Drift and Breaks in Labour Productivity

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This paper:

An investigation of changes in equilibrium labour productivity growth over the post-WWII era

- **Productivity measure: output per hour worked**
- **Countries: U.S., Eurozone, U.K., Japan, Australia**
- **Methodology:**
  - **tests for breaks in the mean**
  - **the Stock-Watson (1996, 1998) time-varying parameters median-unbiased estimation method**
- **Key results:**
  - **in the U.S., we identify both the 1970s' slowdown, and the 1990s' productivity resurgence**
  - **in the Eurozone, a marked slowdown since the 1980s**
  - **in the U.K., a marked slowdown since the 1960s, and some weaker evidence of a further deceleration in recent years**

Motivation:

- **Productivity is key for**
  - **a society's long-run standards of living**
  - **crucial policy issues, like the future solvency of pension systems …**

Gordon (1999): ***'day of reckoning of Social Security is postponed until 2072 if mean growth in output per hour is 1.84%; it is postponed until 2116 if mean growth is 2.6%.'***

➔ My estimates of equilibrium growth of output per hour for U.S. business and non-farm business sectors as of 2005:3: 2.7%

- **Monetary policy:**
  - **misperceptions about equilibrium productivity growth may lead to policy mistakes ➔ e.g., Orphanides and the Great Inflation of the 1970s …**
  - **shifts in productivity growth are associated to shifts in the natural rate of interest ➔ Laubach and Williams (2003)**

The Data

United States

- **output per hour in non-farm business and business sectors (1947:1-2005:3) and manufacturing sector (1987:1-2005:3)**

Eurozone

- **real GDP per hour, based on synthetic real GDP from Euro Area Wide dataset, and confidential ECB aggregate hours series (1980:1-2003:4)**

United Kingdom

- **real GDP per hour: official series (1971:1-2005:3) extended back to 1959:3 based on interpolated hours worked series ➔ pre-1971 series less reliable, I will show results for both longer and shorter series …**

Japan

- **real GDP per hour from the *Bank of Japan***

Australia

- **output per hour in private sector and in the whole economy, from the *Reserve Bank of Australia***

Results from Tests for Breaks in the Mean

Methodology: basically, same as Bai and Perron (2003) …

- **test for breaks in the mean by regressing series on a constant**
- **use Newey-West (1987) to control for autocorrelation and/or heteroskedasticity of residuals**

… but:

- **I use both the Andrews (1993) *sup*- and the Andrews-Ploberger (1994) *exp*-Wald statistics**
  ➔ exponential statistics well-known for being superior
- **Bootstrap critical values as in Diebold and Chen (1996)**
- **Use Bai's (1997) method of estimating multiple breaks one at a time, re-estimating each break date conditional on the others**

Let's see the results …

Results based on the *exp*-Wald tests (results based on *sup*-Wald are identical)

Break dates and 90% confidence intervals	*exp*-Wald (*p*-value)	Sub-periods	Mean (standard error)
U.S., output per hour, all persons, business sector:			
1973:2 [1973:1; 1973:3]	2.43 (0.059)	1947:2-1973:1	3.27 (0.35)
1995:4 [1995:3; 1996:1]	4.59 (0.042)	1973:2-1995:3	1.44 (0.34)
		1995:4-2005:3	3.02 (0.26)
U.K., real GDP per hour, whole economy (linked series):			
1973:2 [1973:1; 1973:3]	2.37 (0.06)	1959:3-1973:1	3.69 (0.44)
		1973:2-2005:3	2.06 (0.27)
Eurozone, real GDP per hour:			
1995:2 [1995:1; 1995:3]	5.97 (0.024)	1980:2-1995:1	2.37 (0.18)
		1995:2-2004:4	1.12 (0.24)

Not much evidence of time-variation …

… breaks identified for only three series

- **a marked decrease in equilibrium productivity in both the Eurozone and the United Kingdom …**
- **… and a U-shaped pattern in the U.S. business sector, but without a return, post-1995, to the pre-1970s levels …**
  ➔ results for U.S. business sector almost the same as those of Fernald (paper he'll present tomorrow)

Why are breaks identified for only three series?

