GDP per capita in advanced countries over the 20th century

Third joint conference – ECB / CBRT

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Current debates on GDP per capita growth

- **Long mourning for 1950s and 1960s GDP growth in advanced countries**
  - First slowdown in the 1970s
  - Brief revival with the ICT shock in some countries
  - Current debate on long-term growth: R.Gordon vs J.Mokyr
- **Need for a long term view**
  - 20th century growth: an exceptional period?
  - 1950s and 1960s: role of convergence and technology shock
- **Two related questions in the literature on GDP per capita country comparison:**
  - Factors of growth
  - Convergence

Growth factors in the long run

- Crafts and O'Rourke, 2013:
  - Directed technological change (Acemoglu, 2002)
  - Institutions and social capability
  - Geography and natural resources endowment
  - Events: wars, financial crisis…

- Madsen, 2010:
  - Role of TFP in 20th century growth
  - TFP determined by:
    - R&D,
    - knowledge spillovers through the channel of imports,
    - educational attainment,
    - interaction of educational attainment and distance to the technology frontier

- Gordon, 2014: 6 headwinds for US growth

1/ Demography 2/ Educational attainment plateau 3/ inequalities

4/ Globalization 5/ Energy and environment risk 6/ households and gov. deficits

Convergence

- **Convergence concepts and tests:**
  - Absolute vs conditional
  - Conditional vs club-convergence
  - β- and σ-convergence

- **Empirical findings:**
  - Not automatic, even among advanced countries (Baumol, 1986; Barro, 1991)
  - Factors of convergence:
    - Education
    - Institutions: Property rights; Labour and product market regulations; Financial system; Juridical system; Political regime….
    - Both determine technological progress (Aghion and Howitt, 1998, 2006 and 2009)

- **Literature review: Islam (2003)**

What we do

- **GDP per capita over the period 1895-2013**
  - Only one aspect of economic development: missing inequality, trade-off between leisure and work, sustainability…
  - From 1895 to the Great Crisis
- **17 advanced countries**
  - G7: Canada, France, Germany, Italy, Japan, US, UK
  - Australia, Denmark, Norway, Sweden, Switzerland
  - Belgium, Finland, Portugal, Spain and The Netherlands
  - **+reconstituted Euro area (=93% of 2010 total GDP)**
- **Growth accounting and convergence test**
  - TFP
  - Capital intensity (capital per hours worked)
  - Employment rate (ratio of employment over population)
  - Hours worked per employee

What we find

1. **One big wave at least for each country, but staggered**
2. **Significant decline in GDP per capita growth in the last decades**
3. **Change in GDP per capita leadership**
4. **Overall convergence process among advanced countries, relying on TFP and capital intensity…**
5. **…but not continuous and scattered since 1990, as convergence halted in non-reforming countries**
6. **No employment rates and hours worked convergence**

Data

Data sources

- **For annual data**
  - Starting from Cette, Kocoglu and Mairesse (2009) for US, UK, JP, FR
  - Bergeaud, Cette, Lecat (forthcoming in ROIW) for 13 countries
  - The basis: Maddison, 2001, 2003…
  - …updated by Bolt et alii (2013)…
  - and complemented for specific countries by Baffigi/Broadberry et alii for Italy, Prados for Spain, Villa for France, Smits et alii/Groote et alii for the Netherlands…

- **For quarterly data**
  - From 1974 to 2013 Q4
  - National accounts, Eurostat, OECD and specific national sources
  - 2010 basis integrated

