Testing for Bubbles in Asset prices:

Evidence from QE and other applications

DeNederlandscheBank

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Outline

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- Asset Bubble indicator
  - Theoretical framework
  - GSADF
  - Alternative Unit Root test: Phillips-Perron
- Effects of QE on equity and government bond markets
  - MSCI Europe
  - Government bond yields
- Other applications
- Limitations, conclusions and future research

Introduction

- An asset price bubble is characterized by periods of sustained increases in the price of an asset which is not justified by the value based on fundamental drivers.

- Bubbles in asset prices often precede a crash of a specific market (Tulip Mania, Asian financial crisis, Dot.com, GFC).

Motivation

1. Monetary policy → conventional and unconventional
2. Fragile economic recovery
   → Asset price bubbles, where prices may diverge from fundamental values

Goal

- Tool to monitor existence of bubbles in different asset classes (equities, bond market, commodities, housing prices)

Asset Bubble Indicator: Theoretical framework

Prices of an asset are based on discounted expected cashflows , fundamental drivers and a bubble component:

$$P_t = \sum_{i=0}^{\infty} \left(\frac{1}{1 + r_f} \right)^i \mathbb{E}_t(D_{t+i} + U_{t+i}) + B_t$$

$$\mathbb{E}_t(B_{t+1}) = \left(1 + r_f\right) B_t$$

- P is the price of an asset, r is the risk free rate, D are the cash flows of an asset, U the unobserved fundamental drivers and B a bubble component.

- If B=0 there is no bubble. If B>0 a bubble is present (i.c.w. r>0).

Asset Bubbles Indicator: The GSADF test

- The procedure is developed by Phillips et al. (2015) (Generalized Sup Augmented Dickey Fuller (GSADF)).

$$\Delta y_t = \alpha_{r1,r2} + \boldsymbol{\pi_{r1,r2}} y_{t-1} + \sum_{i=1}^{k} \psi_{r1,r2}^{i} \Delta y_{t-i} + \gamma T + u_t \text{ ADF test} \qquad (1)$$

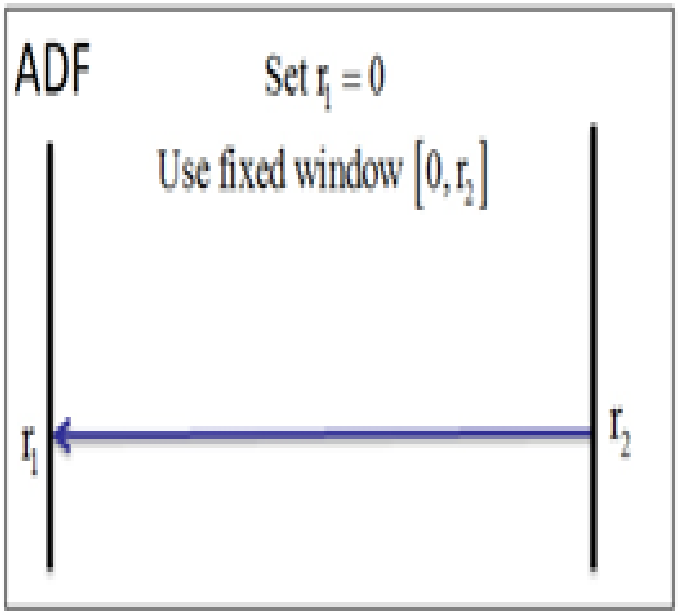
- A unit root (H0) vs. explosive price behavior (H1), $\boldsymbol{\pi_{r1,r2}}=0$ vs $\boldsymbol{\pi_{r1,r2}}>0$.

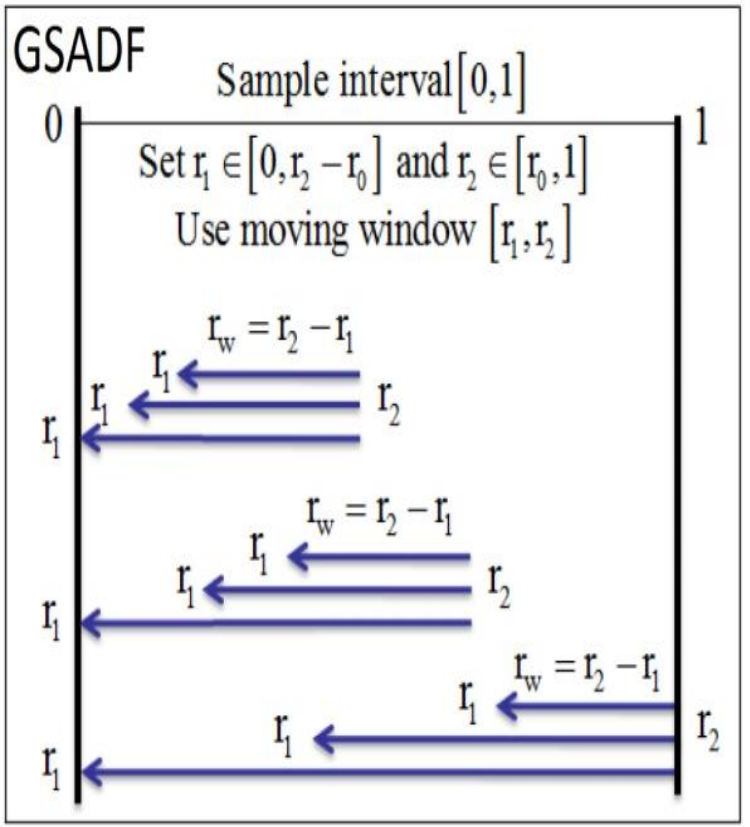
- $ADF_{r1}^{r2} = \frac{\hat{\pi}_{r1,r2}}{\text{s.e.}(\hat{\pi}_{r1,r2})}$ (ADF statistic)

