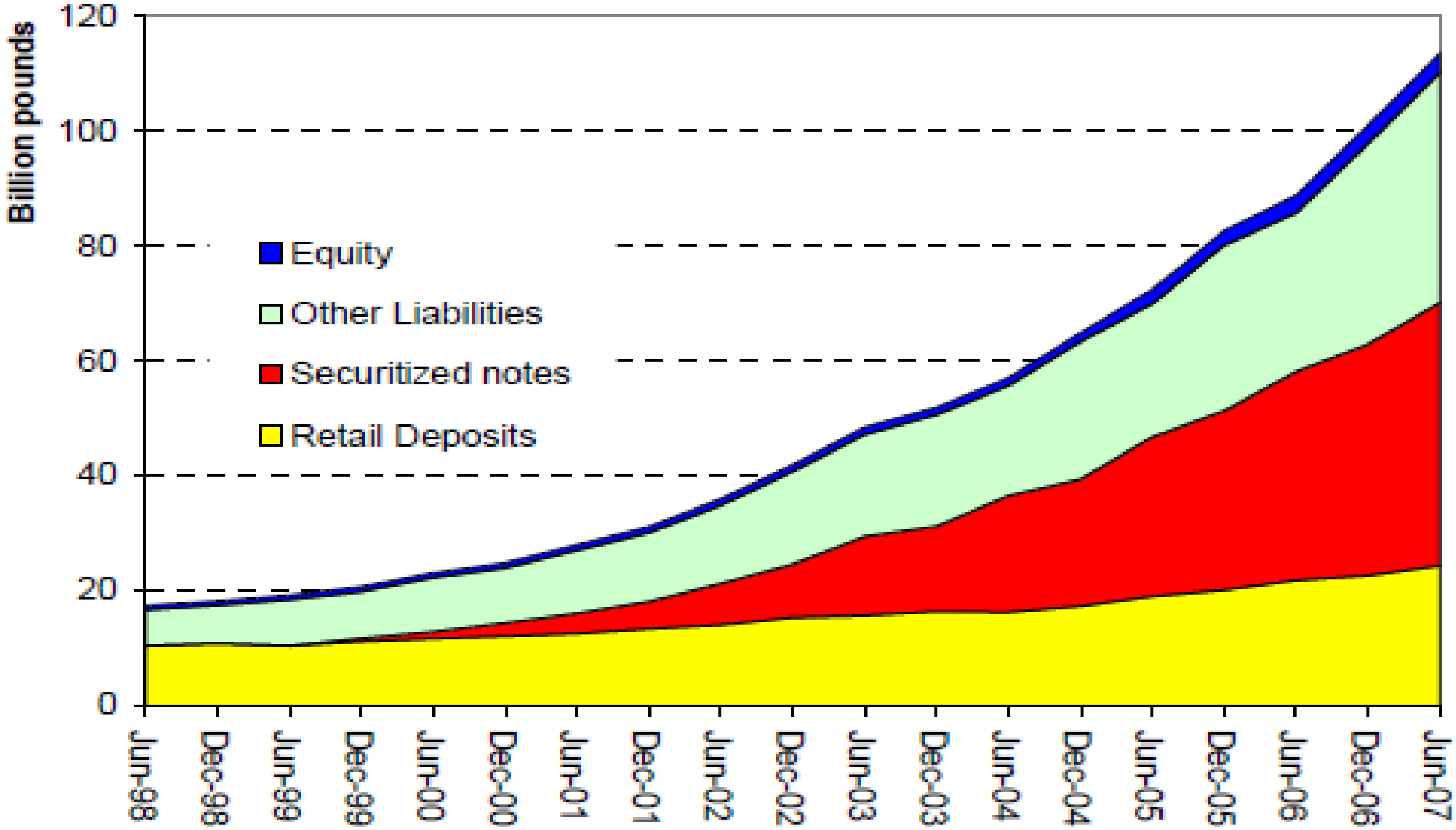


Are financial stress indexes good measures of the financial cycle?



Look at the liability side of FIs' balance sheets

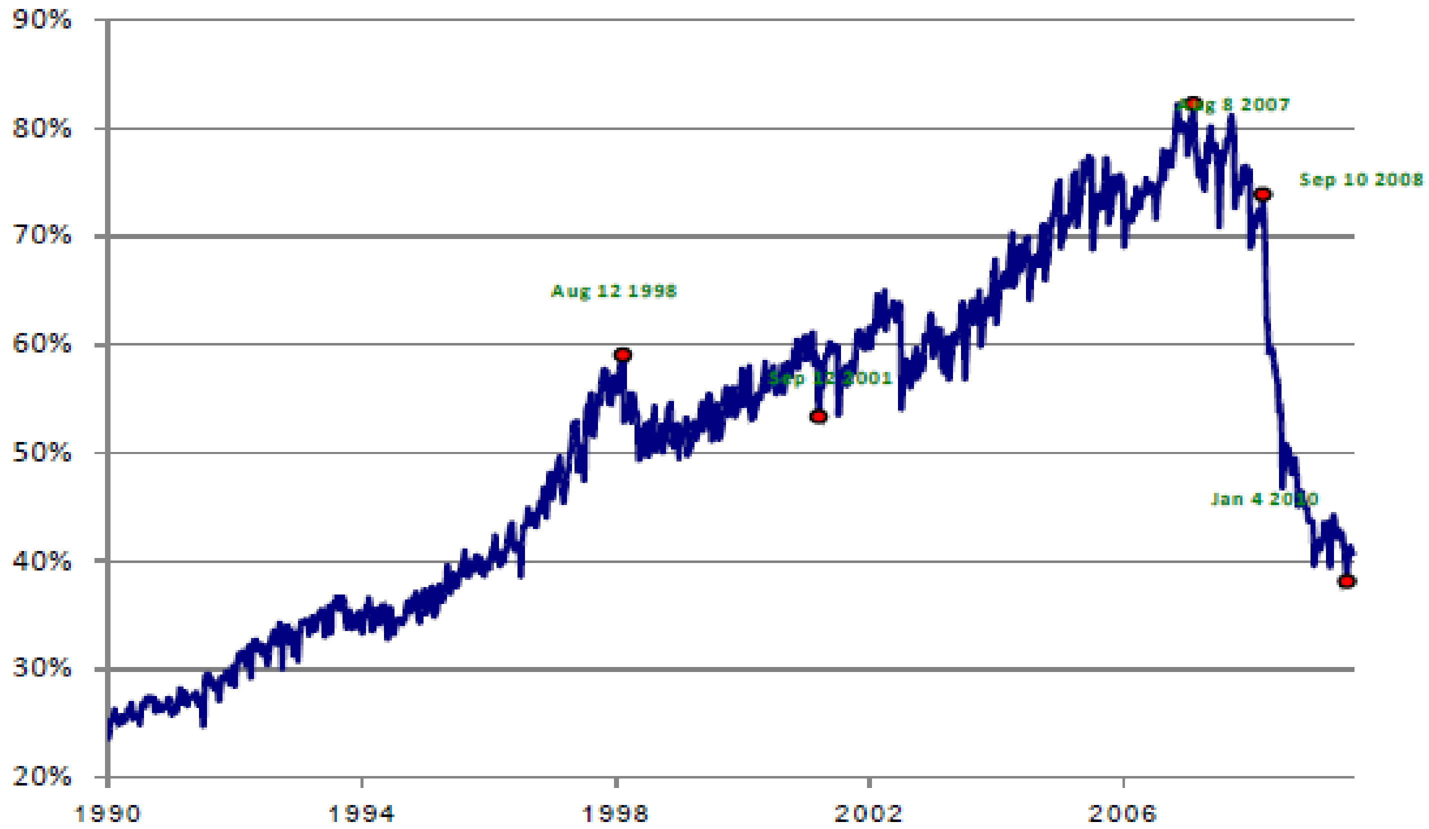
Figure 2: Northern Rock's Liabilities (1998 – 2007)