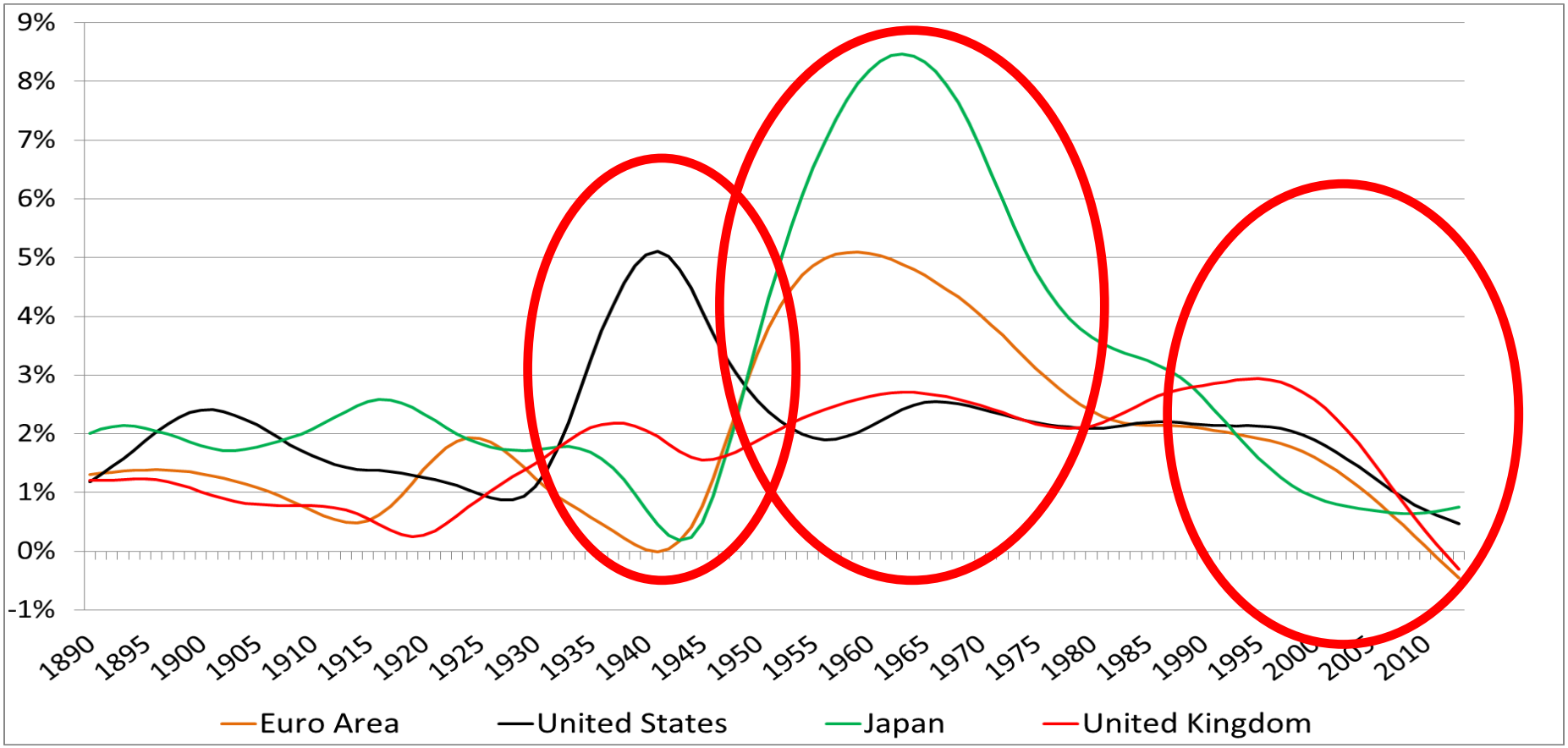
Main assumptions

- **General features**
  - Constant borders
  - Penn world table 2010 PPP conversion rate

- **Main variables**
  - GDP per capita: $\frac{Y}{P}$
  - Employment rate: $\frac{N}{P}$
  - Capital stock: *K*
    - Permanent inventory method
    - Equipment: 10% depreciation rate
    - Buildings: 2,5% depreciation rate
    - War damages estimated

