#### Limits to Arbitrage

Historical Bubbles

Symmetric Information

Pricing Equation Ruling out OLG Models

Asymmetric Information

Expected/Strong Bubble

Necessary Conditions

Limits to Arbitrage

Noise Trader Risk Synchronization Risk

Policy Response

### Asset Pricing under Asymmetric Information Bubbles & Limits to Arbitrage

### Markus K. Brunnermeier

Princeton University

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#### Limits to Arbitrage

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### • All agents are rational

- Bubbles under symmetric information
- Bubbles under asymmetric information
- Interaction between rational arbitrageurs and behavioral traders Limits to Arbitrage
  - Fundamental risk
  - Noise trader risk + Endogenous short horizons of arbs
  - Synchronization risk

### Overview

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#### Limits to Arbitrage

#### Historical Bubbles

- Symmetric Information
- Pricing Equation Ruling out OLG Models
- Asymmetric Information
- Expected/Strong Bubble
- Necessary Conditions
- Limits to Arbitrage
- Noise Trader Risk Synchronization Risk
- Policy Response

Historical Bubbles

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- 1634-1637 Dutch Tulip Mania (Netherlands)
- 1719-1720 Mississippi Bubble (France)
- 1720 South Sea Bubble (England)
- 1990 Japan Bubble
- 1999 Internet/Technology Bubble

Information Limits to	Event	Tulipmania	Crisis of 1763	Crisis of 1772
Arbitrage	Time	1634-1637	1763	1772-1773
Historical Bubbles Symmetric Information	Place	Netherlands	Amsterdam, Hamburg, Berlin	England, Scotland
Pricing Equation Ruling out OLG Models Asymmetric Information Expected/Strong Bubble Necessary Conditions Limits to Arbitrage Noise Trader Risk Synchronization Risk Policy Response	Bubble asset	Tulips	Grains, sugar	Stocks and futures of East India Company, turnpikes, canals, en- closures, building construction

Asset Pricing	Type of bub-	Commodity	Commodity	Securities,
under Asym.	ble asset			real estate
Limits to	Holder of as-	Small-town	Merchant	London spec-
Arbitrage	set	dealers,	bankers	ulators, busi-
Historical		tavern-		ness men
Bubbles		keepers,		
Symmetric Information		horticultural-		
Pricing Equation Ruling out		ists		
OLG Models	Financier of	Sellers of	Amsterdam	Ayr Bank,
Asymmetric Information	asset	bulbs	investors	country
Expected/Strong Bubble Necessary				banks
Conditions	Expansive	No	No	Yes
Limits to Arbitrage	monetary			
Noise Trader Risk	policy			
Synchronization Risk	I	1	1	

Asset Pricing	Lending	No	Yes	Yes
under Asym. Information	boom			
Limits to	Foreign capi-	No	No	No
Arbitrage	tal inflows			
Historical	Financial	No	No	Yes
Bubbles	deregulation			
Symmetric nformation	Severe reces-	No	No	Yes
Pricing Equation Ruling out	sion			
OLG Models Asymmetric	Banking crisis	No	Yes	Yes
	Spillover	No	Yes	Yes
Expected/Strong Bubble Necessary	to other			
Conditions	countries			
limits to Arbitrage	Leaning	No	No	Yes
Noise Trader Risk	Pricking	No	No	No
Synchronization Risk	Use of	No	No	No
Policy Response	quantity			
	instruments			

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### Limits to Arbitrage

Noise Trader Risk Synchronization Risk

Historical Bubbles	Only cleaning	No	Yes	No
Symmetric Information Pricing Equation Ruling out OLG Models	Sources	Garber (1989, 1990), Kindleberger	Kindleberger (2005), Schn- abel & Shin	Hamilton (1956), Hop- pit (1986),
Asymmetric Information Expected/Strong Bubble Necessary Conditions Limits to		(2005)	(2004)	Kindleberger (2005), Sheridan (1960)

Information	Event	Latin Amer-	Dailway ma	Panic of 1857
Limits to	Event		Railway ma-	Famic OF 1007
Arbitrage		ica Mania	nia	
Historical	Time	1824-1825	1840s	1856-1857
Bubbles	Place	England	England	United States
Symmetric Information	Bubble asset	Securities	Railway re-	Railroad
Pricing Equation Ruling out		of Real	lated stocks	stocks and
OLG Models		and imagi-	and property	bonds, land
Asymmetric Information		nary South	classes, corn	
Expected/Strong Bubble		American	0.00000, 00	
Necessary Conditions		governments		
Limits to		<b>.</b> .		
Arbitrage		and mines,		
Noise Trader Risk		joint stock		
Synchronization Risk		companies		
Policy Response	Type of bub-	Securities,	Securities,	Securities,
	ble asset	commodity	commodity	real estate

Asset Pricing	Holder of as-	Widely held	Widely held	
under Asym. Information	set			
Limits to	Financier of	Country	Bank of Eng-	Banks, for-
Arbitrage	asset	banks, Bank	land, govern-	eign investors
Historical		of England	ment	
Bubbles	Expansive	Yes	Yes	Yes
Symmetric Information	monetary			
Pricing Equation Ruling out	policy			
OLG Models Asymmetric	Lending	Yes	Yes	Yes
Information	boom			
Expected/Strong Bubble Necessary	Foreign capi-	No	Yes	Yes
Conditions	tal inflows			
Limits to Arbitrage	Financial	No	No	No
Noise Trader Risk	deregulation			
Synchronization Risk	Severe reces-	Yes	Yes	Yes
Policy Response	sion			

