Asset Price Bubbles and Systemic Risk

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Outline

Motivation

- **Financial crises** are frequently related to booms and busts in asset prices (Borio and Lowe, 2002)
- Bursting asset price **bubbles** can give rise to systemic financial crises
- Not all bubbles are equally harmful (dotcom vs. US subprime housing bubble)
- Severity of crises depend on financial sector developments (**spillovers, contagion risk**)

Literature

- **Bubbles and financial crises**: historical account
  - Shiller (2000); Garber (2000); Kindleberger and Aliber (2005); Allen and Gale (2007); Reinhart and Rogoff (2009); Brunnermeier and Schnabel (2016)
- **Spillovers and contagion risk** due to liquidity and loss spirals
  - Shleifer and Vishny (1992, 1997, 2011); Allen and Gale (1994); Kiyotaki and Moore (1997, 2005); Brunnermeier and Pedersen (2009); Acharya and Viswanathan (2011); Diamond and Rajan (2011); ...
- Effect of macroeconomic variables (including bubbles) on likelihood and costliness of financial crises
  - Jordà, Schularick and Taylor (2015a,b) based on long-run historical data
- Our focus: econometric analysis of the role of bank-level developments in the build-up of systemic risk during asset price bubbles

Research question

- What is the link between asset price bubbles and systemic risk at the bank level?
  - Real estate and stock market bubbles
  - 1,438 banks in 17 countries over almost 30 years
- Does this relationship depend on ...
  - ... bank characteristics?
    - bank size, loan growth, leverage, maturity mismatch
  - ... bubble characteristics?
    - asset classes (stocks vs. real estate)
    - bubble stages (boom vs. bust phase)
    - size and length

Key challenges

What is the link between asset price bubbles and systemic risk at the bank level?

- **Bubbles** need to be identified
  (avoid a sample selection bias)

- **Spillovers/contagion risks** need to be quantified at bank level
  (systemic risk contributions)

Outline

Real estate and stock market bubble episodes

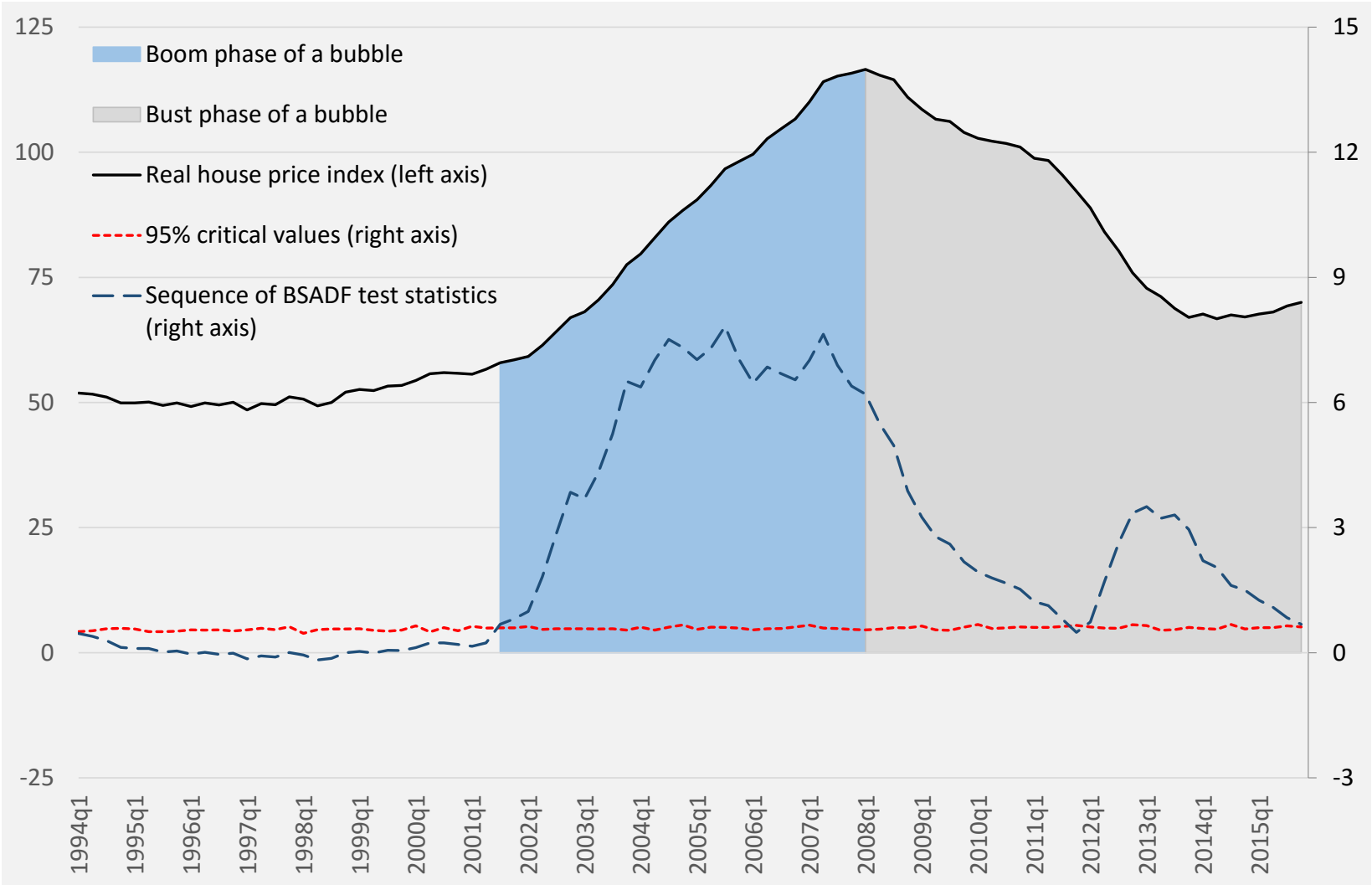
The BSADF test (Phillips, Shi and Yu, 2015a, 2015b)