Source: Shin (2010)

Non-core liabilities of banks are an indicator of the stage of the financial cycle

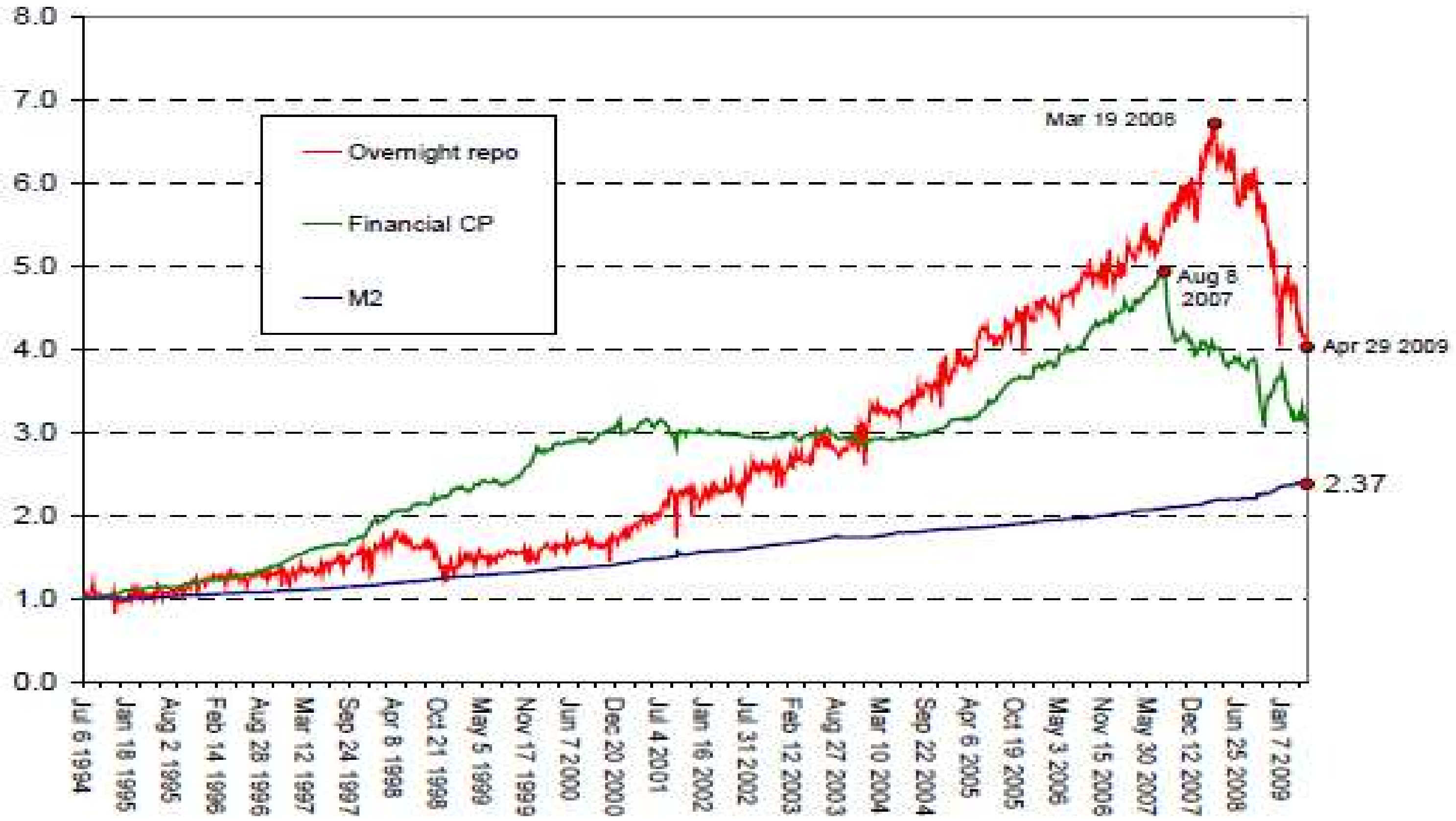
Repos and financial CP as a proportion of M2, USA



Source: Shin (2010)