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Asset Pricing under Asym.	Banking crisis	Yes	Yes	Yes
Information	Spillover	Yes	No	Yes
Limits to Arbitrage	to other			
Historical	countries			
Bubbles	Leaning	Yes	No	No
Symmetric Information	Pricking	Possibly	No	No
Pricing Equation Ruling out	Use of	No	No	No
OLG Models	quantity			
Asymmetric Information	instruments			
Expected/Strong Bubble	Only cleaning	Yes	Yes	Yes
Necessary Conditions	Sources	Bordo	Evans	Calomiris &
Limits to Arbitrage		(1998), Co-	(1849),	Schweikhart
Noise Trader		nant (1915),	Kindleberger	(1991),
Risk Synchronization Risk		Kindleberger	(2005),	Kindleberger
Policy		(2005), Neal	Ward-Perkins	(2005)
Response		(1995)	(1950), WEO	× /
			(2003)	
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Limits to Arbitrage	Event	Gründerkrise	Chicago real estate boom	Crisis of 1882
Historical	Time	1872-1873	1881-1883	1881-1882
Bubbles Symmetric Information	Place	Germany, Austria	Chicago	France
Pricing Equation Ruling out OLG Models Asymmetric Information Expected/Strong Bubble Necessary Conditions Limits to Arbitrage Noise Trader	Bubble asset	Stocks, railroads, houses, land property	New-built apartments, houses from foreclosure proceedings, land	Stocks of new banks

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Synchronization Risk

Asset Pricing	Type of bub-	Securities,	Real estate	Securities
under Asym. Information	ble asset	real estate		
Limits to	Holder of as-		Widely held	Widely held
Arbitrage	set			
Historical	Financier of	Banks	Households	Banks,
Bubbles	asset			caisses de
Symmetric Information				reports,
Pricing Equation Ruling out				individuals
OLG Models Asymmetric	Expansive	Yes	Yes	No
Information	monetary			
Expected/Strong Bubble Necessary	policy			
Conditions	Lending	Yes	No	Yes
Limits to Arbitrage	boom			
Noise Trader Risk	Foreign capi-	Yes	No	Yes
Synchronization Risk	tal inflows			
Policy	1			1

Asset Pricing under Asym. Information	Financial deregulation	Yes	No	No
Limits to Arbitrage	Severe reces- sion	Yes	No	Yes
Historical Bubbles	Banking crisis	Yes	No	Yes
Symmetric Information Pricing Equation Ruling out OI G Models	Spillover to other countries	Yes	No	No
Asymmetric	Leaning	Yes	No	No
Information Expected/Strong	Pricking	No	No	No
Bubble Necessary Conditions Limits to Arbitrage	Use of quantity instruments	No	No	No
Noise Trader Risk Synchronization	Only cleaning	No	No	Yes
Risk Policy Response	Sources	Burhop (2009), Co- nant (1915), McCartney (1935)	Hoyt (1933)	Conant (1915), Kindleberger (2005), White (2007)

Asset Pricing under Asym. Information Limits to Arbitrage	Event	Panic of 1893	Norwegian crisis	Real estate bubble in the US
Historical Bubbles	Time	1890-1893	1895-1905	1920-1926
Symmetric Information	Place	Australia	Norway	United States
Pricing Equation Ruling out	Bubble asset	Mining	Land prop-	Residential
OLG Models		shares, land	erty, new	housing,
Asymmetric Information		property	homes, real	securitization
Expected/Strong Bubble			estate shares	
Necessary Conditions	Type of bub-	Securities,	Real estate	Real estate
Limits to Arbitrage	ble asset	real estate		
Noise Trader Risk	Holder of as-	Borrowers,	Construction	Households,
Synchronization Risk	set	banks, for-	sector, man-	banks
Policy		eign investors	ufacturers,	
Response			brokers,	
			stock market	
			investors	
	Financier of	Pastoral	Commercial	Non-

Asset Pricing under Asym. Information Limits to	Expansive monetary policy	Yes	Yes	Yes
<b>Arbitrage</b> Historical	Lending boom	Yes	Yes	Yes
Bubbles Symmetric Information	Foreign capi- tal inflows	Yes	Yes	No
Pricing Equation Ruling out OLG Models Asymmetric	Financial deregulation	No	No	Yes
Asymmetric Information Expected/Strong Bubble Necessary	Severe reces- sion	Yes	No	No
Conditions	Banking crisis	Yes	Yes	Yes
Limits to Arbitrage Noise Trader Risk Synchronization Risk Policy	Spillover to other countries	Yes	No	No

Limits to Arbitrage	Leaning	No	No	Yes
Historical	Pricking	No	No	No
Bubbles	Use of	No	No	Yes
Symmetric Information	quantity			
Pricing Equation Ruling out	instruments			
OLG Models	Only cleaning	Yes	Yes	No
Asymmetric Information	Sources	Conant	Gerdrup	White (2009)
Expected/Strong Bubble		(1915),	(2003)	
Necessary Conditions		Lauck		
Limits to Arbitrage		(1907),		
Noise Trader Risk		Merrett		
Synchronization Risk		(1997)		

