Productivity trends from 1890 to 2012 in advanced countries

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Productivity and the long run

○ **Major current concerns regarding productivity…**
- Information and communication technology
- US-Europe and Japan divergence
- Impact of the Great Crisis
- Risk of 'secular stagnation'?

○ **… can be enlightened by examining the long run**
- Comparison with previous technology shocks
- Previous convergence paths
- Experience of past major disruptions

Current issues

○ **Information and communication technology**
  - R. Gordon (2012, 2013, 2014): productivity structural slowdown, end of ICT productivity wave?
  - vs Byrne, Oliner and Sichel (2013, 2014), among others: measurement problems?

○ **US-Europe and Japan divergence since mid 1990s**
  - End of a long convergence process
  - Tentative explanations

○ **A new deal with the Great Crisis**
  - What is the future of productivity?
  - Could we suffer from a 'secular stagnation'? (Summers, 2013, …)

Literature

○ **Technological progress, innovations**
- Aghion and Howitt (1998, 2009, 2012) …
- Crafts and O'Rourke (2013) …
- Ferguson and Washer (2004)n…

○ **Convergence**
- Barro and Sala-i-Martin (1997) …
- La Porta, Lopez-De-Silanes and Shleifer (2008) …
- Algan and Cahuc (2010) …

○ **Productivity in the long run**
- Islam (2003) …
- Madsen (2010) …
- Crafts and O'Rourke (2013) …

What we do

○ **Productivity level and evolutions over the period 1890-2012**
- Using annual and quarterly data

○ **13 advanced countries**
- G7: US, UK, Japan, France, Germany, Italy, Canada
- Spain, The Netherlands, Finland
- Australia, Sweden, Norway
- +reconstituted Euro area

○ **Labor Productivity and TFP**
- Filtering: productivity waves (HP filter, λ = 500)
- Breaks (Bai and Perron tests)

Introduction 〉 Data & Methodology 〉 Technology 〉 Convergence 〉 Robustness

What we find

1. **Two productivity growth waves**
2. **In the US, a smaller and shorter-lived ICT productivity wave**
3. **In other countries, delayed productivity waves, if any**
4. **Two main productivity leadership changes**
5. **No global and permanent convergence process**
6. **Global productivity breaks due to global shocks**
7. **Country-specific breaks due to idosyncratic shocks**
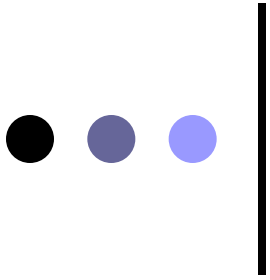
DATA AND METHODOLOGY

Computing productivity

- Labor productivity per hour $LP_{i,t} = \dfrac{Y_{i,t}}{H_{i,t}}$ with *H* total number of hours worked

- Total factor productivity

$$TFP_{i,t} = \frac{Y_{i,t}}{H_{i,t}^{1-\alpha} K_{i,t-1}^{\alpha}} \qquad \alpha = 0,3$$

- The capital stock:
  - Permanent inventory method δ=10% (equipment) / 2.5% (building)
  - Distinguishing building and equipment
  - Taking into account war/earthquake damages

- Productivity level: 2005 PPP USD from Penn world tables

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Data sources

- **For annual data**
  - Starting from Cette, Kocoglu and Mairesse (2009) for US, UK, JP, FR
  - The basis: Maddison (2001, 2003)…
  - …updated by Bolt *et al.* (2013) and others…
  - and complemented for specific countries by Baffigi / Broadberry *et al.* for Italy, Prados for Spain, Villa for France, Smits *et al.*/Groote *et al.* for the Netherlands…
  - Particular weakness for Hours worked per employee

- **For quarterly data**
  - From 1960 to 2012 Q4
  - National accounts, Eurostat, OECD and specific national sources

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Filtering and breaks

○ **Filtering**
  - Hodrick-Prescott filtering
  - 30-years cycles ($\lambda = 500$)

○ **Breaks**
  - Bai and Perron (1998): optimal number and datation of breaks+trends
  - Minimum gap between 2 breaks: 7 years for annual data; 5 years for quarterly data
  - After 1960: breaks on quarterly data reported on annual data
  - Dealing with wars:
    - major disruptions and unreliable data
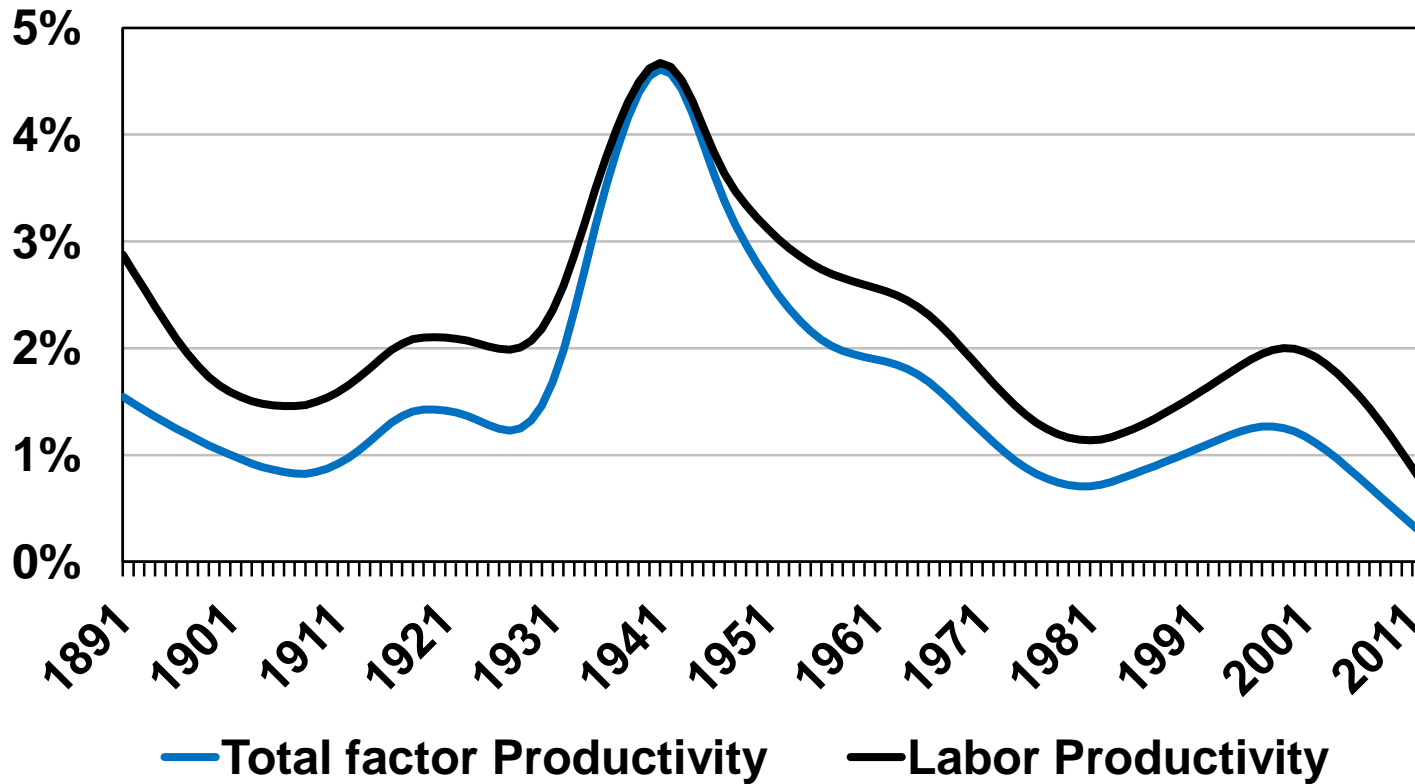   - Testing breaks in trend and intercept through dummies
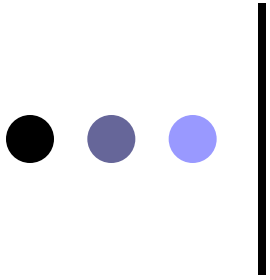
TECHNOLOGY
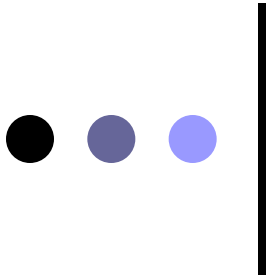
1. Two productivity growth waves

Two productivity growth waves

United States:
HP filtering of Productivity growth (with λ=500)

Total factor Productivity   Labor Productivity

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Two productivity growth waves

- **1st productivity growth wave**
  - 2nd industrial revolution: electricity, internal combustion engine, chemistry, communication (Gordon, 2000 : 'The big wave')
  - But also production organization, financial markets, education… (Ferguson and Washer, 2004)
  - Long lag in diffusion: cf. electricity (David, 1990)
- **2nd productivity growth wave**
  - ICTs

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2. **In the US, a smaller and shorter-lived ICT productivity wave**

A smaller and shorter-lived ICT wave

Labour productivity growth (in %)
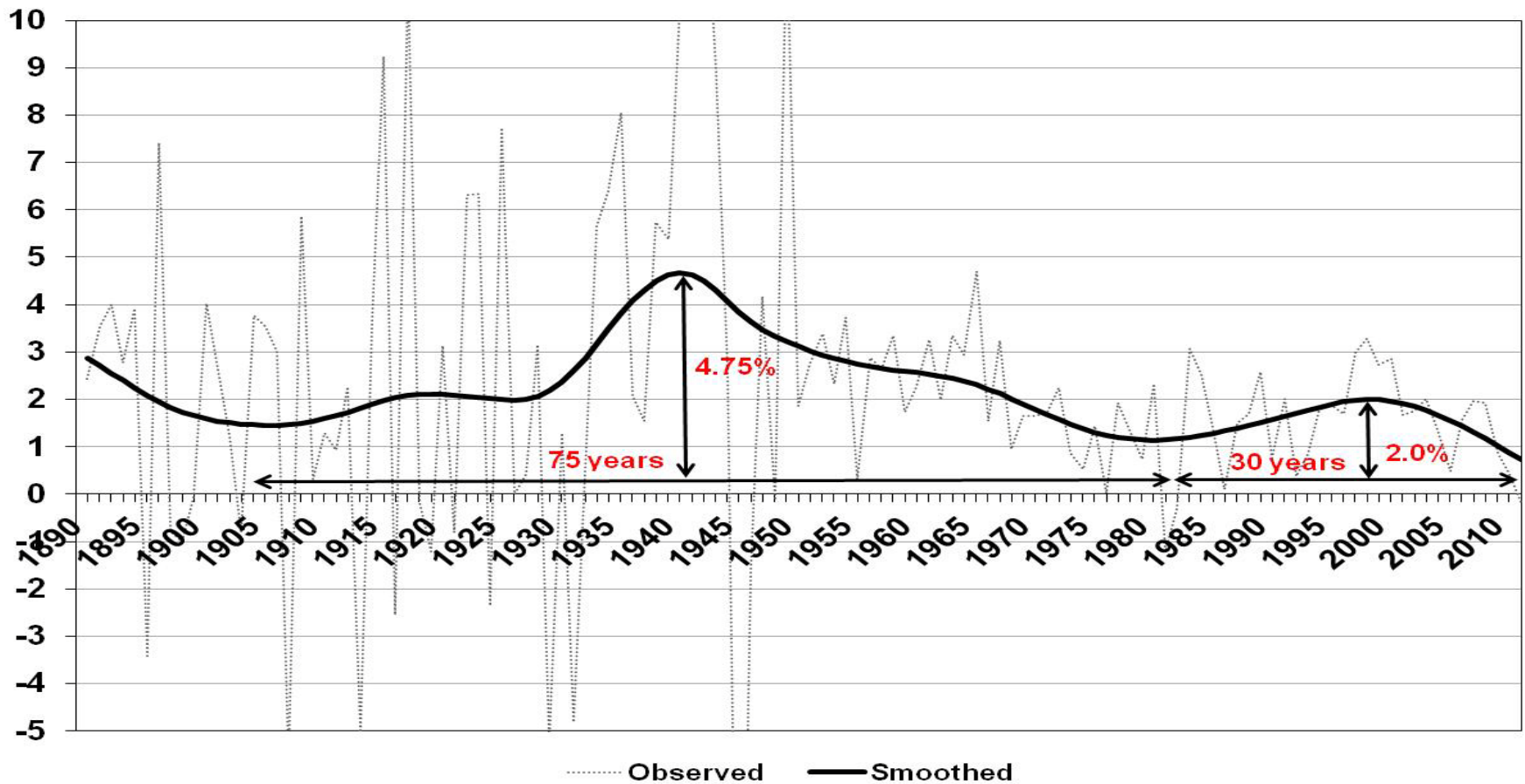
A smaller and shorter-lived ICT wave