- The test is based on varying starting points and ending points in time.

- Post long-depression period (1879M10-1880M04), the great crash episode (1928M11-1929M10), the postwar boom in 1954 (1955M01-1956M04), black Monday in October 1987 (1986M06-1987M09), and the dot-com bubble (1995M11-2001M08).

Asset Bubbles Indicator: GSADF test





GSADF test – summary of procedure

1) Determine the model specification, minimum observations, nr. of simulations etc.

2) Compute the critical values (GSADF/BSADF) with Monte carlo simulations.

3) Perform ADF regressions for the subperiods and calculate ADF statistics.

4) Take the maximum value of the ADF statistics to examine bubbles at each point in time (BSADF statistics). Take the maximum of the BSADF statistics (GSADF).

5) Choose a confidence level and compare GSADF statistic with the critical value.

6) Determine the starting and ending point of a bubble → (BS)ADF statistic > critical value (starting point), (BS)ADF statistic < critical value (ending point).

Phillips-Perron Unit root test

$$\Delta y_t = \alpha_{r1,r2} + \boldsymbol{\pi_{r1,r2}} y_{t-1} + +\gamma T + u_t \text{ PP test} \qquad (2)$$

- Unit root test to examine a unit root (H0) vs stationary process (H1).
- Newey-West standard errors robust against autocorrelation of unknown form.
- Same hypothesis formulation as GSADF: H0 unit root, H1 explosive process.
- Advantages/ drawbacks:
  - \+ Robust against unknown form of autocorrelation.
  - \+ Procedure with Phillips-Perron allows more datapoints to be used
  - − Performance ADF test is more efficient if the lag structure is known
  - − More complex than the ADF test (Newey-West standard errors)

Monetary policy & Quantitative Easing

- Low interest rate environment

Key interest rate	December 2008	October 2015
Deposit facility	2%	-0.20%
Main refinancing operations	2.5%	0.05%
Marginal lending facility	3%	0.3%

- Extended Asset Purchasing Program (EAP)
  - CBPP3: Covered Bonds since 20 October, ~EUR 131 bln (October 2015 holdings)
  - ABSPP: Asset Backed Securities since 21 November 2014, ~EUR 14 bln (October 2015 holdings)
  - PSPP: Public sector securities since 9 March 2015, ~EUR 393 bln. (October 2015 holdings)

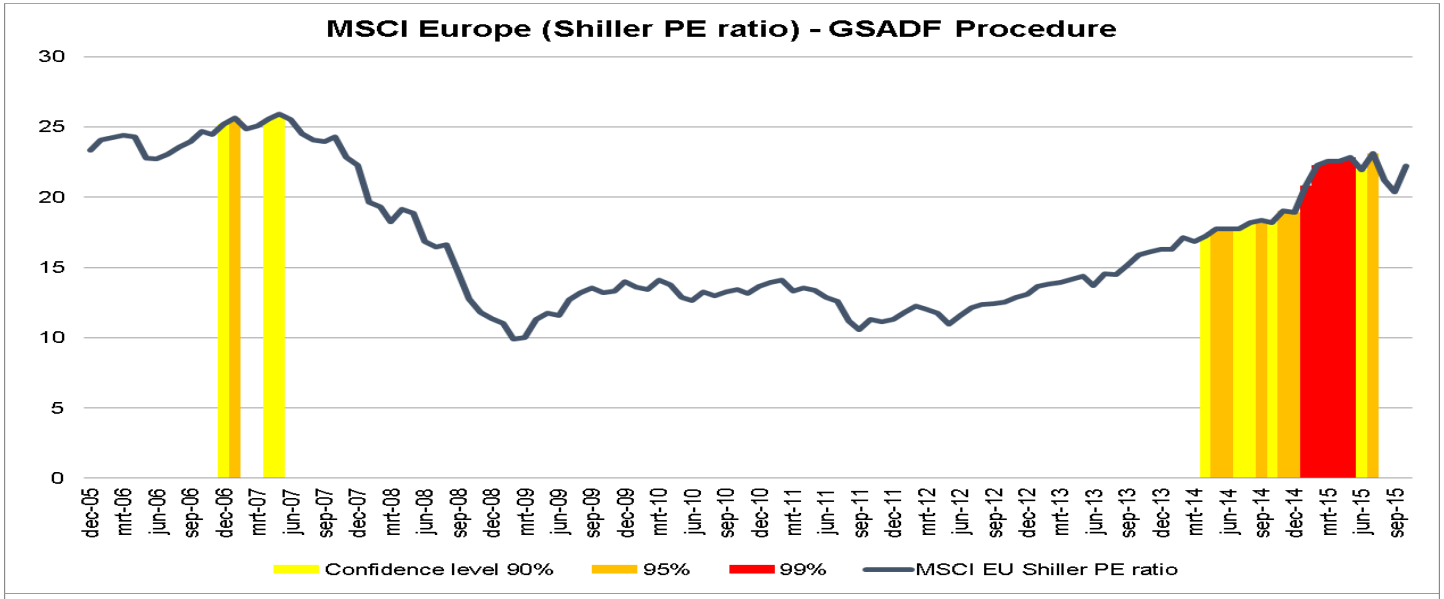
During the crisis central banks took all kinds of unconventional measures