Asset Pricing
under Asym.
Information

Limits to	
Arbitrage	

Historical Bubbles

Symmetric Information

Pricing Equation Ruling out OLG Models

Asymmetric Information

Expected/Stror Bubble Necessary Conditions

Conditions

Limits to Arbitrage

Noise Trader Risk Synchronization Risk

Asym. nation	Event	German stock	US stock	Lost decade
its to trage		price bubble	price bubble	
	Time	1927	1928-1929	1985-2003
cal s	Place	Germany	United States	Japan
etric ation	Bubble asset	Stocks	Stocks, real	Stocks, real
Equation			estate	estate
odels	Type of bub-	Securities	Securities,	Securities,
etric ation	ble asset		Real estate	Real estate
ed/Strong	Holder of as-	Wealthy	Widely held	Widely held
iry ons	set	individuals,		
to ge		institutional		
rader		investors,		
nization		banks		
	Financier of	Banks, for-	Domestic	Trusts, banks
	asset	eign investors	banks, later	
			private in-	
			vestors,	
			corporation	

Asset Pricing under Asym. Information Limits to	Expansive monetary policy	No	No	Yes
Arbitrage	Lending	No	Yes	Yes
Historical Bubbles Symmetric Information	boom Foreign capi- tal inflows	Yes	Yes	No
Pricing Equation Ruling out OLG Models Asymmetric	Financial deregulation	No	No	No
Asymmetric Information Expected/Strong Bubble Necessary	Severe reces- sion	Yes	Yes	Yes
Conditions	Banking crisis	Yes	Yes	Yes
Limits to Arbitrage Noise Trader Risk Synchronization Risk Policy	Spillover to other countries	No	Yes	No

Limits to	Leaning	Yes	Yes	Yes
Arbitrage	Pricking	Yes	Yes	Yes
Historical Bubbles	Use of	Yes	No	Yes
Symmetric	quantity			
Information Pricing Equation	instruments			
Ruling out OLG Models	Only cleaning	No	No	No
Asymmetric	Sources	Voth (2003)	Kindleberger	Kaufman et
			(2005),	al. (2003),
Expected/Strong Bubble			· · ·	```
Necessary Conditions			White (1990)	Kindleberger
				(2005),
Limits to Arbitrage				Patrick
Noise Trader				
Risk Synchronization				(1998),
Risk				Posen (2003)
Policy				1 0000)

Limits to Arbitrage	Event	Scandinavian crisis: Nor-	Scandinavian crisis: Swe-	Scandinavian crisis: Fin-
Historical		way	den	land
Bubbles	Time	1988-1992	1990-1992	1991-1992
Symmetric Information	Place	Norway	Sweden	Finland
Pricing Equation Ruling out	Bubble asset	Commercial	Commercial	Land,
OLG Models Asymmetric		real estate,	real estate	dwellings
Information Expected/Strong		housing		
Bubble Necessary	Type of bub-	Real estate	Real estate	Securities,
Conditions Limits to	ble asset			Real estate

Synchronization Risk Policy

Noise Trader Risk

Asset Pricing	Holder of as-	Firms, house-		Households,
under Asym. Information	set	holds		business
Limits to	Financier of	Banks	Banks,	Banks
Arbitrage	asset		finance com-	
Historical			panies	
Bubbles	Expansive	No	No	No
	monetary			
Ruling out	policy			
	Lending	Yes	Yes	Yes
	boom			
Bubble	Foreign capi-	Yes	No	Yes
Conditions	tal inflows			
Arbitrage	Financial	Yes	Yes	Yes
Noise Trader Risk	deregulation			
Risk	Severe reces-	Yes	Yes	Yes
Policy Response	sion			
Symmetric Information Pricing Equation Ruling out OLG Models Asymmetric Information Expected/Strong Bubble Necessary Conditions Limits to Arbitrage Noise Trader Risk Policy	monetary policy Lending boom Foreign capi- tal inflows Financial deregulation Severe reces-	Yes Yes Yes	Yes No Yes	Yes Yes Yes

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Limits to	
Arbitrage	

Historical Bubbles

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Limits to Arbitrage

Noise Trader Risk Synchronization Risk

Banking crisis	Yes	Yes	Yes
Spillover	No	No	No
to other			
countries			
Leaning	No	Yes	Yes
Pricking	No	No	No
Use of	No	Yes	Yes
quantity			
instruments			
Only cleaning	Yes	No	No
Sources	Gerdrup	Englund	Nyberg
	(2003), Vale	(1999), Her-	(1994)
	(2004)	ring, Wachter	
		(1998)	

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Limits to Arbitrage	Event	Asian crisis	Dotcom bub- ble	Real estate bubble in Australia
Bubbles	Time	1997-1998	1995-2000	2002-2004
Symmetric Information	Place	Thailand	United States	Australia
Pricing Equation Ruling out OLG Models	Bubble asset	Stocks, hous-	New technol-	Dwelling
Asymmetric		ing, commer-	ogy company	
Information Expected/Strong		cial real es-	stocks	
Bubble Necessary		tate		
Conditions	Type of bub-	Securities,	Securities	Real estate
Limits to Arbitrage	ble asset	real estate		
Noise Trader Risk	Holder of as-		Households,	Households
Synchronization Risk	set		retail in-	
Policy Response			vestors	

Asset Pricing under Asym. Information Limits to Arbitrage	Financier of asset	Finance and securities companies, banks	Venture capi- talists	Banks, mort- gage origina- tors
Historical Bubbles Symmetric Information	Expansive monetary policy	Yes	Yes	No
Pricing Equation Ruling out OLG Models	Lending boom	Yes	No	Yes
Asymmetric Information Expected/Strong Bubble Necessary	Foreign capi- tal inflows	Yes	Yes	No
Conditions Limits to Arbitrage	Financial deregulation	Yes	Yes	Yes
Noise Trader Risk Synchronization Risk Policy	Severe reces- sion	Yes	No	No