- **A possible explanation: changes may have been too gradual to be detectable via break tests …**
  ➔ Cogley and Sargent (RED, 2005): 'break tests have remarkably low power in the case of random-walk time-variation …

Let's see random-walk time-variation … Two possibilities here:

- **a Bayesian approach, in the spirit of Cogley-Sargent:**
  ➔ good: it allows you perfect control of heteroskedasticity, *via* stochastic volatility
  ➔ bad: you have to start with a prior on the extent of random-walk time-variation … which is not great
- **The Stock-Watson (1996, 1998) Classical approach:**
  ➔ it allows you to test for and estimate the extent of random-walk time-variation … which is great!!

Results Based on the Stock-Watson TVP-MUB Method

A brief outline of the Stock-Watson method …

$$(1) \quad \pi_t = \mu_t + \phi_{1,t}\pi_{t-1} + \ldots \phi_{p,t}\pi_{t-p} + u_t \equiv \theta_t' z_t + u_t, \qquad u_t \sim N\left(0, \sigma^2\right)$$

$$(2) \quad \theta_t = \theta_{t-1} + \eta_t \qquad\qquad \eta_t \sim i.i.d.\ N\left(0_{p+1}, \lambda^2\sigma^2 Q\right)$$

Following Nyblom (1989) and Stock-Watson (1996, 1998) we set $Q = \left[E\left(z_t z_t'\right)\right]^{-1}$**, and we estimate it as:**

$$\hat{Q} = \left[T^{-1}\sum_{t=1}^{T} z_t z_t'\right]^{-1}$$

Under this normalisation, the coefficients on the transformed regressors follow a (*p*+1)-dimensional standard random walk

➔ **λ is key parameter, as it governs the amount of random-walk drift in the model …**

Searching for random-walk time-variation, and median-unbiased estimation of λ

We follow Stock and Watson (1996, 1998):

- **do an *exp*-Wald (*sup*-Wald) test for a joint break in μ and ρ—call the test statistic L^***
- **simulate (1)-(2) conditional on a grid of values for λ**
- **for each simulation, do an *exp*-Wald (*sup*-Wald) test for a joint break in μ and ρ, thus building up the empirical distribution of the test statistic**
- **MUB estimate of λ is that value, λ_{MUB}, such that median of simulated distribution conditional on λ_{MUB} is equal to L^***
- **deconvolute the PDF of λ_{MUB} *via* the procedure detailed in Appendix *A***
- **compute confidence bands for TVP estimates of $\mu_t/(1-\rho_t)$ and ρ_t based on the Monte Carlo integration procedure**

described in appendix *B*—adaptation to the case at hand of the Hamilton (*J. of Econometrics*, 1986) procedure

- **in particular, we control for time-variation in the volatility of reduced-form innovations along the lines of Boivin (2004):**

  ➔ test for multiple breaks at unknown points in the sample in the innovation variance …

  … when running the Kalman filter, impose the volatility breaks

- **Why is controlling for changes in volatility so important?**

  ➔ Stock's (2002) comment on Cogley and Sargent's *NBER Macro Annuals* paper: 'you don't control for changes in volatility, you systematically overestimate the amount of random-walk drift …'

Results:

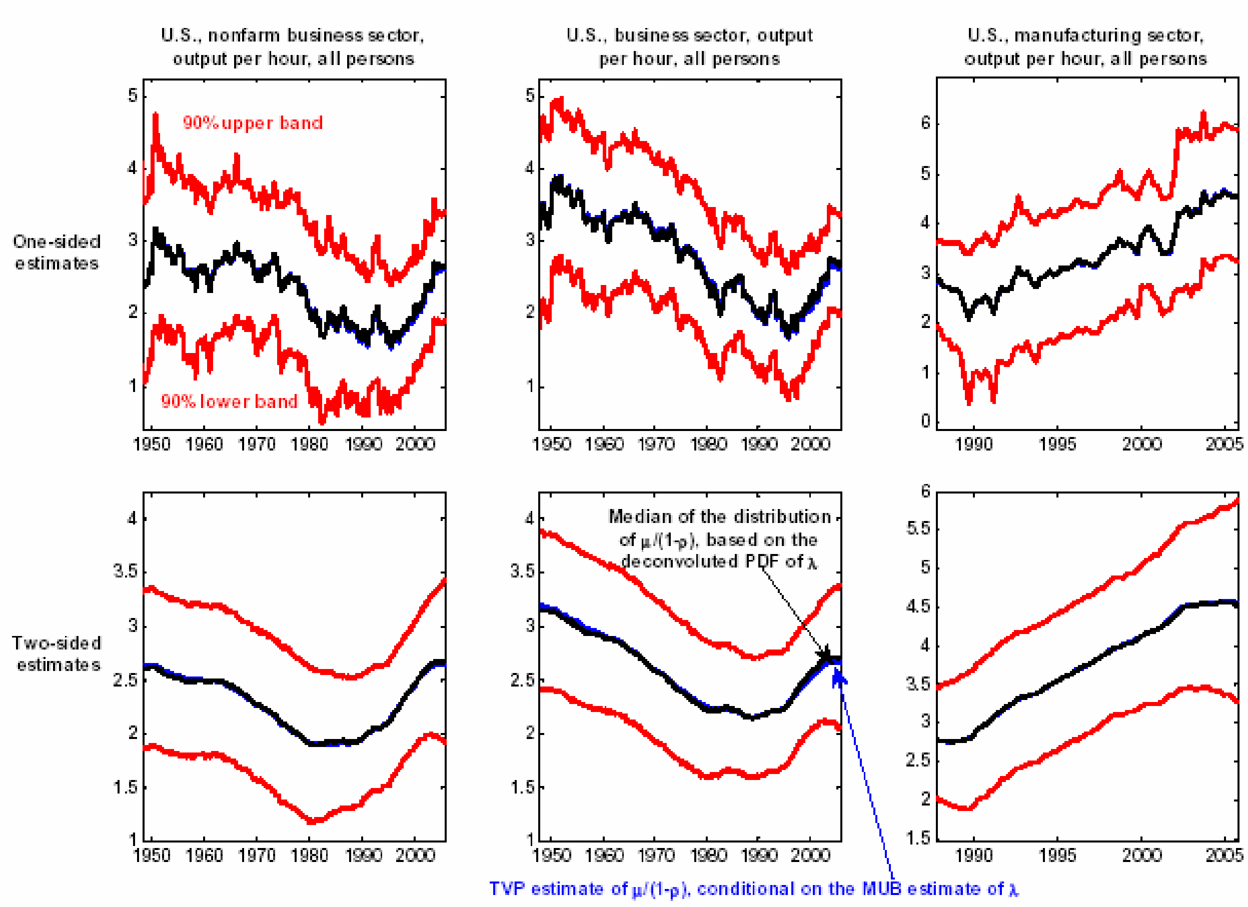
	exp-Wald (*p*-value)	$\hat{\lambda}$	*sup*-Wald (*p*-value)	$\hat{\lambda}$
U.S., output per hour, all persons:				
nonfarm business sector	3.13 (0.061)	0.02241	14.78 (0.013)	0.03793
business sector	2.47 (0.117)	0.01897	8.26 (0.168)	0.01724
manufacturing sector	9.13 (0.001)	0.05172	24.50 (0.001)	0.05172
U.K., real GDP per hour				
linked series	2.557 (0.102)	0.02414	8.61 (0.142)	0.02241
ONS-LFS series	0.715 (0.699)	0	3.82 (0.705)	0
Eurozone, real GDP per hour	14.048 (0)	0.05172	32.920 (0.001)	0.05172
Japan, real GDP per hour	1.12 (0.454)	0.01379	4.87 (0.500)	0.00345
Australia: output per hour:				
market sector	2.08 (0.165)	0.03448	7.40 (0.210)	0.03103
all industries	16.84 (0)	0.05172	42.26 (0.000)	0.05172

- **based on simulated *p*-values, evidence of time-variation is strong only for Eurozone, U.S. non-farm business and manufacturing sectors, and Australia, all industries …**
- **… but a *p*-value greater than 10% should be regarded as strong evidence against time-variation only if we had very strong reasons for believing in time-invariance …**

  ➔ not clear to me why this should be the case …

  ➔ more reasonable to assume time-variation and to estimate its extent … **Let’s see some results**