The growth in non-core liabilities is accompanied by a shortening of maturity …

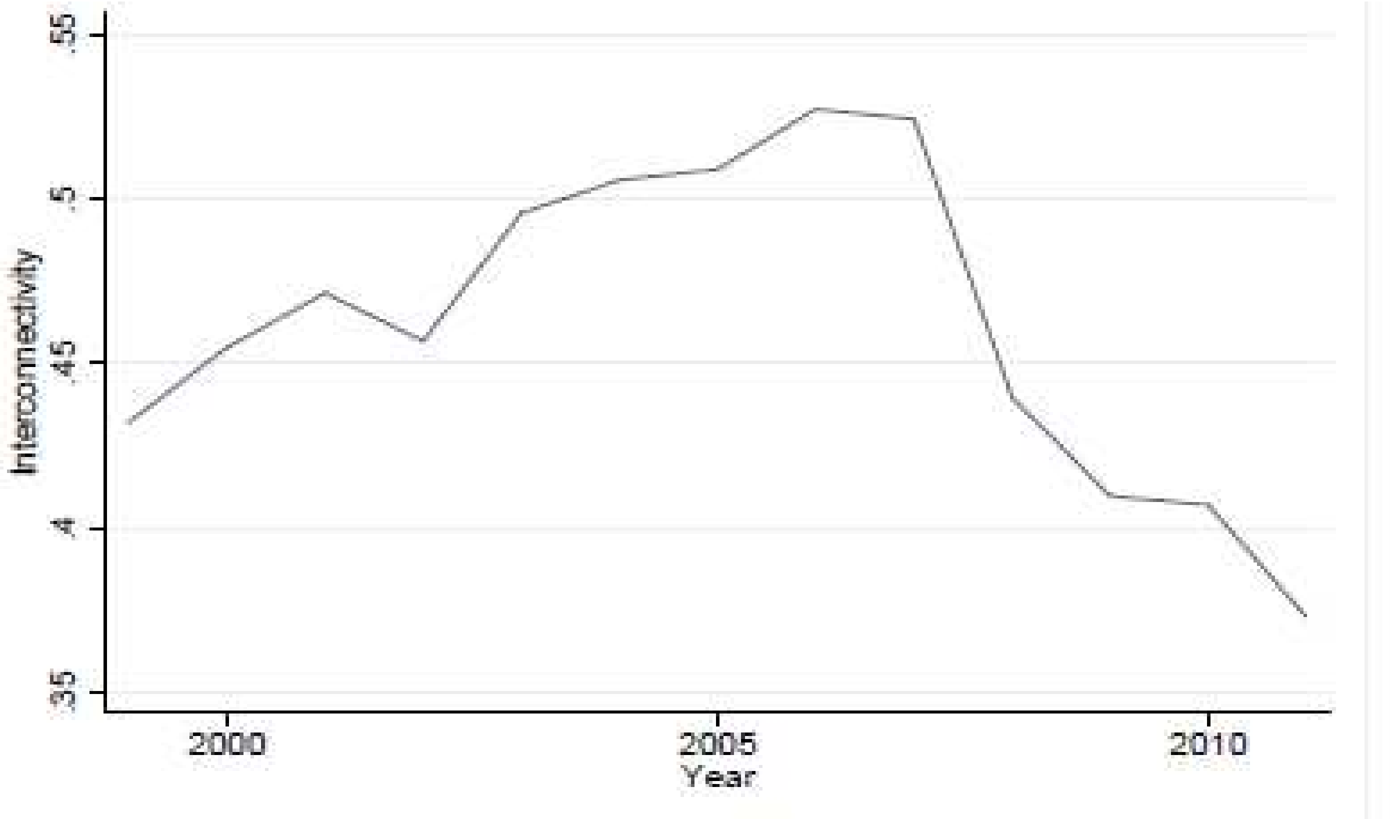
Overnight Repos and M2, normalized to 1 on July 1994.



Source: Shin (2010)

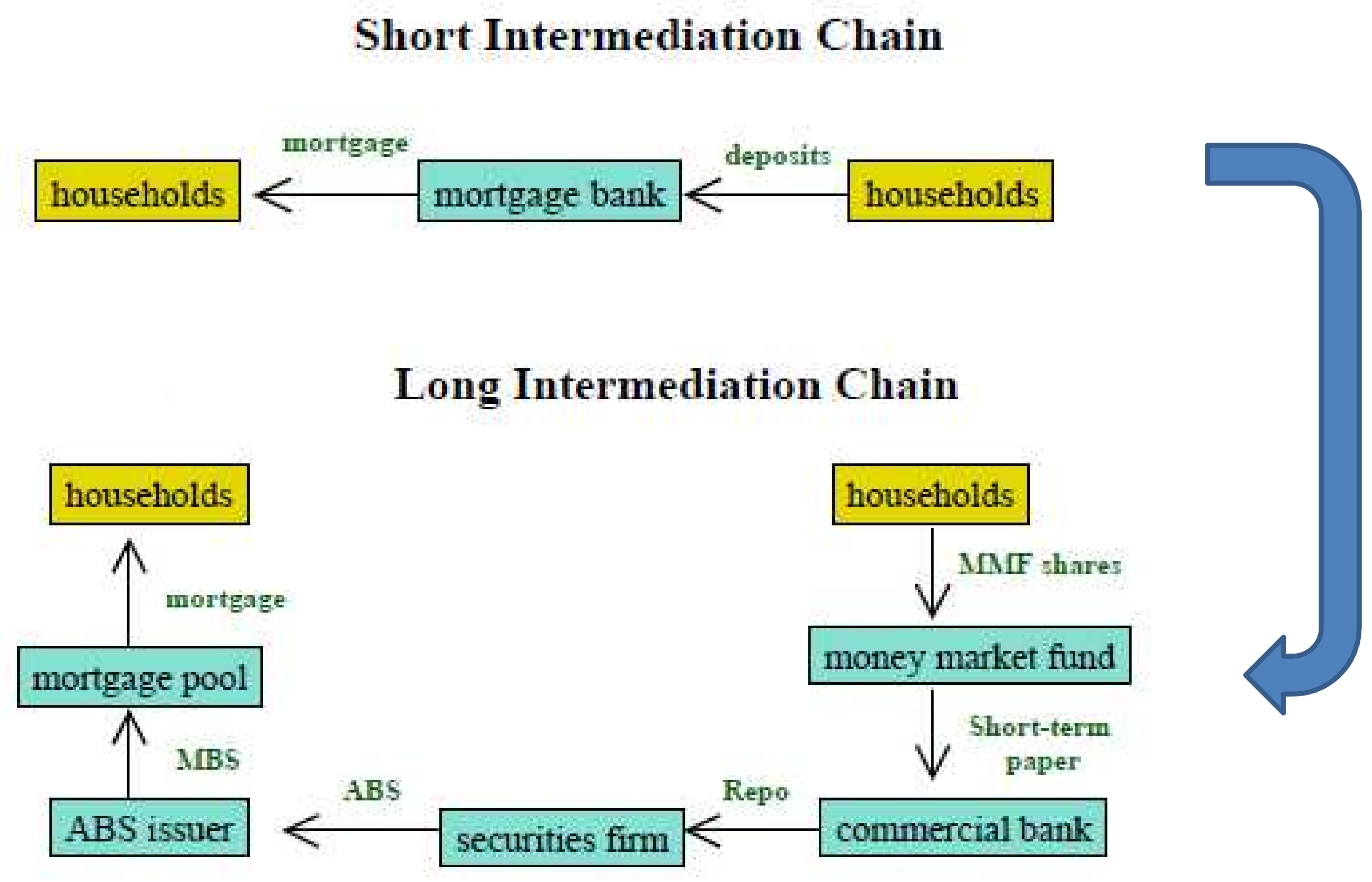
… and an increase of banks' interconnectivity

Ratio of non-core liabilities over total assets for the US banking sector



Source: Barattieri et al. (2015)

The prevalence of short-maturity liabilities is a consequence of longer intermediation chains



- Take-aways from the empirical evidence:
    i. The length and the variability of the financial cycle are higher than those of the business cycle.
    ii. Some credit booms are “bad” (ending in financial crisis) but other are not.
    iii. The leverage of financial intermediaries increases over the ascending phase of the financial cycle.
    iv. The debt of intermediaries is short-term.
    v. Leverage is associated with interconnectedness.