Asset Pricing					
under Asym. Information	Banking crisis		Yes	No	No
Limits to	Spillover		Yes	No	No
Arbitrage	to	other			
Historical	countries				
Bubbles	Leaning		No	Yes	Yes
Symmetric Information	Prickin	g	No	Yes	No
Pricing Equation Ruling out	Use	of	No	No	Yes
OLG Models Asymmetric	quantit	y			
Information Expected/Strong	instruments				
Bubble Necessary	Only c	leaning	Yes	No	No
Conditions	Source	s	Collyns, Sen-	BIS	BIS 76th An-
Limits to Arbitrage			hadji (2002),	70th/71st	nual Report,
Noise Trader Risk			Corsetti et al.	Annual	Bloxham,
Synchronization Risk			(1999)	Report,	Kent (2010)
Policy Response				Greenspan	, ,
				(2002)	

Asset Pricing under Asym. Information	Event	Subprime	Spanish hous-
Limits to Arbitrage		housing bubble	ing bubble
Historical	Time	2007-	2008-
Bubbles	Place	United States	Spain
Symmetric Information	Bubble asset	Subprime	
Pricing Equation Ruling out		mortgages	
OLG Models Asymmetric	Type of bub-	Real estate	Real estate
Information	ble asset		
Expected/Strong Bubble Necessary	Holder of as-	Widely held	Widely held
Conditions Limits to	set		
Arbitrago			

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Noise Trader Risk Synchronization Risk

Asset Pricing	F	Financie	r (
under Asym. Information	ā	asset	
Limits to	E	Expansiv	/e
Arbitrage	r	monetar	у
Historical	F	policy	
Bubbles		Lending	
Symmetric Information	ł	boom	
Pricing Equation Ruling out	F	Foreign	сар
OLG Models	t	tal inflov	NS
Asymmetric Information		Financia	I
Expected/Strong Bubble	C	deregula	tion
Necessary Conditions		Severe	
Limits to Arbitrage	S	sion	
Noise Trader Risk	E	Banking	cris
Synchronization Risk		Spillover	-
Policy Response		to	oth
	C	countrie	s

Financier of	Banks	Banks, saving
asset		banks
Expansive	Yes	Yes
monetary		
policy		
Lending	Yes	Yes
boom		
Foreign capi-	Yes	Yes
tal inflows		
Financial	Yes	No
deregulation		
Severe reces-	Yes	Yes
sion		
Banking crisis	Yes	Yes
Spillover	Yes	No
to other		
countries		
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Leaning	No	Yes
Pricking	No	No
Use of	No	Yes
quantity		
instruments		
Only cleaning	Yes	No
Sources	Brunnermeier	BoS (2012),
	(2009), Gor-	Carballo-Cruz
	ton and	(2011)
	Metrick	
	(2012)	

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# A Technology Company

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- Company X introduced a revolutionary wireless communication technology.
- It not only provided support for such a technology but also provided the informational content itself.
- It's IPO price was \$1.50 per share. Six years later it was traded at \$ 85.50 and in the seventh year it hit \$ 114.00.
- The P/E ratio got as high as 73.
- The company never paid dividends.

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### The Story of RCA in 1920's

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Company: Radio Corporate of America (RCA) Technology: Radio Years: 1920s

### Figure : RCA's Stock Price from Dec 25 to Dec 50.

RCA peaked at \$ 397 in Feb. 1929, down to \$ 2.62 in May 1932

RCA's stock price was below \$ 25 at least until 1950

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### NASDAQ and "Neuer Markt"

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# Figure : NASDAQ and Neuer Markt during "Technology Bubble".

> Limits to Arbitrage

Historical Bubbles

#### Symmetric Information

Pricing Equation Ruling out OLG Models

Asymmetric Information

Expected/Strong Bubble

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Policy Response

### Bubbles under Symmetric Information

- Keynes' distinction between speculation and long-run investment:
  - Speculation: Buy "overvalued" in the hope to sell it to someone else at an even higher price
  - Investing: Buy and hold strategy
- Fundamental value: Was ist das?
   "highest WTP" if one forces agents to buy & hold the asset

no uncertainty: uncertainty w/ risk-neutral agent: uncertainty w/ risk-averse agents: discounted value of dividends expected discounted value take expectations w.r.t. EMN

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### Bubbles under Symmetric Information

- Problem of Keynes' buy and hold definition of fundamental value:
  - Retrade does also occur to dynamically complete the market (not only for speculation).
  - With retrade a different allocation can be achieved and hence the EMM is different.
  - Allow for retrade and take EMM which leads to highest fundamental value.