- Agnostic approach, commonly used in the literature
- Outperforms comparable approaches in terms of size and power in case of multiple bubble episodes within a sample (Breitung and Homm, 2012; Phillips, Shi and Yu 2015a)

- Key idea
  - Search for **episodes of explosiveness**
  - Systematically consider subsamples of a price series to also detect bubbles emerging in rapid succession

Estimation of bubble episodes

Example: the recent Spanish real estate bubble



Descriptive statistics on bubble episodes

	Real estate		Stock market	
	Boom	**Bust**	**Boom**	**Bust**
Number of episodes				
Average per country	1.9	1.6	2.8	2.7
Min per country	1	0	1	1
Max per country	4	5	5	5
Total	35	28	50	49
Length of episodes				
Average	60	13	21	6
Min	10	1	3	1
Max	318	93	64	37

Differences in the number of booms and busts of bubble episodes are due to bubbles that take place only partly during the sample period.

Measurement of systemic risk contributions

ΔCoVaR (Adrian and Brunnermeier, 2016)

- Key idea
  - Compare the value at risk (VaR) of the financial system conditional on an institution being under distress and conditional on it being in a normal state
  - The estimation is based on **tail correlations** of equity returns
- Advantage for the main analysis
  - Estimation of institution-specific systemic risk contributions
  - Account for general risk factors (e. g. stock market volatility) during these estimations

Estimation of ΔCoVaR

Estimate the value at risk of institution i based on quantile regressions:

$$\widehat{VaR}^{i}_{q,t} = \hat{X}^{i}_{t} = \hat{\alpha}^{i}_{q} + \hat{\gamma}^{i}_{q} M_{t-1} \tag{1}$$

Estimate the conditional VaR of the financial system:

$$\hat{X}^{system|i}_{q,t} = \hat{\alpha}^{system|i}_{q} + \hat{\gamma}^{system|i}_{q} M_{t-1} + \hat{\beta}^{system|i}_{q} X^{i}_{t} \tag{2}$$

$$CoVaR^{i}_{q,t} = \hat{\alpha}^{system|i}_{q} + \hat{\gamma}^{system|i}_{q} M_{t-1} + \hat{\beta}^{system|i}_{q} \widehat{VaR}^{i}_{q,t} \tag{3}$$