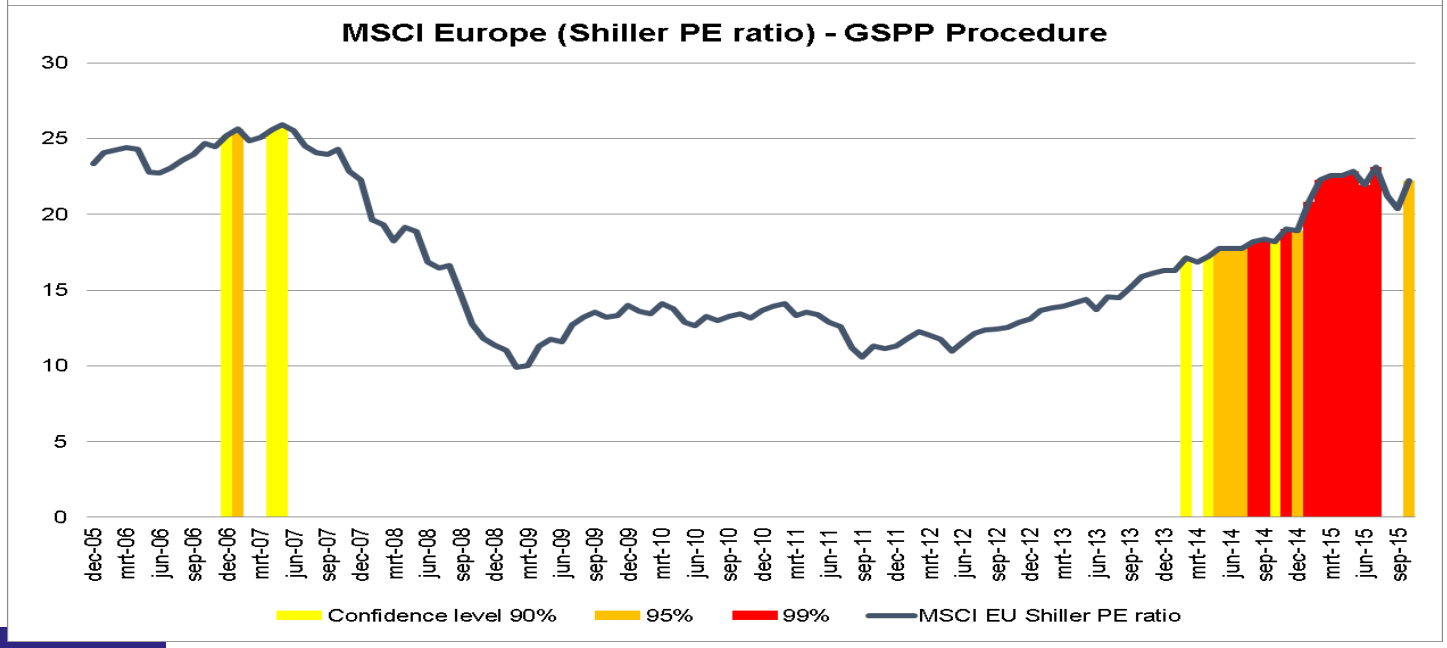
"Hello, young man.
I'm with the Federal Reserve.
Today, we're buying baseball cards."

Effect on MSCI Europe

Equity market

- Shiller Price/earnings ratio: Current market price index is divided by a 7 year average of the earnings in real terms.
- This measure is often used to examine overvaluation of a specific stock or index.
- Monthly data from 01-2003 until 10-2015.
- Monte Carlo is based on 2000 simulations and 3 lags in GSADF according to SBIC criterion.
- In the Phillips-Perron procedure 10 Newey-West lags are specified to calculate the standard errors.