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# Bubbles under Symmetric Information

 with stochastic discount factor m<sub>t</sub> (or pricing kernel m<sub>t</sub><sup>\*</sup>) the price of an asset is given by

$$m_t p_t = E_t [m_{t+1} (p_{t+1} + d_{t+1})]$$

where  $m_{t+1}$  is related to MRS (divided by prob. of state)

• Alternatively one can also write pricing equation in terms of the equivalent martingale measure

$$oldsymbol{p}_t = E_t^{\widehat{Q}}\left[rac{1}{1+r_t^f}\left(oldsymbol{p}_{t+1}+oldsymbol{d}_{t+1}
ight)
ight]$$

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- Securities with Finite Maturity
  - Reiterate pricing equation
  - Backwards induction rules out bubbles

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# Bubbles under Symmetric Information

- Securities with Infinite Maturity
  - Backwards induction argument fails since there is no well defined final period
  - "Lack of market clearing at  $t = \infty$ "
  - Split the price in a fundamental component p<sup>f</sup><sub>t</sub> and a bubble component b<sub>t</sub>.
  - By pricing equation, we get the following expectational difference equation

$$b_t = E_t^{\hat{Q}} \left[ \frac{1}{1 + r_t^f} b_{t+1} \right]$$

- Example 1: deterministic bubble
  - $\Rightarrow$  has to grow at the risk-free rate
- Example 2 (Blanchard & Watson 1982): (risk-neutral investors)
  - bubble bursts in each period with prob.  $(1 \pi)$ , persists with prob.  $\pi$
  - $\Rightarrow$  bubble has to grow by a factor  $\frac{1+r_t^2}{\pi}$  (if it doesn't burst)

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Policy Response Bubbles under Symmetric Information

- How can we rule out bubbles?
  - Negative bubbles (Blanchard & Watson 1982, Diba & Grossman 1988)
    - For  $b_t < 0$  difference equation implies that  $p_t$  will become negative.
    - Free disposal rules out negative prices.
  - Positive bubbles on assets with positive net supply if g < r (Brock, Scheinkman, Tirole 85, Santos & Woodford 97)
    - Argument: (bubbles would outgrow the economy if r > g)
    - At any point in time t + τ, the aggregate wealth of the economy contains bubble component b<sub>τ</sub>.
    - NPV\_t of aggregate wealth  $W_{t+\tau}$  does not converge to zero as  $\tau \to \infty$
    - If aggregate consumption<sub>t+ $\tau$ </sub> is bounded or grows at a rate g < r, NPV<sub>t+ $\tau$ </sub> ( $C_{t+\tau}$ )  $\rightarrow$  0 as  $\tau \rightarrow \infty$ .
    - Household wealth exceeds PV of C for all  $t + \tau$  sufficiently far in the future.
    - This is inconsistent with optimization since household would consume part of wealth.

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Policy Response

### Bubbles under Symmetric Information

• 5 Counter Examples (Santos and Woodford (1997)):

• Example 1: fiat money (=bubble) in OLG models

- allows (better) intergeneral transfers
- without bubble households want to save more and hence MRS "implicit  $r^{\prime\prime} < g$

(can lead to overaccumulation of private capital and hence, dynamic inefficiency (see also Abel et al. (1989)))

- Geerolf (2014) overturns result with OECD data: sufficient conditions for dynamic efficiency are not satisfied (e.g. Japan is unambiguously inefficient)
- Example 2: ...
- Common theme:

Pure existence of a bubble enlarges the trading space. leads to different allocation and EMM.

#### Limits to Arbitrage

Historical Bubbles

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# Overlapping Generations

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• Samuelson (1958) considers an infinite-horizon economy with two-period lived overlapping agents

• Population growth rate = n

- Preferences given by  $u(c_t^t, c_{t+1}^t)$ 
  - Pareto optimal allocation satisfies  $\frac{u_1}{u_2} = 1 + n$
- OLG economies have multiple equilibria that can be Pareto ranked

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## OLG: Multiple Equilibria

• Assume:

$$u(c_t^t, c_{t+1}^t) = \log c_t^t + \beta \log c_{t+1}^t$$

Endowment:  $y_t^t = e$ ,  $y_{t+1}^t = 1 - e$ 

- Assume complete markets and interest rate r
- Agents FOC implies:

$$\frac{c_{t+1}^t}{\beta c_t^t} = 1 + r$$

- For r = n, this corresponds to the *Pareto Solution*
- For  $r = \frac{1-e}{\beta e} 1$ , agents will consume their endowment
- Autarky solution is clearly Pareto inferior

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# OLG: Completion with Durable Asset

- Autarky solution is the **unique** equilibrium implemented in a sequential exchange economy
  - Young agents cannot transfer wealth to the next period
  - ... relates to Chris Sims's lecture
- A durable asset provides a store of value
  - Effective store of value reflects market liquidity
  - Pareto solution can be attained as a competitive equilibrium in which the price level grows at same rate as the population, i.e.  $b_{t+1} = (1 + n)b_t$

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Old agents trade durable asset for young agents' consumption goods

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### OLG: Production

- Diamond (1965) introduces a capital good and production
  - Constant-returns-to-scale (CRS) production:

$$Y_t = F(K_t, L_t)$$

• Optimal level of capital is given by the golden rule, i.e.

$$f'(k^{\star}) = n$$

Here, lowercase letters signify per capita values

• Individual (and firm) optimization implies that:

$$\frac{u_1}{u_2} = 1 + r = 1 + f'(k)$$

It is possible that  $r < n \Rightarrow k > k^* \Rightarrow$  Pareto inefficient

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# OLG: Production & Efficiency

- Diamond recommends issuing government debt at interest rate *r*
- Tirole (1985) introduces a rational bubble asset trading at price *b<sub>t</sub>*:

$$b_{t+1} = \frac{1+r_{t+1}}{1+n}b_t$$

- Both solutions crowd out investment and increase r
  - If baseline economy is inefficient, then an appropriately chosen debt issuance or bubble size can achieve Pareto optimum with *r* = *n*

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# OLG: Crowding-out vs. Crowding-in

- Depending on the framework, government debt and presence of bubbles can have two opposite effects:
  - Crowding-out refers to the decreased investment to increase in the supply of capital