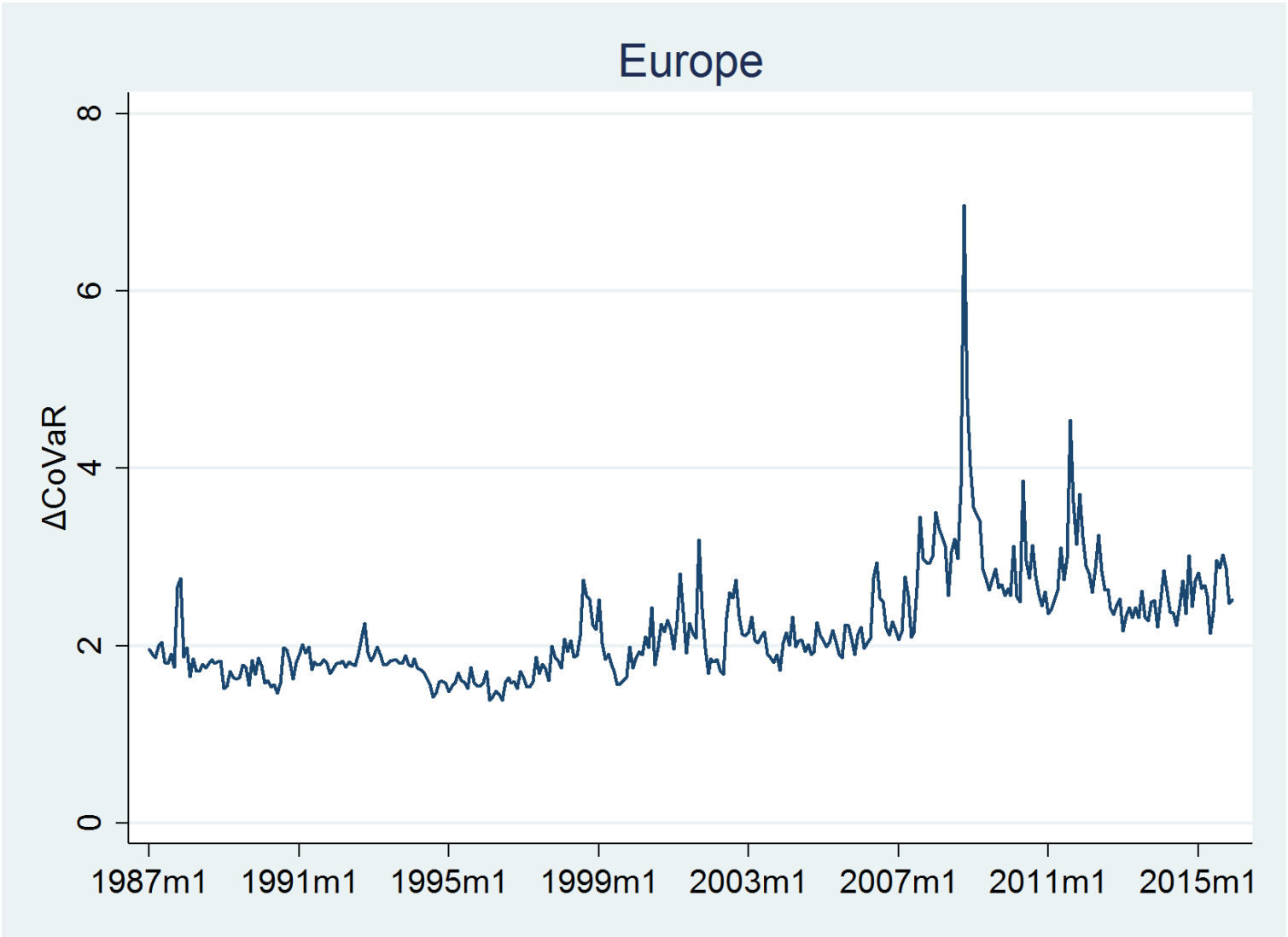
Then:

$$\Delta CoVaR^{i}_{q,t} = CoVaR^{i}_{q,t} - CoVaR^{i}_{50,t} \tag{4}$$

Where

- X: return losses on market equity
- M: general risk factors at the financial-system level
- q: quantile of the quantile regressions

