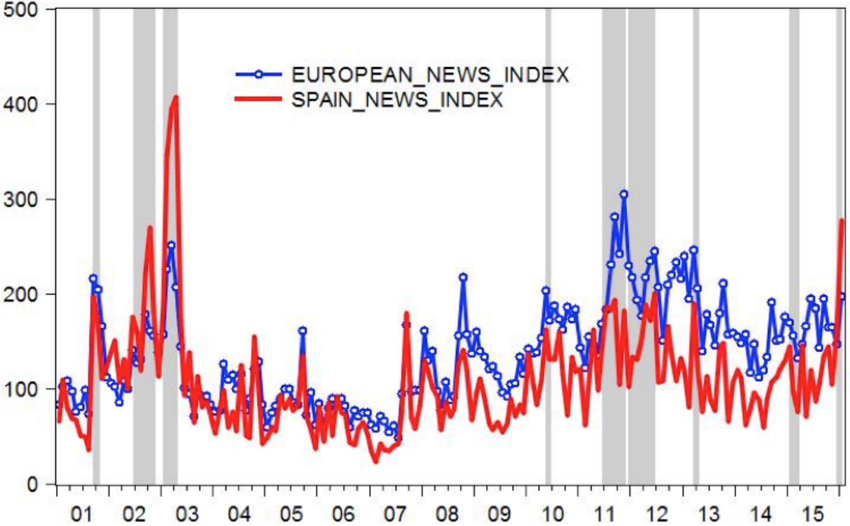
Empirical Evidence

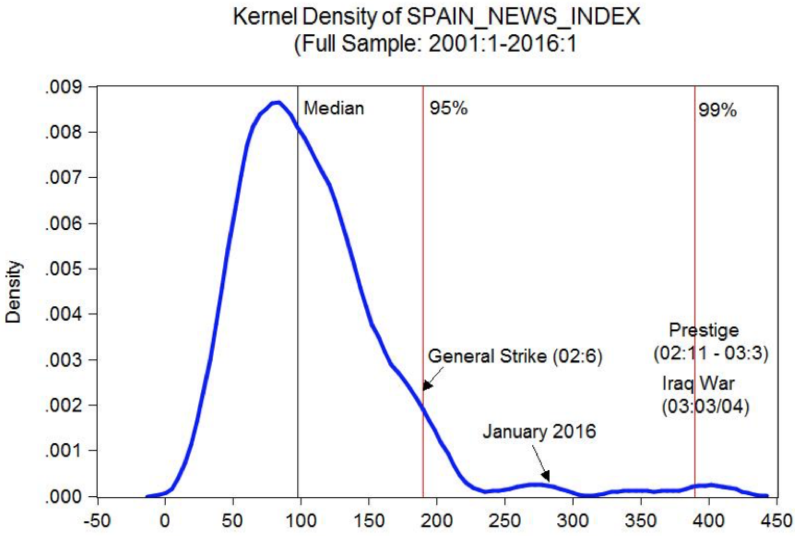
Jesús Fernández-Villaverde

University of Pennsylvania

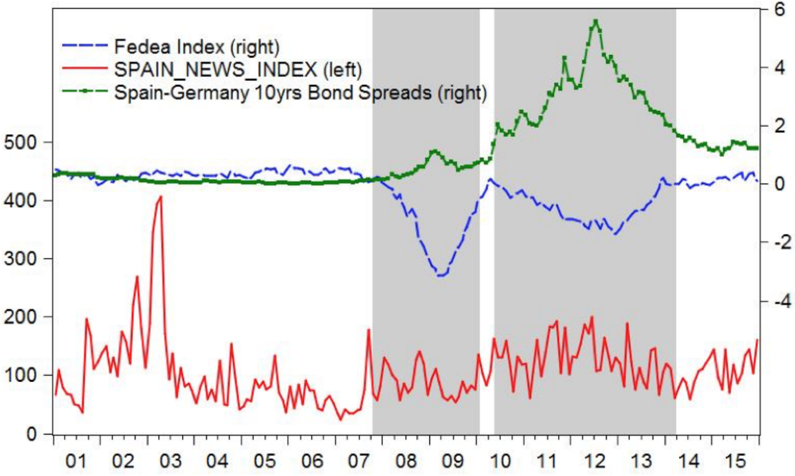
March 7, 2016

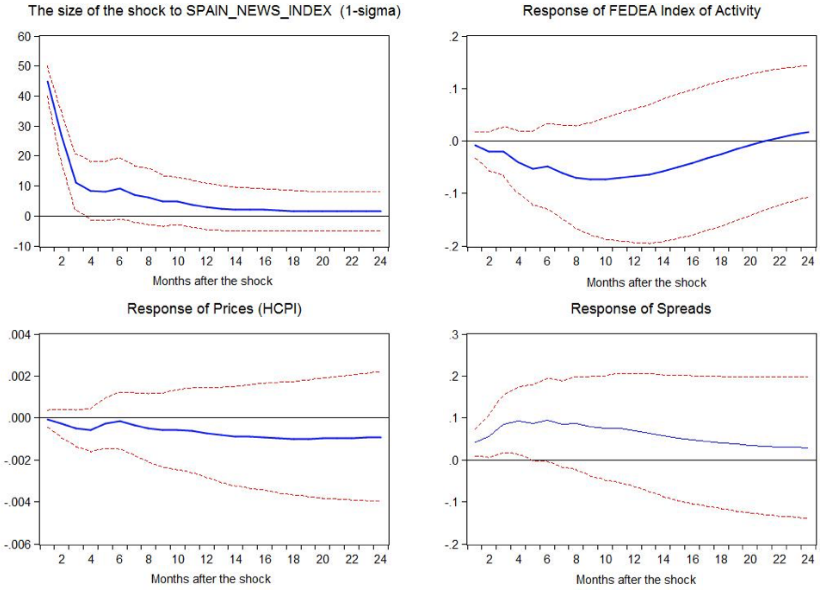


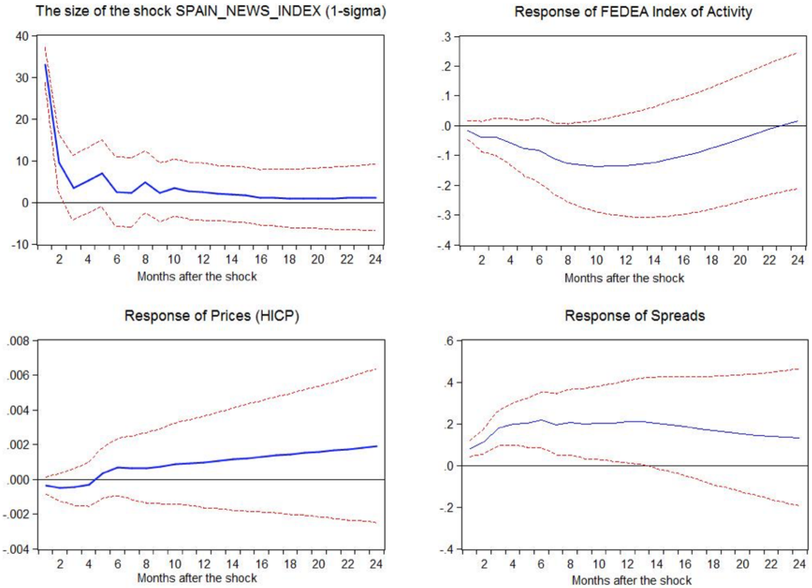
EUROPEAN_NEWS_INDEX
SPAIN_NEWS_INDEX
500
400
300
200
100
0
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15

