BANCO DE ESPAÑA

# Discussion: "On the sources of the Great Moderation" by Jordi Galí and Luca Gambetti

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DG ECONOMICS, RESEARCH, AND STATISTICS

## Main findings

1. Output has a decrease in volatility larger than hours
2. **Shrinking contribution of non-technology shocks to output volatility**
3. **Change in the cyclical response of labor productivity to non-technology shocks**
4. Change over time in the response of hours to technology shocks

- **The "strong" version of the good luck hypothesis is rule out**
- Is not clear about the "weak" version
- Is not conclusive about the structural sources behind the "Great Moderation"
- A paper that leaves the reader wanting for more….but….even in its current version,
- The paper has helped us to better understand some points that have been stopping us with our own research. Thanks Jordi and Luca.

# Quick review of VAR identification with Long Term Restrictions

- Reduced form VAR (1) : $x_t + A_1 x_{t-1} + .....A_p x_{t-p} = u_t \quad u_t \to N(0,\Sigma\ )$
- Structural VAR (2): $K^{-1} x_t + K_1 x_{t-1} + .....K_p x_{t-p} = \varepsilon_t \quad \varepsilon_t \to N(0, I\ )$
- MA representation of (1) $x_t = u_t + B_1 u_{t-1} + B_2 u_{t-2} + ... = B(L) u_t$
- MA representation of (2) $x_t = C_0 \varepsilon_t + C_1 \varepsilon_{t-1} + C_2 \varepsilon_{t-2} + ... = C(L) \varepsilon_t$
- From (1) and (2) : $u_t = K\varepsilon_t \quad C(L) = B(L)K \quad C(1) = B(1)K$
- Identification:

$$C(1)C(1)' = B(1)\Sigma B(1)' \ \ with\ C_{12}(1) = 0 \quad K = B(1)^{-1} C(1) \quad C_i = B_i K$$

## VAR with changing parameters

- Reduced form VAR : $x_t + A_1^t x_{t-1} + .....A_p^t x_{t-p} = u_t \;\; u_t \rightarrow N(0, \Sigma^t)$
- They assume (A1): $\theta_t = vec(A_1^t, .....A_p^t)$

$$\theta_t = \theta_{t-1} + w_t$$

- They assume (A2): $\Sigma^t = F^t D^t F^t \; \gamma_t = vec((F^t)^{-1}) \, and \, \sigma_t = vec(D^t)$

$$\gamma_t = \gamma_{t-1} + \varsigma_t$$

$$\log(\sigma_t) = \log(\sigma_{t-1}) + \xi_t$$

- They assume (A3) $\varsigma_t, \xi_t, w_{t,} u_t \;\; independent$

## Key variable in Galí and Gambetti (2008) C(L)

- The key coefficients to make inference are : $C^t(L) = B^t(L)K^t$

- That is identified from: $C^t(1)C^t(1)' = B^t(1)\Sigma^t B^t(1)' \quad with\ C^t{}_{12} = 0$

- The MA representation: $x_{t+k} = u_{t+k} + B_1^{t+k-1} u_{t+k-1} + B_2^{t+k-2} u_{t+k-2} + \ldots$

- Long run effect of a shock: $\dfrac{\partial L x_{t+\infty}}{\partial u_t} = B_0^t + B_1^{t+1} + B_2^{t+2} + \ldots = B^t(1)$

- In order to calculate that they use future information But then, the unit shock? $\dfrac{\partial L x_{t+\infty}}{\partial u_t} = I + A_1^{t+1} + A_2^{t+2} + A_2^{t+2}(A_1^{t+1}) + \ldots$

- And the assumption of random walk is used when there is not future information

$$\frac{\partial L x_{t+\infty}}{\partial u_t} = I + A_1^{t+1} + A_2^{t+2} + (A_1^{t+1} A_2^{t+2}) + \ldots = I + (A_1^t + w_1^t) +$$

$$+ (A_2^t + w_2^t + w_1^t) + (A_2^t + w_2^t + w_1^t)(A_1^t + w_1^t) + \ldots \neq I + (A_1^t) + (A_2^t) + (A_2^t)(A_1^t) + .$$