United States

Labor productivity
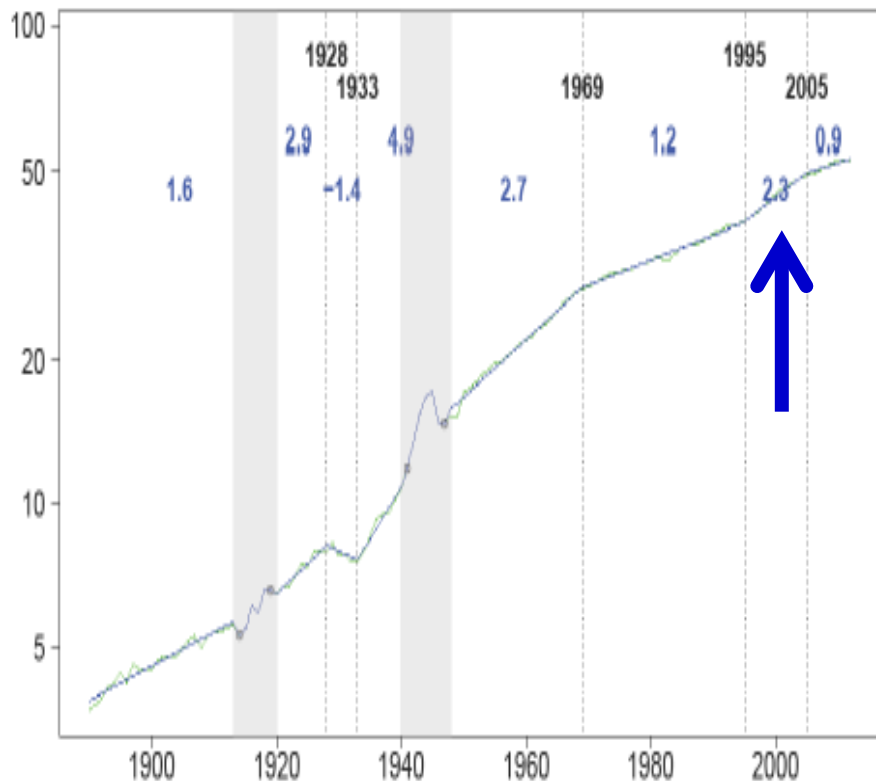
TFP
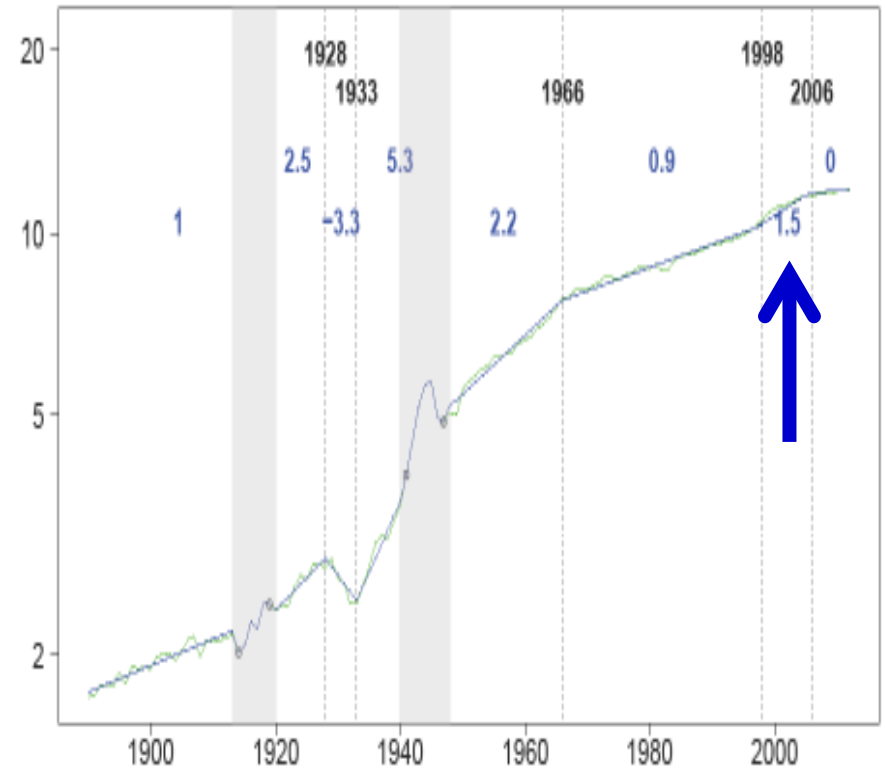

US$ PPP of 2005 (log scale)
Areas in grey: war periods

A smaller and shorter-lived ICT wave

○ **Mid-1990s upward break in US productivity**
- Stressed by Jorgenson (2001) and others
- TFP in ICT-producing sectors
- Capital deepening in ICT-using sectors

○ **Downward break in 2002 / 2004**
- Before the financial crisis
- Deceleration in Moore's law (Gordon, 2012, 2013, 2014, …)?

A smaller and shorter-lived ICT wave

○ **Annual growth rate of investment price relative to GDP price – In %**
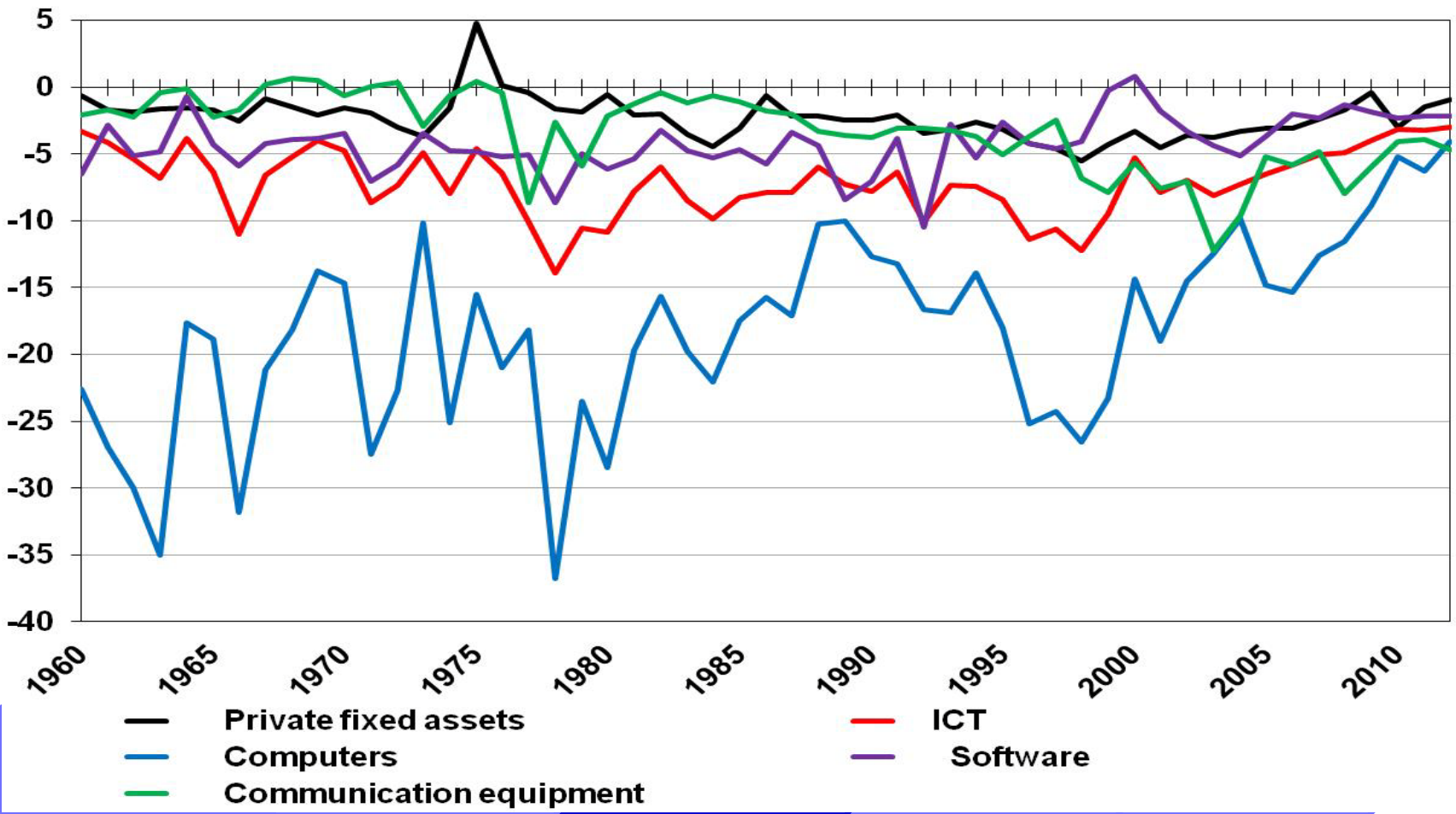
A smaller and shorter-lived ICT wave

➤ **Simple model from Cette, Mairesse and Kokoglu (2005)**

- **Cobb-Douglas production function** in growth rate:

$$\overset{o}{Q} = \overset{o}{TFP} + \alpha.\overset{o}{K} + (1-\alpha).\overset{o}{N}$$

- **Long term constraint**: $\overset{o}{P_Q} + \overset{o}{Q}* = \overset{o}{P_K} + \overset{o}{K}*$ or: $\overset{o}{K}* = \overset{o}{Q}* + (\overset{o}{P_Q} - \overset{o}{P_K})$

- Then **potential growth**: $\overset{o}{Q}* = \dfrac{\overset{o}{TFP}}{1-\alpha} + \dfrac{\alpha}{1-\alpha}.(\overset{o}{P_Q} - \overset{o}{P_K}) + \overset{o}{N}*$

- If $\overset{o}{P_Q} = \overset{o}{P_K}$ as in usual one product models,

  we get the usual expression of potential growth: $\overset{o}{Q}* = \dfrac{\overset{o}{TFP}}{1-\alpha} + \overset{o}{N}*$

➤ From this model and previous numbers, assuming alpha = ¼
Average annual contribution of relative investment price decrease, in the USA, over 1959-2012: ¾ pp which is large, but 0 pp last years…

A smaller and shorter-lived ICT wave

➢ **The fall of ICT price decrease from the 2000s,
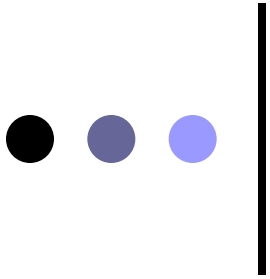3 explanations:**

- Back to a three-year cycle (Pillai, 2011)?
  And even a longer cycle recently?

- Increase of price-cost markups in chip industry
  (Aizcorbe, Oliner, Sichel, 2008 ; Byrne, Oliner, Sichel, 2013, 2014)
  From unsustainable R&D research costs (Pillai, 2011)?

- BLS matched-model methodology over-evaluates chip price evolution
  from 2001?
  No change in chip price evolution
  Discount not taken into account (Byrne, Oliner, Sichel, 2013, 2014)
  Discount from over-capacities?

A smaller and shorter-lived ICT wave

➤ **If ICT relative price remains at the low decrease rate of recent years**
  ▪ End of the ICT TS?
  ▪ Long term low productivity growth – 'Secular stagnation'? (Summers, 2013,)
  ▪ Gordon (2012, 2013, 2014) is right

➤ **Some other possible steps for the ICT Technological Shock**
  ▪ In some years, 3D chips…
  ▪ In the long term, quantum computing, bio chips…
  ▪ *International Technology Roadmap for Semiconductors* (2012): optimistic on Moore's law continuation until 2020-2025

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3. **In other countries, delayed productivity growth waves (if any)**

Delayed productivity growth waves in other countries
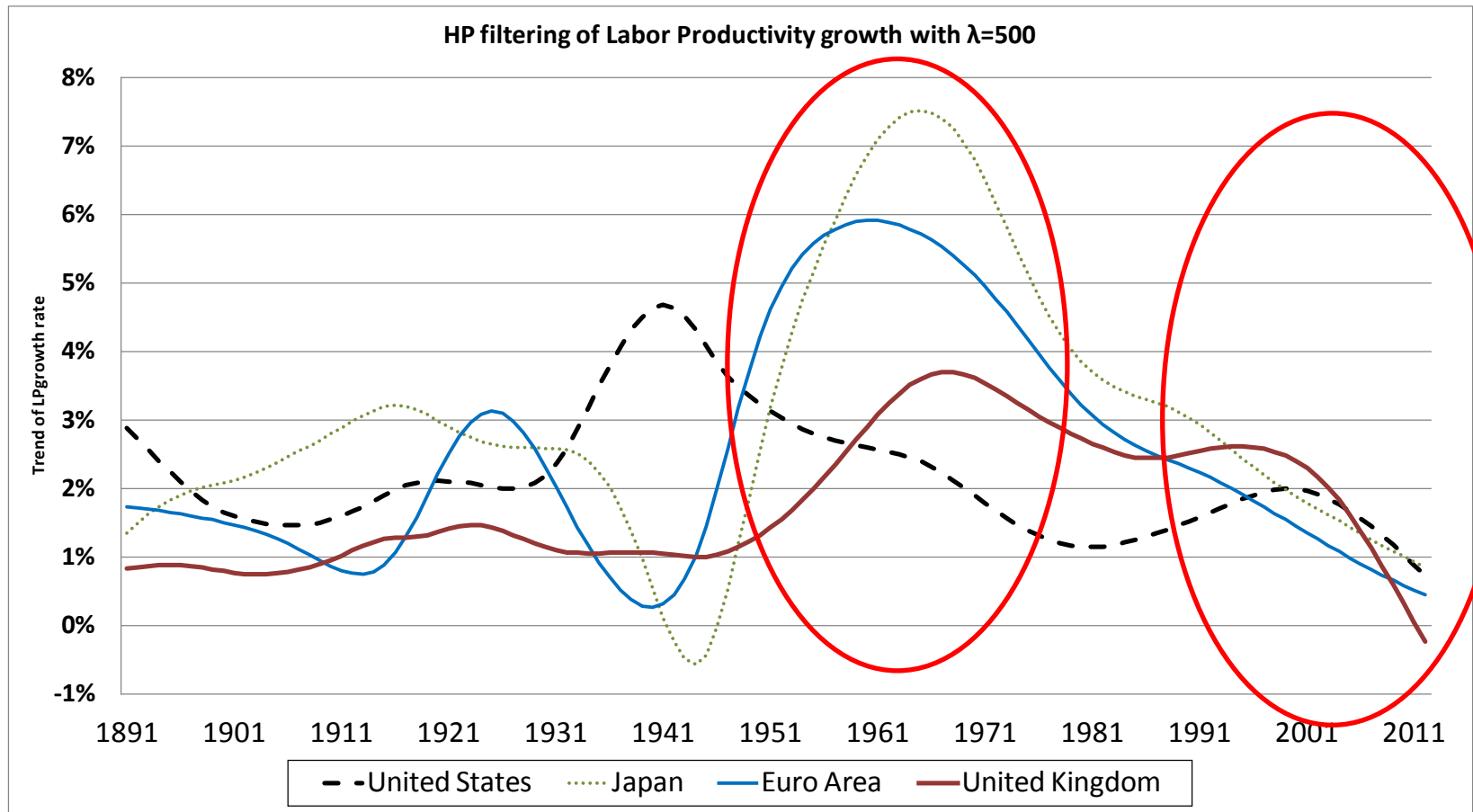
HP filtering of Labor Productivity growth with λ=500