United States



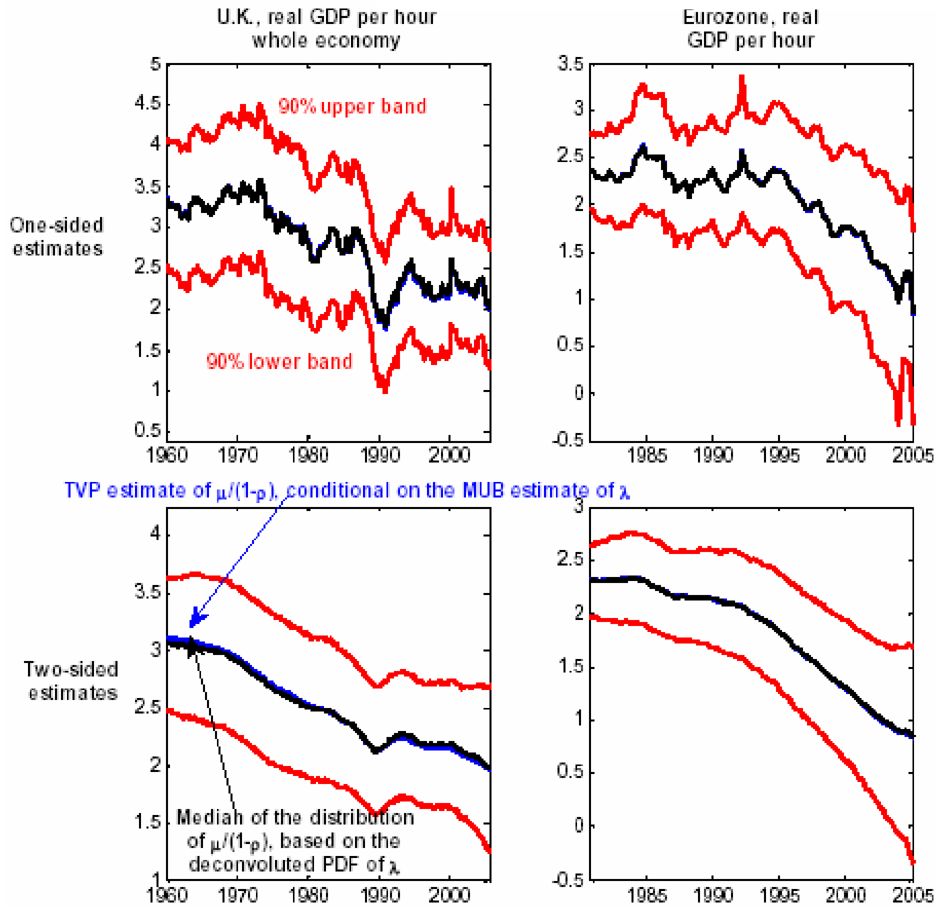
A broadly U-shaped pattern over the post-WWII era …

… very much in line with the traditional U.S. narrative of a productivity slowdown in the 1970s and a 'new economy' resurgence in the 1990s …

Equilibrium productivity growth in 2005:3: 2.7%, 2.7%, 4.5%

➔ for non-farm business sector, estimates near-numerically identical to those of Jorgenson-Ho-Stiroh (2004), 2.6% …