## Key variable in Galí and Gambetti (2008) C(L)

- But, in addition to the previous technical point, there is a major issue:

$$\varsigma_t, \xi_t, w_t, u_t \ \textit{independent}$$

- Three main characteristics of impulse response function in linear frameworks:

*Symmetry, Proportionality, Invariance w.r.t. time*

- Galí and Gambetti keeps two of them:

*Symmetry, Proportionality*

- The size and sign of the shock never affect the transmission mechanism of the economy because of the independece of the shocks

## Key variable in Galí and Gambetti (2008) C(L)

- Let´s illustrate the problem with an example:

$$(Lx_{t+2} - E(Lx_{t+2} / \Omega_{t-1})) = (x_{t+2} - E(x_{t+2} / \Omega_{t-1})) +$$

$$+ (x_{t+1} - E(x_{t+1} / \Omega_{t-1})) + (x_t - E(x_t / \Omega_{t-1}) = Iu_{t+2} + B_1^{t+1} u_{t+1} + B_2^{t+2} u_t =$$

$$= u_{t+2} + (B_1^t + \omega_{11}) u_{t+1} + (B_2^t + \omega_{21} + \omega_{22}) u_t =$$

$$= K^{t+2} e_{t+2} + (B_1^t + \omega_{11}) K^{t+1} e_{t+1} + (B_2^t + \omega_{21} + \omega_{22}) K^t u_t =$$

$$(K^t + (\varsigma_{t+2} \mid \xi_{t+2}) + (\varsigma_{t+1} \mid \xi_{t+1})) e_{t+2} +$$

$$+ (B_1^t + \omega_{11})(K^t + (\varsigma_{t+1} \mid \xi_{t+1})) e_{t+1} +$$

$$+ (B_2^t + \omega_{21} + \omega_{22}) K^t e_t$$

- These dynamics are too rich and too full of economic content to just simplify them with zero correlations.

## Key variable in Galí and Gambetti (2008) C(L)

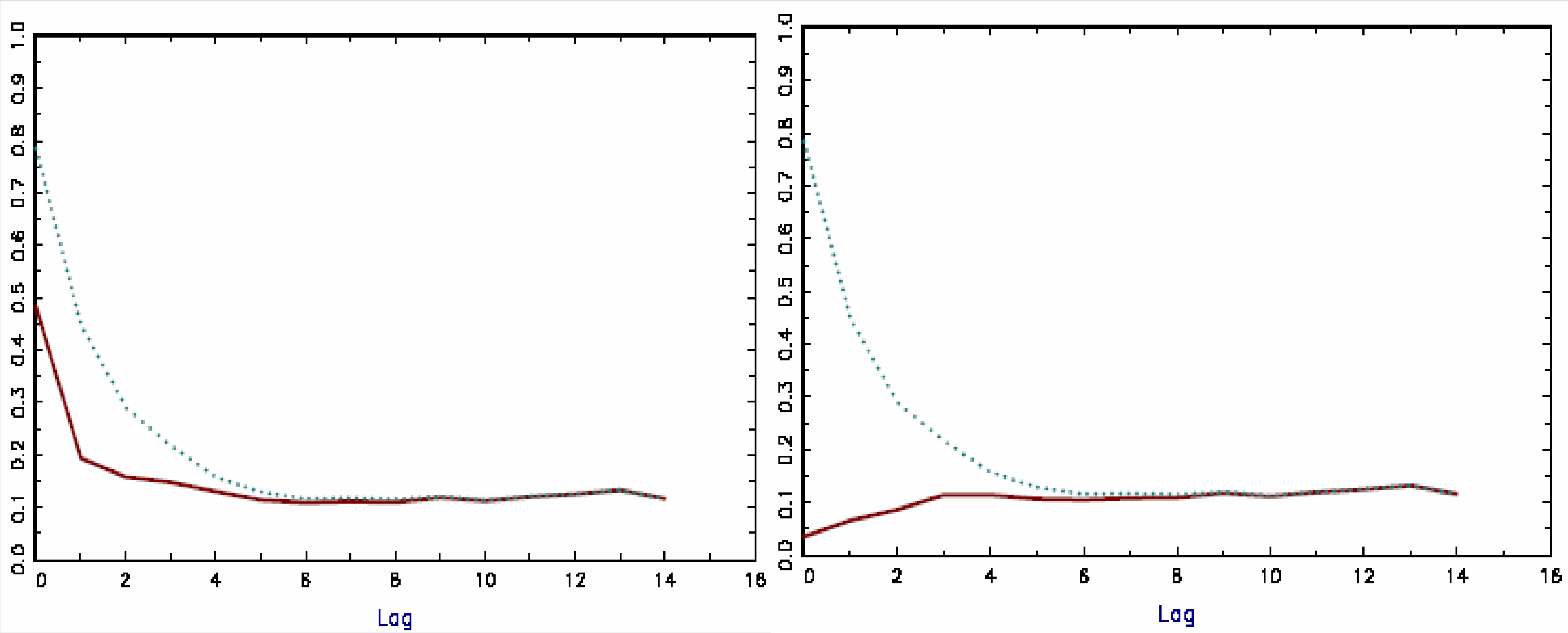
- Possible solutions :
- Debate vs Harding and Pagan and Hamilton (2003)