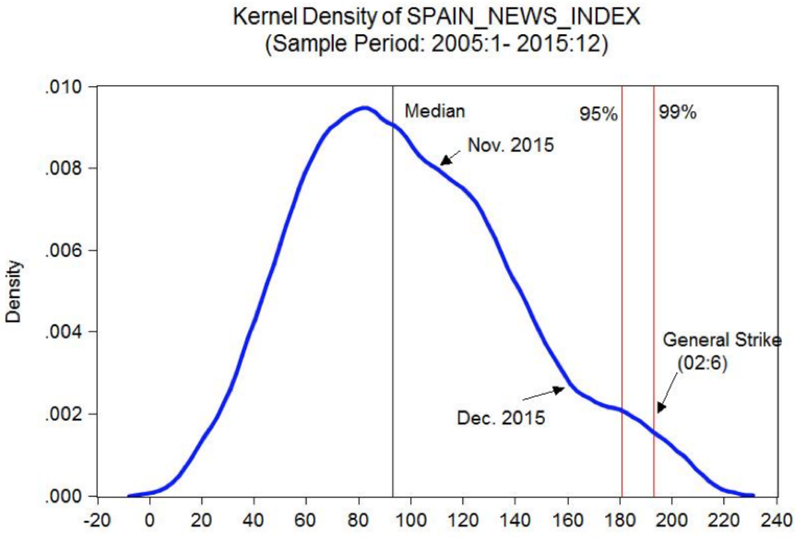


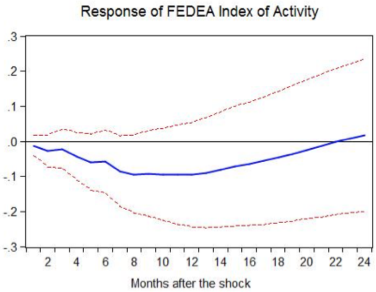
Kernel Density of SPAIN_NEWS_INDEX
(Full Sample: 2001:1-2016:1
Density
.009
.008
.007
.006
.005
.004
.003
.002
.001
.000
-50
0
50
100
150
200
250
300
350
400
450
Median
95%
99%
General Strike (02:6)
Prestige
(02:11 - 03:3)
Iraq War
(03:03/04)
January 2016


Fedea Index (right)
SPAIN_NEWS_INDEX (left)
Spain-Germany 10yrs Bond Spreads (right)
500
400
300
200
100
0
6
4
2
0
-2
-4
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15


The size of the shock to SPAIN_NEWS_INDEX (1-sigma)
Response of FEDEA Index of Activity
Response of Prices (HCPI)
Response of Spreads
Months after the shock
Months after the shock
Months after the shock
Months after the shock


The size of the shock SPAIN_NEWS_INDEX (1-sigma)
Months after the shock
Response of FEDEA Index of Activity
Months after the shock
Response of Prices (HICP)
Months after the shock
Response of Spreads
Months after the shock


Kernel Density of SPAIN_NEWS_INDEX
(Sample Period: 2005:1- 2015:12)
Density
.010
.008
.006
.004
.002
.000
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
Median
95%
99%
Nov. 2015
Dec. 2015
General Strike
(02:6)


Response of FEDEA Index of Activity
.3
.2
.1
.0
-.1
-.2
-.3
2 4 6 8 10 12 14 16 18 20 22 24
Months after the shock
Response of Unemployment Changes
.8
.4
.0
-.4
-.8
2 4 6 8 10 12 14 16 18 20 22 24
Months after the shock

A long tradition...

- Applied macroeconomic is concerned with the effects of shocks on certain key variables.
- Shocks have been characterized by temporary changes in the conditional mean of stochastic processes feeding our models.

  1. The RBC program analyzes the consequences of temporary changes in the conditional mean of productivity (Kydland and Prescott, 1982).
  2. Monetary models are focused on the effects of temporary changes in the conditional mean of innovations to the nominal interest rates (Woodford, 2003, or Christiano, Eichenbaum, and Evans, 2005).
  3. International devotes time to understand temporary changes in the conditional mean of the real interest rate (Mendoza, 1991 or Neumeyer and Perri, 2005) or the terms of trade (Mendoza, 1995).

...and a continuation

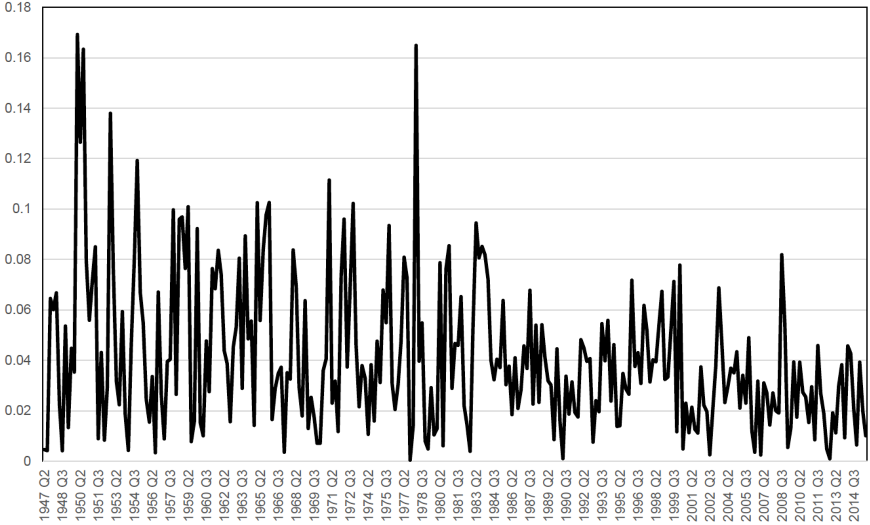
- More recently, applied macroeconomists have started moving their attention towards situations where shocks are characterized by temporary changes in the conditional second moments of the stochastic processes.

- In particular, time-varying standard deviations.

- A first motivation for this move comes from the realization that time series have a strong time-varying variance component.

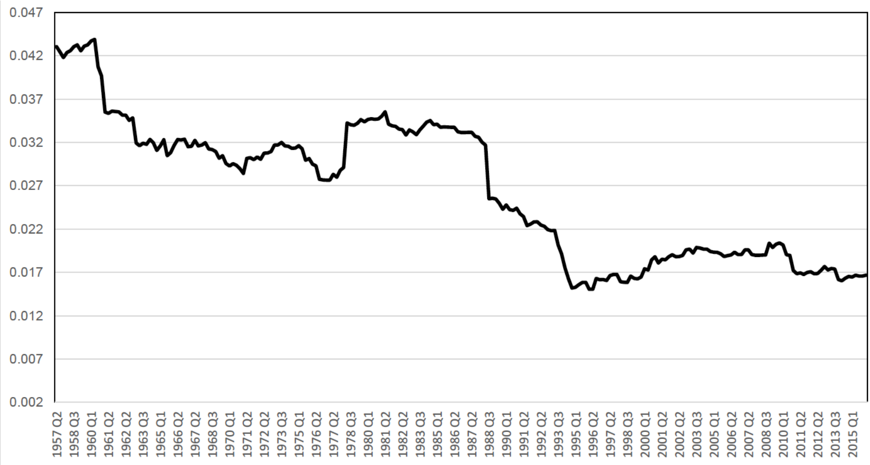
- Perhaps the most famous of those episodes was "the great moderation" of aggregate fluctuations that the U.S. economy.