Measurement of systemic risk - estimation results



Unweighted mean of ΔCoVaR in weekly percentage points for the European financial system.

Data sources

Estimation of bubble episodes

- Real estate data: OECD
- Stock market data: Datastream (and OECD)

Estimation of systemic risk contributions

- Equity market data: Datastream
- System-level risk factors: Bloomberg, Datastream, OECD, FRED

Balance sheet data

- Bankscope

Macroeconomic variables for the main analysis

- BIS, OECD, Datastream, National Central Banks

Descriptive statistics

Variable	Mean	Median	Std. Dev.	Min	Max
Dependent variable					
ΔCoVaR	1.96	1.68	1.65	-9.33	26.12
Bank characteristics					
Bank size [billion USD]	67.19	2.02	266.87	0.02	3,807.89
log(bank size)	1.23	0.64	2.19	-2.39	7.20
Loan growth	0.007	0.006	0.015	-0.046	0.074
Leverage	13.43	11.70	7.14	1.04	52.51
Maturity mismatch	0.69	0.75	0.19	-0.10	0.89
Macroeconomic variables					
Real GDP growth	0.021	0.022	0.020	-0.102	0.076
Interest rate	4.21	4.20	1.81	0.12	15.14
log(interest rate)	1.33	1.43	0.51	-2.12	2.72
Inflation	0.021	0.021	0.013	-0.025	0.123
Investment-to-GDP growth	-0.004	0.010	0.061	-0.501	0.274
Credit-to-GDP growth	0.010	0.014	0.035	-0.129	0.207

Final dataset: 1,438 banks in 17 OECD countries over the period 1987m1 - 2015m12.

Baseline model

$$\Delta CoVaR_{i,t} = \alpha_i + \beta \cdot Bubble_{c,t} + \gamma \cdot B_{i,t-1} + \delta \cdot Bubble_{c,t} \cdot B_{i,t-1} + \lambda \cdot C_{c,t-1} + u_{i,t}$$

- Dimensions: bank(i), country(c), time(t)
- α: bank fixed effects
- *Bubble*: vector of bubble indicators
- B: bank characteristics (demeaned)
  - size, loan growth, leverage, maturity mismatch
- C: country-specific macroeconomic variables
  - credit-to-GDP growth, inflation, GDP growth, investment growth, interest rates
- Standard errors: clustered at bank and country-time level

Outline

Asset price bubbles and systemic risk in booms and busts

	(1)	(2)	(3)	(4) Baseline
Real estate boom	0.02	0.07	0.04	0.00
	(0.604)	(0.251)	(0.573)	(0.935)
Real estate bust	0.50***	0.38***	0.28**	0.24*
	(0.000)	(0.003)	(0.032)	(0.055)
Stock market boom	0.11**	0.29***	0.36***	0.33***
	(0.027)	(0.000)	(0.000)	(0.000)
Stock market bust	0.27***	0.33***	0.36***	0.36***
	(0.000)	(0.000)	(0.000)	(0.000)
Bank FE	Yes	Yes	Yes	Yes
Macroeconomic Controls	No	Yes	Yes	Yes
Bank characteristics	No	No	Yes	Yes
Bank characteristics · Bubble indicators	No	No	No	Yes
No. of banks	1,264	1,264	1,264	1,264
No. of obs.	165,149	165,149	165,149	165,149
Adj. R^2	0.810	0.817	0.823	0.827
Adj. R^2 within	0.037	0.073	0.100	0.120

The role of bank characteristics during bubble episodes (1)