1. Inside their framework: Allow for dependence of the parameters and compute generalized impulse response functions
2. Outside their framework: In a non linear context, Camacho, Pérez Quirós and Rodríguez (2008) three dependent markov processes for the productivity slowdown, break in volatility and expansion and recessions but also dependent on the realization of the shocks ut.

# Key variable in Galí and Gambetti (2008) C(L)

**Predicted probabilities of recession in 2001.4 (low volatility; recession)**

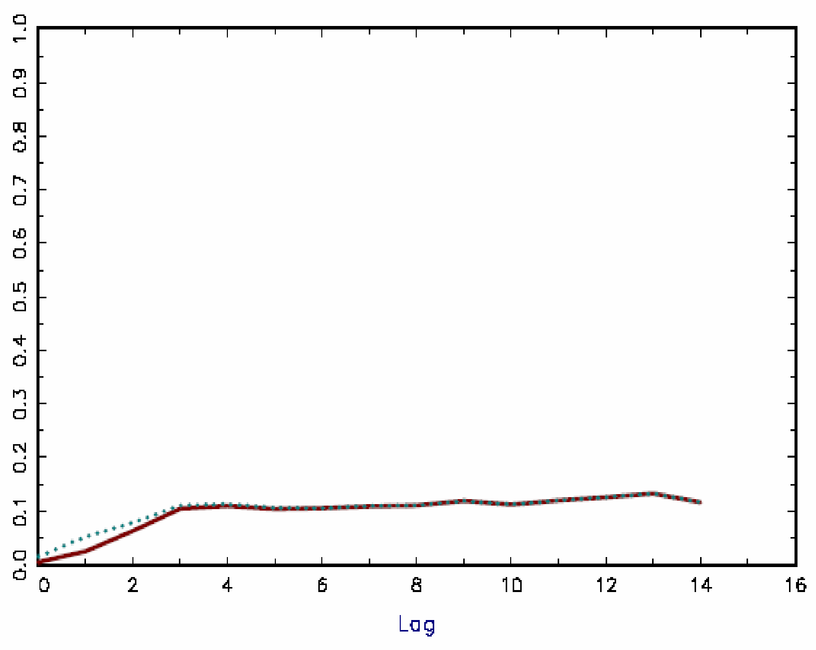
**after positive productivity shock of size 1 SD** **after positive hours shock of size 1 SD**