United Kingdom and Eurozone



A collapse in the Eurozone

- equilibrium productivity in 2004:4 estimated at 0.9%

In the U.K. a continuous deceleration since the 1960s

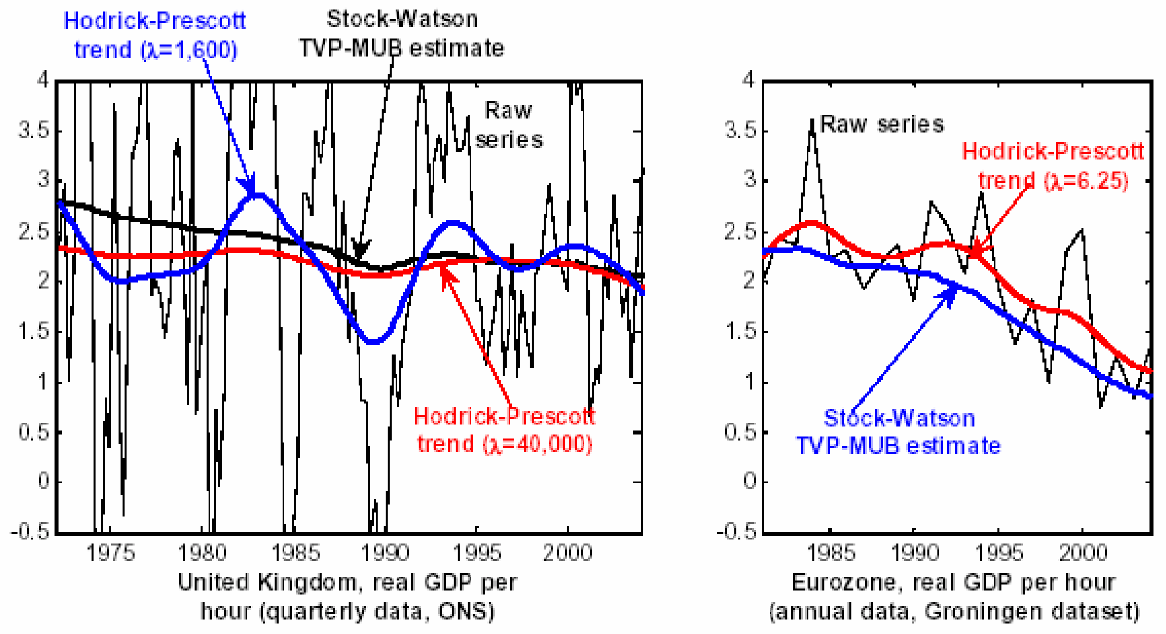
- no acceleration in productivity over most recent past …
- … equilibrium productivity in 2005:3 estimated at 2.0%

How robust are these results?

- In both cases hours have been (partly) interpolated
- U.K. post-1971 (more reliable): $\lambda_{MUB}=0$

Let's see some results based on filtering of non-interpolated annual (Eurozone) and quarterly (U.K.) series …

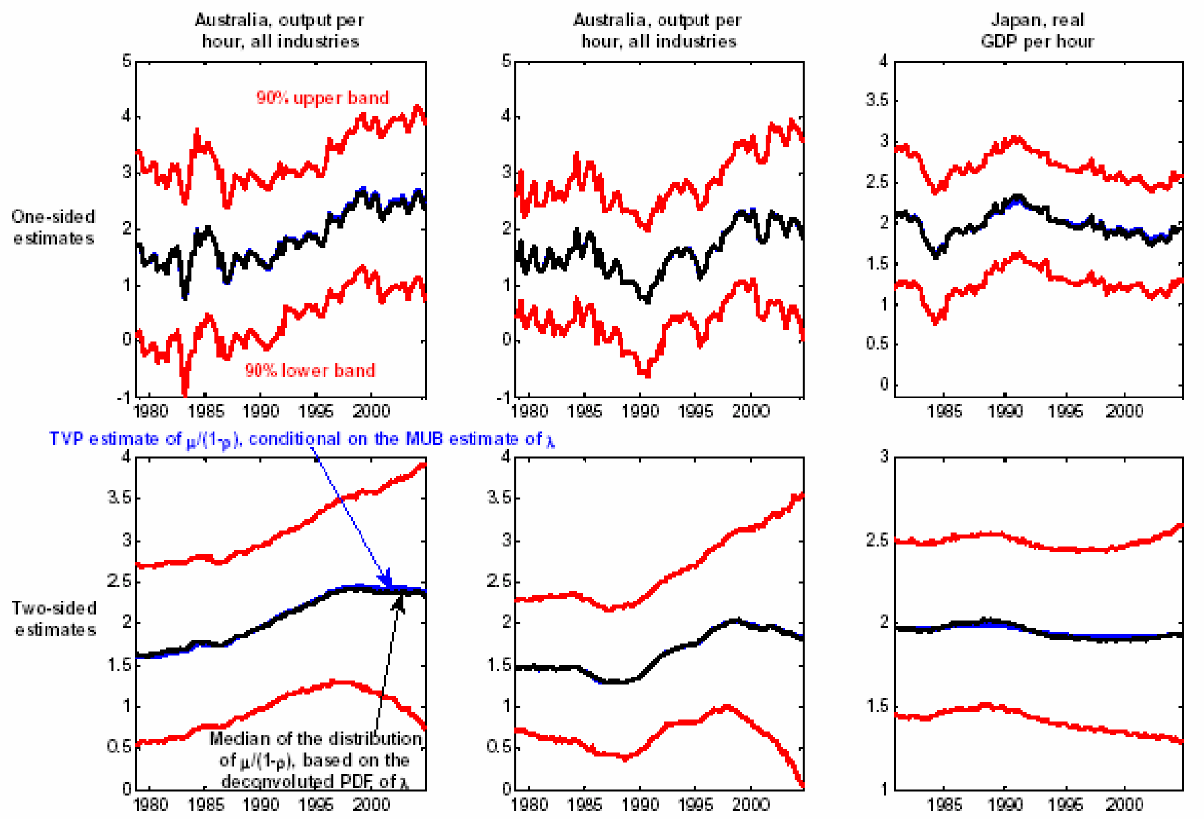
U.K. and Eurozone: raw series and HP trends