Legend: ---- United States ⋯⋯ Japan —— Euro Area —— United Kingdom

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Delayed productivity growth waves in other countries

HP filtering of TFP growth with λ=500

Legend: United States, Japan, Euro Area, United Kingdom
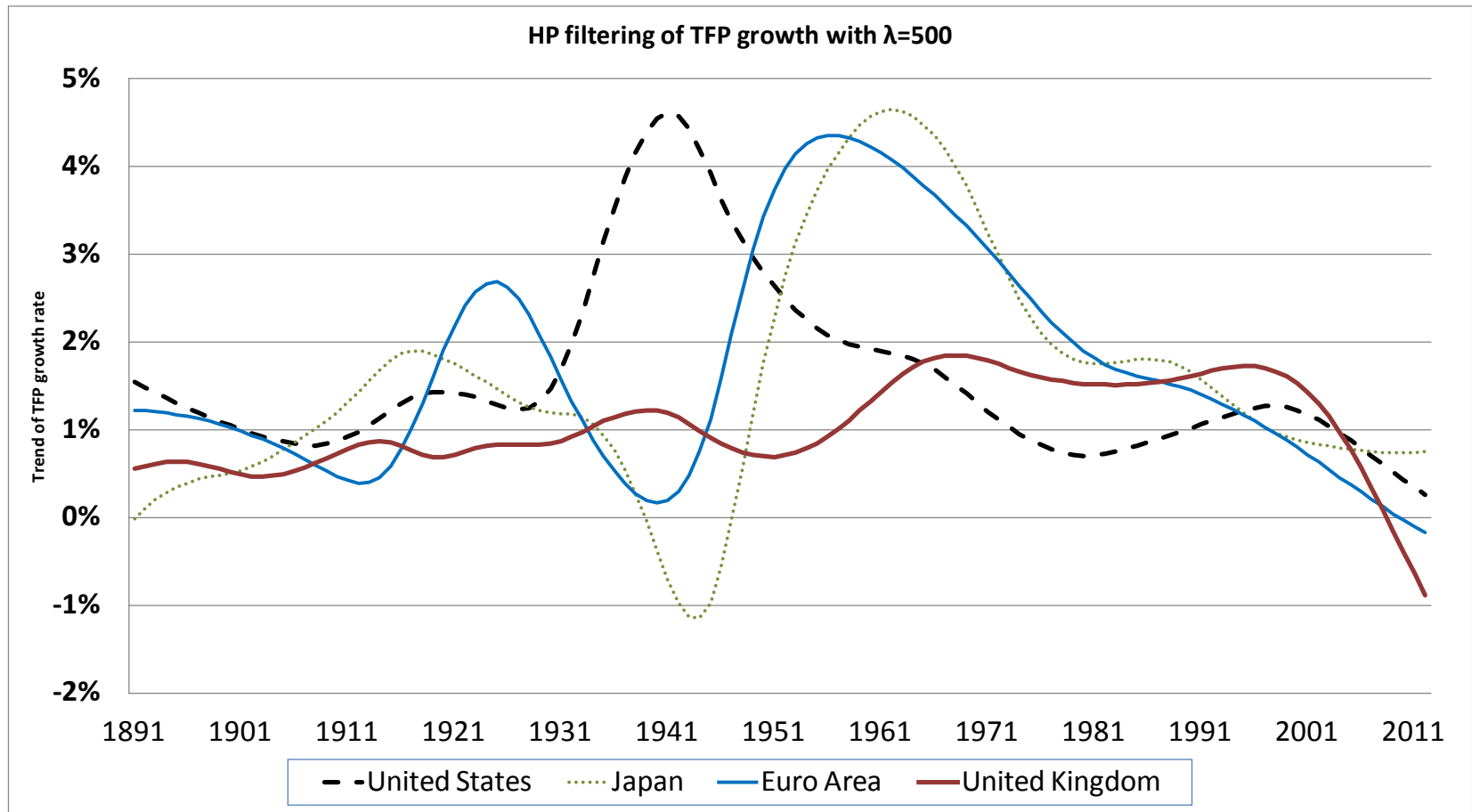
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Delayed productivity growth waves in other countries

- **1st productivity growth wave**
  - Hitting the Euro Area, Japan and UK after WWII
  - Different amplitudes but from different productivity levels

- **2nd productivity growth wave**
  - Absent so far in the Euro Area and Japan
  - Low productivity growth in the 1990s: Role of labor market policy
  - Low ICT diffusion: Role of market rigidities / education
  - A delayed wave?

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Delayed productivity growth waves in other countries

ICT capital coefficient (x 100), at current prices
Scope: the whole economy - ratio of ICT capital stock to GDP in current prices - Source: Cette and Lopez (2012)
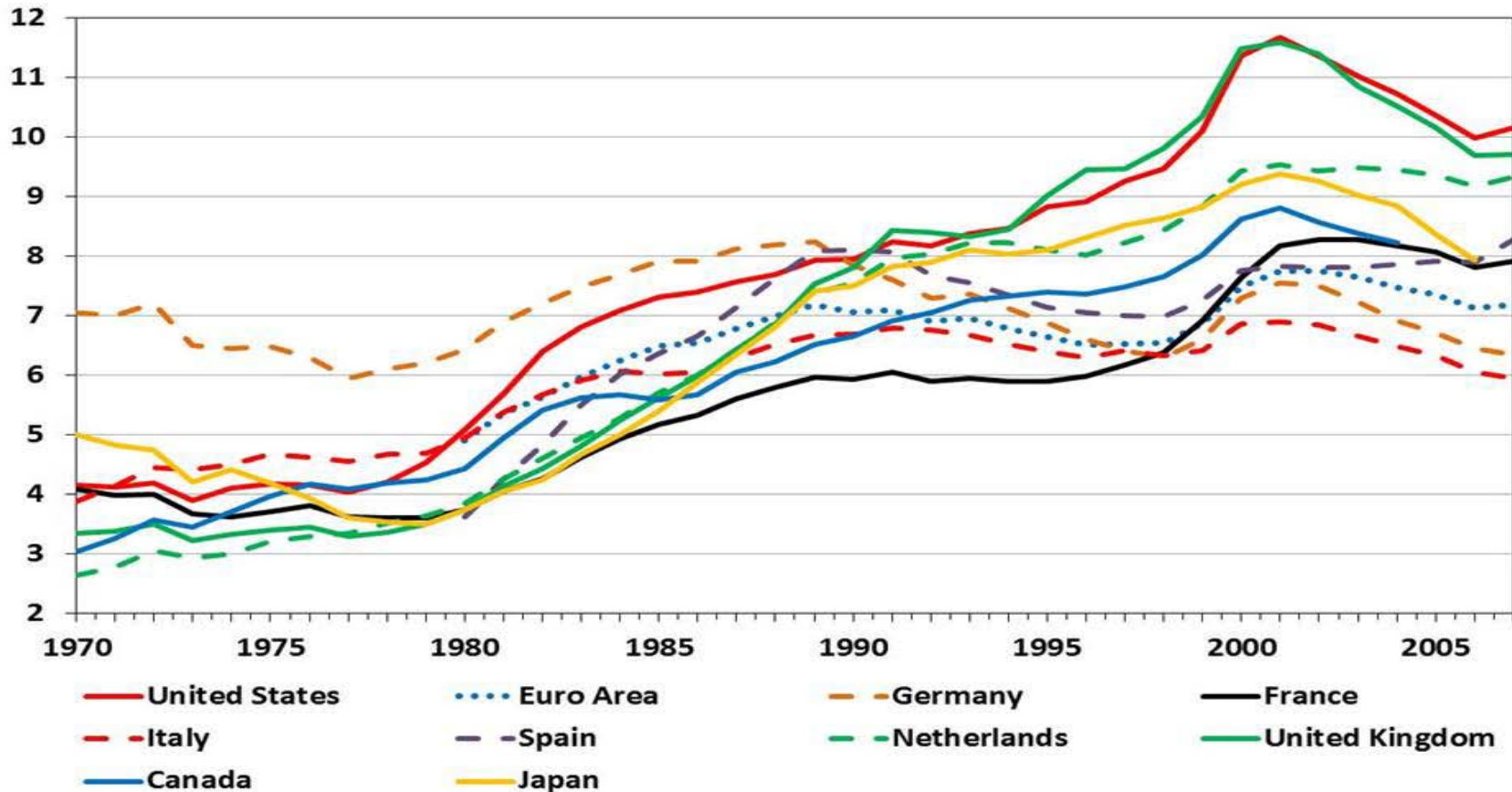
Delayed productivity growth waves in other countries

Sources of ICT capital coefficient gap with the US in 2007

In % of the gap - Scope: the whole economy

Source: Cette and Lopez (2012)
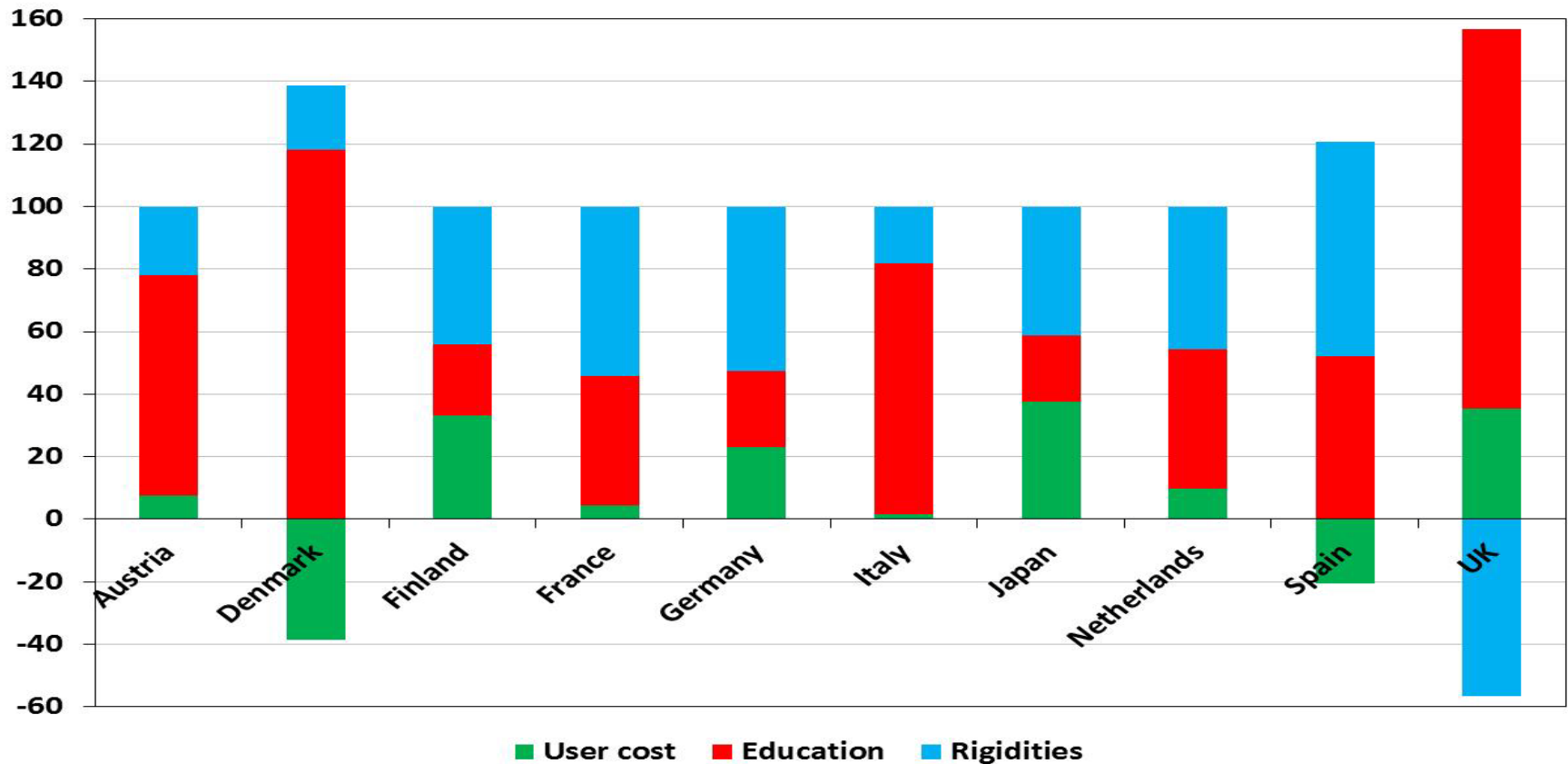
Delayed productivity growth waves in other countries

➢ **In non-US contries, possible catch-up of the US ICT diffusion level**
  - ICT diffusion stabilisation since 2000 in numerous developed countries
  - At a lower level than the US one (except The UK)
  - A catch-up could offer a large potential productivity improvement
  - Among others: OECD (2002) Van Ark *et al.* (2002), Van Ark *et al.* (2008),

➢ **Why the current lower ICT diffusion level?**
  - Average education level of the working age population
  - Labour and product market rigidities
  - Van Ark *et al.* (2008), Aghion *et al.* (2008), Cette and Lopez (2012) …