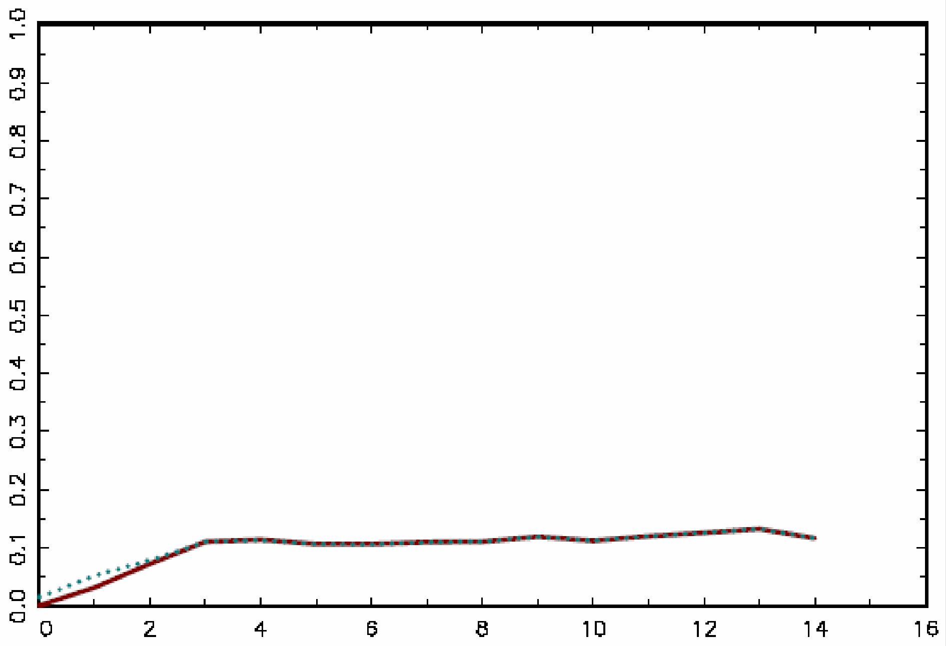
# Key variable in Galí and Gambetti (2008) C(L)

**Predicted probabilities of recession in 1997.4 (low volatility; expansion)**

**after positive productivity shock of size 1 SD**




**after positive hours shock of size 1 SD**



## Key variable in Galí and Gambetti (2008) C(L)

- Major problem of Generalized Impulse Response functions:

$$C(1)^{(t,u_t)} C(1)^{(t,u_t)}{}' = B(1)^{(t,u_t)} \Sigma^{(t,u_t)} B(1)^{(t,u_t)}{}'$$

$$K^{(t,ut)} = (B(1)^{(t,ut)})^{-1} C(1)^{(t,ut)}$$

$$u_t = K^{(t,ut)} \varepsilon_t$$

- Identification of shocks depends on the size of the shocks. And we can not just substitute the shocks with its future realizations.
- It is a difficult problem. Independence is just a starting point. Your results might only be valid under this restrictive assumption

## Variance decomposition. Good luck vs Structural change

•Even if we trust their calculations of $C^t(L)$

$$Var(x_{j,t}) = \sum_{i=0}^{\infty} (C_{i,a}^{t,j})^2 + \sum_{i=0}^{\infty} (C_{i,d}^{t,j})^2$$

Variance conditional to shock d

$$Cov(x_{j,t}, x_{r,t}) = \sum_{i=0}^{\infty} (C_{i,a}^{t,j})(C_{i,a}^{t,r}) + \sum_{i=0}^{\infty} (C_{i,d}^{t,j})(C_{i,d}^{t,r})$$

$$C_i^t = B_i^t K^t$$

Suppose that we only had good luck hypothesis:

$$K^{-1}x_t + K_1 x_{t-1} + .....K_p x_{t-p} = \varepsilon_t \quad \varepsilon_t \to N(0, I\ )$$

$$K^{-1} = \begin{pmatrix} k_a^{-1} & k_b^{-1} \\ k_c^{-1} & k_d^{-1} \end{pmatrix} \quad k_a^{-1}, k_d^{-1}\ change \quad K = \frac{1}{\det(K^{-1})} \begin{pmatrix} k_d^{-1} & -k_b^{-1} \\ -k_c^{-1} & k_a^{-1} \end{pmatrix}$$

Pure good luck, if it does not reduce volatility in exactly the same proportion will be reflected in change in conditional variance

## Variance decomposition. Good luck vs Structural change

- Suppose than only the first shock has reduced its variance by 1/2:

$$C_i^t = \begin{pmatrix} B_{i,11}^t & B_{i,12}^t \\ B_{i,21}^t & B_{i,22}^t \end{pmatrix} \begin{pmatrix} k_{11}^t & k_{12}^t \\ k_{21}^t & k_{22}^t \end{pmatrix} \qquad C_i^{tp} = \begin{pmatrix} B_{i,11}^t & B_{i,12}^t \\ B_{i,21}^t & B_{i,22}^t \end{pmatrix} \begin{pmatrix} \frac{k_{11}^t}{2} & k_{12}^t \\ k_{21}^t & k_{22}^t \end{pmatrix}$$