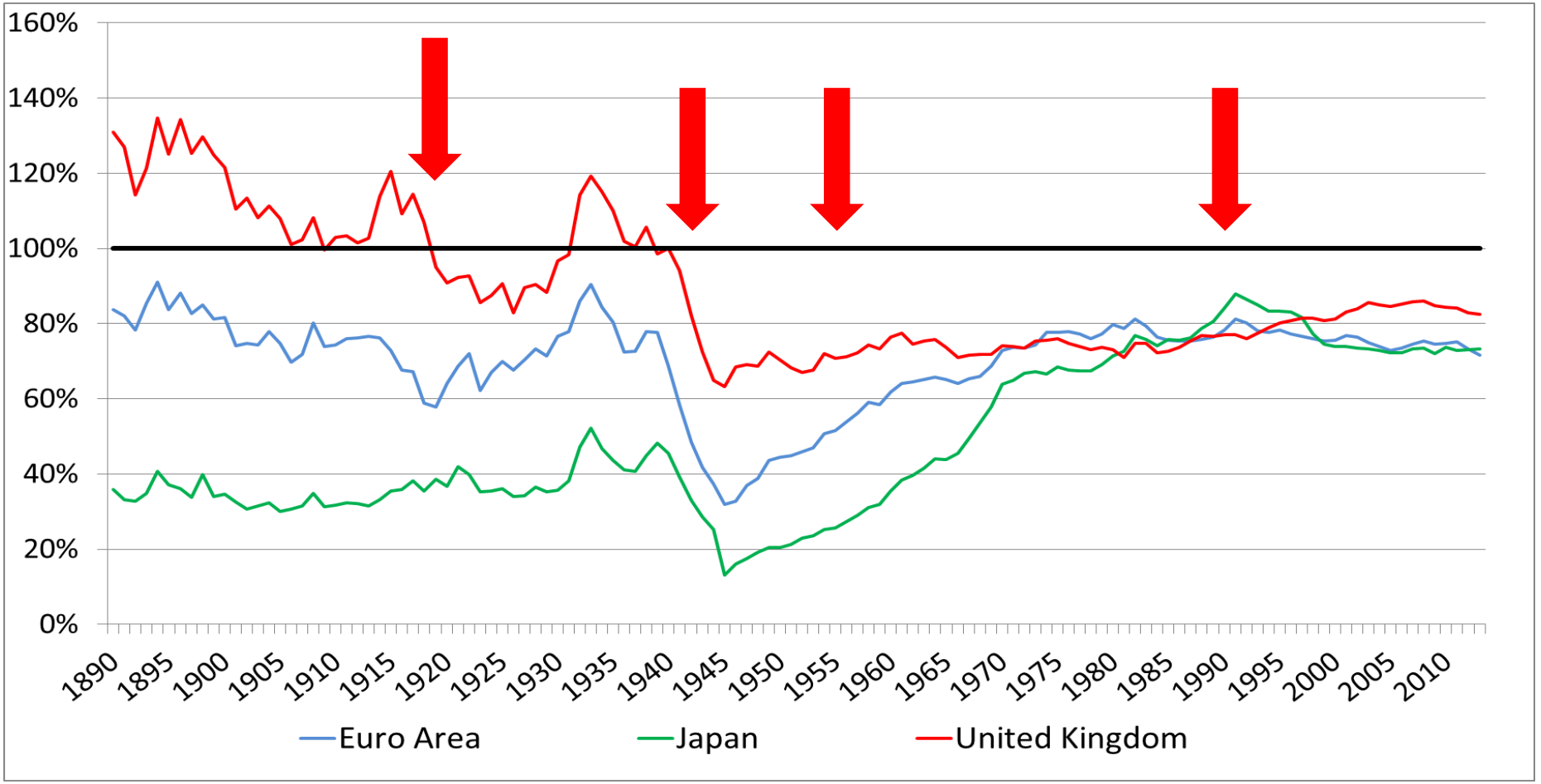
GDP per capita: One main growth wave in the century

Smoothed (by Hodrick-Prescott filtering, λ=500) annual growth of GDP per capita in the United States, the Euro Area, the United Kingdom and Japan 1890-2013 – In %



Convergence: an uneven process

Ratio of GDP per capita in Euro Area, Japan and the United Kingdom with respect to the USA - 1890-2013 - $ 2010 ppp