MSCI Europe (Shiller PE ratio) - GSADF Procedure
30
25
20
15
10
5
0
dec-05 mrt-06 jun-06 sep-06 dec-06 mrt-07 jun-07 sep-07 dec-07 mrt-08 jun-08 sep-08 dec-08 mrt-09 jun-09 sep-09 dec-09 mrt-10 jun-10 sep-10 dec-10 mrt-11 jun-11 sep-11 dec-11 mrt-12 jun-12 sep-12 dec-12 mrt-13 jun-13 sep-13 dec-13 mrt-14 jun-14 sep-14 dec-14 mrt-15 jun-15 sep-15
Confidence level 90%
95%
99%
MSCI EU Shiller PE ratio


MSCI Europe (Shiller PE ratio) - GSPP Procedure
30
25
20
15
10
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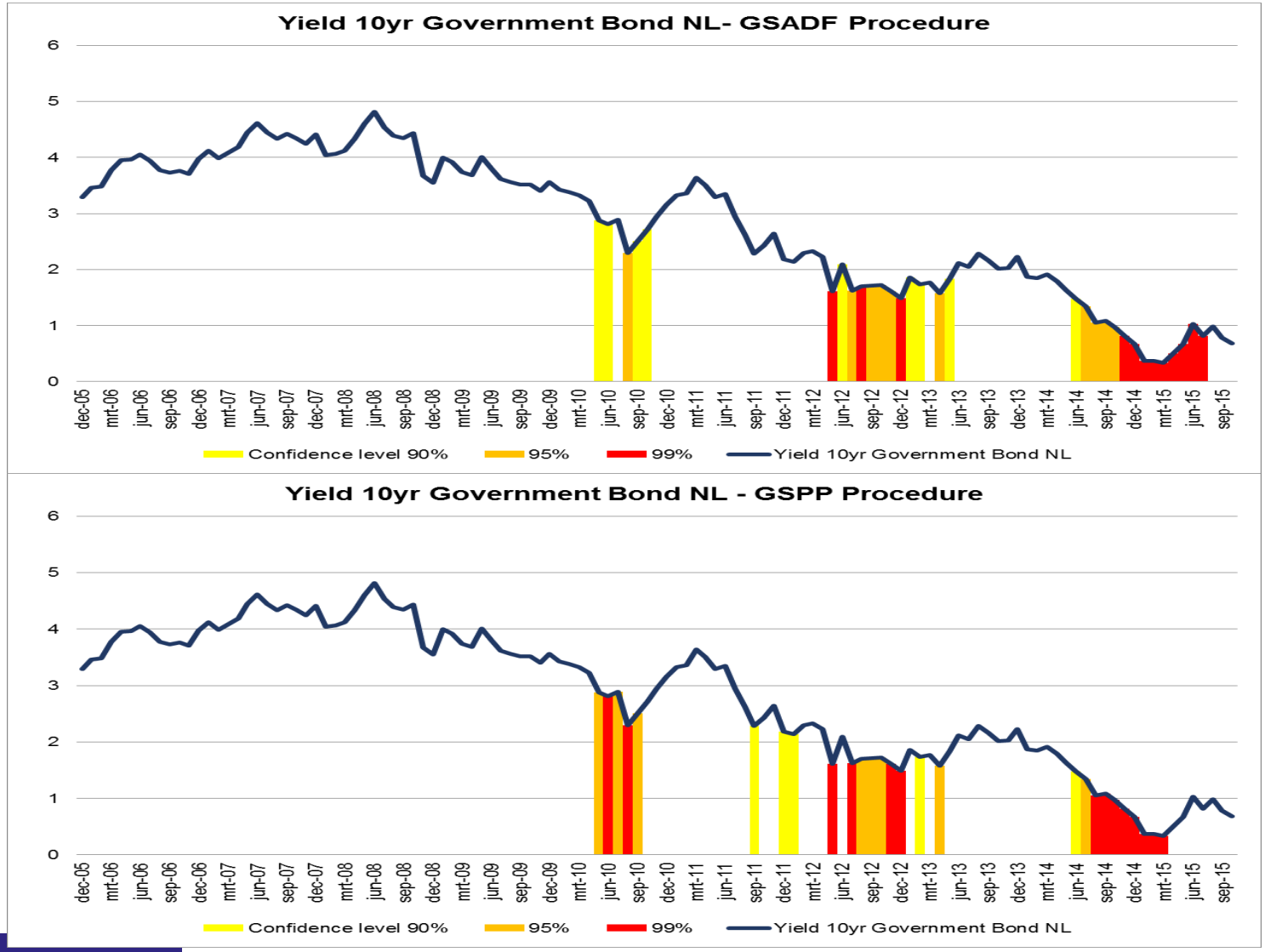
dec-05 mrt-06 jun-06 sep-06 dec-06 mrt-07 jun-07 sep-07 dec-07 mrt-08 jun-08 sep-08 dec-08 mrt-09 jun-09 sep-09 dec-09 mrt-10 jun-10 sep-10 dec-10 mrt-11 jun-11 sep-11 dec-11 mrt-12 jun-12 sep-12 dec-12 mrt-13 jun-13 sep-13 dec-13 mrt-14 jun-14 sep-14 dec-14 mrt-15 jun-15 sep-15
Confidence level 90%
95%
99%
MSCI EU Shiller PE ratio