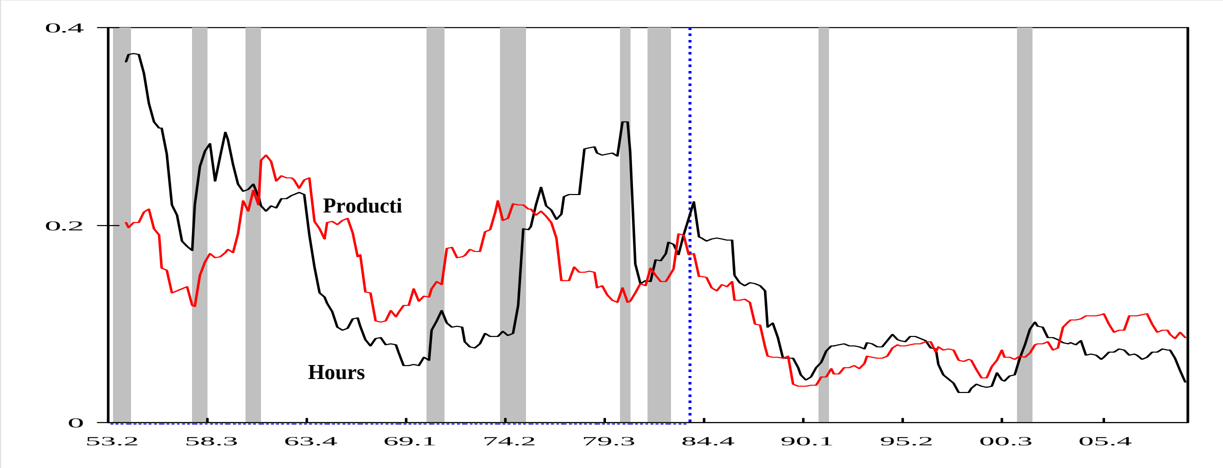
- Different effect on $C_i^t$ : that can explain the change in conditional correlations and the variations in impulse response functions.

- In that sense, the only thing that they rule out is the “strong” version of the good luck hypothesis, but perhaps they could go for more!

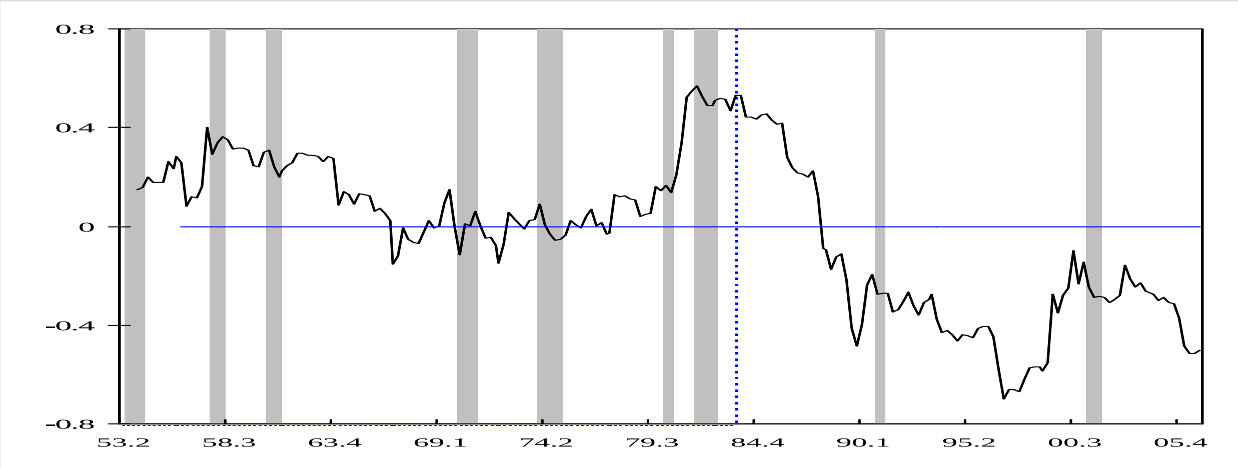
## One additional point. Economics vs Statistics