➢ **Room for policies**

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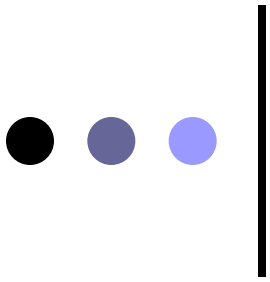
CONVERGENCE

4. Two main productivity leadership changes

Leadership changes

Labor Productivity per hour:
Level relative to the current US level
Non-Euro Area countries, 1890-2012, $2005 PPP, US level = 100
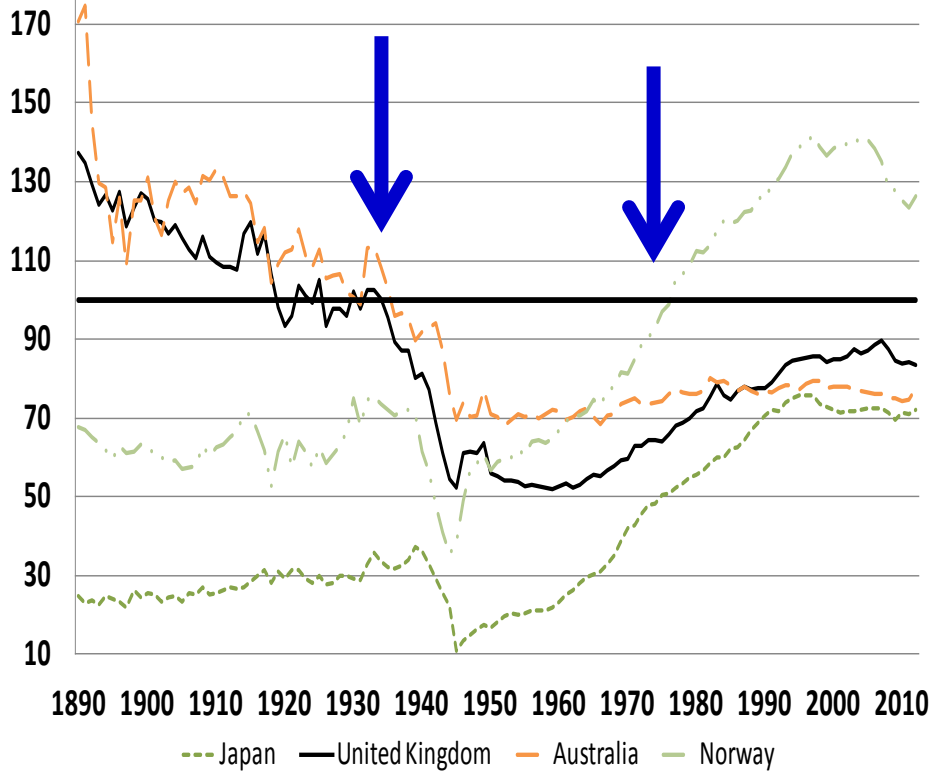
Total Factor Productivity:
Level relative to the current US level
Non Euro Area countries, 1890-2012, $2005 PPP, US level=100
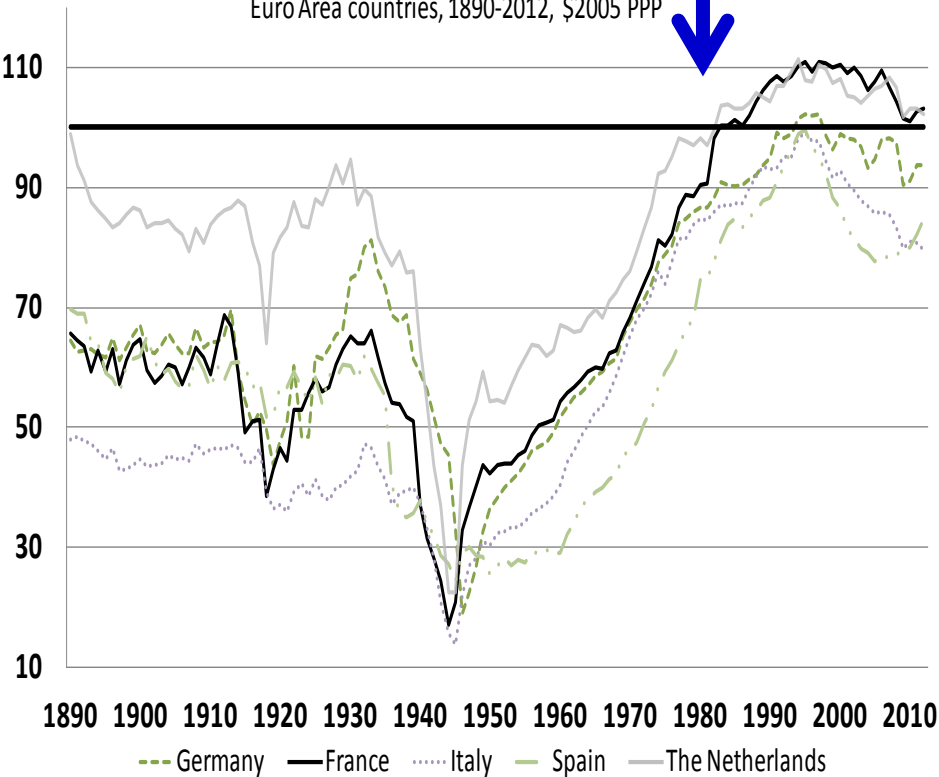

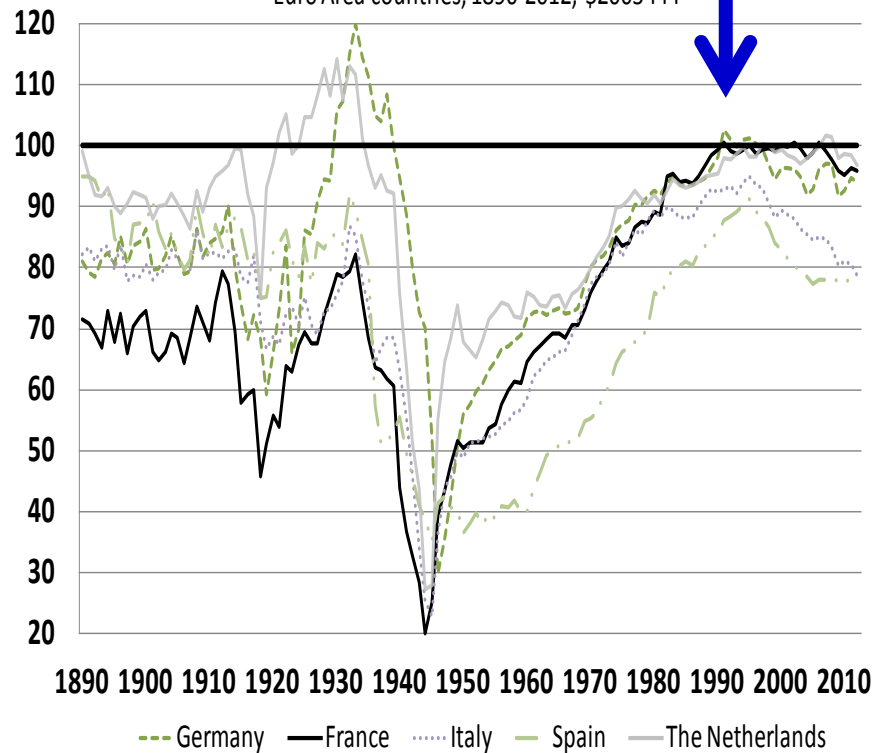Introduction › Data & Methodology › Technology › **Convergence** › Robustness

Leadership changes

Labor Productivity per hour:
Level of relative to the current US level
Euro Area countries, 1890-2012, $2005 PPP

Total Factor Productivity:
Level relative to the current US level
Euro Area countries, 1890-2012, $2005 PPP

Legend: ---Germany —France ···Italy —Spain —The Netherlands

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Leadership changes

- **1st leadership change: From UK to US leadership**
  - Early US leadership in manufacturing
  - But sectoral composition effect long in favor of the UK (Broadberry, 1997)

- **2nd leadership change: From US to FR, NL and NO leadership?**
  - End of the convergence process?
  - Specific reasons:
    - Lower employment rate/hours worked in FR and NL (Bourlès-Cette, 2005)
    - Sectoral structure in Norway

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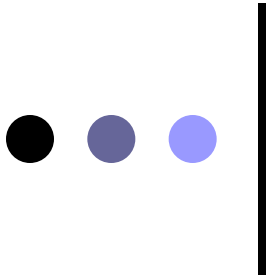
5. **No global and permanent convergence process**

Convergence process

United Kingdom

Labor productivity
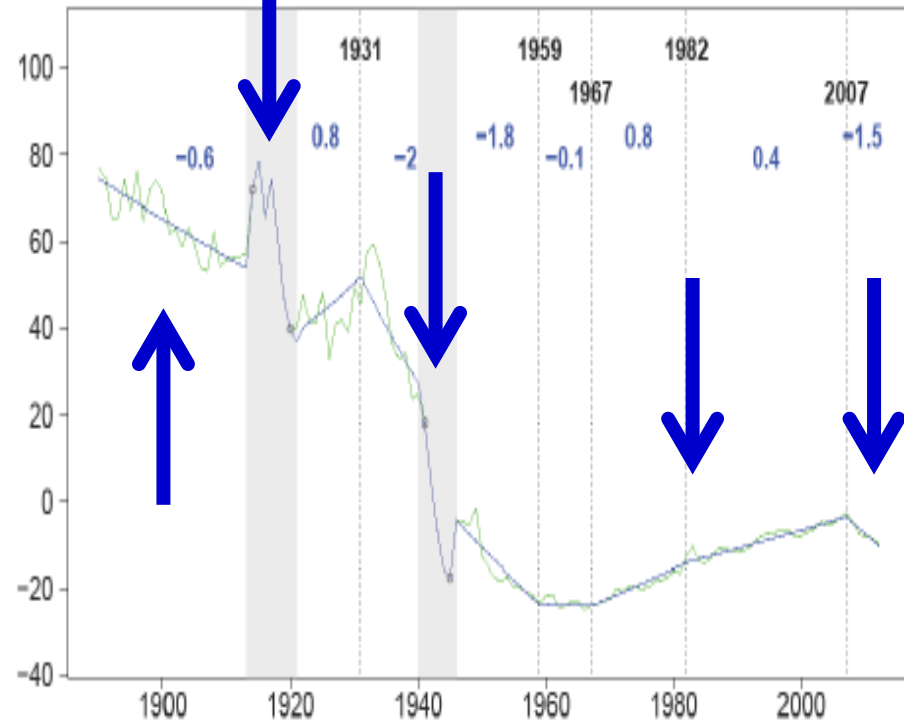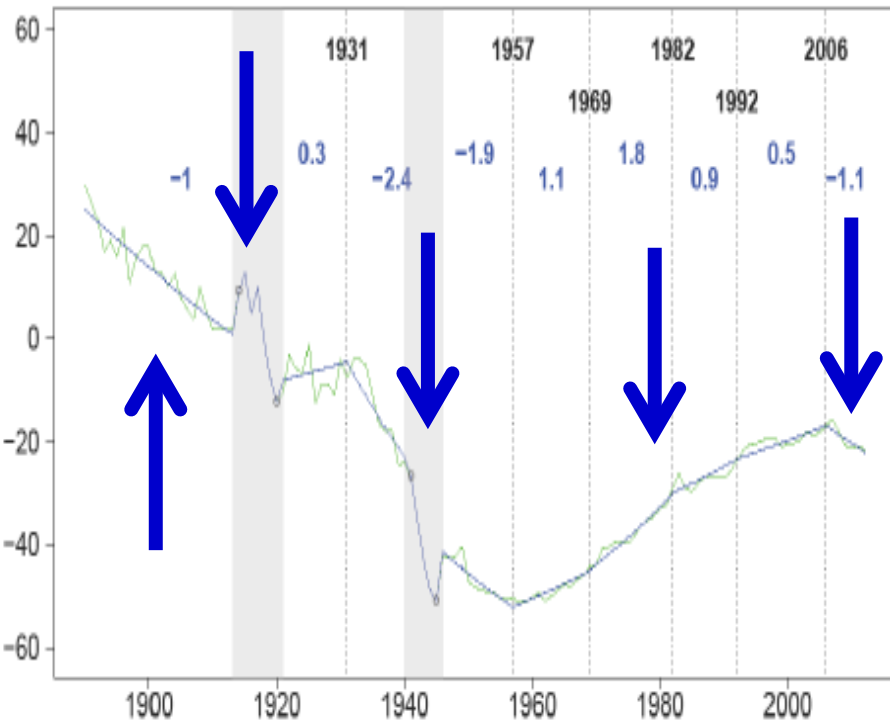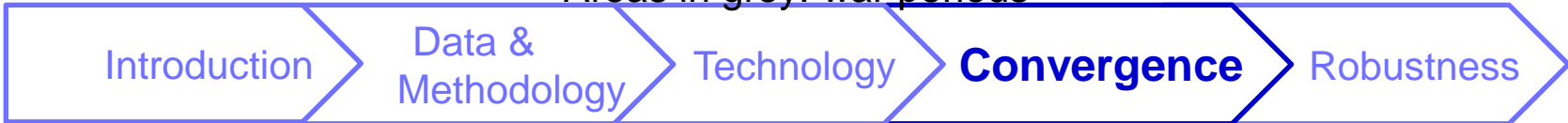
TFP
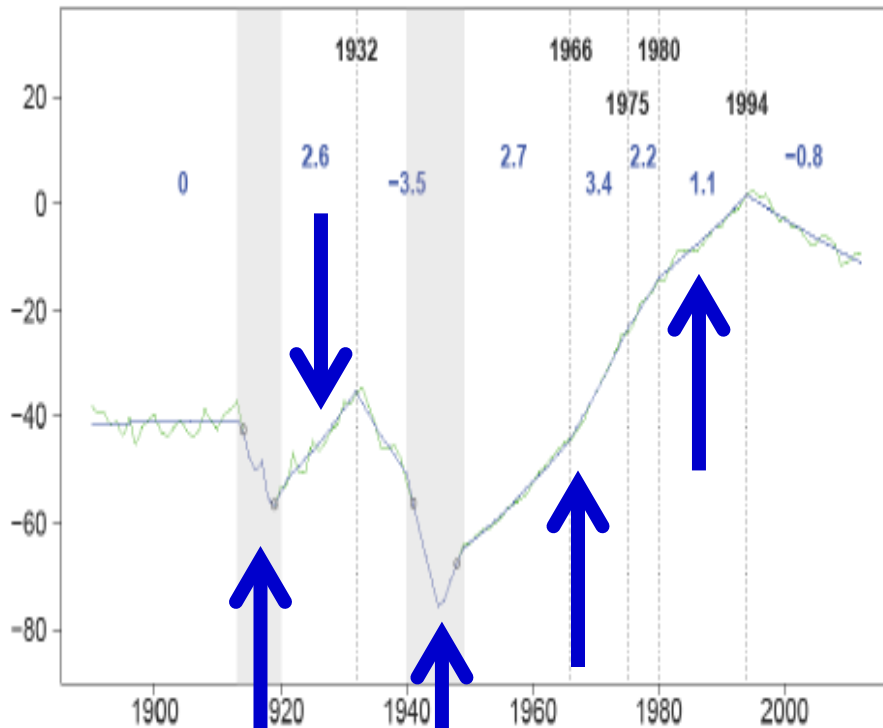