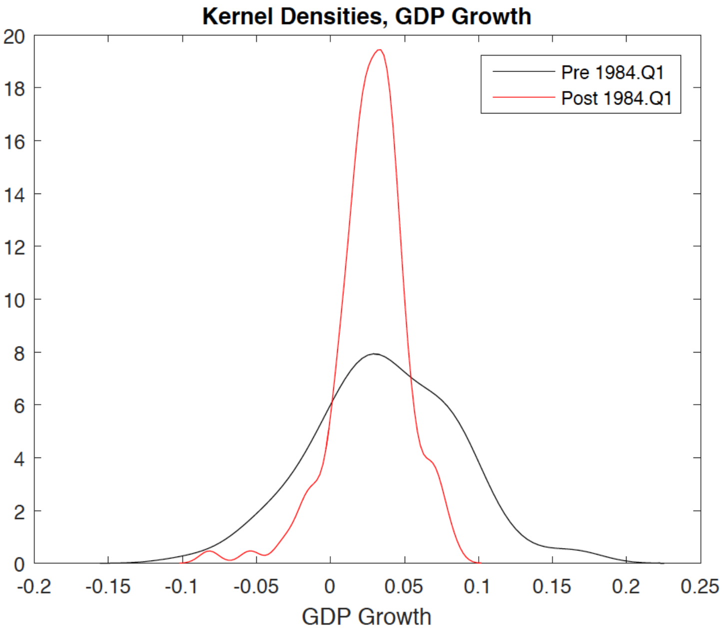
GDP growth



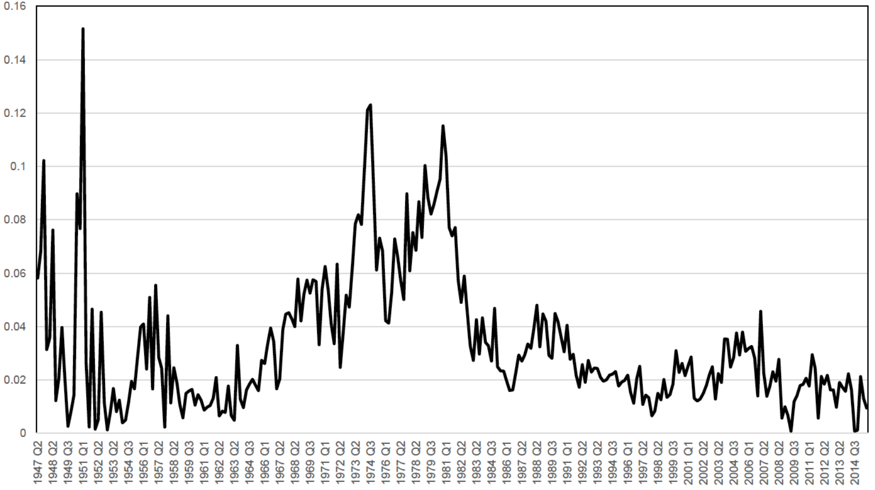
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1947 Q2
1948 Q3
1950 Q2
1951 Q3
1953 Q2
1954 Q3
1956 Q2
1957 Q3
1959 Q2
1960 Q3
1962 Q2
1963 Q3
1965 Q2
1966 Q3
1968 Q2
1969 Q3
1971 Q2
1972 Q3
1974 Q2
1975 Q3
1977 Q2
1978 Q3
1980 Q2
1981 Q3
1983 Q2
1984 Q3
1986 Q2
1987 Q3
1989 Q2
1990 Q3
1992 Q2
1993 Q3
1995 Q2
1996 Q3
1998 Q2
1999 Q3
2001 Q2
2002 Q3
2004 Q2
2005 Q3
2007 Q2
2008 Q3
2010 Q2
2011 Q3
2013 Q2
2014 Q3

GDP volatility

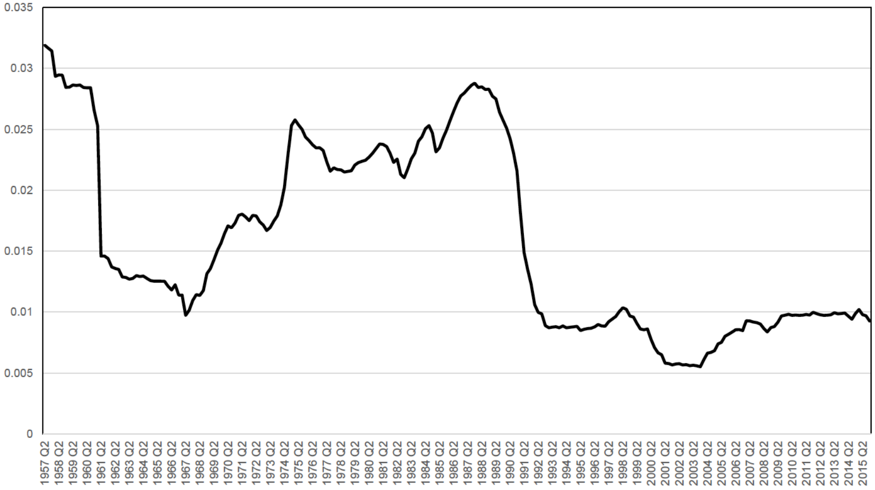


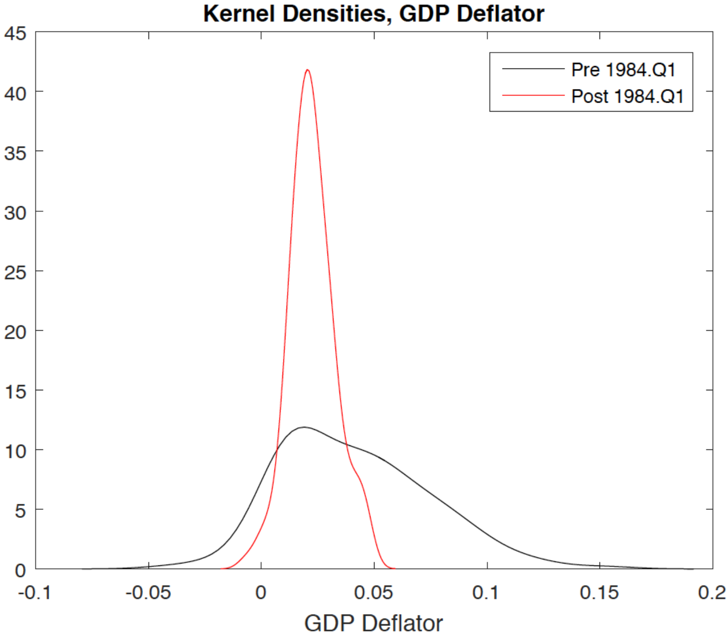

Kernel Densities, GDP Growth
20
18
16
14
12
10
8
6
4
2
0
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
GDP Growth
Pre 1984.Q1
Post 1984.Q1

GDP deflator

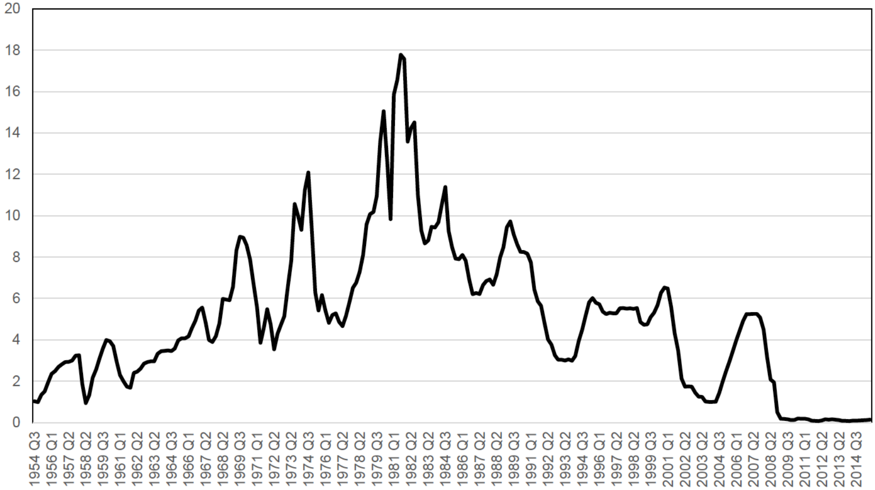


GDP deflator volatility



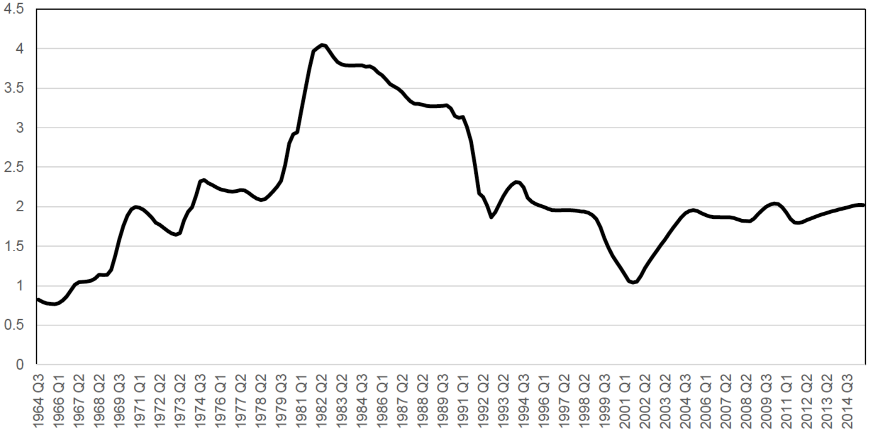

Kernel Densities, GDP Deflator
45
40
35
30
25
20
15
10
5
0
-0.1
-0.05
0
0.05
0.1
0.15
0.2
GDP Deflator
Pre 1984.Q1
Post 1984.Q1