	(1) Baseline continued	(2) Quarterly obs.	(3) Country-time FE
log(Bank size)	0.27***	0.22***	0.01
	(0.000)	(0.000)	(0.818)
log(Bank size) · Real estate boom	0.00	0.01	-0.04*
	(0.895)	(0.500)	(0.093)
log(Bank size) · Real estate bust	0.15***	0.15***	0.20***
	(0.000)	(0.001)	(0.000)
log(Bank size) · Stock market boom	0.05***	0.03	0.07***
	(0.007)	(0.122)	(0.001)
log(Bank size) · Stock market bust	0.11***	0.14***	0.14***
	(0.000)	(0.000)	(0.000)
Loan growth	-4.38***	-4.33***	-2.01***
	(0.000)	(0.000)	(0.000)
Loan growth · Real estate boom	4.38***	4.21***	2.22***
	(0.000)	(0.000)	(0.000)
Loan growth · Real estate bust	7.95***	7.86***	3.17**
	(0.000)	(0.000)	(0.015)
Loan growth · Stock market boom	3.26***	3.36***	0.69
	(0.000)	(0.001)	(0.194)
Loan growth · Stock market bust	3.92***	4.28***	1.14*
	(0.000)	(0.000)	(0.082)

The role of bank characteristics during bubble episodes (2)

	(1) Baseline continued	(2) Quarterly obs.	(3) Country-time FE
Leverage	0.01***	0.01***	0.00**
	(0.005)	(0.004)	(0.040)
Leverage · Real estate boom	0.01**	0.01	0.01***
	(0.030)	(0.153)	(0.000)
Leverage · Real estate bust	-0.01	-0.01	-0.01***
	(0.196)	(0.180)	(0.004)
Leverage · Stock market boom	-0.01***	-0.01**	-0.01***
	(0.001)	(0.013)	(0.002)
Leverage · Stock market bust	-0.02***	-0.02***	-0.02***
	(0.000)	(0.004)	(0.000)
Maturity mismatch	-0.68***	-0.64***	-0.32***
	(0.000)	(0.000)	(0.006)
Maturity mismatch · Real estate boom	0.27***	0.30***	0.18**
	(0.006)	(0.010)	(0.033)
Maturity mismatch · Real estate bust	0.45**	0.56**	-0.13
	(0.034)	(0.042)	(0.436)
Maturity mismatch · Stock market boom	0.67***	0.59***	0.03
	(0.000)	(0.000)	(0.743)
Maturity mismatch · Stock market bust	0.38***	0.54***	-0.02
	(0.007)	(0.009)	(0.787)
Bubble indicators	Yes	Yes	No
Bank FE	Yes	Yes	Yes
Country-time FE	No	No	Yes
No. of banks	1,264	1,262	1,264
No. of obs.	165,149	55,128	165,192
Adj. R^2	0.827	0.849	0.891
Adj. R^2 within	0.120	0.137	0.044

The importance of bank-level developments

Percentile of bank characteristics	(1) 50^{th}	(2) 75^{th}	(3) 85^{th}	(4) 95^{th}
Real estate boom	0.00	0.09	0.15*	0.30***
	(0.977)	(0.285)	(0.100)	(0.006)
Real estate bust	0.21	0.55***	0.72***	1.04***
	(0.106)	(0.001)	(0.000)	(0.000)
Stock market boom	0.38***	0.48***	0.50***	0.52***
	(0.000)	(0.000)	(0.000)	(0.000)
Stock market bust	0.37***	0.56***	0.62***	0.70***
	(0.000)	(0.000)	(0.000)	(0.000)
Bank FE	Yes	Yes	Yes	Yes
Bank characteristics	Yes	Yes	Yes	Yes
Bank characteristics · Bubble indicators	Yes	Yes	Yes	Yes
Macroeconomic control variables	Yes	Yes	Yes	Yes
No. of banks	1,264	1,264	1,264	1,264
No. of obs.	165,149	165,149	165,149	165,149
Adj. R^2	0.827	0.827	0.827	0.827
Adj. R^2 within	0.120	0.120	0.120	0.120

Bank size and loan growth contribute most to this pattern. Bubble episodes are associated with systemic risk increased by up to two standard deviations of ΔCoVaR aggregated at the financial-system level.