Government Bonds

- Examine the yield of the 10 yr Government Bond for the Netherlands and Italy. (01-2003 until 10-2015)
- In the academic literature several determinants of yields are often used (debt to GDP, inflation, GDP growth, fiscal deficit to GDP, bid-ask spread, EONIA rate, VIX index, current account balance etc).
- Debt to GDP seems to be an often used important long-term determinant.
- Monte Carlo is based on 2000 simulations and 4 lags in GSADF.
- In the Phillips-Perron procedure 10 Newey-West lags are specified to calculate the standard errors.


Yield 10yr Government Bond NL- GSADF Procedure
6
5
4
3
2
1
0
dec-05 mrt-06 jun-06 sep-06 dec-06 mrt-07 jun-07 sep-07 dec-07 mrt-08 jun-08 sep-08 dec-08 mrt-09 jun-09 sep-09 dec-09 mrt-10 jun-10 sep-10 dec-10 mrt-11 jun-11 sep-11 dec-11 mrt-12 jun-12 sep-12 dec-12 mrt-13 jun-13 sep-13 dec-13 mrt-14 jun-14 sep-14 dec-14 mrt-15 jun-15 sep-15
Confidence level 90%
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99%
Yield 10yr Government Bond NL
Yield 10yr Government Bond NL - GSPP Procedure
6
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2
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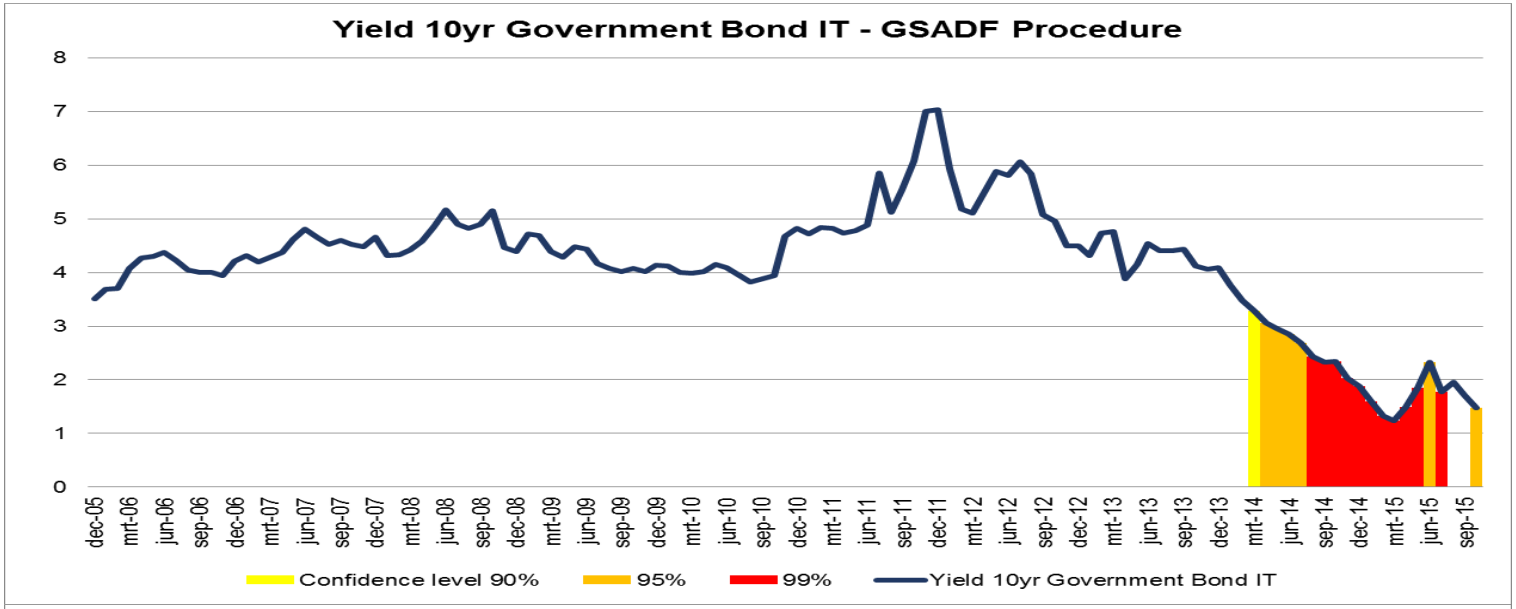
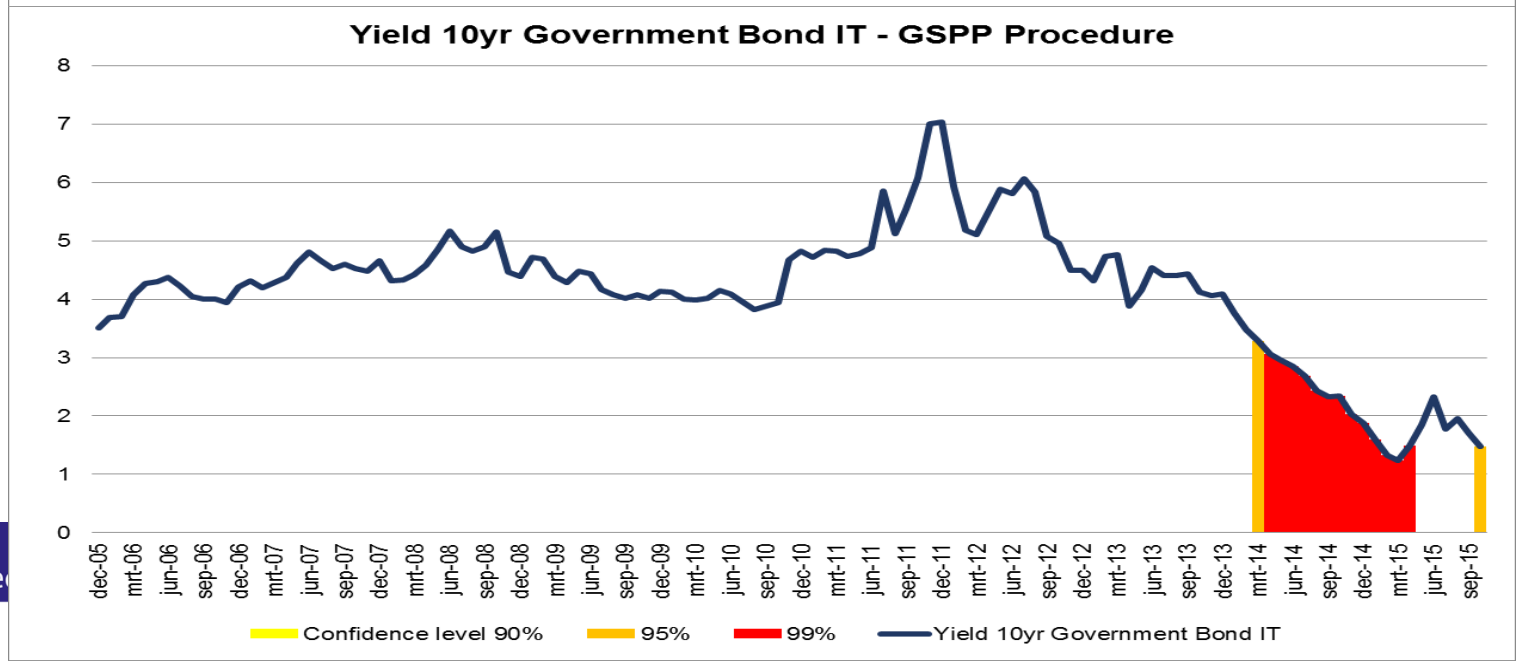
dec-05 mrt-06 jun-06 sep-06 dec-06 mrt-07 jun-07 sep-07 dec-07 mrt-08 jun-08 sep-08 dec-08 mrt-09 jun-09 sep-09 dec-09 mrt-10 jun-10 sep-10 dec-10 mrt-11 jun-11 sep-11 dec-11 mrt-12 jun-12 sep-12 dec-12 mrt-13 jun-13 sep-13 dec-13 mrt-14 jun-14 sep-14 dec-14 mrt-15 jun-15 sep-15
Confidence level 90%
95%
99%
Yield 10yr Government Bond NL