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- Crowding-in refers to increased investment due to improved risk transfer
- Woodford (1990) explores both of these effects

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## Bubbles and Credit Frictions

- Samuelson-Tirole model implications are hard to reconcile with the following stylized facts:
  - 1 bubbles seem to pop up & burst (not deterministic) in reality
  - bubbles are associated with consumption booms, as well as rapid expansions in capital stock and output
- Martin and Ventura (2012) address these shortcomings in an OLG framework by introducing:
  - investor sentiment shocks
  - capital market imperfections
- Takeaway: bubbles are not only reduce inefficient investments, but also increase efficient ones

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### Bubbles and Credit Frictions: Model

- Risk-neutral individuals; utility:  $U_{it} = E_t[c_{it+1}]$ 
  - each generation contains a measure 1 of individuals
  - $-\,$  live for two periods & supply 1 unit of labour when young
- Technology:  $F(l_t, k_t) = l_t^{1-\alpha} k_t^{\alpha}$ 
  - fraction  $\epsilon \in [0,1]$  of productive individuals produce 1 unit of capital with one unit of output; unproductive produce  $\delta < 1$  units of capital with 1 unit of output

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 Financial Friction: no borrowing allowed ⇒ unproductive investors have to make own investments

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### Bubbles and Credit Frictions: Model

• Dynamics of capital stock in the presence of bubbles:

$$k_{t+1} = egin{cases} Ask^lpha_t + (1-\delta)b^P_t - \delta b_t & ext{if } rac{b_t + b^P_t}{(1-\epsilon)sk^lpha_t} < 1 \ sk^lpha_t - b_t & ext{if } rac{b_t + b^P_t}{(1-\epsilon)sk^lpha_t} \geq 1 \end{cases}$$

- **Crowding-out**: when old sell bubble to young, consumption grows and investment falls; bubble crowds out unproductive investments first, then productive investments. Average investment efficiency rises and crowding-out effect minimized.
- **Crowding-in**: when productive young sell bubble to unproductive young, productive investments replace unproductive ones. This further raises average investment efficiency.

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### Bubbles under Asymmetric Information

• "Dynamic Knowledge Operator"

$$\mathcal{K}_{t}^{i}\left( E
ight) =\left\{ \omega\in\Omega^{dynamic}:\mathcal{P}_{i}^{t}\left( \omega
ight) \subseteq E
ight\}$$

• Expected Bubbles versus Strong Bubbles

#### • expected bubble:

 $p_t$  > every agents marginal valuation at a date state  $(t, \omega)$ 

• strong bubble: (arbitrage?)

 $p_t$  > all agents know that no possible dividend realization can justify this price.

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### Necessary Conditions for Bubbles

- Model setup in Allen, Morris & Postlewaite 1993: risky asset pays dividend d<sub>T</sub> (ω) : Ω → ℝ<sub>+</sub> at t = T
- Necessary Conditions for Expected Bubbles

**1** Initial allocation (interim) Pareto inefficient (Tirole 1982)

- rational traders is not willing to buy "bubble asset" since some traders have realized their gains leaving a negative sum game for the buyers
- Short-sale constraint strictly binds at some future time in some contingency for all i
  - only don't sell to the position limit now, since shorting might be more profitable in the future

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### Necessary Conditions for Bubbles

- Additional Necessary Conditions for Strong Bubbles
  - asymmetric information is necessary since traders must believe that the other traders do not know this fact.
  - ❷ Net trades of all traders cannot be CK (since CK of actions negates asymmetric info about events)
     ⇒ no bubbles in economies with only two types of traders.
- Morris, Postelwaite & Shin (1995)-Model setup
  - now, all agents are risk-neutral
  - $p_T = d_T$  and  $p_t = \max_i E_t^i \left[ p_{t+1} | \mathcal{P}_t^i \right]$  for all  $\omega \in \Omega$  and t = 1, ..., T.
  - Let's focus on  $\omega$ , where  $d_T = 0$ ,  $E_T^{d_T=0}: \{\omega \in \Omega | d_T(\omega) = 0\}$

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Policy Response

### Necessary Conditions for Bubbles

- Main Result: Strong bubble can be ruled out at time t if  $\mathcal{K}_{t}^{G}\mathcal{K}_{t+1}^{G}\cdots\mathcal{K}_{T-1}^{G}\left(E_{T}^{d_{T}=0}\right) = \{\omega \in \Omega | p_{t}(\omega) = 0\}$ 
  - (That is, it is mutual knowledge in t that in period t + 1 it will be mutual knowsledge that ... in (T − 1) it will be mutual knowledge that d<sub>T</sub> = 0.)
  - Sketch argument:
    - if it is mutual knowledge at T-1 that  $d_T = 0$ , then  $p_{T-1} = 0$ .
  - if it is mutual knowledge at T 2 that  $p_{T-1} = 0$ , then  $p_{T-2} = 0$ .
  - ...
  - Since knowledge can only improve over time. If it is at t already (T t)-mutual knowledge that d<sub>T</sub> = 0, p<sub>t</sub> = 0.