Bubble characteristics

- *Length*: number of months since the beginning or climax of the respective bubble phase and episode
- *Size*: asset price relative to its pre-bubble level during the boom or relative to its peak level during the bust
- both variables equal zero in the absence of the bubble

Descriptive statistics during bubble episodes

Variable	Mean	Median	Std. Dev.	Min	Max
Length					
Stock market boom	29	28	17.8	1	64
Stock market bust	8	8	5.5	1	37
Real estate boom	69	68	40.1	1	318
Real estate bust	15	10	16.8	1	93
Size					
Stock market boom	0.78	0.72	0.54	0.00	8.42
Stock market bust	0.12	0.13	0.08	0.00	0.35
Real estate boom	0.38	0.33	0.29	0.00	1.71
Real estate bust	0.06	0.05	0.07	0.00	0.43

Bubble characteristics: regression model

$$\begin{aligned}\Delta CoVaR_{i,t} = \alpha_i &+ \beta_1 \cdot Bubble_{c,t} + \gamma \cdot B_{i,t-1} + \delta \cdot Bubble_{c,t} * \cdot B_{i,t-1} \\ &+ \beta_2 \cdot Bubble\_characteristics_{c,t} \\ &+ \lambda \cdot C_{c,t-1} + u_{i,t}\end{aligned}$$

Bubble characteristics enter the regressions demeaned

Bubble characteristics: results

	(1)	(2)	(3)
Stock market boom	0.335***	0.313***	0.340***
	(0.000)	(0.000)	(0.000)
Stock market boom length		0.015***	
		(0.000)	
Stock market boom size			0.423***
			(0.000)
Stock market bust	0.364***	0.337***	0.360***
	(0.000)	(0.000)	(0.000)
Stock market bust length		-0.022***	
		(0.005)	
Stock market bust size			-1.077
			(0.152)
Real estate boom	0.005	-0.067	-0.046
	(0.935)	(0.331)	(0.497)
Real estate boom length		-0.002**	
		(0.023)	
Real estate boom size			-0.123
			(0.259)
Real estate bust	0.244*	0.155	0.178
	(0.055)	(0.253)	(0.198)
Real estate bust length		-0.009***	
		(0.008)	
Real estate bust size			-1.679**
			(0.032)
Bank FE	Yes	Yes	Yes
All variables of the main regressions	Yes	Yes	Yes
No. of banks	1,264	1,264	1,264
No. of obs.	165,149	165,149	165,149
Adj. R^2	0.827	0.831	0.829
Adj. R^2 within	0.120	0.142	0.134

Outline

Main robustness checks

The results ...

- are not specific to variation in ΔCoVaR due to financial system variables
- apply to small and large banks (yet in different magnitudes)
- hold when eliminating the US bias in the sample
- are not driven by outstanding episodes (e. g. the GFC)

All regression results on these robustness checks are provided in the paper.

Outline

Conclusion (1 of 2)

A bursting bubble goes along with increased systemic risk **at the bank level**

- ... by 14 to 18% on average

This relation exists already during the emergence of asset price bubbles...

- ... although to a somewhat lesser extent.

The size of the relation strongly depends on bank characteristics

- An **average** bubble can be associated with systemic risk increased by as much as 53% (i. e. more than two standard deviations of ΔCoVaR aggregated at the financial system level)

Conclusion (2 of 2)

The size of the relationship also depends on bubble characteristics

- They additionally help to explain the heterogeneity of effects across bubble episodes

Bubbles in both asset classes considerably threaten financial stability

- Ordering depends on bank characteristics

Comments, questions, suggestions?

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Selected references and appendix

References on applied measures

Adrian, Tobias; Brunnermeier, Markus K. (2016)

CoVaR

American Economic Review 106(7), pp. 1705-1741.