Distance to US level, %
Areas in grey: war periods

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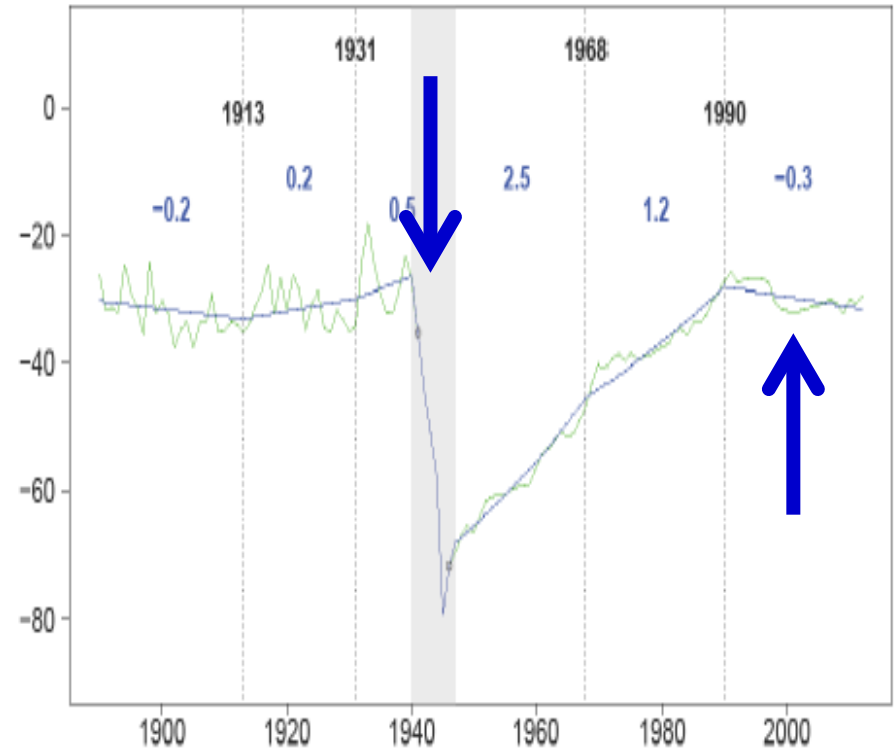
Convergence process

Euro area

Labor productivity

TFP

Distance to US level, %
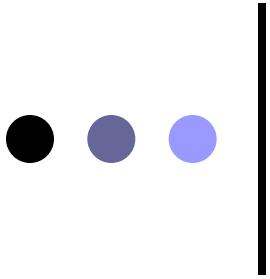Areas in grey: war periods

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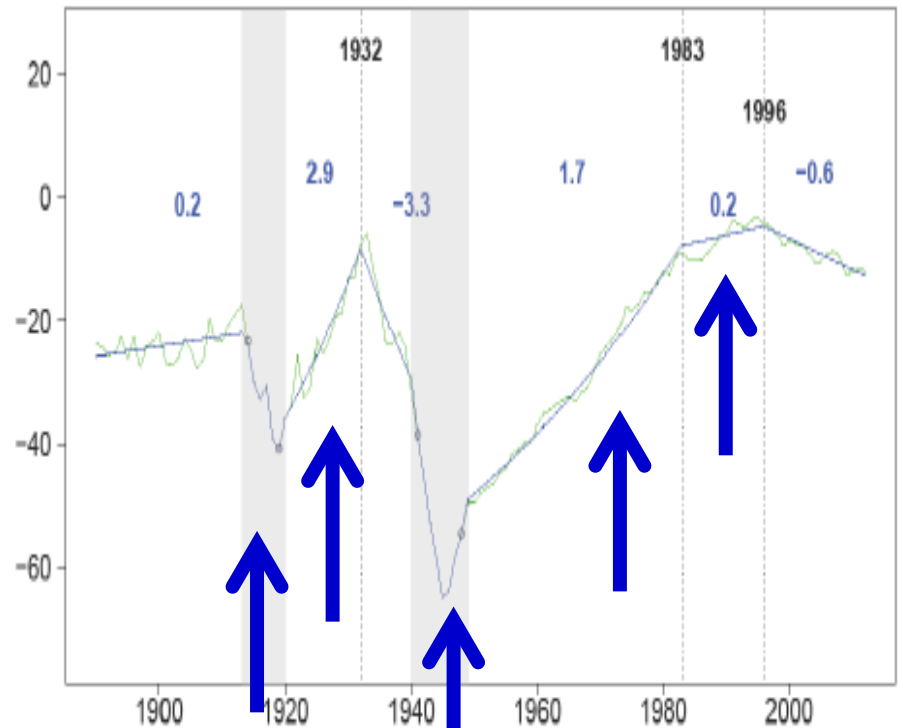
Convergence process

Japan

Labor productivity
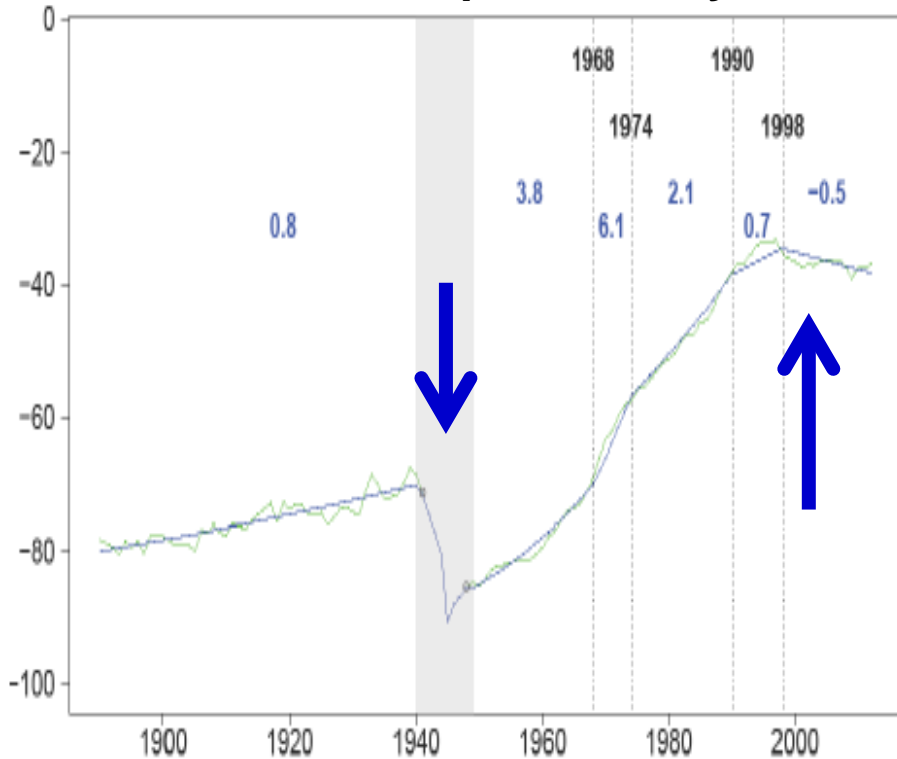
TFP

Distance to US level, %
Areas in grey: war periods

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Convergence process

Convergence does take place…
- Before WWI, catching-up with the UK
- In the Interwar period, until the US recovery from the Great Depression
- After WWII and until the ICT productivity wave
- Major role of sectoral composition, while productivity gap in manufacturing were persistent until WWII (Broadberry, 1993)

…but it is an erratic and conditional process
- Large drop for laggards due to wars and innovation clusters
- Role of institutions, market rigidities and education levels (Aghion and Howitt, 2006)
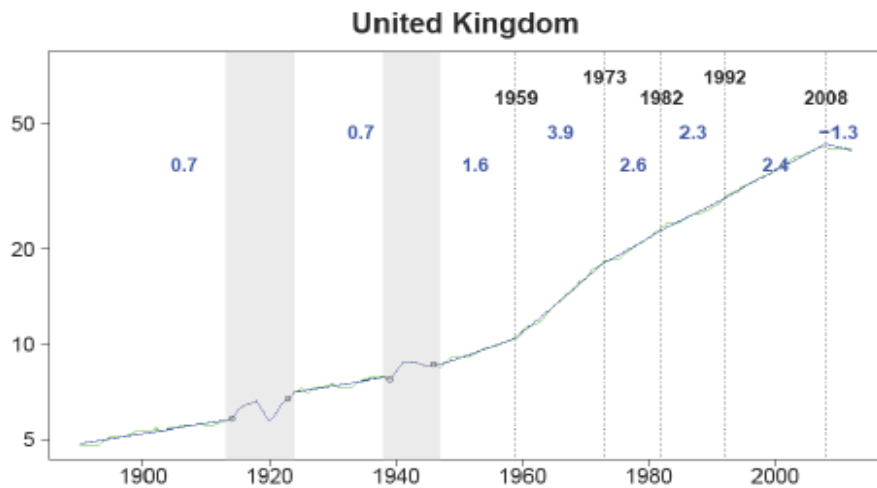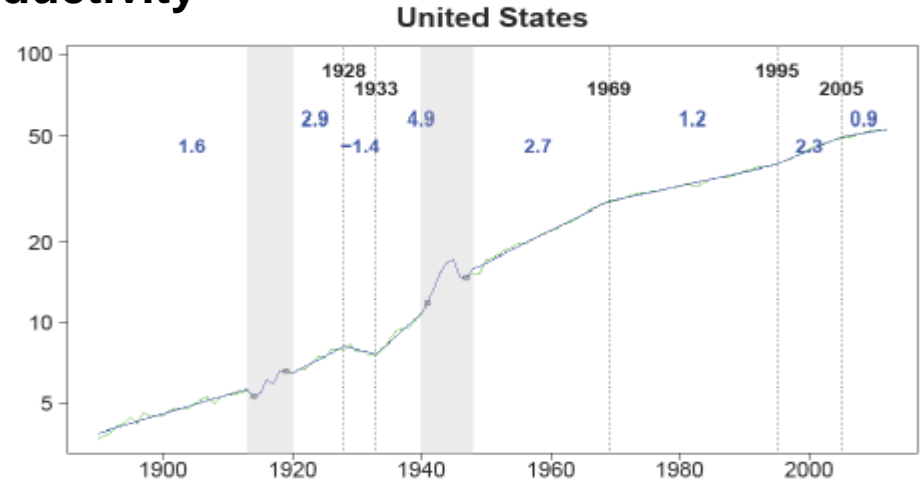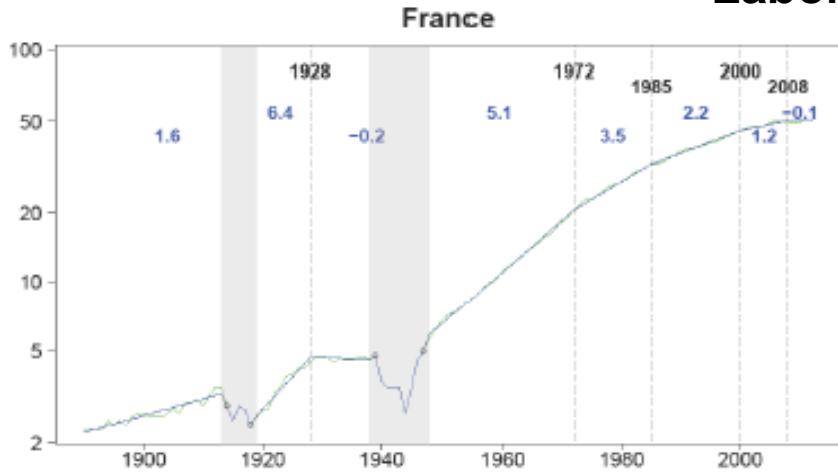
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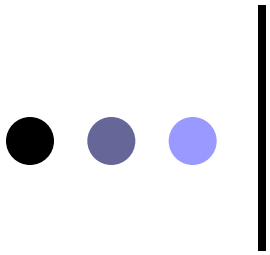**6.** **Global productivity breaks due to global shocks**