- **Eurozone: the broad trend seems to be there…**
- **U.K.: λ=1,600 gives you too much trend variability; with a larger λ—e.g. λ=40,000—you get results even 'worse' than those based on Stock-Watson …**

  ➔ but both results suggest a gentle decline in recent years

Australia and Japan



Japan

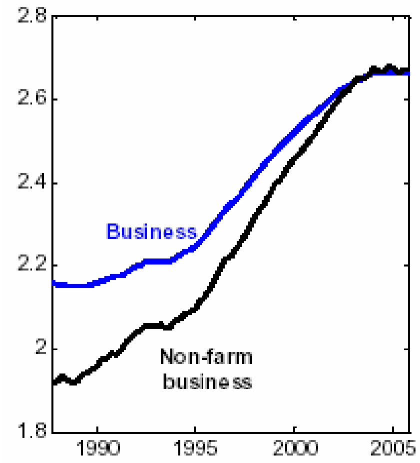
- **virtually no time-variation**
- **consistent with large simulated *p*-values (0.45, 0.50)**

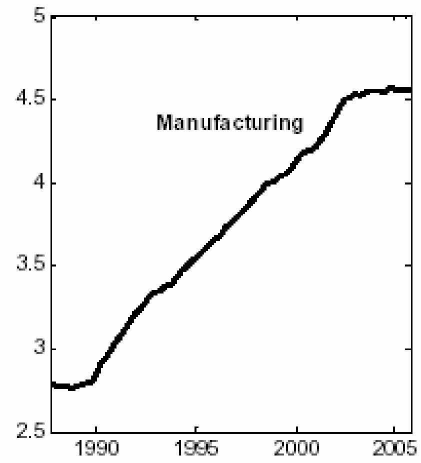
Australia

- **clear acceleration in private sector, with *plateau* reached in mid-1990s …**
- **… more complex picture in whole economy**

Summing up

- **In the United States, the productivity acceleration is undeniable:**
  - **detected based on 3 series**
  - **starts in the first half of the**
  - **1990s in all three sectors**
  - **interestingly, in all three sectors the acceleration seems to have reached a *plateau* in the last 2-3 years:**

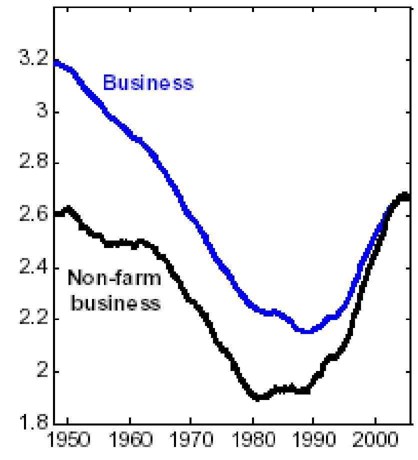




  - **a convergence between business and non-farm business sectors …**

    ➔ not clear (to me) how to interpret this …

    ➔in U.S., share of agriculture is broadly unchanged since the 1970s …



In the Eurozone, the deceleration is undeniable …

➔ you may quarrel with the specific point estimate of equilibrium productivity growth—0.9 vs. 1.1—but the collapse is there …

- **In the United Kingdom, the picture for the most recent period is not 100% clear, but evidence points towards a gentle deceleration in productivity growth …**

Implications for monetary policy

- **The natural rate of interest should in general be regarded as time-varying**
- **The problems discussed by Orphanides are a permanent part of the 'macroeconomic landscape'**

And therefore, a conceptually related question …

‘How large is the permanent component of labour productivity growth?’