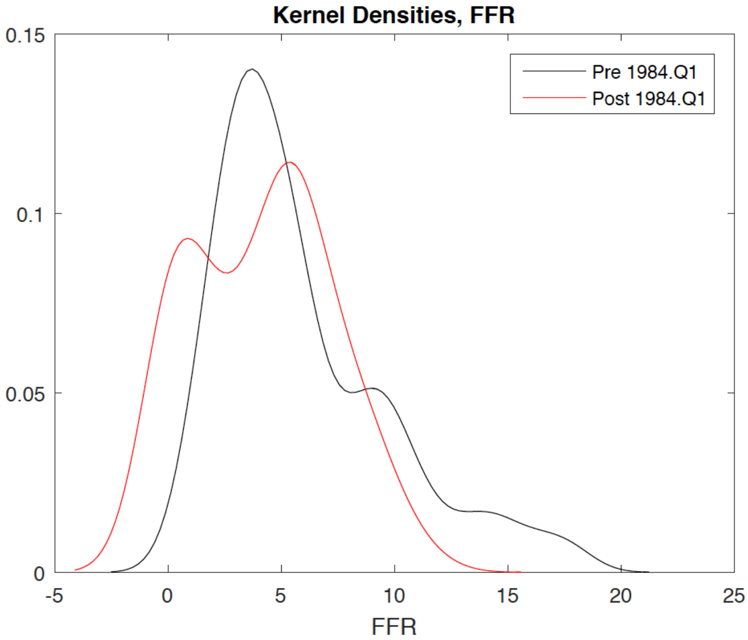
FFR



20
18
16
14
12
10
8
6
4
2
0
1954 Q3
1956 Q1
1957 Q2
1958 Q2
1959 Q3
1961 Q1
1962 Q2
1963 Q2
1964 Q3
1966 Q1
1967 Q2
1968 Q2
1969 Q3
1971 Q1
1972 Q2
1973 Q2
1974 Q3
1976 Q1
1977 Q2
1978 Q2
1979 Q3
1981 Q1
1982 Q2
1983 Q2
1984 Q3
1986 Q1
1987 Q2
1988 Q2
1989 Q3
1991 Q1
1992 Q2
1993 Q2
1994 Q3
1996 Q1
1997 Q2
1998 Q2
1999 Q3
2001 Q1
2002 Q2
2003 Q2
2004 Q3
2006 Q1
2007 Q2
2008 Q2
2009 Q3
2011 Q1
2012 Q2
2013 Q2
2014 Q3

FFR volatility




Kernel Densities, FFR
0.15
0.1
0.05
0
-5
0
5
10
15
20
25
FFR
Pre 1984.Q1
Post 1984.Q1

Data

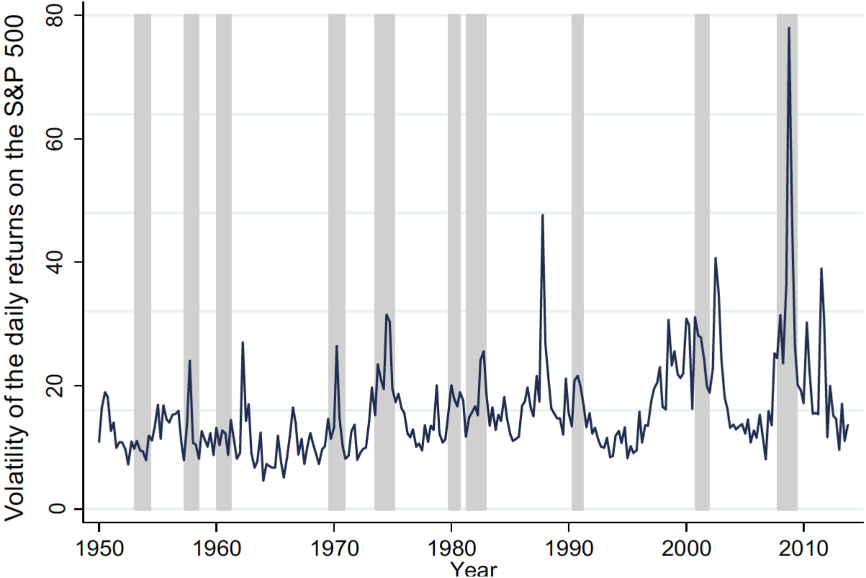
Changes in Volatility of U.S. Aggregate Variables

	Means		
	Inflation	Output Growth	FFR
All sample	3.2427	3.2375	5.0157
Pre 1984.Q1	4.1082	3.6742	5.9683
After 1984.Q1	2.2488	2.7359	4.1449
Post-1984.Q1/pre-1984.Q1	0.5474	0.7446	0.6945

Data

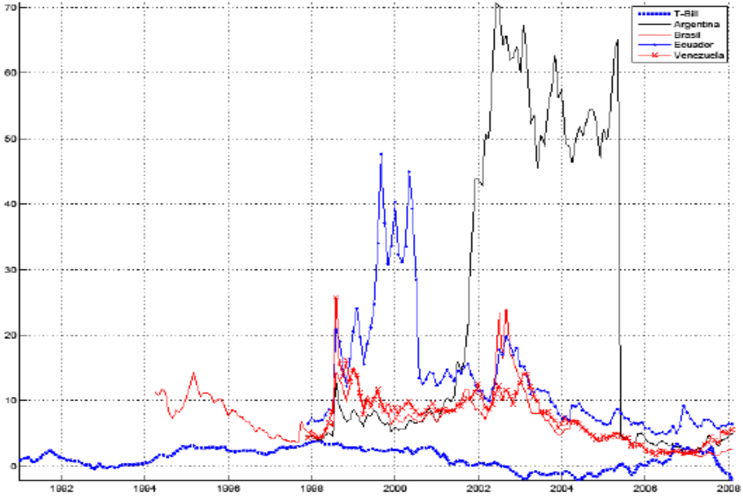
Changes in Volatility of U.S. Aggregate Variables

	Standard Deviations		
	Inflation	Output Growth	FFR
All sample	2.6360	3.9327	3.5662
Pre 1984.Q1	3.2440	4.8338	3.8809
After 1984.Q1	1.016	2.4561	3.0128
Post-1984.Q1/pre-1984.Q1	0.3130	0.5081	0.7763



Volatility of the daily returns on the S&P 500
0
20
40
60
80
1950
1960
1970
1980
1990
2000
2010
Year

Interest rates



Stochastic volatility I

- Stochastic volatility:

$$x_t = \rho x_{t-1} + \sigma_t \varepsilon_t,\ \varepsilon_t \sim \mathcal{N}(0,1).$$

  and

$$\log \sigma_t = (1-\rho_\sigma)\log \sigma + \rho_\sigma \log \sigma_{t-1} + \left(1-\rho_\sigma^2\right)^{\frac{1}{2}} \eta u_t,\ u_t \sim \mathcal{N}(0,1).$$

- This can be a process for many observable x_t: productivity, taxes, asset returns.
- Level innovations vs. volatility innovations.
- Interpretation.
- Non-linear structure.
- Discrete time process. Alternative with diffusion processes in continuous time.

Stochastic volatility II

- Richer specifications:

  1. More lags and moving average components.
  2. Additional regressors.
  3. VAR(MA)-SV.
  4. Non-Gaussian innovations.
  5. Correlation among innovations.
  6. Threshold effects.
  7. Asymmetries.

Other specifications I

- Markov-regime switching models:

$$\sigma_t \in [\sigma_1, ..., \sigma_n]$$

with transition matrix

$$P_{ij} = \begin{bmatrix} p_{11} & \dots & p_{1n} \\ \vdots & & \vdots \\ p_{n1} & \dots & p_{nn} \end{bmatrix}$$

- Advantages and disadvantages (econometric and theoretical).
- Mixed-models.