STRATEGIC COMPLEMENTARITIES IN RISK-TAKING

- How to explain the financial cycle?
- Financial intermediaries tend to correlate their exposure to risk because of strategic complementarities, meaning that the payoff from a certain strategy increases with the number of other agents undertaking the same strategy.
- Main examples are:
  i. anticipated bail-outs (Fahri and Tirole, 2012);
  ii. endogenously chosen correlation of returns on assets (Acharya, 2009);
  iii. concerns for reputation by bank managers paying attention to their relative performance (Rayan, 1994);
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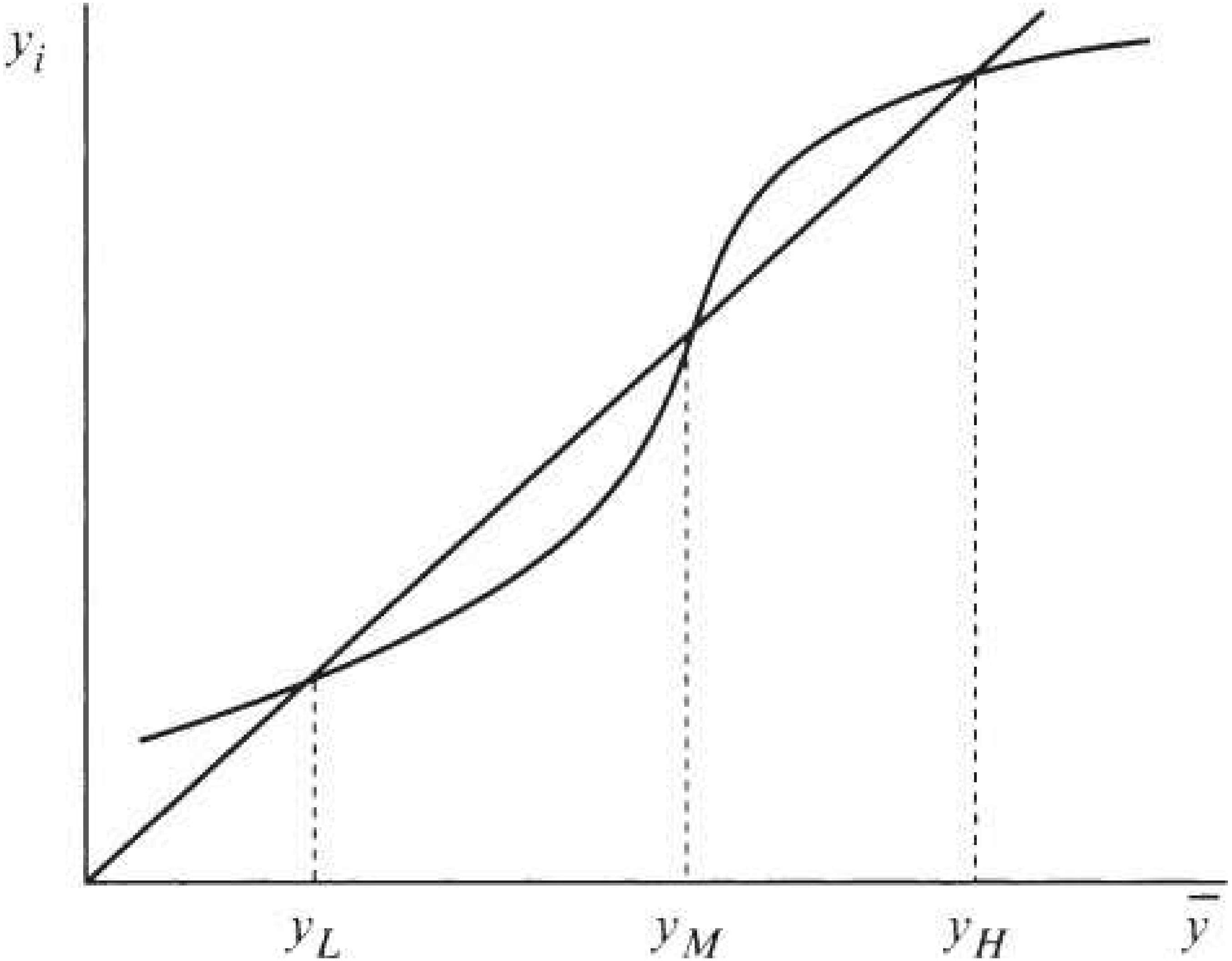
MULTIPLE EQUILIBRIA