#### Limits to Arbitrage

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Policy Response

# Limits to Arbitrage - Overview

- Efficient Market Hypothesis 3 levels of justifications
  - All traders are rational, since behavioral will not survive in the long-run (their wealth declines)
  - Behavioral trades cancel each other on average
  - Rational arbitrageurs correct all mispricing induced by behavioral traders.
- Fama/Friedman contra Keynes
  - "If there are many sophisticated traders in the market, they may cause these "bubbles" to burst before they really get under way." (Fama 1965)
  - "It might have been supposed that competition between expert professionals, possessing judgment and knowledge beyond that of the average private investor, would correct the vagaries of the ignorant individual left to himself." (Keynes 1936)

#### Limits to Arbitrage

Historical Bubbles

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- Pricing Equation Ruling out OLG Models
- Asymmetric Information
- Expected/Strong Bubble
- Necessary Conditions

#### Limits to Arbitrage

Noise Trader Risk Synchronization Risk

Policy Response

### Limits to Arbitrage - Overview

- Reasons for limits to arbitrage
  - Fundamental risk
  - Noise trader risk (DSSW 1990a, Shleifer & Vishny 1997)
  - Synchronization risk (Abreu & Brunnermeier 2002, 2003)

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• Special case of market frictions (incl. liquidity)

#### Limits to Arbitrage

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# • *Idea:* Arbitrageurs do not fully correct the mispricing caused by noise traders due to

- arbitrageurs short horizons
- arbitrageurs risk aversion (face noise trader risk)
- Noise traders survive in the long-run (they are not driven out of the market.)

# Noise Trader Risk

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### Noise Trader Risk - DSSW 1990a

- Model Setup of DSSW 1990a
  - OLG model
    - agents live for 2 periods
    - make portfolio decisions when they are young
  - 2 assets

•	safe asset <i>s</i>	pays fixed real dividend $r$
		perfect elastic supply
		numeraire, i.e. $p_s=1$
	unsafe asset <i>u</i>	pays fixed real dividend r
		no elastic supply of $X^{sup} = 1$
		price at $t = p_t$

• Fundamental value of *s* = Fundamental value of *u* (perfect substitutes)

#### agents

- mass of  $(1-\mu)$  of arbitrageurs
- mass of  $\mu$  of noise traders, who misperceive next period's price by  $\rho_t \sim \mathcal{N}\left(\rho_t^*, \sigma_\rho^2\right)$ , ( $\rho^*$  measures bullishness)
- CARA utility function  $U(W) = -\exp\{-2\gamma W\}$  with certainty equivalent  $E[W] \gamma Var[W]$ .

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### Noise Trader Risk - DSSW 1990a

- Individual demand
  - arbitrageur's  $E[W] - \gamma Var[W] = c_0 + x_t^a [r + E_t [p_{t+1}] - p_t (1 + r)] - \gamma (x_t^a)^2 Var_t [p_{t+1}]$ • noise traders  $E[W] - \gamma Var[W] = c_0 + x_t^n [r + E_t [p_{t+1}] + \rho_t - p_t (1 + r)] - \gamma (x_t^a)^2 Var_t [p_{t+1}]$ • Taking FOC arbitrageurs:  $x_t^a = \frac{r + E_t [p_{t+1}] - (1 + r)p_t}{2\gamma Var_t [p_{t+1}]}$

noise traders: x

$${}_{t}^{n} = \frac{r + E_{t}[p_{t+1}] - (1+r)p_{t}}{2\gamma Var_{t}[p_{t+1}]} + \frac{\rho_{t}}{2\gamma Var_{t}[p_{t+1}]}$$

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- Market Clearing
  - $(1-\mu)x_t^a + \mu x_t^n = 1$

$$p_{t} = rac{1}{1+r} \left[ r + E_{t} \left[ p_{t+1} 
ight] - 2\gamma Var_{t} \left[ p_{t+1} 
ight] + \mu 
ho_{t} 
ight]$$

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### Noise Trader Risk - DSSW 1990a Solve recursively,

$$p_{t+1} = \frac{1}{1+r} [r + E_{t+1} [p_{t+2}] - 2\gamma \operatorname{Var}_{t+1} [p_{t+2}] + \mu \rho_{t+1}]$$
  
$$E_t [p_{t+1}] = \frac{1}{1+r} [r + E_t [p_{t+2}] - 2\gamma \operatorname{Var}_t [p_{t+2}] + \mu \rho^*]$$

we will see later that  $Var_t[p_{t+\tau}]$  is a constant for all  $\tau$ . Solve first order difference equation

$$p_t = 1 + rac{\mu \left( 
ho_t - 
ho^* 
ight)}{1 + r} + rac{\mu 
ho^*}{r} - rac{2\gamma}{r} Var_t \left[ p_{t+1} 
ight]$$

Note that  $\rho_t$  is the only random variable. Hence,  $Var_t [p_{t+1}] = Var [p_{t+1}] = \frac{\mu^2 \sigma_{\rho}^2}{(1+r)^2}$   $p_t = 1 + \frac{\mu (\rho_t - \rho^*)}{1+r} + \frac{\mu \rho^*}{r} - \frac{(2\gamma) \mu^2 \sigma_{\rho}^2}{r (1+r)}$ 

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### Noise Trader Risk - DSSW 1990a

$$p_{t} = 1 + \frac{\mu \left(\rho_{t} - \rho^{*}\right)}{1 + r} + \frac{\mu \rho^{*}}{r} - \frac{(2\gamma) \mu^{2} \sigma_{\rho}^{2}}{r \left(1 + r\right)}$$