Other specifications II

- GARCH(p,q):

$$x_t = \rho x_{t-1} + a_t$$

where

$$a_t = \sigma_t \varepsilon_t, \ \varepsilon_t \sim \mathcal{N}(0,1)$$

and

$$\sigma_t = \sqrt{\omega + \sum_{i=1}^{p} \alpha_i a_{t-i}^2 + \sum_{i=1}^{q} \beta_i \sigma_{t-i}^2}$$

- Advantages and disadvantages (econometric and theoretical).

- Dozens of possible variations.

A real life example

- Decomposition of interest rates:

$$r_t = \underbrace{r}_{\text{mean}} + \underbrace{\varepsilon_{tb,t}}_{\text{T-Bill shocks}} + \underbrace{\varepsilon_{r,t}}_{\text{Spread shocks}}$$

- $\varepsilon_{tb,t}$ and $\varepsilon_{r,t}$ follow:

$$\varepsilon_{tb,t} = \rho_{tb}\varepsilon_{tb,t-1} + e^{\sigma_{tb,t}} u_{tb,t},\ u_{tb,t} \sim \mathcal{N}(0,1)$$

$$\varepsilon_{r,t} = \rho_r \varepsilon_{r,t-1} + e^{\sigma_{r,t}} u_{r,t},\ u_{r,t} \sim \mathcal{N}(0,1)$$

- $\sigma_{tb,t}$ and $\sigma_{r,t}$ follow:

$$\sigma_{tb,t} = \left(1 - \rho_{\sigma_{tb}}\right)\sigma_{tb} + \rho_{\sigma_{tb}}\sigma_{tb,t-1} + \eta_{tb} u_{\sigma_{tb},t},\ u_{\sigma_{tb},t} \sim \mathcal{N}(0,1)$$

$$\sigma_{r,t} = \left(1 - \rho_{\sigma_r}\right)\sigma_r + \rho_{\sigma_r}\sigma_{r,t-1} + \eta_r u_{\sigma_r,t},\ u_{\sigma_r,t} \sim \mathcal{N}(0,1)$$

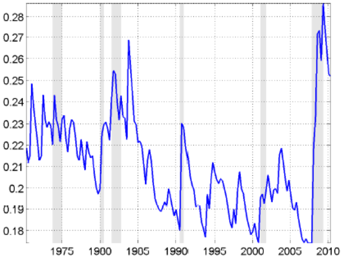
An alternative motivation

- A second motivation for this move is that temporary changes in the conditional standard deviation of shocks can capture the spreading out of distributions of events in the future.

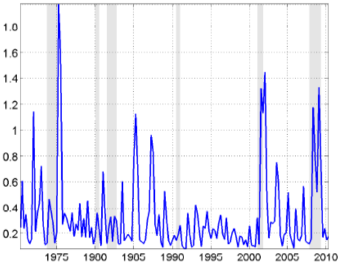
- For example, an increase in the variance of future paths of fiscal policy can be captured by a temporary increase in the standard deviation of the innovations to some fiscal policy rules.

- Similarly, the higher volatility of sovereign debt markets as the one currently observed can be included in our models as a temporary increase in the standard deviation in the innovations to a country-specific spread.

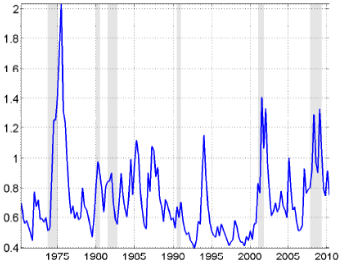
Government spending



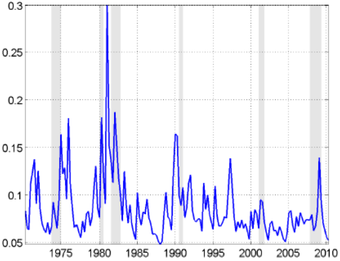
Labor Tax



Capital Tax



Consumption Tax



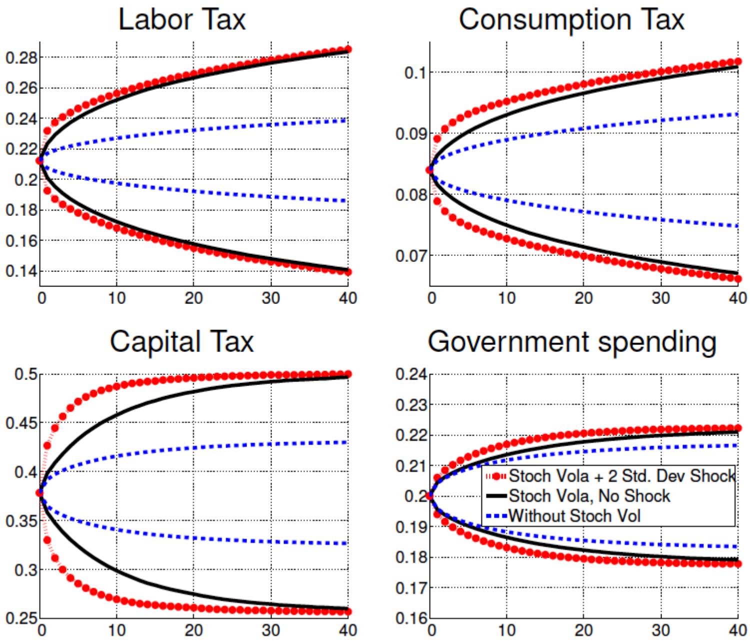
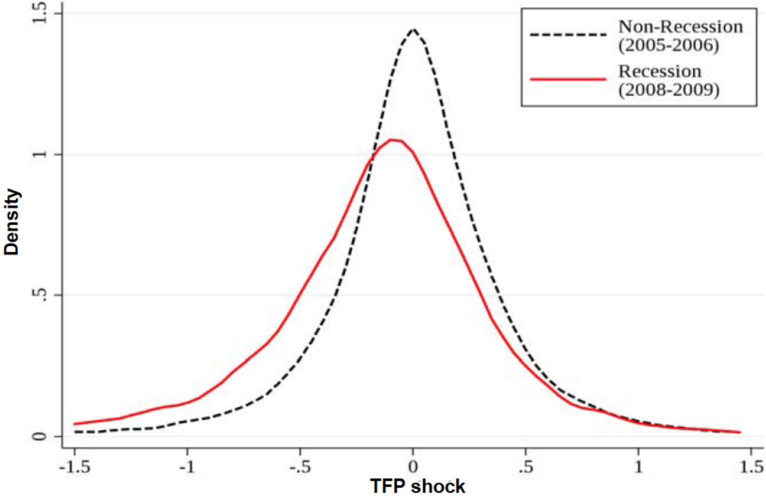
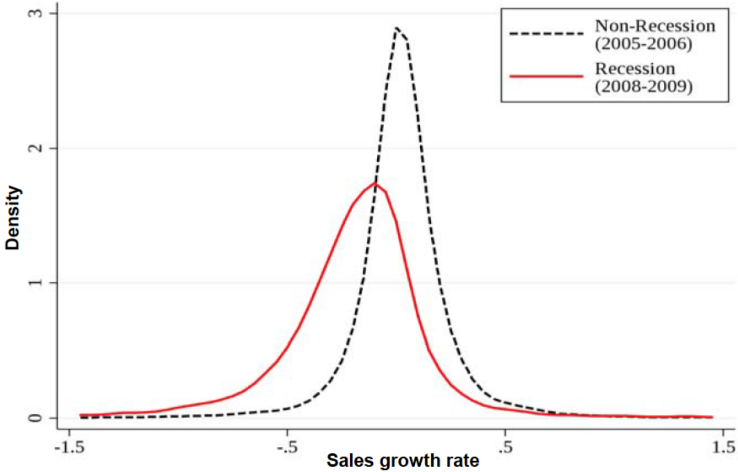

Labor Tax
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0
10
20
30
40
Consumption Tax
0.1
0.09
0.08
0.07
0
10
20
30
40
Capital Tax
0.5
0.45
0.4
0.35
0.3
0.25
0
10
20
30
40
Government spending
0.24
0.23
0.22
0.21
0.2
0.19
0.18
0.17
0.16
0
10
20
30
40
Stoch Vola + 2 Std. Dev Shock
Stoch Vola, No Shock
Without Stoch Vol