Growth accounting

Growth accounting decomposition: GDP per capita level

Total factor productivity : $TFP = \frac{Y}{K^{\alpha}.(N.H)^{1-\alpha}}$

Y : GDP in constant price

K : capital stock in constant prices

α = 0,3

N : number of workers

H : average hours worked per year and per worker

Capital intensity : $KI = \frac{K}{N.H}$

Employment rate: $\frac{N}{P}$

P : total population

GDP per capita : $\frac{Y}{P} = TFP.KI^{\alpha}.H.\frac{N}{P}$

Breakdown of relative distance for GDP per capita with the US

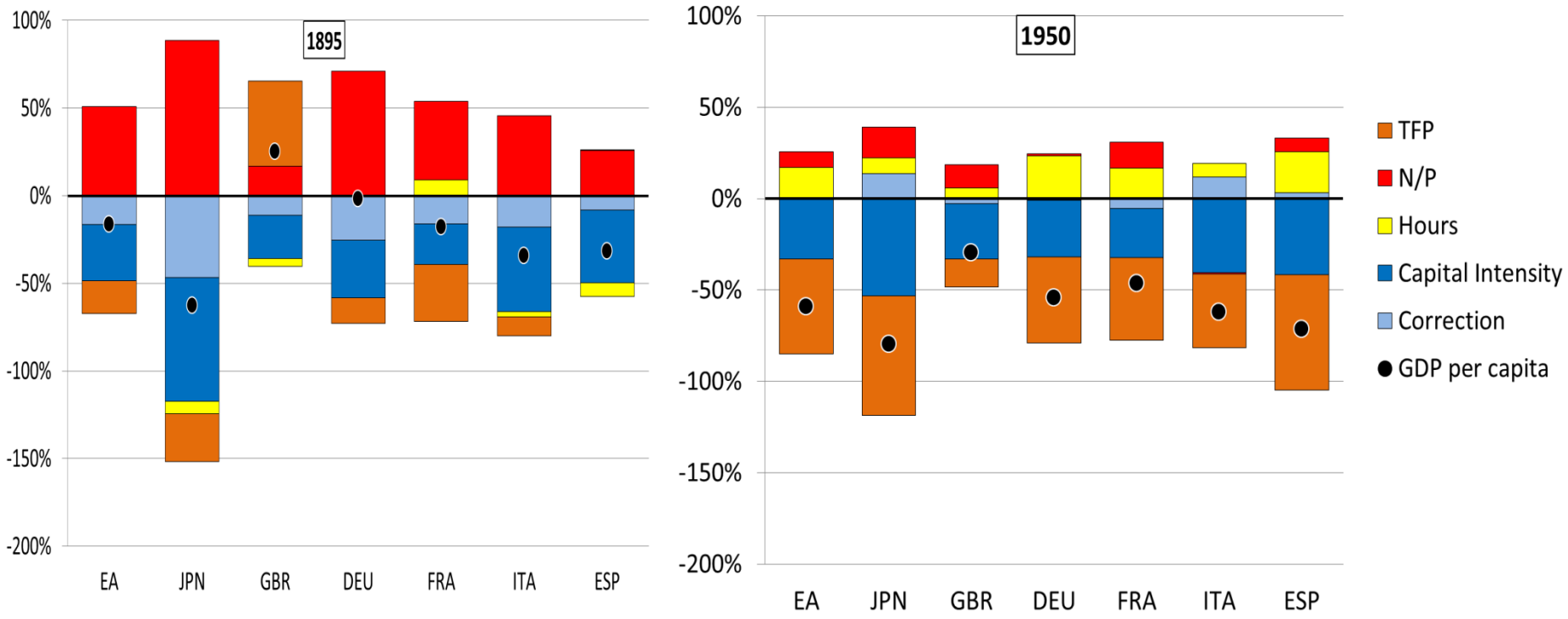
$$\Delta^{US}\left(\frac{Y}{P}\right) = \Delta^{US}(TFP) + \Delta^{US}(KI) + \Delta^{US}(H) + \Delta^{US}\left(\frac{N}{P}\right) + CORR$$