Productivity breaks: global shocks

Labor productivity
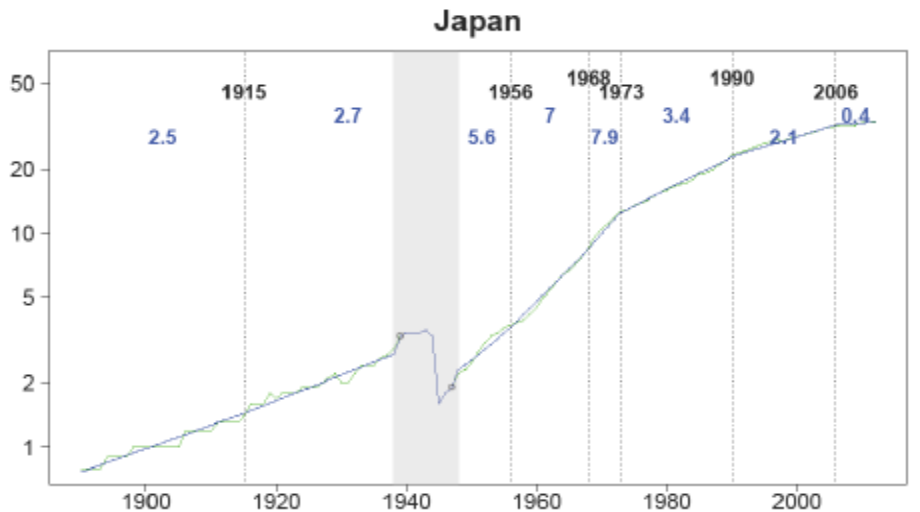
US$ PPP of 2005 (log scale)
Areas in grey: war periods

Productivity breaks: global shocks
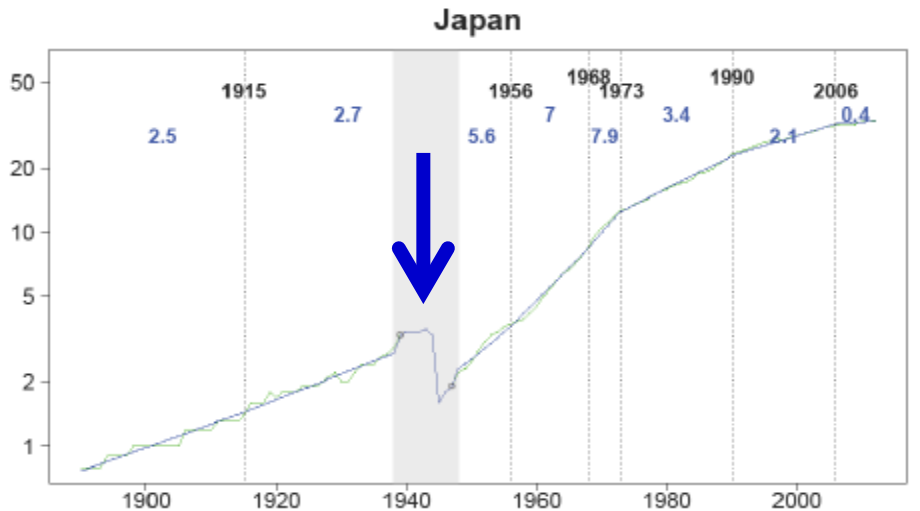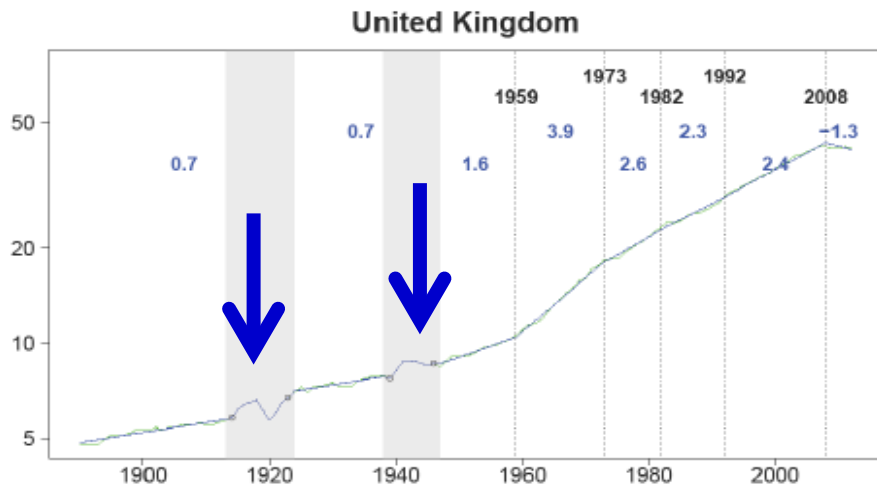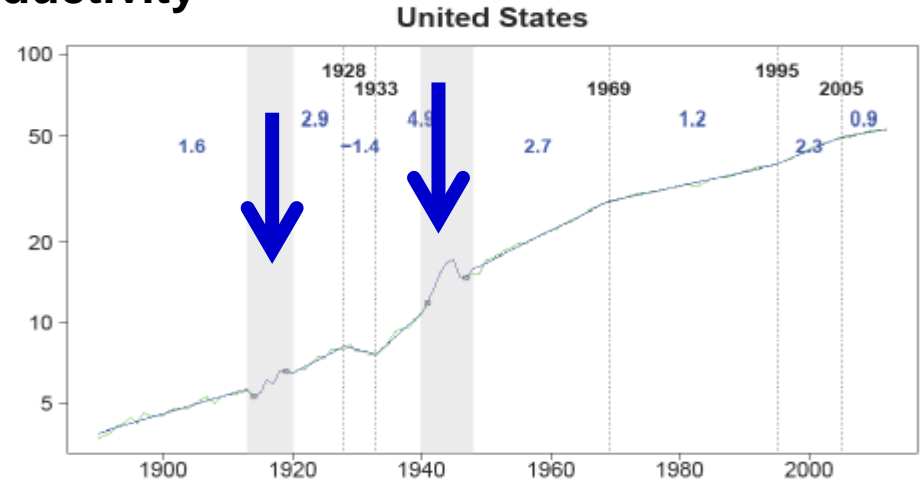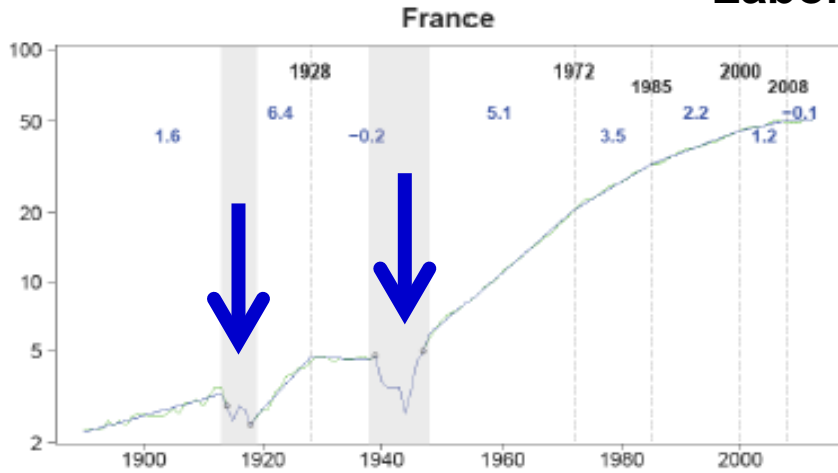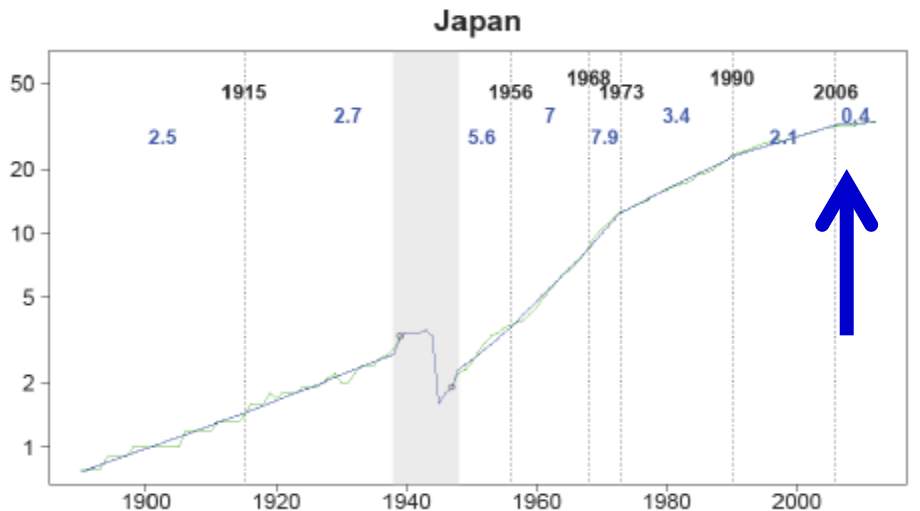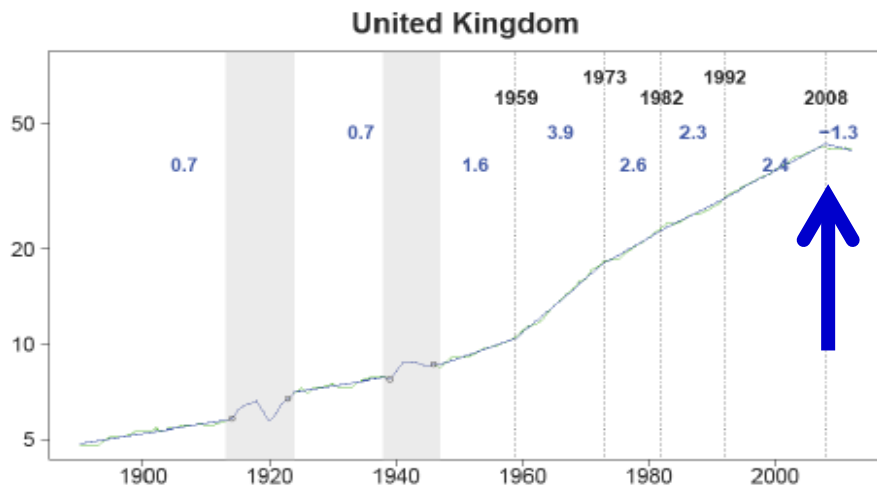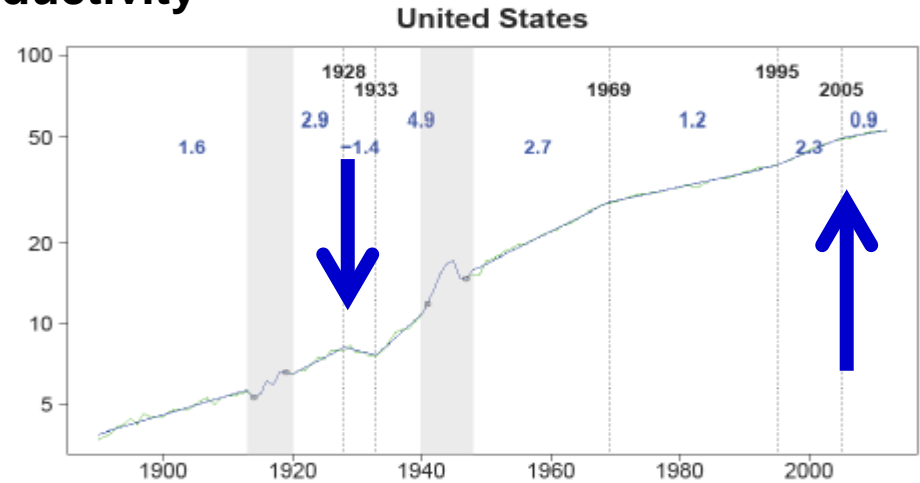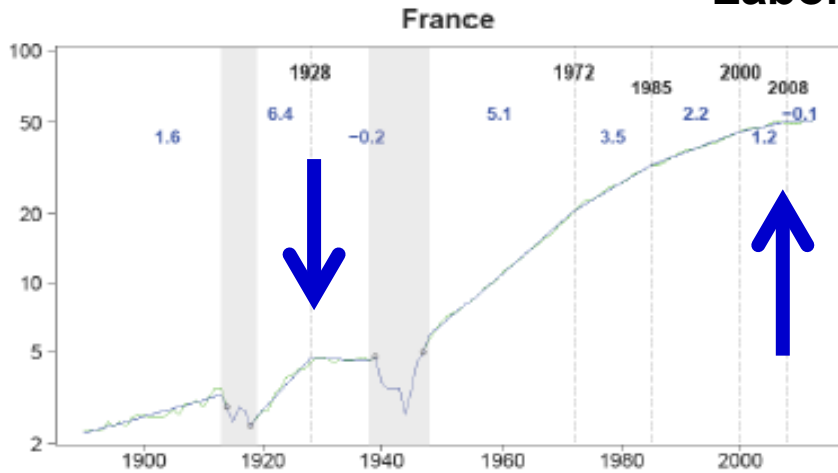## Wars