#### where

- 1 = fundamental value
- $\frac{\mu(\rho_t \rho^*)}{1 + r}$  = deviation due to current misperception of noise traders
- $\frac{\mu \rho^*}{r}$  = average misperception of noise traders
- $-\frac{(2\gamma)\mu^2\sigma_{\rho}^2}{r(1+r)} =$  arbitrageurs' risk-premium
- Homework:
  - Check limiting cases
    - $\begin{array}{c} \mathbf{1} \quad \gamma \to \mathbf{0} \\ \mathbf{2} \quad \sigma_{\rho}^2 \to \mathbf{0} \end{array}$
  - 2 Check whether there is also a fundamental equilibrium, where  $p_t = 1$  for all t
    - (no risk  $\Rightarrow$  arbitrageurs buy everything)

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Policy Response Do Noise Traders Die Out over Time (Evolutionary Argument)

- Relative Expected Returns
- Difference in returns
- $\Delta R_{n-a} = (x_t^n x_t^a) [r + p_{t+1} p_t (1+r)]$
- Aside 1:  $(x_t^n x_t^a) = \frac{\rho_t}{(2\gamma) Var_t[p_{t+1}]} = \frac{(1+r)^2 \rho_t}{(2\gamma) \mu^2 \sigma_\rho^2}$ (Note for  $\mu \to 0$ ,  $(x_t^n - x_t^a) \to \infty$ )
- Aside 2: By market clearing  $E[r + p_{t+1} p_t(1+r)] =$ (2 $\gamma$ )  $Var_t[p_{t+1}] - \mu \rho_t = \frac{(2\gamma)\mu^2 \sigma_{\rho}^2}{(1+r)^2} - \mu \rho_t$

$$\Rightarrow E_t \left[ \Delta R_{n-a} \right] = \rho_t - \frac{\left( 1 + r \right)^2 \left( \rho_t \right)^2}{\left( 2\gamma \right) \mu^2 \sigma_\rho^2}$$

• Taking unconditional expectations

$$E\left[\Delta R_{n-a}\right] = \rho^* - \frac{(1+r)^2 \,\rho^* + (1+r)^2 \,\sigma_{\rho}^2}{(2\gamma) \,\mu^2 \sigma_{\rho}^2} > 0 \text{ only if } \rho^* > 0$$

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# Do Noise Traders Survive over Time (Evolutionary Argument)

• Taking unconditional expectations

$$E\left[\Delta R_{n-a}\right] = \rho^* - \frac{(1+r)^2 \,\rho^* + (1+r)^2 \,\sigma_{\rho}^2}{(2\gamma) \,\mu^2 \sigma_{\rho}^2} > 0 \text{ only if } \rho^* > 0$$

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- "Overoptimistic/bullish" traders hold riskier positions and have higher expected returns.
- In evolutionary process, they will have more off-springs and hence they won't die out.

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Policy Response

# Myopia due to Liquidation Risk

- Why are professional arbitrageurs myopic?
- Model setup of Shleifer & Vishny (1997) [slightly modified]
  - Two assets
    - risk free bond and
    - risky stock with final value v
  - Two types of fund managers:
    - Good fund managers know fundamental value v
    - Bad fund managers have no additional information (just gamble with "other people's money").
  - Two trading rounds t = 1 and 2 (in t = 3 v is paid out)
  - Individual investors
    - entrust their money F<sub>1</sub> to a fund manager without knowing the fund managers' skill level - "separation of brain and money"
    - can withdraw their funds in t = 2
  - Noise traders submit random demand

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Risk

Policy Response

# Myopia due to Liquidation Risk

- Price setting:
  - $P_3 = v$
  - $P_2$  is determined by aggregate demand of fund managers and liquidity/noise traders
- Focus on case where
  - 1  $P_1 < v$  (asset is undervalued)
  - **2**  $P_2 < P_1$ asset price goes even further down in  $t_2$  due to
    - sell order by noise traders
    - sell order by other informed traders
- Performanced-based fund flows (see Chevalier & Ellison 1997)
  - If price drops, the probability increases that the fund manager is "bad".
  - Individual investors withdraw their money at t = 2.
  - Shleifer & Vishny assume  $F_2 = F_1 aD_1\left(1 \frac{P_2}{P_1}\right)$ , where  $D_1$  is the amount the fund manager invested in the stock.

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### Myopia due to Liquidation Risk

- "Good" manager's problem who has invested in risky asset
  - He has to liquidate his position at P<sub>2</sub> < P<sub>1</sub> (exactly when mispricing is the largest!)

That is, he makes losses, even though the asset was initially undervalued.

• Due to this "early liquidation risk", at t = 1 a rational fund manager is reluctant to fully exploit arbitrage opportunities at t = 1.

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 Focus on short-run price movements ⇒ myopia of professional arbitrageurs

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# Synchronization Risk

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- "Bubbles and Crashes" (Abreu & Brunnermeier 2003) (for bubbles)
- "Synchronization Risk and Delayed Arbitrage" (Abreu & Brunnermeier 2002)

(for any form of mispricing)

• see power point slides (file "08 slides Eco525.ppt")

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### Clean vs. Lean

- Long-standing debate about the role of monetary policy with regard to asset price bubbles:
  - "Cleaning" view (Greenspan (1999, 2002)): mitigate the consequences of bursting bubbles rather than trying to detect and prevent asset price bubbles when they emerge
  - "Leaning" view (BIS): try to prevent the build-up of bubbles by reacting early on to upward-trending asset prices
- Issues related to "leaning-against the wind":
  - 1 Bubbles are hard to identify (as fundamental asset values)
  - Ø Monetary policy instruments are too blunt when aimed at containing bubbles (may overly suppress output/inflation)
  - Bubbles could instead be tackled with financial regulation
- Recent crisis experience tilted views towards more intervention, closer to the BIS view (Stein (2013, 2014))