$\Delta^{US}(X)$: relative distance between country *i* and the US for variable X

CORR : correcting term including all interacting factors of order 2 and more

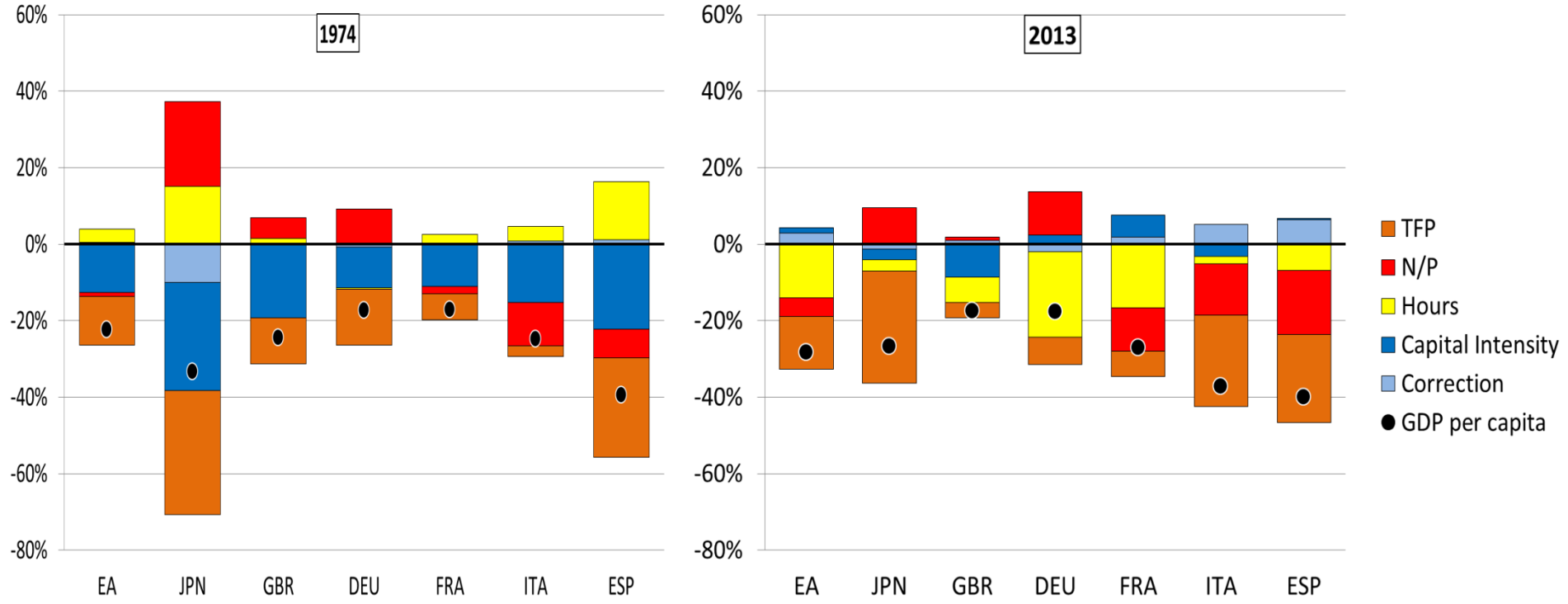
1895-1950: US leadership based on TFP and capital intensity

Decomposition of GDP per capita level with respect to the USA for 16 countries and the Euro Area



1974-2013: reversal of relative hours worked contribution

Decomposition of GDP per capita level with respect to the USA for 16 countries and the Euro Area