Labor productivity

US$ PPP of 2005 (log scale)
Areas in grey: war periods

Productivity breaks: global shocks
Global financial crisis

Labor productivity

US$ PPP of 2005 (log scale)
Areas in grey: war periods

Productivity breaks: global shocks
Global supply shocks

Labor productivity
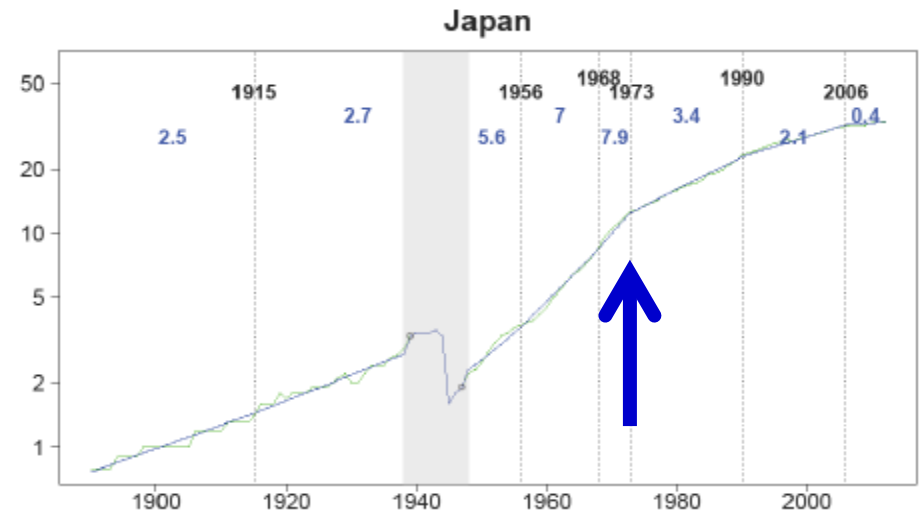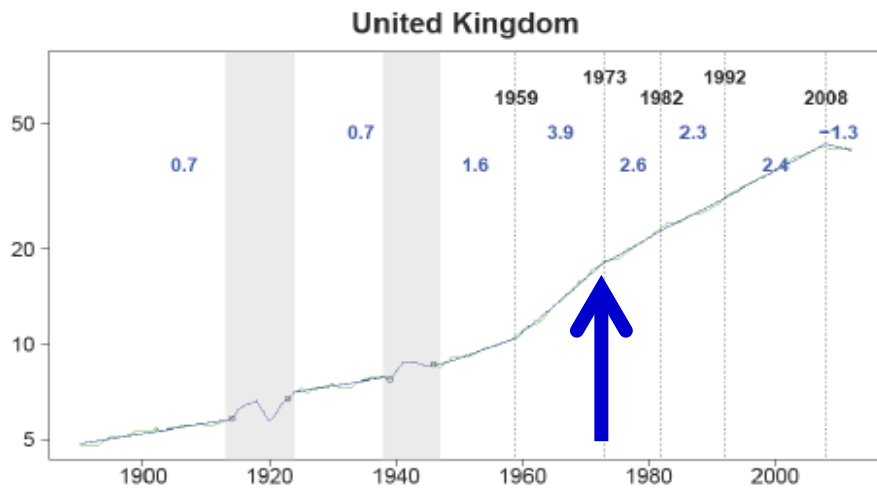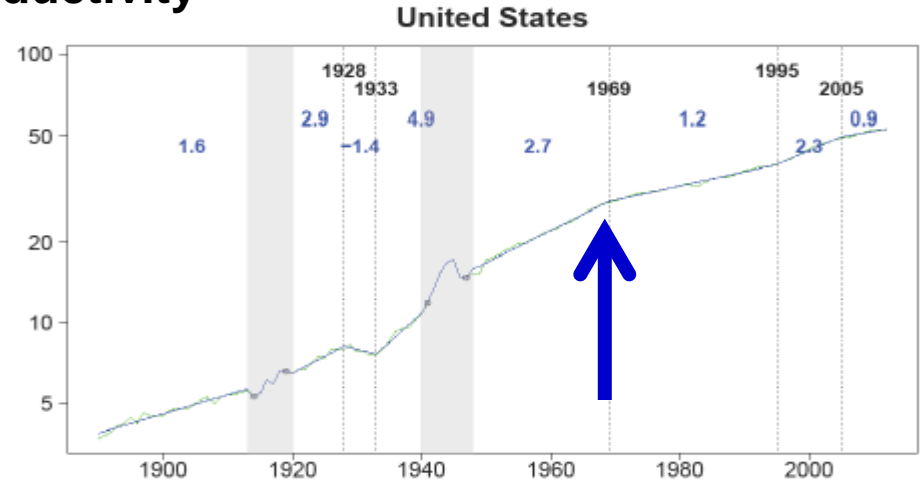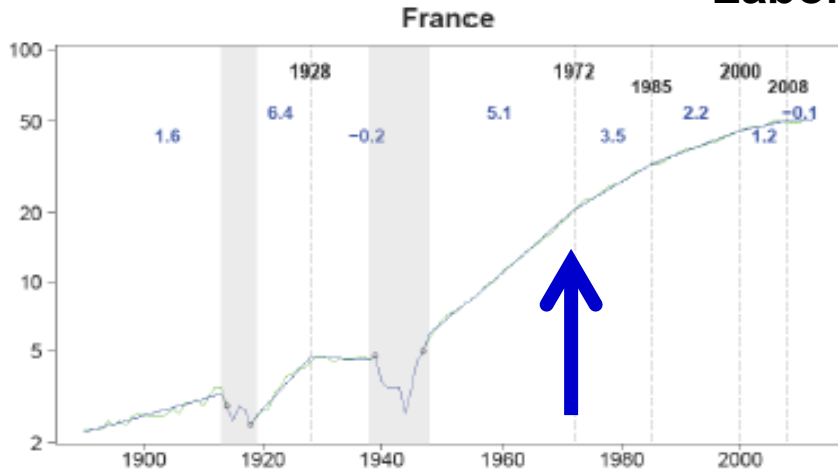
US$ PPP of 2005 (log scale)
Areas in grey: war periods

Global Productivity breaks

- **Due to wars, but in a divergent way**
  - Upward level break for the United States (no war on their own soil)
  - Downward for France, Germany and Japan (war on their own soil)
  - Limited impact for the UK

- **Due to the Great Depression, but very different recovery**
  - Most countries affected, but Japan, Italy and the UK
  - Exit through war for most countries
  - But strong rebound in the US and Canada

- **Due to global supply shocks**
  - Generalized impact of the first oil shock
  - But different timings: US 1966/69

- **Due to the financial crisis**
  - Early break in the US?

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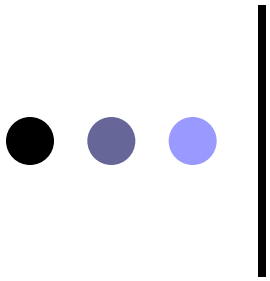
7. Country-specific productivity breaks due to idiosyncratic shocks

Productivity breaks:
country-specific shocks
## Sweden

Labor productivity
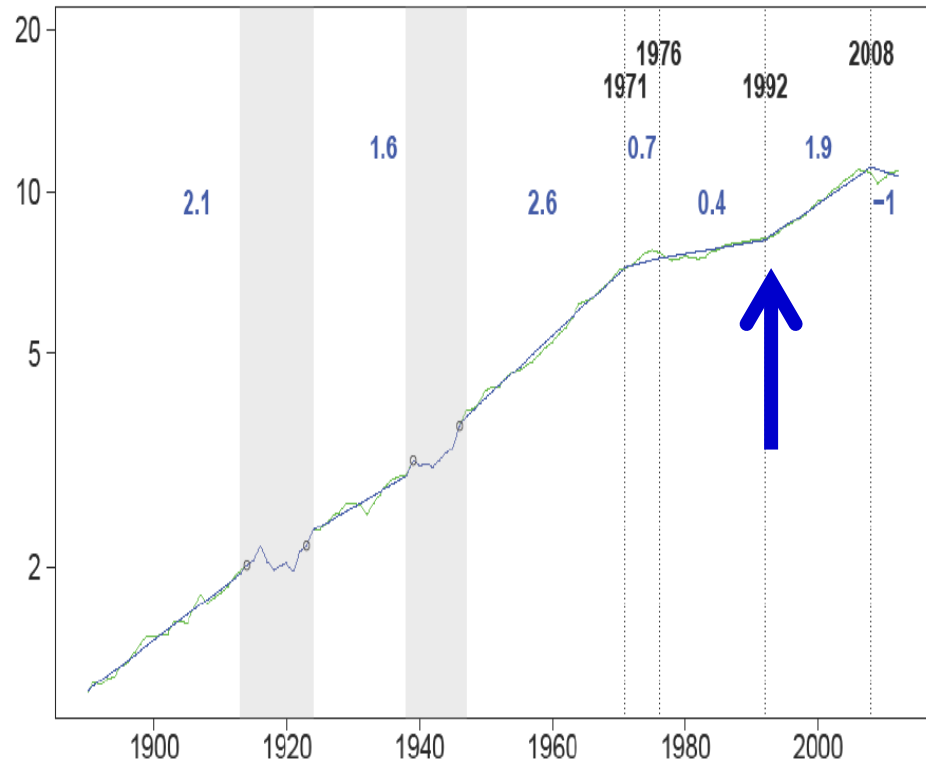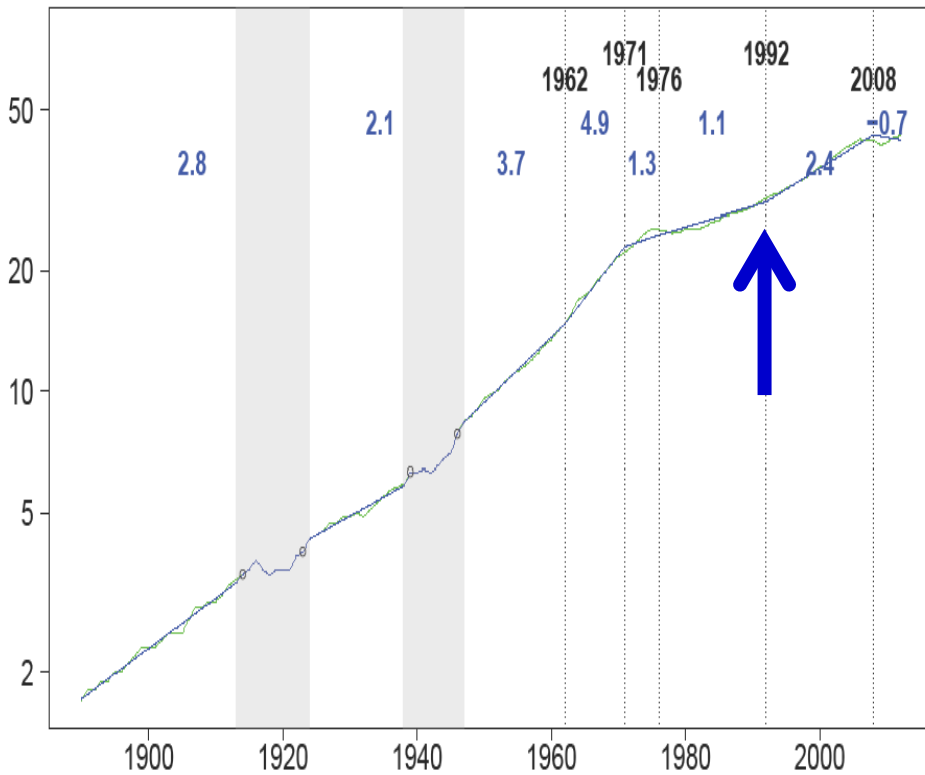
Total Factor Productivity

US$ PPP of 2005 (log scale)
Areas in grey: war periods

Productivity breaks: country-specific shock
Japan

Labor productivity
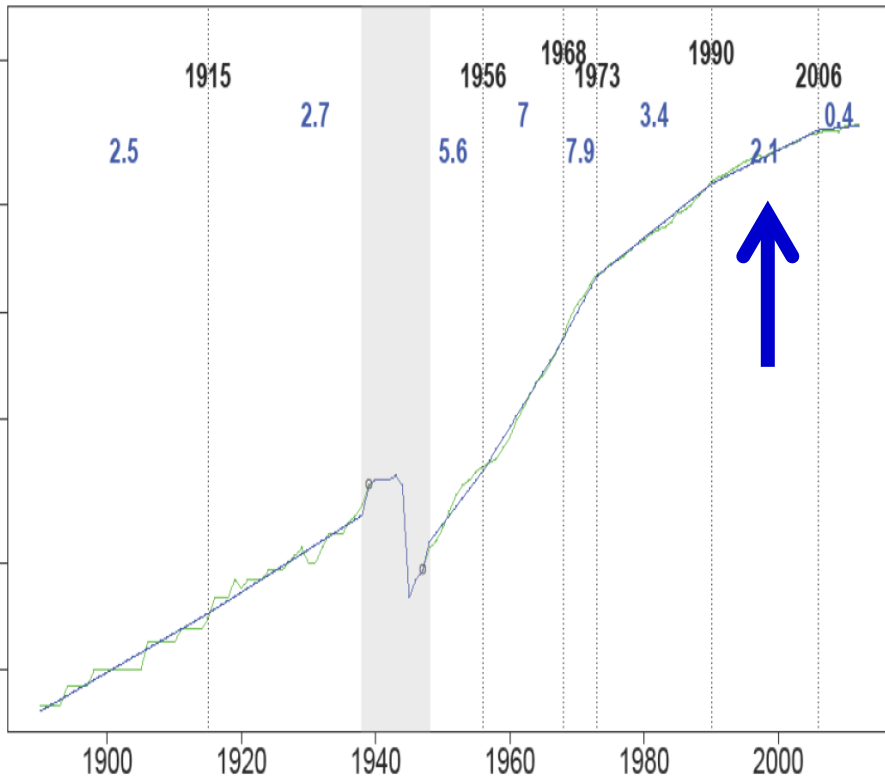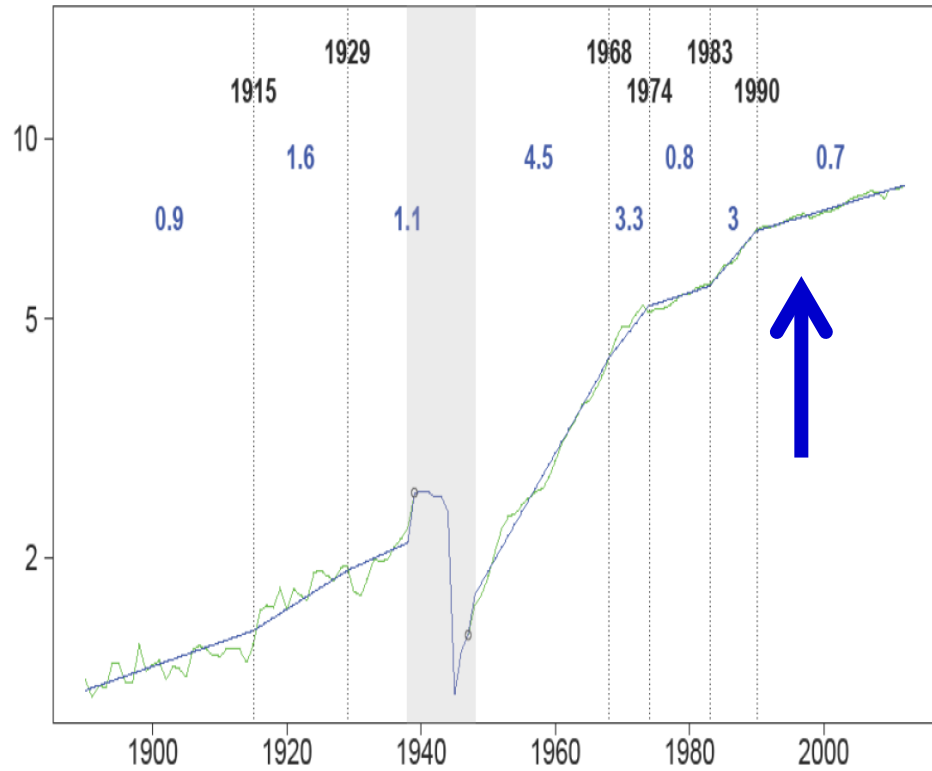
Total Factor Productivity