**Figure 1. Productivity and hours growth rates**

**Variances**



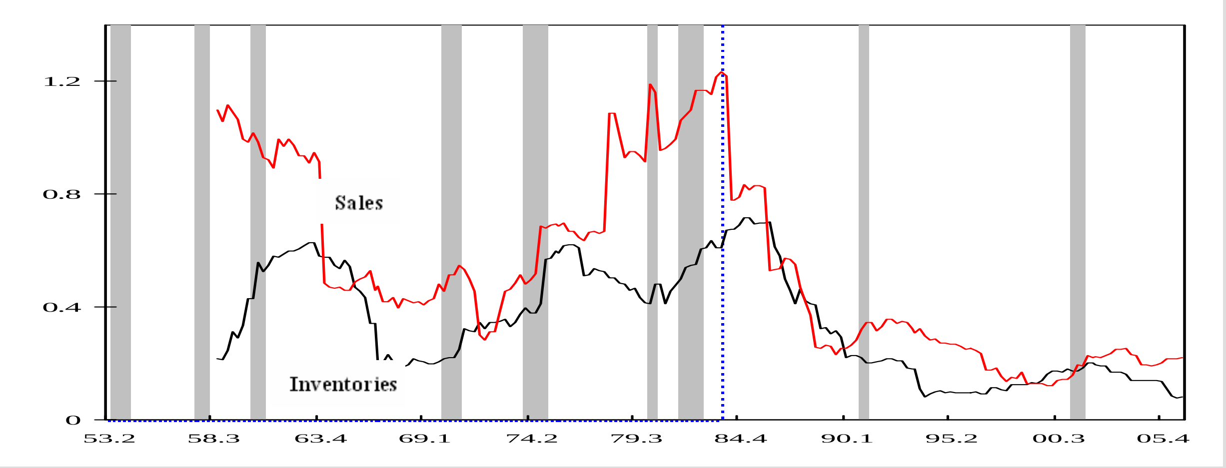

**Correlations**



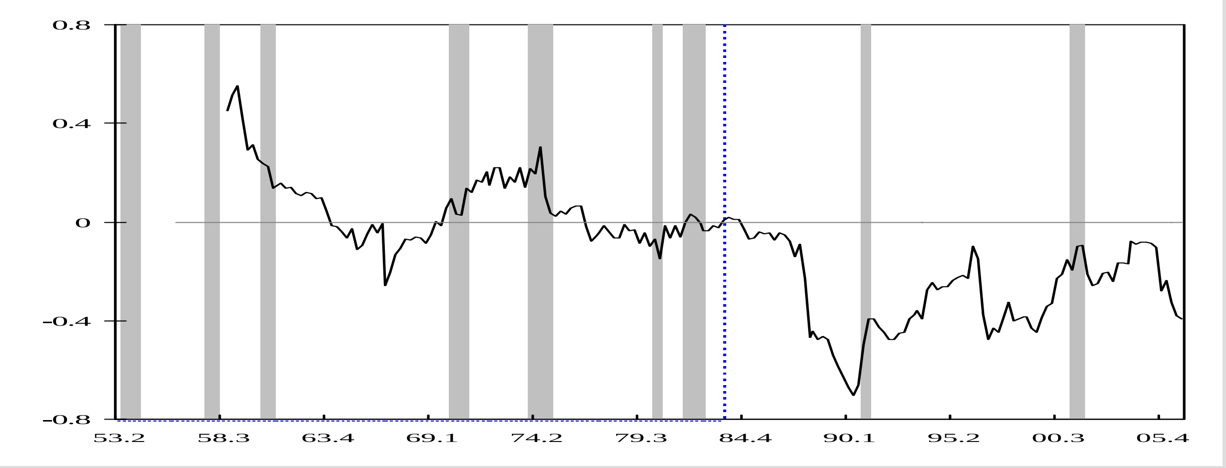
# One additional point. Economics vs Statistics

**Figure 2. Growth contributions of sales and inventories**

**Variances**




**Correlations**



## To conclude

- Interesting paper that gives new insides on the analysis of the Great Moderation.
- Good contribution to the literature. It could orientate future research on the topic towards new issues such as the changes in comovements or the relative role of different shocks that have not been explored.
- I think that the authors are aware that the paper raises more questions that it solves, as they point out in their conclusions when they recognize that they are not searching for casual relations or they understand that the possible explanations are still speculative.
- Their main message: Changes in macroeconomic performance of the US economy are far more complex than implied by the "good luck" hypothesis.
- My congratulations to Jordi and Luca.