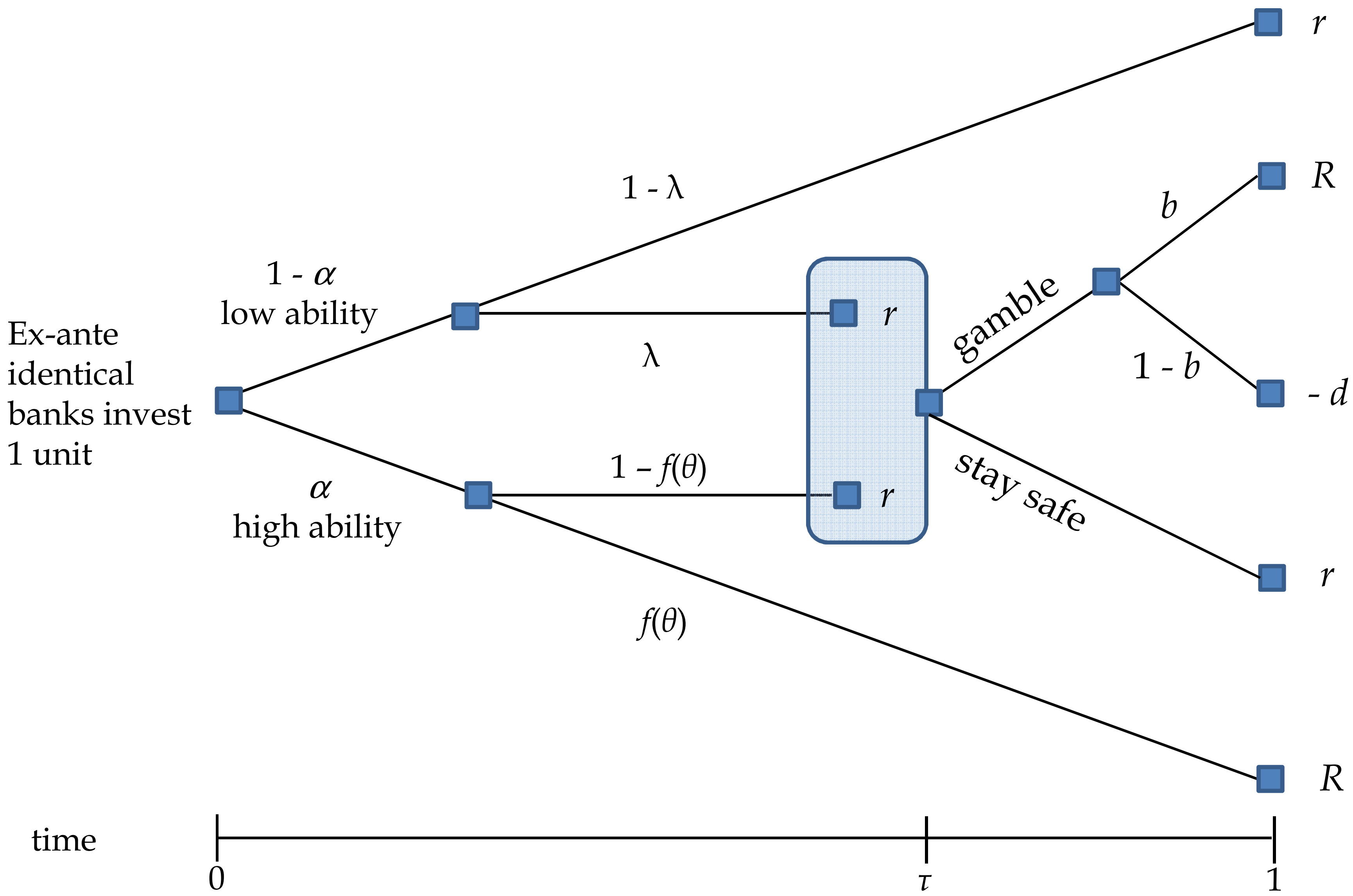


- A simple model with a financial friction generating strategic complementarities, based on Aikman *et al*. (2015)
- A dynamic extension, showing that the financial cycle can be partially disjoint from the business cycle.
- Growth in short-term credit is linked to growth of FIs' leverage.
- A natural gateway to connect the two dimensions of systemic risk.

- The model consists of three dates, $t = 0,\ \tau,\ 1$.
- There is a continuum of ex-ante identical banks of measure 1.
- In $t = 0$, each bank is endowed with 1 unit of equity, and draws its ability type, which it observes privately. With probability α the bank has high ability, and with probability $1 - \alpha$ its ability is low.
- Each bank originates a risky asset, the return on which depends on:
    i. the bank ability,
    ii. macroeconomic fundamentals, indexed by θ.
- The return can be high (R) or low (r), with $R > r > 1$.
- The return on the risky asset is observed privately by banks at $t = \tau$, and must be disclosed to the market at $t = 1$.

- A high ability bank has a probability $f(\theta)$ to receive the high return R, with $f'(\theta) > 0$. If it is unlucky, with probability $1 - f(\theta)$, it observes r.
- A low ability bank observes always r.
- Recall that results are observed privately at $t = \tau$, but disclosed to the market at $t = 1$. Banks with a low return may try to repair their financial accounts before presenting them to shareholders by taking additional risk.

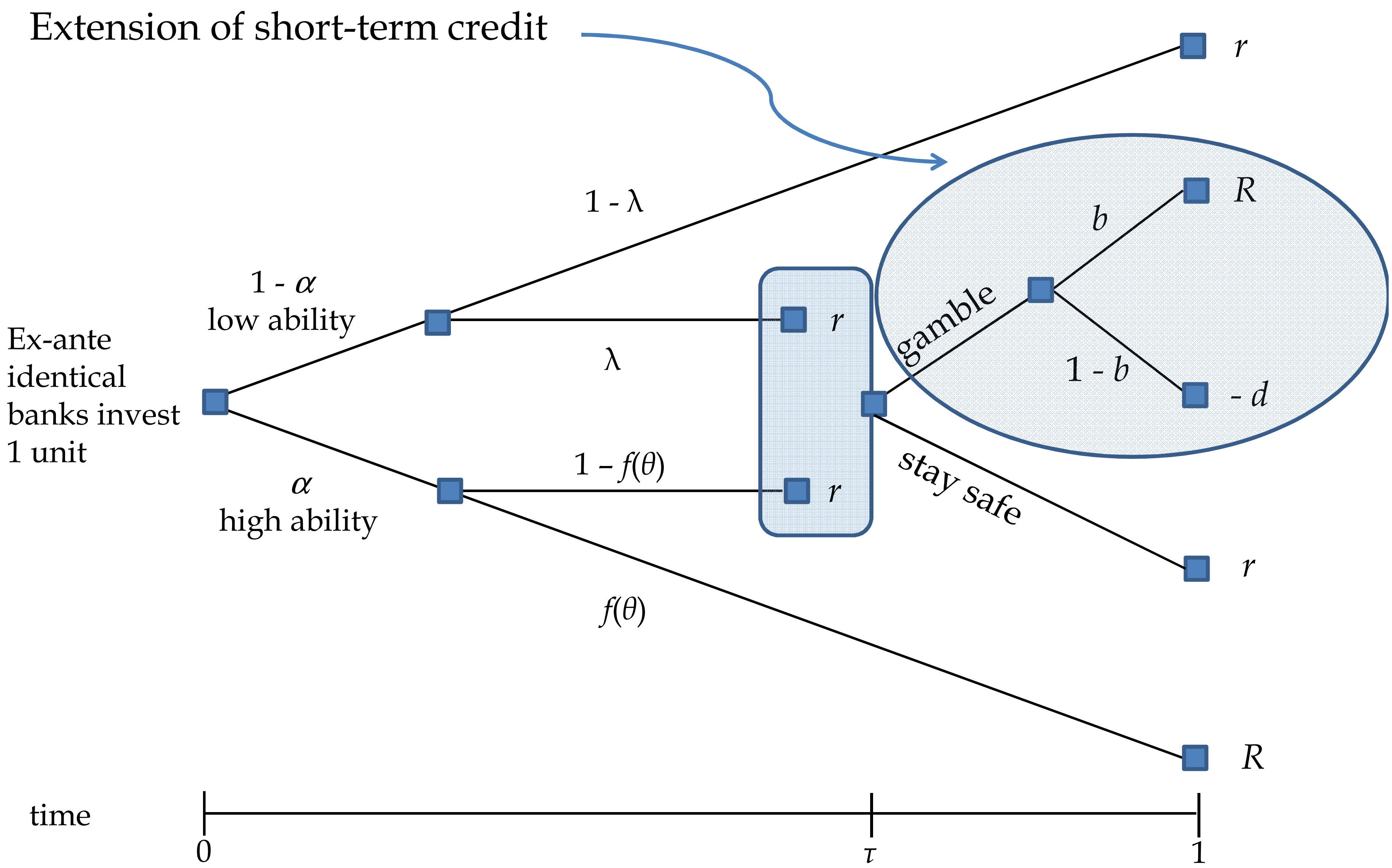
- The "gamble for resurrection" strategy is always available to unlucky high ability banks. Low ability banks can take the gamble with probability $\lambda \in (0, 1)$.
- With probability $b \in (0, 1)$ the gamble is successful and allows the bank to report R. With probability $1 - b$, however, the final results is equal to $- d < 0$.
- The probability of success of the gamble does not depend on ability.