Figure 1: The variance of establishment-level TFP shocks increased by 76% in the Great Recession



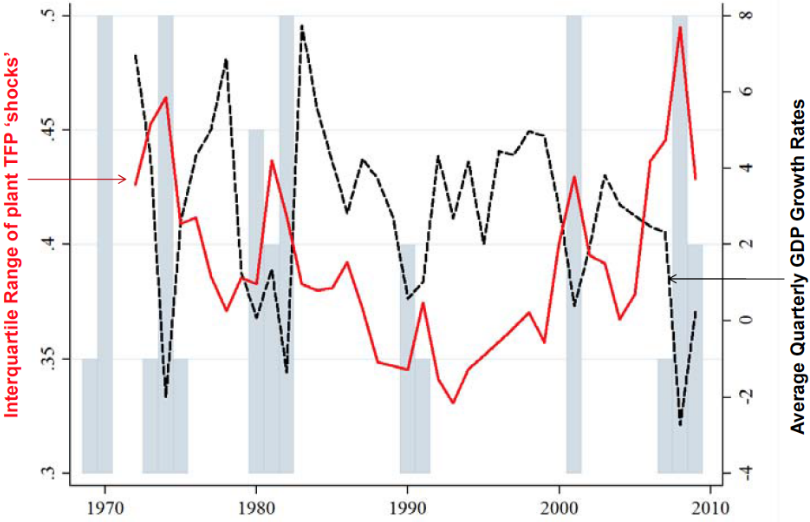
Notes: Constructed from the Census of Manufactures and the Annual Survey of Manufactures using a balanced panel of 15,752 establishments active in 2005-06 and 2008-09. Moments of the distribution for non-recession (recession) years are: mean 0 (-0.166), variance 0.198 (0.349), coefficient of skewness -1.060 (-1.340) and kurtosis 15.01 (11.96). The year 2007 is omitted because according to the NBER the recession began in December 2007, so 2007 is not a clean "before" or "during" recession year.

Figure 2: The variance of establishment-level sales growth rates increased by 152% in the Great Recession



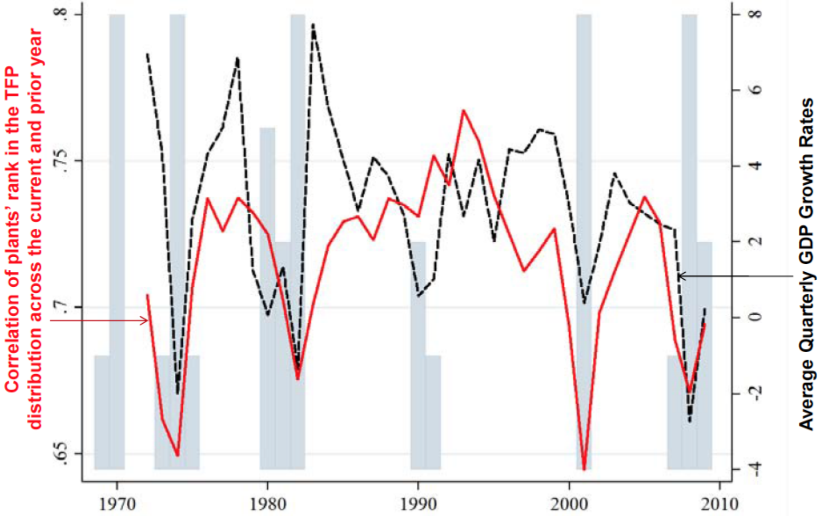
Notes: Constructed from the Census of Manufactures and the Annual Survey of Manufactures using a balanced panel of 15,752 establishments active in 2005-06 and 2008-09. Moments of the distribution for non-recession (recession) years are: mean 0.026 (-0.191), variance 0.052 (0.131), coefficient of skewness 0.164 (-0.330) and kurtosis 13.07 (7.66). The year 2007 is omitted because according to the NBER the recession began in December 2007, so 2007 is not a clean "before" or "during" recession year.

Figure 3: TFP 'shocks' are more dispersed in recessions



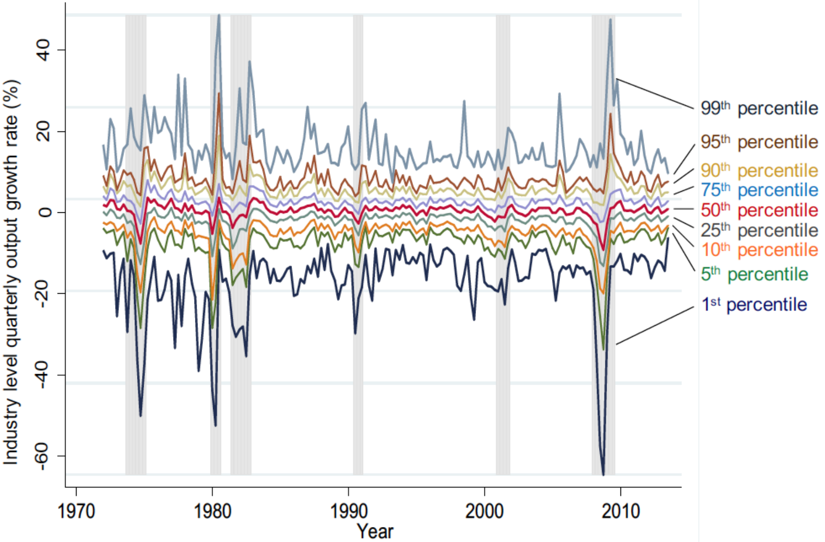
Notes: Constructed from the Census of Manufactures and the Annual Survey of Manufactures establishments, using establishments with 25+ years to address sample selection. Grey shaded columns are share of quarters in recession within a year.

Figure 4: Recessions increase turbulence: plant rankings in the TFP distribution churn more in recessions



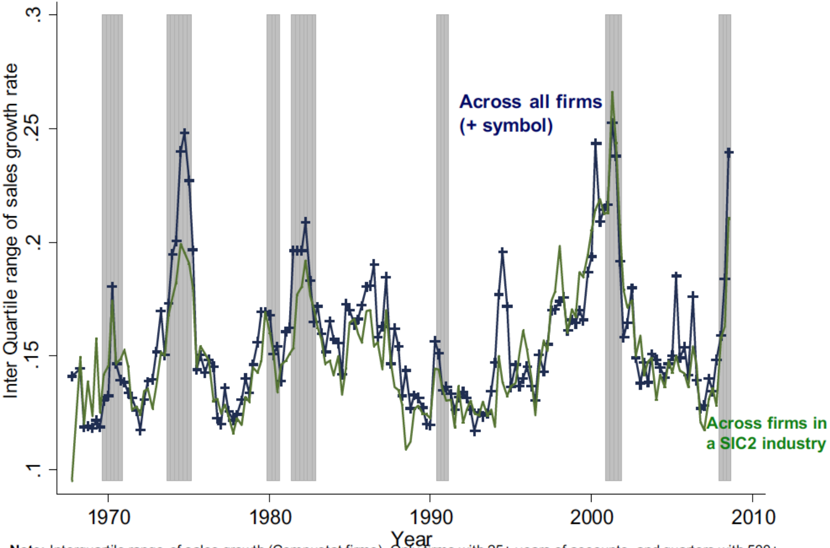
Notes: Constructed from the Census of Manufacturers and the Annual Survey of Manufacturing establishments, using establishments with 25+ years to address sample selection. Grey shaded columns are share of quarters in recession within a year. Plants' rank in the TFP distribution is their decile within the industry and year TFP ranking.