➔ ‘What fraction of quarter-on-quarter change in labour productivity growth should be regarded as permanent?’

Let’s see, based on Cochrane’s variance ratio estimator …

- **compute confidence intervals *via* spectral bootstrapping**
- **only consider series with more than 40 years of observations**
  ➔ the ‘size of the unit root’ pertains to the infinite long run of a series, so you need very long series …

Let’s see some results …

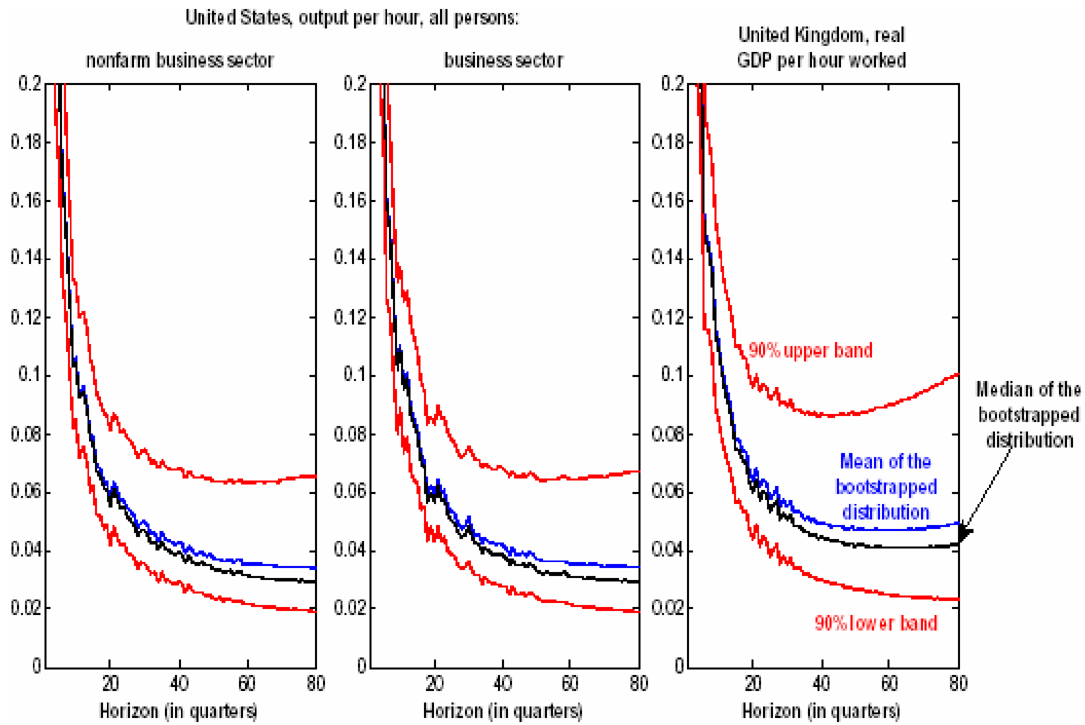


Table 4 Bootstrapped distribution of Cochrane's variance ratio estimator at the 20-year horizon (percentage points)

	Median	Mean	90% confidence interval
U.S., output per hour, all persons:			
nonfarm business sector	2.94	3.41	[1.91; 6.57]
business sector	2.93	3.44	[1.91; 6.74]
U.K., real GDP per hour, whole economy (linked series)	4.18	4.94	[2.33; 10.08]

Not surprisingly, a large uncertainty surrounding the estimates …

In the U.S., about 3-4% of the quarter-on-quarter change in productivity growth is estimated to be permanent

In the U.K., about 4-5%

➔ definitely non-negligible fractions …