Ex-ante identical banks invest 1 unit
1 - α
low ability
α
high ability
1 - λ
λ
1 – f(θ)
f(θ)
r
r
r
gamble
stay safe
b
1 - b
R
- d
r
R
time
0
τ
1

- Information structure
  1. Asymmetric information on type α
  2. Complete information on θ

- Pay-off returns
  1. $\alpha f(\theta)$ banks gain R
  2. $\alpha[1 - f(\theta)] + (1 - \alpha)$ banks gain r
  3. $\alpha[1 - f(\theta)] + \lambda(1 - \alpha)$ banks are allowed to take actions aimed at signaling their type (truthfully for high types, dishonestly for low types)

- $0 < \lambda < 1$ ensures that low returns signal low ability
  1. Suppose $\lambda = 1 \rightarrow$ low returns do not signal ability
  2. Suppose $\lambda = 0 \rightarrow$ low returns are a strong signal of low ability
  3. Strategic complementarities for $\lambda \leq \lambda^*$


Extension of short-term credit
r
R
b
1 - λ
gamble
1 - α
low ability
r
Ex-ante
identical
banks invest
1 unit
λ
1 - b
- d
stay safe
1 – f(θ)
α
high ability
r
r
f(θ)
R
time
0
τ
1

Risk-taking is associated to leverage

- At τ, a banker can pledge the return r to obtain a fully collateralized equal amount of short-term debt, whose interest rate is normalized to 0.
- The r units are invested in a short-term risky security. If the gamble is successful, the return is H such that the banker remains with R after repaying the debt r

$$H = R + r$$

- If the gamble is unsuccessful, the return is 1. Since the banker has to pay back r to his lender (collateralized debt has high seniority), his final payoff is

$$-d = 1 - r$$

- When gambling, the bank's leverage ratio (i.e., $\frac{asset}{equity}$) increases from 1 to 2.

- The shot-term debt, being fully collateralized by what is now a certain amount *r*, is «information-insensitive» (Gorton and Pennacchi, 1990), and adverse selection is absent.
- When this is the case, it is not profitable for any agent to produce (costly) private information about the assets backing the debt.
- Easy to add to the model the assumption that a certain time a (small) shock generates a loss of confidence in the quality of the backing collateral, causing a collateral crisis (Gorton and Ordoñez, 2014).

- The financial friction arises from coordination failures among banks, which get engaged in an arms race when reporting performance.

> *"A sound banker, alas, is not one who foresees danger and avoids it, but one who, when he is ruined, is ruined in a conventional and orthodox way with his fellows, so that no one can really blame him"*
>
> J. M. Keynes (1931)

- The reputational concern can matter for reasons linked to remuneration, future job prospects, or threatening of hostile takeovers.

- The empirical evidence suggests that poor performance comes with a damage to reputation (Rajan, 1994; Golapan *et al.*, 2011).
- We assume that a banker announcing r suffers a reputational damage $p(\theta, \ell) \in [0, 1]$, where
  - $\frac{\partial p(\theta,\ell)}{\partial \theta} > 0$ $\rightarrow$ in a boom, announcing disappointing returns has a higher reputational cost
  - $\frac{\partial p(\theta,\ell)}{\partial \ell} > 0$ $\rightarrow$ as the proportion of gamblers $\ell \in (0, 1)$ increases the reputational damage of announcing low returns increases

- Suppose a low return is privately observed in τ.
- The expected pay-off from gambling is

$$\pi(1, \theta, \ell) = bR + (1 - b)[-d - p(\theta, \ell)]$$

- While the pay-off from staying safe is

$$\pi(0, \theta, \ell) = r - p(\theta, \ell)$$

- Gambling for resurrection is ***socially inefficient*** if

$$b < \frac{d}{R + d} = \bar{b}$$

- The banker *i*'s marginal payoff to gambling is

$$\pi(\theta, \ell) = \pi(1, \theta, \ell) - \pi(0, \theta, \ell)$$
$$= \{bR + (1 - b)[-d - p(\theta, \ell)]\} - [r - p(\theta, \ell)]$$
$$= b[R + p(\theta, \ell)] - (1 - b)d - r$$

- The better is the macro state, the greater bank's incentive to pursue risky projects to preserve reputation, as the market attributes low returns to low ability.
- One bank's announcement of high earnings encourages others to announce high returns by setting risky policies too.

- The number of equilibria depends on θ:
    i. In sufficiently good states, banks coordinate on risky policies («credit booms»).
    ii. If the macroeconomic state is sufficiently low, banks coordinate on safe policies («credit crunches»).
    iii. In between, either equilibria are possible (self-fulfilling expectations).

- The credit boom comes with socially inefficient risk-taking due to the reputational externality.

- Multiple equilibria models have downsides:
    i. Lose predictive power – just knowing the parameters of the economy can't say which equilibrium it will be in.
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GLOBAL GAMES (Carlsson and Van Damme, 1993; Morris and Shin, 1998; 2003)

- Multiplicity of equilibria arises from the implicit assumption of common knowledge of the fundamental.
- A ***global game*** is a game of incomplete information within a strategic environment in which players receive private signals on unknown economic fundamentals.
- The private signal offers information about the fundamental, but little or no information about the information embedded in others' signals. Even if the idiosyncratic noise is tiny, players remain highly uncertain about others‘ actions.
- The entire hierarchy of beliefs can be captured in sufficient statistics by means of iterative deletion of dominated strategies.