Yield 10yr Government Bond IT - GSADF Procedure
8
7
6
5
4
3
2
1
0
dec-05 mrt-06 jun-06 sep-06 dec-06 mrt-07 jun-07 sep-07 dec-07 mrt-08 jun-08 sep-08 dec-08 mrt-09 jun-09 sep-09 dec-09 mrt-10 jun-10 sep-10 dec-10 mrt-11 jun-11 sep-11 dec-11 mrt-12 jun-12 sep-12 dec-12 mrt-13 jun-13 sep-13 dec-13 mrt-14 jun-14 sep-14 dec-14 mrt-15 jun-15 sep-15
Confidence level 90%
95%
99%
Yield 10yr Government Bond IT


Yield 10yr Government Bond IT - GSPP Procedure
8
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1
0
dec-05 mrt-06 jun-06 sep-06 dec-06 mrt-07 jun-07 sep-07 dec-07 mrt-08 jun-08 sep-08 dec-08 mrt-09 jun-09 sep-09 dec-09 mrt-10 jun-10 sep-10 dec-10 mrt-11 jun-11 sep-11 dec-11 mrt-12 jun-12 sep-12 dec-12 mrt-13 jun-13 sep-13 dec-13 mrt-14 jun-14 sep-14 dec-14 mrt-15 jun-15 sep-15
Confidence level 90%
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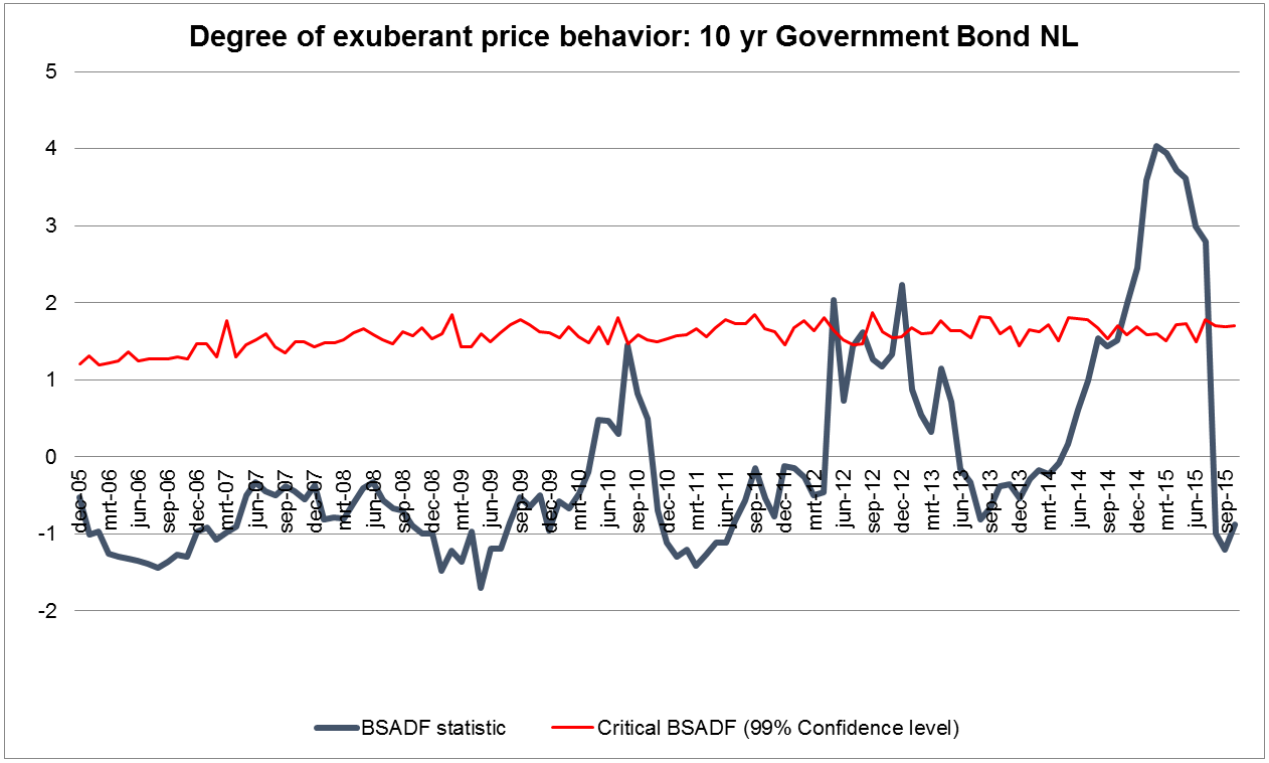
Yield 10yr Government Bond IT



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Other applications

- **Energy stock prices**: Bohl et al. (2015) – *International Review of Financial Analysis.*
- **Oil prices**: Caspi et al. (2015) – *Energy Economics*
- **Residential Property**: Yiu et al. (2013) – *Journal of Asian Economics*
- **Food commodity prices**: Etienne et al. (2014) – *Journal of International Money and Finance*
- **Sterling-Dollar FX rate**: Bettendorf & Chen (2013) – *Economics Letters*
- **Chinese RMB-Dollar FX rate**: Jiang et al. (2015) – *Applied Economics*
- **International housing prices:** (2013) Federal Reserve Dallas Working Paper

- <u>Our results with housing prices:</u>
- For Real Housing Prices NL: strongest signal between Q31996 – 2008Q3
- For Housing price/disposable income: weaker post 80s signals, but still signals between 1996Q3-2003Q3