Industry growth dispersion (by month)



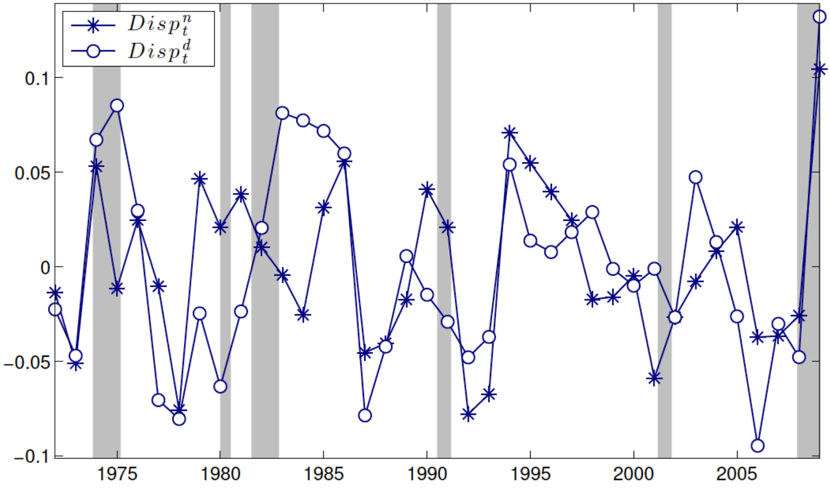
Note: 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th and 99th percentiles of 3-month growth rates of industrial production within each quarter. All 196 manufacturing NAICS sectors in the Federal Reserve Board database. Source: Bloom, Floetotto and Jaimovich (2009)

Firm growth dispersion (by quarter)



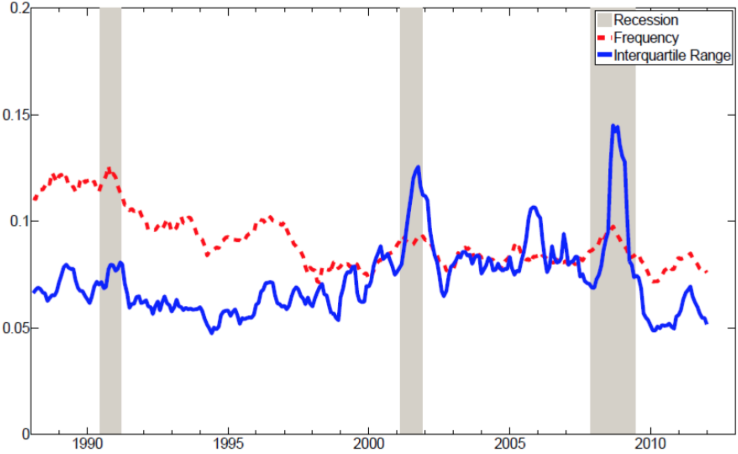
Note: Interquartile range of sales growth (Compustat firms). Only firms with 25+ years of accounts, and quarters with 500+ observations. SIC2 only cells with 25+ obs. SIC2 is used as the level of industry definition to maintain sample size. The grey shaded columns are recessions according to the NBER. Source: Bloom, Floetotto, Jaimovich, Saporta and Terry (2011)

Figure 1: Dispersion in productivity levels



Product level price dispersion (by quarter)

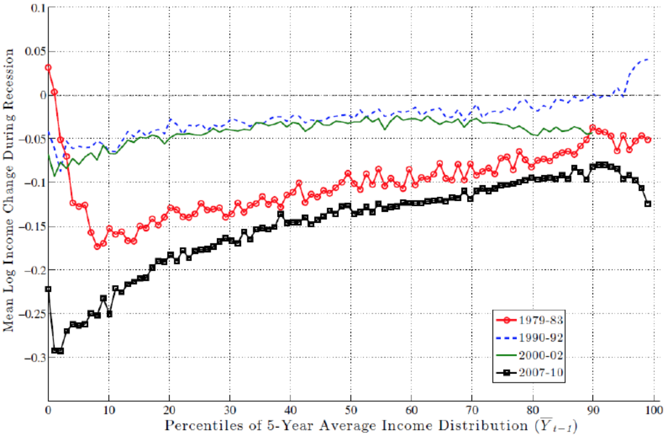
Figure 1: Price Changes Across Time



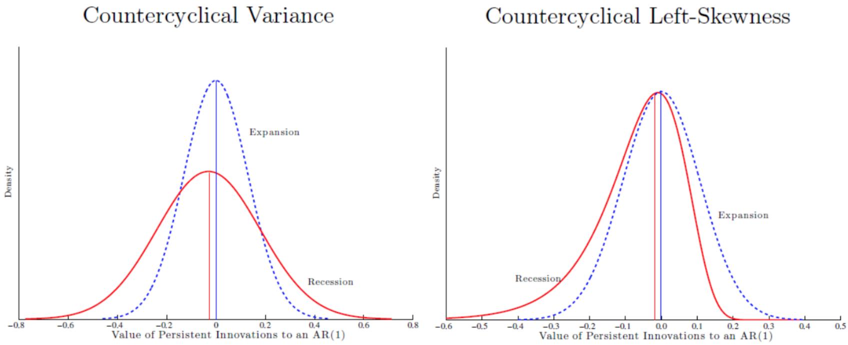
Data is seasonally adjusted using 12 monthly dummies and smoothed with a 6 month moving average.
Frequency is the Median Frequency of Adjustment.

Source: Joe Vavra (2014, QJE) "Inflation dynamics and time varying volatility"

But SSA data on several million individuals shows rising 3rd moment but flat 2nd moment in recessions



Guvenen, Ozkan & Song, "The nature of countercyclical income risk" (2014, JPE)
Notes: Uses about 5m obs per year from the US Social Security Administration earnings data

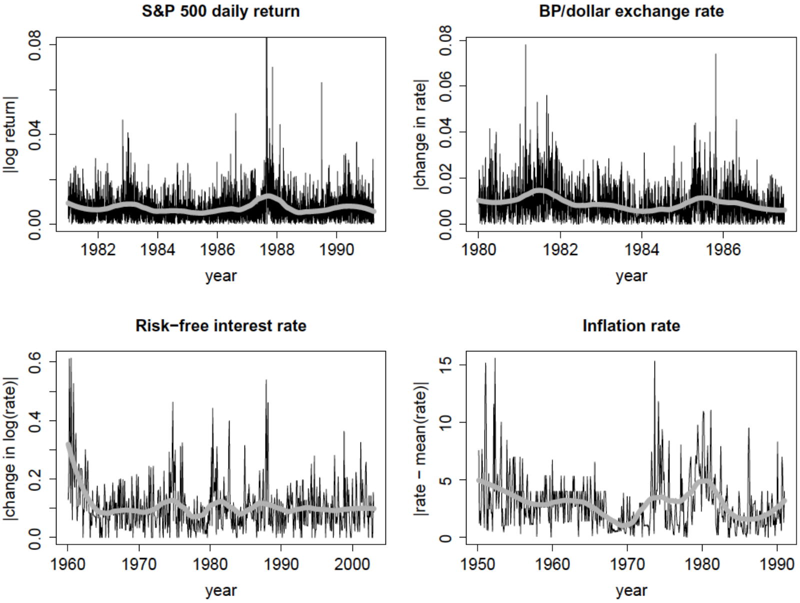


Macro, industry, firms, plants and prices

Wages

Literature I

- In one form or another, economists have talked for a long time about time-varying volatility.
- A breakthrough came with Engle's (1982) paper on autoregressive conditional heteroscedasticity, or ARCH.
- Engle postulated that the evolution of variance over time of time series x_t was an autoregressive process that is hit by the square of the (scaled) innovation on the level of x_t.
- The application in Engle's original paper was the estimation of an ARCH process for British inflation.
- Early indication that this was a central issue in macroeconomics.
- But it was not in macro where ARCH models came to reign: the true boom was in finance.


S&P 500 daily return
|log return|
0.00
0.04
0.08
1982
1984
1986
1988
1990
year
BP/dollar exchange rate
|change in rate|
0.00
0.02
0.04
0.06
0.08
1980
1982
1984
1986
year
Risk−free interest rate
|change in log(rate)|
0.0
0.2
0.4
0.6
1960
1970
1980
1990
2000
year
Inflation rate
|rate − mean(rate)|
0
5
10
15
1950
1960
1970
1980
1990
year

Literature II

- The situation changed after Kim and Nelson (1998), McConnell and Pérez-Quirós (2000), and Blanchard and Simon (2001).

- Documented that the volatility of U.S. aggregate fluctuations had changed over time. Stock and Watson (2002) named this phenomenon "the great moderation."