- Before the game starts, a state $\theta \in \Re$ is drawn from an uniform distribution on the real line.
- This represents a *diffuse* (i.e., uninformative) common prior belief about θ. Combined with the probability distribution of new data it yields a posterior distribution, which in turn is used for future inferences and decisions.
- Each bank $i \in [0, 1]$ receives a noisy private signal about the fundamental state of the economy

$$x_i = \theta + \sigma\varepsilon_i, \qquad \sigma > 0$$

where $\frac{1}{\sigma^2}$ denotes precision, while ε_i has a continuous density $g(.)$ with support $\Re$.

- Conditional probabilities are well defined: a player observing signal x_i puts posterior density $\left(\frac{1}{\sigma}\right) g\left(\frac{x_i-\theta}{\sigma}\right)$ on state θ.

- Pay-offs satisfy the following properties:

  i. ***Action Monotonicity***: $\pi(\theta, \ell)$ is non-decreasing in ℓ.

  ii. ***State Monotoni*** … $\pi(\theta, \ell)$ is non-decreasing in θ.

  iii. ***Strict Laplaci*** … ique θ^* solvi …

  iv. … ch

  2) $\pi(\theta, \ell) > \varepsilon$ for all $\ell \in [0, 1]$ and $\theta \leq \overline{\theta}$;

  v. ***Continuity***: $\int_{\ell=0}^{1} g(\ell)\pi(x,\ell)d\ell$ is continuous with respect to signal x and density $g(.)$.

  vi. ***Finite expectations of signals***: $\int_{-\infty}^{\infty} zg(z)dz$ is well defined.

> The are ***strategic complementarities*** between players' actions: the best response of bank *i* to an increase in the number of competitors gambling is to gamble as well.

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  iv. *Li* … uch

The equilibrium response to a common shock to the state exceeds the partial response by an agent taking the actions of other as given: ***multiplier***.

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When θ increases, the initial response of a bank with r is to gamble. The aggregate response is magnified by the presence of strategic complementarity. Better macroeconomic fundamentals comes with stronger risk-taking

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  i. *Action Monotonicity*: $\pi(\theta, \ell)$ is non-decreasing in ℓ.

  ii. *State Monotonicity*: $\pi(\theta, \ell)$ is non-decreasing in θ.

  iii. ***Strict Laplacian Monotonicity***: there exists a unique θ^* solving $\int_{\ell=0}^{1} \pi(\theta *, \ell) d\ell = 0$.

  iv. *Limit Dominan*... ere exist $\underline{\theta} \in \Re$, $\bar{\theta} \in \Re$ and $\varepsilon > 0$ such that

  vi. *Finite expectations of signals*: $\int_{-\infty}^{\infty} zg(z)dz$ is well defined.

There is at most one crossing for a player with Laplacian beliefs. This means that strategic complementarity is necessary and sufficient for multipliers (Cooper and John, 1988; Proposition 3)

- Pay-o

> Staying safe is a dominant strategy for sufficiently low signal, while gambling is a dominant strategy for sufficiently high signal.

i.

ii. *St*

iii. ***Strict Laplaci***... there exists a unique θ^* solving $\int_{\ell=0}^{1} \pi(\theta$ ... $)d\ell = 0$.

iv. ***Limit Dominance***: there exist $\underline{\theta} \in \Re$, $\bar{\theta} \in \Re$ and $\varepsilon > 0$ such that

1) $\pi(\theta, \ell) \leq -\varepsilon$ for all $\ell \in [0, 1]$ and $\theta \leq \underline{\theta}$;
2) $\pi(\theta, \ell) > \varepsilon$ for all $\ell \in [0, 1]$ and $\theta \leq \overline{\theta}$;

v. ***Continuity***: $\int_{\ell=0}^{1} g(\ell)\pi(x,\ell)d\ell$ is continuous with respect to signal x and density $g(.)$.

vi. ***Finite expectations of signals***: $\int_{-\infty}^{\infty} zg(z)dz$ is well defined.

- Pay-offs satisfy the following properties:

  i. ***Action Monotonicity***: $\pi(\theta, \ell)$ is non-decreasing in ℓ.

  ii. ***State Monotonicity***: $\pi(\theta, \ell)$ is non-decreasing in θ.

  iii. ***Strict Laplacian Monotonicity***: there exists a unique θ^* solving $\int_{\ell=0}^{1} \pi(\theta *, \ell) d\ell = 0$.

  iv. ***Limit Do***... ...d $\varepsilon > 0$ such that

  1) $\pi(\theta,$ ...
  2) $\pi(\theta, \ell) > \varepsilon$ fo... $\in [0, 1]$ and $\theta \leq \overline{\theta}$;

Standard regularity conditions

  v. ***Continuity***: $\int_{\ell=0}^{1} g(\ell)\pi(x, \ell) d\ell$ is continuous with respect to signal x and density $g(.)$.

  vi. ***Finite expectations of signals***: $\int_{-\infty}^{\infty} z g(z) dz$ is well defined.

- After receiving the signal, a banker observing low returns and with the possibility to gamble faces a binary option

$$\{gamble, safe\}$$

to maximize his expected pay-off.

- Suppose i uses a switching strategy

$$s(x) = \{gamble \text{ if } x_i \geq \theta^*; safe \text{ if } x_i < \theta^*\}$$

- If the six conditions above hold true, the following result from Morris and Shin (2003) applies

Let θ^* be defined by condition *iii*). For any $\delta > 0$, there exists $\bar{\sigma} > 0$ such that for all $\sigma < \bar{\sigma}$, if strategy s survives iterated deletion of strictly dominated strategies, then $s(x) = \{safe\}$ for all $x \leq \theta^* - \delta$ and $s(x) = \{gamble\}$ if $x > \theta^* + \delta$.

- In our model the unique symmetric switching equilibrium θ^* is given by

$$\int_0^1 p(\theta^*, \ell)d\ell = \frac{(1-b)d + r - bR}{b}$$

- Suppose $p(\theta, \ell) = \theta + \ell - 1$. It follows

$$\theta^* = \frac{1}{2} + \frac{1-b}{b}d - (bR - r)$$

Cost of adopting a risky strategy

Expected gain from gambling

- Note that $\frac{\partial \theta^*}{\partial d} > 0$; $\frac{\partial \theta^*}{\partial b} < 0$.

