Productivity trends from 1890 to 2012 in advanced countries

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Forthcoming in The Review of Income and Wealth
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**
  - 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
  - Crafts and O’Rourke (2013) …
  - Ferguson and Washer (2004) …

- 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, $\lambda = 500$)
  - Breaks (Bai and Perron tests)
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 idiosyncratic shocks
DATA AND METHODOLOGY
Computing productivity

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

- Total factor productivity:
  \[ TFP_{i,t} = \frac{Y_{i,t}}{H_{i,t}^{1-\alpha} K_{i,t-1}^{\alpha}} \quad \alpha = 0, 3 \]

- The capital stock:
  - Permanent inventory method \( \delta=10\% \) (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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**Introduction** | **Data & Methodology** | **Technology** | **Convergence** | **Robustness**
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
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 $\lambda=500$)

- Total factor Productivity
- Labor Productivity

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Two productivity growth waves

1\textsuperscript{st} productivity growth wave
- 2\textsuperscript{nd} 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)

2\textsuperscript{nd} productivity growth wave
- ICTs
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:
    \[ \dot{Q} = \dot{TPF} + \alpha \cdot \dot{K} + (1 - \alpha) \cdot \dot{N} \]
  - **Long term constraint:**
    \[ \dot{P}_Q + \dot{Q}^* = \dot{P}_K + \dot{K}^* \text{ or: } \dot{K}^* = \dot{Q}^* + (\dot{P}_Q - \dot{P}_K) \]
  - **Then potential growth:**
    \[ \dot{Q}^* = \frac{\dot{TPF}}{1 - \alpha} + \frac{\alpha}{1 - \alpha} \cdot (\dot{P}_Q - \dot{P}_K) + \dot{N}^* \]
  - If \( \dot{P}_Q = \dot{P}_K \) as in usual one product models,
    we get the usual expression of potential growth:
    \[ \dot{Q}^* = \frac{\dot{TPF}}{1 - \alpha} + \dot{N}^* \]

- From this model and previous numbers, assuming alpha = \( \frac{1}{4} \)
  Average annual contribution of relative investment price decrease, in the USA, over 1959-2012: \( \frac{3}{4} \) pp which is large, but 0 pp last years…
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…
3. In other countries, delayed productivity growth waves (if any)
Delayed productivity growth waves in other countries

HP filtering of Labor Productivity growth with $\lambda=500$

- United States
- Japan
- Euro Area
- United Kingdom

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Delayed productivity growth waves in other countries

HP filtering of TFP growth with $\lambda=500$

- United States
- Japan
- Euro Area
- United Kingdom
Delayed productivity growth waves in other countries

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

- **2\textsuperscript{nd} 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?
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)
In non-US countries, 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
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
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

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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
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

Labor productivity

Japan

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)
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?
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 vs. 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

- **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 from 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: Student test for the break coefficient (coefficient $\beta_k$ in equation 1, section 3.1)

*: less than 10%; **: less than 5%; ***: less than 1% significance

<table>
<thead>
<tr>
<th>Country</th>
<th>Total factor productivity (TFP)</th>
<th>Labor productivity (LP)</th>
</tr>
</thead>
</table>
**Capital share**

*TFP* robustness test with respect to $\alpha$, the capital share – Break dates

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Benchmark value $\alpha = 0.3$</th>
<th>High value $\alpha = 0.35$</th>
<th>Low value $\alpha = 0.25$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>1915, 1929, 1968, 1974, 1983, 1990</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1963, 1974, 1992, 2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Euro Area</td>
<td>1928, 1974, 1995, 2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Germany</td>
<td>1928, 1969, 1980, 1990, 2006</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Italy</td>
<td>1975, 1981, 1995, 2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Finland</td>
<td>1928, 1969, 1975, 1990, 2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Canada</td>
<td>1898, 1928, 1933, 1941, 1966, 1974, 1990, 2000</td>
<td>-</td>
<td>1933^-</td>
</tr>
<tr>
<td>Australia</td>
<td>1897, 1971, 1990, 2002</td>
<td>1928^+</td>
<td>1928^-</td>
</tr>
<tr>
<td>Sweden</td>
<td>1971, 1976, 1992, 2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Norway</td>
<td>1902, 1980, 1988, 1998, 2005</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
### Depreciation rate

TFP robustness test with respect to \( \delta \), 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

<table>
<thead>
<tr>
<th>Country</th>
<th>Benchmark value ( \delta^E = 0.1 ) and ( \delta^B = 0.025 )</th>
<th>High value ( \delta^E = 0.15 ) and ( \delta^B = 0.05 )</th>
<th>Low value ( \delta^E = 0.05 ) and ( \delta^B = 0.015 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>1915, 1929, 1968, 1974, 1983, 1990</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Euro Area</td>
<td>1928, 1974, 1995, 2008</td>
<td>1989(^+), 1995(^-), 2000(^+), 2008(^-)</td>
<td>-</td>
</tr>
<tr>
<td>Germany</td>
<td>1928, 1969, 1980, 1990, 2006</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>France</td>
<td>1928, 1974, 1992, 2000, 2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Finland</td>
<td>1928, 1969, 1975, 1990, 2008</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Australia</td>
<td>1897, 1971, 1990, 2002</td>
<td>-</td>
<td>1966(^+)</td>
</tr>
<tr>
<td>Norway</td>
<td>1902, 1980, 1988, 1998, 2005</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
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