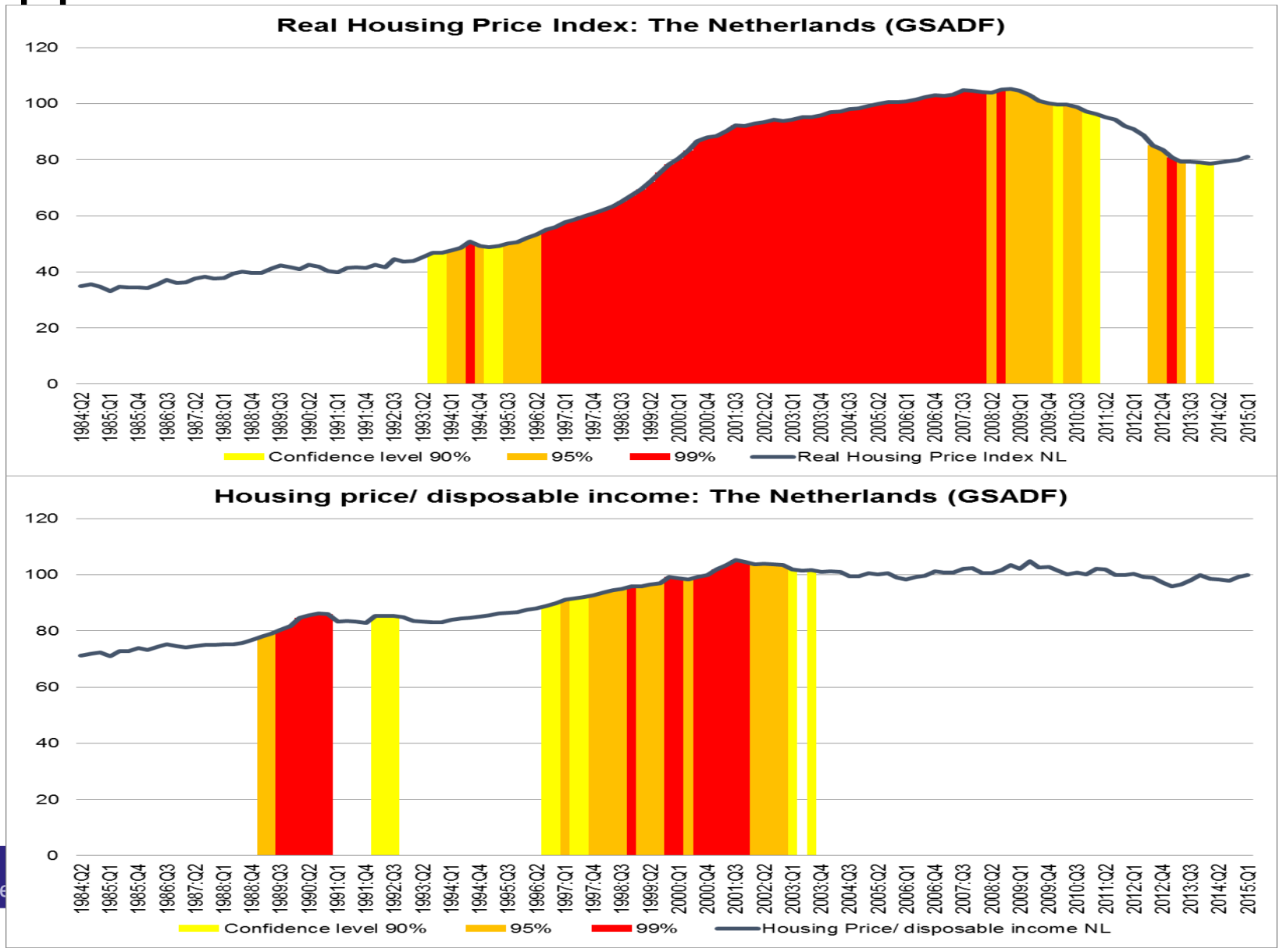
Data & Model limitations

- For each asset or asset class it is difficult to choose appropriate fundamentals.
- The methodology focuses on strong price movements rather than price levels.
- With both procedures it is difficult to choose the correct model specification (lag structure, constant, trend).
- Also may flag explosive behavior in strong declining markets.
- Procedure is less applicable in short time series.
- Monte carlo simulations may take a considerable amount of computational time.

Conclusions

- The GSADF and GSPP are statistical procedures to examine the existence of explosive price behavior.
- The GSPP is less efficient in small samples but more robust against unknown form of autocorrelation.
- The anticipation and implementation of QE has an effect on equity and government bond markets in Europe.
- Exogenous shocks like the political uncertainty in Greece and China mitigate effects of QE.

Appendix


Real Housing Price Index: The Netherlands (GSADF)
120
100
80
60
40
20
0
1984:Q2
1985:Q1
1985:Q4
1986:Q3
1987:Q2
1988:Q1
1988:Q4
1989:Q3
1990:Q2
1991:Q1
1991:Q4
1992:Q3
1993:Q2
1994:Q1
1994:Q4
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2000:Q4
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2002:Q2
2003:Q1
2003:Q4
2004:Q3
2005:Q2
2006:Q1
2006:Q4
2007:Q3
2008:Q2
2009:Q1
2009:Q4
2010:Q3
2011:Q2
2012:Q1
2012:Q4
2013:Q3
2014:Q2
2015:Q1
Confidence level 90%
95%
99%
Real Housing Price Index NL
Housing price/ disposable income: The Netherlands (GSADF)
120
100
80
60
40
20
0
1984:Q2
1985:Q1
1985:Q4
1986:Q3
1987:Q2
1988:Q1
1988:Q4
1989:Q3
1990:Q2
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2012:Q4
2013:Q3
2014:Q2
2015:Q1
Confidence level 90%
95%
99%
Housing Price/ disposable income NL