- Sims and Zha (2006) estimated a structural vector autoregression (SVAR) with Markov-regime switching both in the autoregressive coefficients and in the variances of the disturbances.

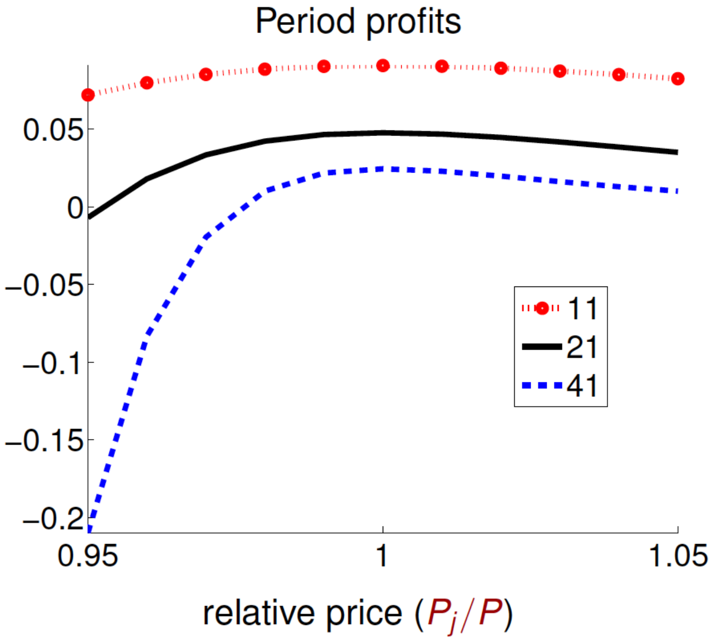
- They concluded that models with shocks that have time-varying volatilities are a key in applied macroeconomics.

Literature III

- Big boom, however, is after Bloom (2009).
- Many papers after it (including mine!).
- We will discuss some of them as we go along.
- There are:
  1. Methodological issues (solution, estimation).
  2. Data.
  3. Conceptual: endogenous vs. exogenous uncertainty, beliefs vs. DGP.
  4. Economic intuition.

Mechanisms behind uncertainty shocks

1. Utility function.
2. Price decisions.
3. Oi-Hartman-Abel effect.
4. Option value effect.
5. Ss-rules.
6. Non-conventional preferences, Gilboa and Schmeidler (1989).


Period profits
0.05
0
–0.05
–0.1
–0.15
–0.2
0.95
1
1.05
11
21
41
relative price (P_j/P)

Oi-Hartman-Abel effect

- Oi (1961), Hartman (1972) and Abel (1983).

- A higher variance of productivity increases investment, hiring, and output because the optimal capital and labor choices are convex in productivity.

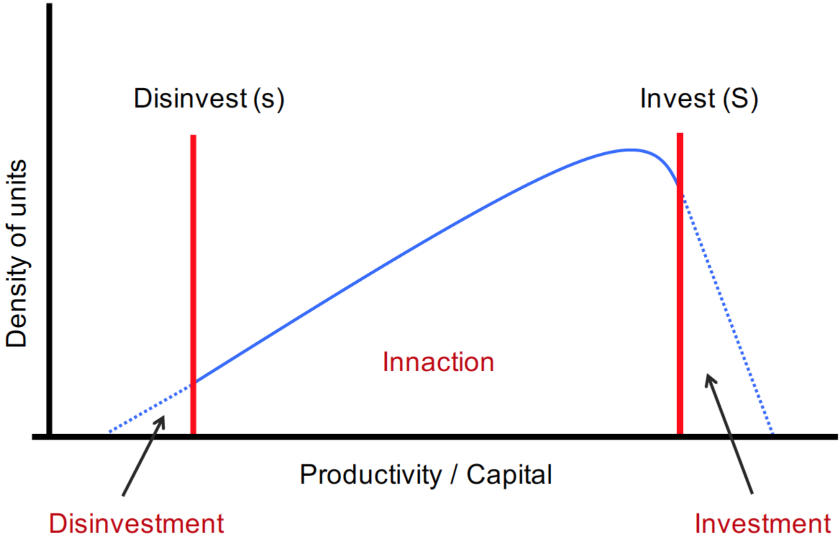
- Example:

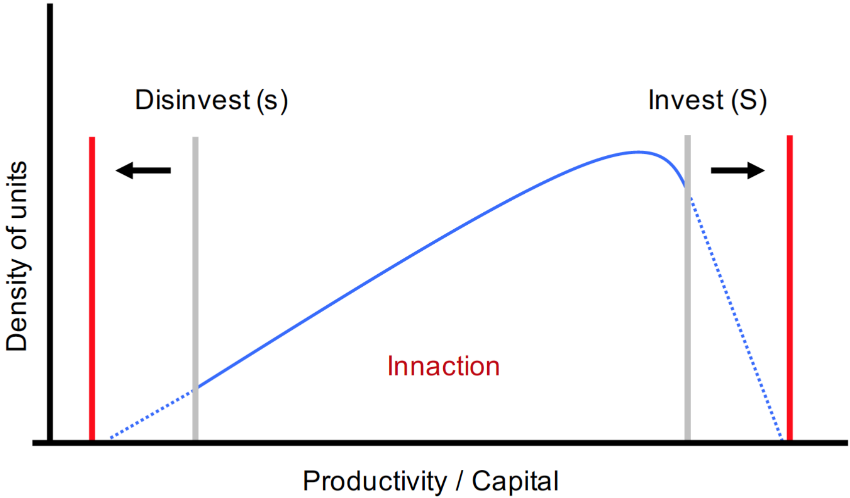
$$y = Ak^{\alpha} l^{\beta}$$

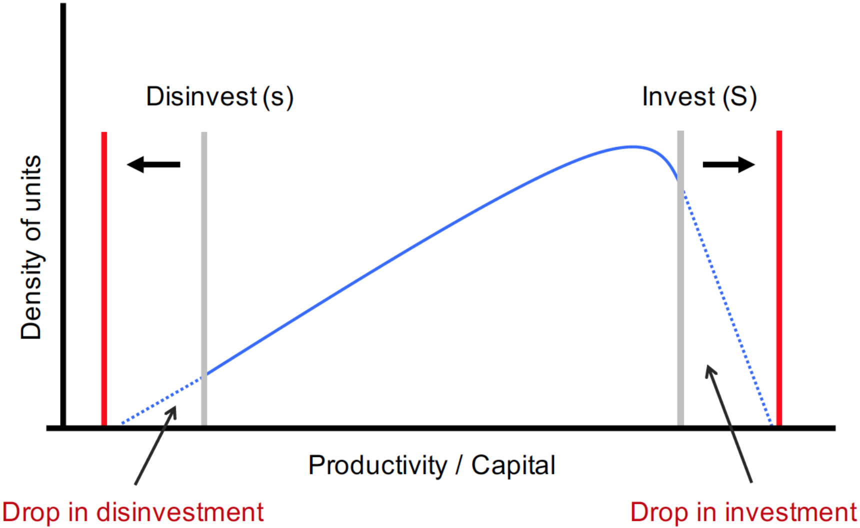
where $\alpha + \beta < 1$.

- Then:

$$\begin{aligned} k^* &= \mu_1 A^{\frac{1}{1-\alpha-\beta}} \\ l^* &= \mu_2 A^{\frac{1}{1-\alpha-\beta}} \end{aligned}$$


Disinvest (s)
Invest (S)
Density of units
Innaction
Productivity / Capital
Disinvestment
Investment


Disinvest (s)
Invest (S)
Density of units
Innaction
Productivity / Capital


Disinvest (s)
Invest (S)
Density of units
Productivity / Capital
Drop in disinvestment
Drop in investment

Ambiguity aversion

- Agents do not know dispersion of shocks.

- Problem:

$$V(k,z) = \max_{c,l,k'} \left[u(c_t, l_t) + \beta \min_{\lambda \in \left[\underline{\sigma_t}, \overline{\sigma_t}\right]} \mathbb{E}_{k.z} V\left(k', z'\right) \right]$$

$$\text{s.t. } c + k' = e^z k^\alpha l^{1-\alpha} + (1-\delta) k$$

$$z' = \lambda z + \sigma_t \varepsilon'$$

- Intuition.