- The support of the fundamental can be divided into two regions:
  1. $\theta < \theta^*$: banks coordinate on choosing the safe option conditional on observing low initial returns. Fundamentals are not sufficiently high to cause severe reputational damage in announcing low returns when all other banks do so too.
  2. $\theta > \theta^*$: high fundamentals imply a large degree of reputational damage in announcing low return. All banks coordinate on the gambling option, to minimize the reputational downside to having made a bad initial investment.

A SIMPLE DYNAMIC EXTENSION

- Suppose the same game is played for T periods, and that strategic complementarities operate both within and between periods:

$$p(\theta, \ell, \ell_{-1})$$

with $\frac{\partial p(.)}{\partial \ell_{-1}} > 0 \rightarrow$ as the proportion of gamblers increases during the last period, the reputational damage of announcing low returns today increases.

- Rationale: the gambling scenario involves credit extension to the non-financial sector, as well as credit extension within the financial sector. Suppose that the higher was credit in the last period, the worst is for reputation to shrink it now (ex., Thakor, 2005).

- $p(\theta, \ell, \ell_{-1}) = \theta + \ell + \chi\ell_{-1} - 1$
- The fraction of banks that can gamble is

$$\omega(\theta) = \alpha[1 - f(\theta)] + \lambda(1 - \alpha), \text{ with } \omega'(\theta) < 0$$

- Let's see what happens period by period

$$t = 0 \quad \rightarrow \quad \hat{\theta}_0 = \frac{1}{2} + \frac{1-b}{b} d - (bR - 1) = \theta^*$$

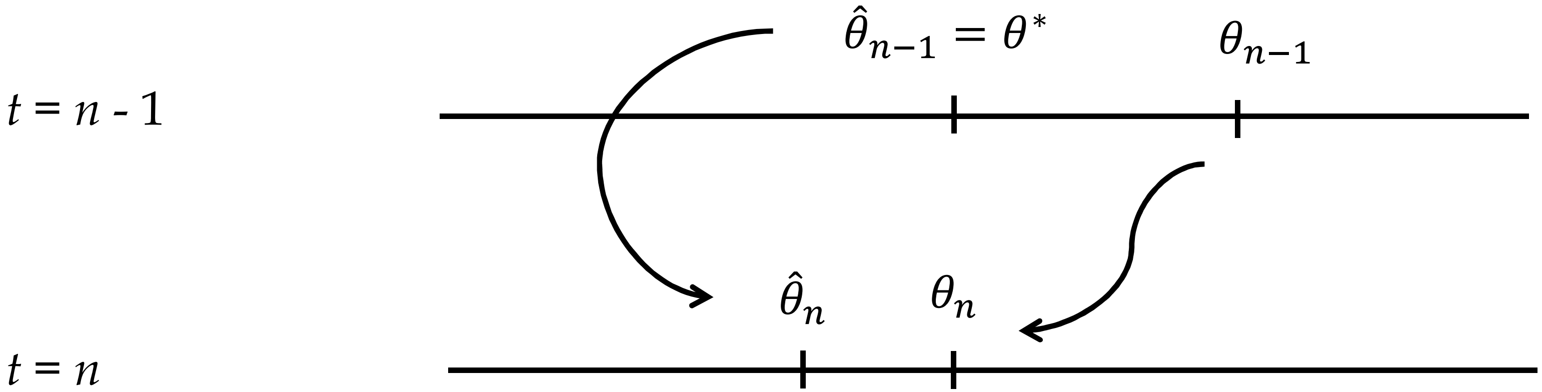
$$t = 1 \quad \rightarrow \quad \hat{\theta}_1 = \theta^* - \omega(\theta_0) \frac{\chi}{\sigma} F\left(\frac{\theta_0 - \hat{\theta}_0}{\sigma}\right)$$

…

$$t = n \quad \rightarrow \quad \hat{\theta}_n = \theta^* - \omega(\theta_{n-1}) \frac{\chi}{\sigma} F\left(\frac{\theta_{n-1} - \hat{\theta}_{n-1}}{\sigma}\right)$$

- For a sufficiently precise private signal
  - If $\theta_{n-1} > \hat{\theta}_{n-1} \rightarrow \hat{\theta}_n = \theta^* - \omega(\theta_{n-1})\chi$, as $\frac{1}{\sigma} F\left(\frac{\theta_{n-1}-\hat{\theta}_{n-1}}{\sigma}\right) \rightarrow 1$
  - If $\theta_{n-1} < \hat{\theta}_{n-1} \rightarrow \hat{\theta}_n = \theta^*$, as $\frac{1}{\sigma} F\left(\frac{\theta_{n-1}-\hat{\theta}_{n-1}}{\sigma}\right) \rightarrow 0$
- Now the switching threshold oscillates over time, and the financial cycle may be disconnected from the business cycle.

- Suppose the history is such that at $t = n - 1$ we inherit $\hat{\theta}_{n-1} = \theta^*$, and the economy enters a real boom, i.e. $\theta_{n\text{-}1} > \theta^*$.
- Suppose also that the following period the real economy gets back to its normal, $\theta_n = \theta^*$.



- Let's change slightly the assumptions regarding the reputational damage.
- Suppose that each agent is compared with just one mate at a time, but agents are organized as a network (N, g).
- "Never gamble alone!" is motto

1) $\pi(0, \theta, 0) = r$ → p = 0
2) $\pi(0, \theta, 1) = r - 1 = d$ → p = 1
3) $\pi(1, \theta, 1) = bR - d(1 - b) = \gamma$ → p = 0
4) $\pi(1, \theta, 0) = bR - (1 + d)(1 - b) = \kappa$ → p = 1

- Example: $R = 1.5$; $r = 1.2$

If $0.24 < b < 0.89$ for example $b = 0.5$

$\gamma = 0.65$ $\kappa = 0.15$

	1	0
1	0.65; 0.65	0.15; 0.2
0	0.2; 0.15	1.2; 1.2

As we normalize
d to 0

	1	0
1	L; L	- C; 0
0	0; - C	H; H

- Two Nash equilibria.
- The equilibrium (0; 0) is payoff-dominant
- The solution depends on expectations
  - If $q > q^*$ play 1
  - If $q < q^*$ play 0
  - where $q^* = \frac{C+H}{L+C+H}$.
- The topological structure of the network matters. Suppose small trembles are admitted. If the network is ***complete*** the unique stochastically stable state is the risk-dominant equilibrium (Kandori et al., 1993).
- If the network is a star, two stochastically stable states depending on what the hub plays (Jackson and Watts, 2002).

Thank you all!

Edoardo Gaffeo
Department of Economics and Management
University of Trento