US$ PPP of 2005 (log scale)
Areas in grey: war periods

Productivity breaks:
country-specific shocks
United Kingdom

Labor productivity

Total Factor Productivity
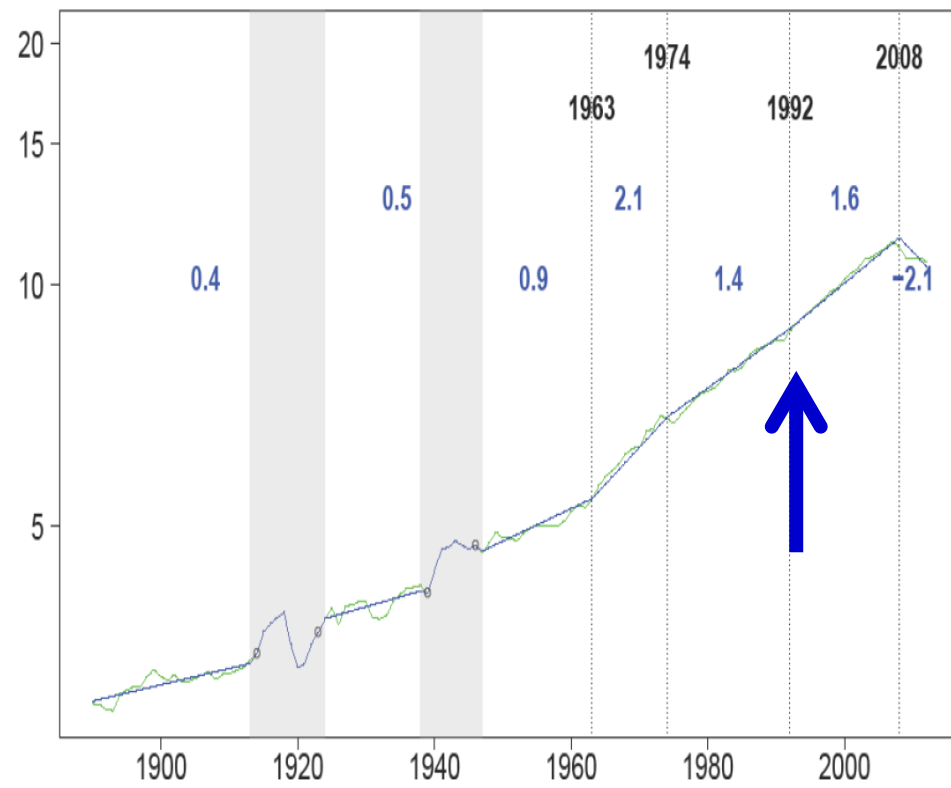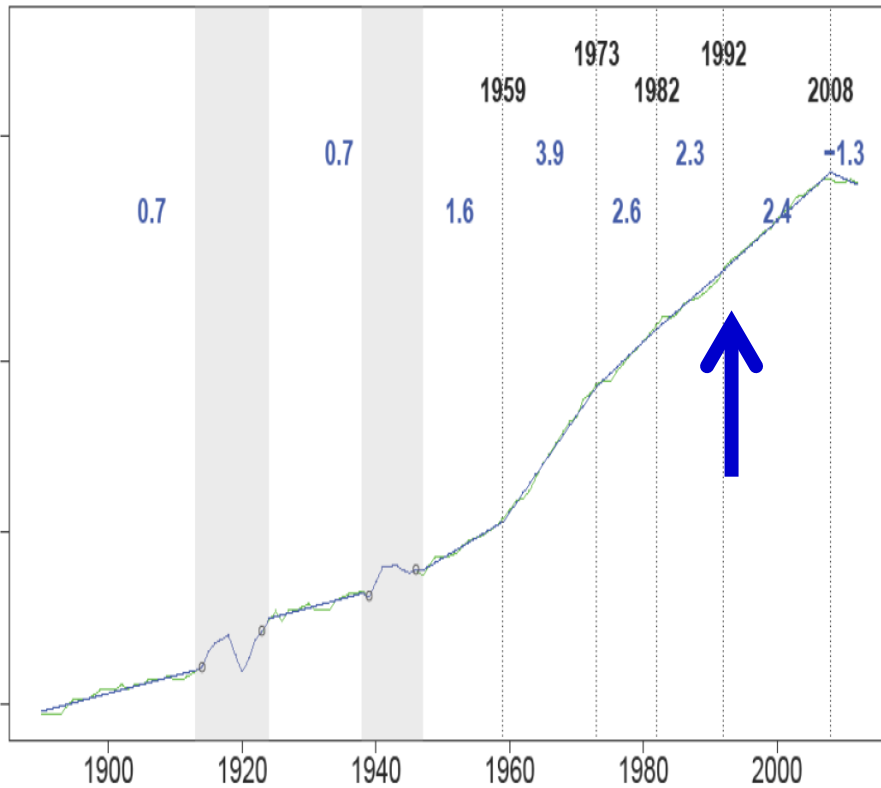
US$ PPP of 2005 (log scale)
Areas in grey: war periods

Country-specific Productivity breaks

- **Due to localized innovation clusters**
  - US 1933: 2nd industrial revolution
  - US 1995: ICT (Jorgenson, 2001, …)
- **Due to policy shocks/structural reforms**
  - **The Netherlands**, following the Wassenaard agreement, 1982
    TFP growth: 1977-1983 0.5%, 1983-2002 1.5%
  - **Canada**, reforms from the early 1990s
    TFP growth: 1974-1990 0.3 %, 1990-2000 1.1%
  - **Australia**, reforms fro the early 1990s
    TFP growth: 1971-1990 0.4%, 1990-2002 1.4%
  - **Sweden**, reforms from the early 1990s
    TFP growth: 1976-1992 0.4 %, 1992-2008 1.9%
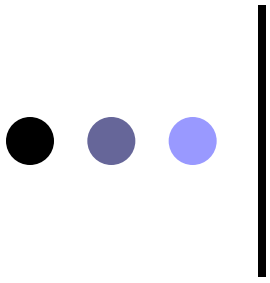
ROBUSTNESS

Break dates significance

Break dates significance: Student test for the break coefficient (coefficient β_k in equation 1, section 3.1)
*: less than 10%; **: less than 5%; ***: less than 1% significance

Country	Total factor productivity (TFP)	Labor productivity (LP)
United States	1928***, 1933***, 1966***, 1998***, 2006***	1928***, 1933***, 1966***, 1998***, 2006***
Japan	1915***, 1929, 1968**, 1974***, 1983***, 1990***	1915, 1956**, 1968, 1973***, 1990***, 2006**
United Kingdom	1963***, 1974***, 1992*, 2008***	1959***, 1973***, 1982, 1992, 2008***
Euro Area	1928***, 1974***, 1995***, 2008***	1928***, 1974***, 1996***, 2008***
Germany	1928***, 1969***, 1980, 1990*, 2006*	1929***, 1972***, 1980, 1990*, 2008***
France	1928***, 1974***, 1992, 2000*, 2008	1928***, 1972***, 1985***, 2000***, 2008
Italy	1975***, 1981*, 1995***, 2008***	1972***, 1982***, 1995***, 2008**
Spain	1919***, 1928***, 1961***, 1966***, 1980***, 1995***	1919***, 1928***, 1961***, 1966***, 1980***, 1995***
The Netherlands	1928***, 1977***, 1983***, 2002, 2008*	1928***, 1973, 1978***, 1983, 2008***
Finland	1928***, 1969***, 1975***, 1990, 2008***	1928***, 1955***, 1975***, 1993***, 2008***
Canada	1898, 1928***, 1933***, 1941***, 1966***, 1974**, 1990**, 2000*	1898**, 1928***, 1933***, 1940***, 1972***, 1990**, 2000
Australia	1897***, 1971***, 1990***, 2002***	1896***, 1928, 1970***, 1984***, 1990***, 2001***
Sweden	1971***, 1976, 1992***, 2008***	1962***, 1971***, 1976, 1992***, 2008***
Norway	1902***, 1980***, 1988***, 1998***, 2005***	1902***, 1980***, 1987**, 1998, 2004***

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Capital share

TFP robustness test with respect to α, the capital share – Break dates
----[+] (resp ----[-]) stands for appearing (resp disappearing) break date when changing coefficient to a higher or lower value

Country	Benchmark value $\alpha = 0.3$	High value $\alpha = 0.35$	Low value $\alpha = 0.25$
United States	1928, 1933, 1966, 1998, 2006	-	1905[+]
Japan	1915, 1929, 1968, 1974, 1983, 1990	-	-
United Kingdom	1963, 1974, 1992, 2008	-	-
Euro Area	1928, 1974, 1995, 2008	-	-
Germany	1928, 1969, 1980, 1990, 2006	-	-
France	1928, 1974, 1992, 2000, 2008	1992[-]	-
Italy	1975, 1981, 1995, 2008	-	-
Spain	1919, 1928, 1961, 1966, 1980, 1995	1972[+], 1980[-], 1988[+]	-
The Netherlands	1928, 1977, 1983, 2002, 2008	-	1983[-]
Finland	1928, 1969, 1975, 1990, 2008	-	-
Canada	1898, 1928, 1933, 1941, 1966, 1974, 1990, 2000	-	1933[-]
Australia	1897, 1971, 1990, 2002	1928[+]	1928[+]
Sweden	1971, 1976, 1992, 2008	-	-
Norway	1902, 1980, 1988, 1998, 2005	-	-

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Depreciation rate

TFP robustness test with respect to δ, the depreciation rate of the capital – Break dates

----[+] (resp ----[-]) stands for appearing (resp disappearing) break date when changing coefficient to a higher or lower value

Country	Benchmark value $\delta^E = 0.1$ and $\delta^B = 0.025$	High value $\delta^E = 0.15$ and $\delta^B = 0.05$	Low value $\delta^E = 0.05$ and $\delta^B = 0.015$
United States	1928, 1933, 1966, 1998, 2006	-	1980[+]
Japan	1915, 1929, 1968, 1974, 1983, 1990	-	-
United Kingdom	1963, 1974, 1992, 2008	1987[+]	-
Euro Area	1928, 1974, 1995, 2008	1989[+], 1995[-], 2000[+], 2008[-]	-
Germany	1928, 1969, 1980, 1990, 2006	-	-
France	1928, 1974, 1992, 2000, 2008	-	-
Italy	1975, 1981, 1995, 2008	1968[+], 1995[-], 2000[+], 2008[-]	-
Spain	1919, 1928, 1961, 1966, 1980, 1995	1972[+], 1980[-], 1985[+]	-
The Netherlands	1928, 1977, 1983, 2002, 2008	1973[+], 2002[-]	1983[-]
Finland	1928, 1969, 1975, 1990, 2008	-	-
Canada	1898, 1928, 1933, 1941, 1966, 1974, 1990, 2000	-	1966[-], 1984[+]
Australia	1897, 1971, 1990, 2002	-	1966[+]
Sweden	1971, 1976, 1992, 2008	-	1971[-], 1984[+]
Norway	1902, 1980, 1988, 1998, 2005	-	-

Introduction — Data & Methodology — Technology — Convergence — **Robustness**
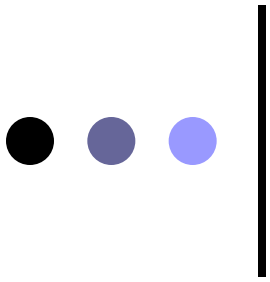
Robustness

- **To breaks significance**
  - High significance of most shocks
  - Some breaks not significant both for TFP and LP but major events
  - Some breaks not significant and could be disregarded: SW 1976, UK 1982, Fr 1992, NL 2002

- **To computation of TFP**
  - Capital share: no change for JP, UK, EA, DE, IT, FI, SW, NO. Changes for Spain.
  - Depreciation rate: breaks after 1970 affected for EA.

CONCLUSION

Productivity and the long run

○ **Major contribution of long-run analysis**

○ **Technology**
- Long lag in innovation diffusion
- « One big wave » staggered across countries
- Small and short-lived ICT productivity wave so far
- End of the ICT technological shock?

○ **Convergence**
- Erratic convergence process
- Leadership changes
- Major role of wars and innovation clusters
- Interaction with institutions and education
- Large impact of structural reforms