Phillips, Peter C. B.; Shi, Shuping; Yu, Jun (2015a)

Testing for Multiple Bubbles: Historical Episodes of Exuberance and Collapse in the S&P 500

International Economic Review 56(4), pp. 1043-1078.

Phillips, Peter C. B.; Shi, Shuping; Yu, Jun (2015b)

Testing for Multiple Bubbles: Limit Theory of Real-Time Detectors

International Economic Review 56(4), pp. 1079-1134.

Appendix

- Appendix A: estimation of bubble episodes
- Appendix B: additional tables

Appendix A: estimation of bubble episodes

The BSADF test statistic specific to ending fraction r_2 of the sample is based on a sequence of ADF tests applied to a backwards expanding sample:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \{BADF_{r_1}^{r_2}\} \ , \tag{5}$$

where r_1 refers to the starting fraction and r_0 determines the minimum size of the fraction of the sample to which ADF tests are applied.
To identify bubble episodes:

- Calculate a sequence of these test statistics by varying ending fraction r_2.
- Obtain the sequence of critical values from Monte Carlo Simulations.
- Identify points in time at which the test statistics exceeds the critical values and those at which it falls back below again.

Appendix A: estimation of bubble episodes

Formally, the estimators of the beginning $\hat{r}_e$ and end $\hat{r}_f$ of bubble episodes:

$$\hat{r}_e = \inf_{r_2 \in [r_0, 1]} [r_2 : BSADF_{r_2}(r_0) > scv^{\beta}_{r_2}] \tag{6}$$

$$\text{and } \hat{r}_f = \inf_{r_2 \in [\hat{r}_e + \delta log(T), 1]} [r_2 : BSADF_{r_2}(r_0) < scv^{\beta}_{r_2}] \, . \tag{7}$$

The distinction between boom and bust of each bubble episode is taken based on the maximum of the underlying price series. Denoting the beginning of bubble episode k in country c by $\tau_e^{k,c}$, the corresponding end by $\tau_f^{k,c}$, and the point in time at which the price series reaches its maximum by $\tau_m^{k,c}$,

$$Bubble\_Boom_{c,t} = \begin{cases} 1 \text{ if } t \in [\tau_e^{k,c}, \tau_m^{k,c}] \text{ for any } k \\ 0 \text{ else} \end{cases} , \tag{8}$$

$$Bubble\_Bust_{c,t} = \begin{cases} 1 \text{ if } t \in]\tau_m^{k,c}, \tau_f^{k,c}] \text{ for any } k \\ 0 \text{ else} \end{cases} . \tag{9}$$

Appendix B: additional tables

Sample coverage

	Full sample			Large banks			Small banks		
Country	Banks	# Obs.	% Obs.	Banks	# Obs.	% Obs.	Banks	# Obs.	% Obs.
Australia	16	2,732	2	9	1,605	6	7	1,127	1
Belgium	5	597	0	3	514	2	2	83	0
Canada	14	1,976	1	9	1,662	6	5	314	0
Denmark	19	2,981	2	3	440	2	16	2,541	2
Finland	4	696	0	2	114	0	2	582	0
France	48	6,515	4	10	1,776	6	38	4,739	3
Germany	24	3,581	2	15	1,960	7	9	1,621	1
Italy	36	5,917	4	22	2,498	9	14	3,419	3
Japan	112	6,210	4	66	3,652	13	46	2,558	2
Netherlands	9	1,198	1	3	283	1	6	915	1
Norway	24	3,369	2	3	283	1	21	3,086	2
Portugal	7	969	1	3	341	1	4	628	0
Spain	14	2,724	2	10	1,588	6	4	1,136	1
Sweden	6	1,192	1	4	1,084	4	2	108	0
Switzerland	23	3,609	2	10	786	3	13	2,823	2
UK	20	3,633	2	12	2,233	8	8	1,400	1
US	883	117,250	71	59	7,493	26	824	109,757	80
Total	1,264	165,149	100	243	28,312	100	1,021	136,837	100