Breakdown of GDP per capita growth rate

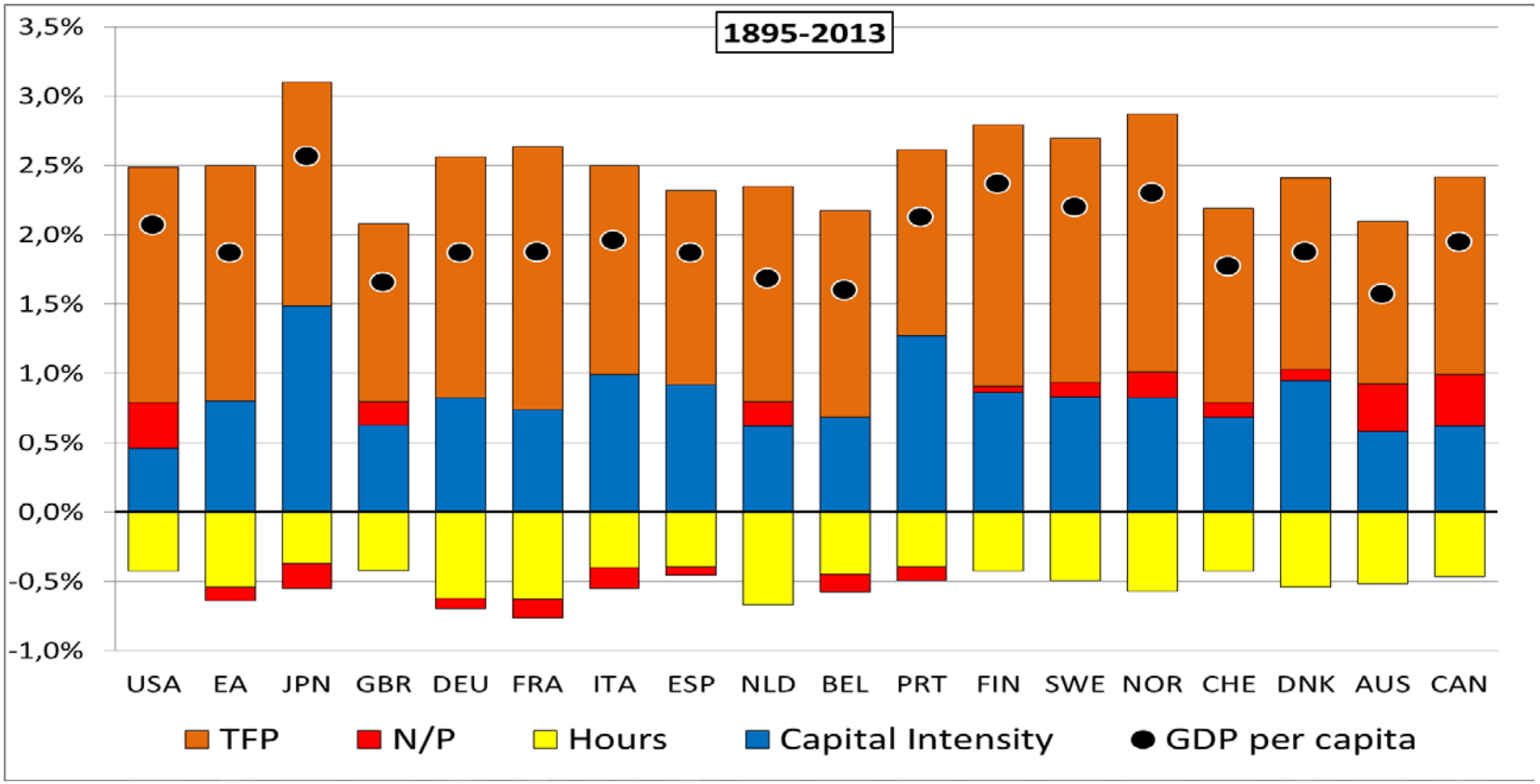
Growth rate of GDP per capita :

$$\Delta\left(\frac{\boldsymbol{y}}{\boldsymbol{p}}\right) = \Delta(\boldsymbol{tfp}) + \boldsymbol{\alpha}.\Delta(\boldsymbol{ki}) + \Delta(\boldsymbol{h}) + \Delta\left(\frac{\boldsymbol{n}}{\boldsymbol{p}}\right)$$

x *:* logarithm of variable *X* ($x = log(X)$)
Δx : usual approximation for the growth rate of *X*

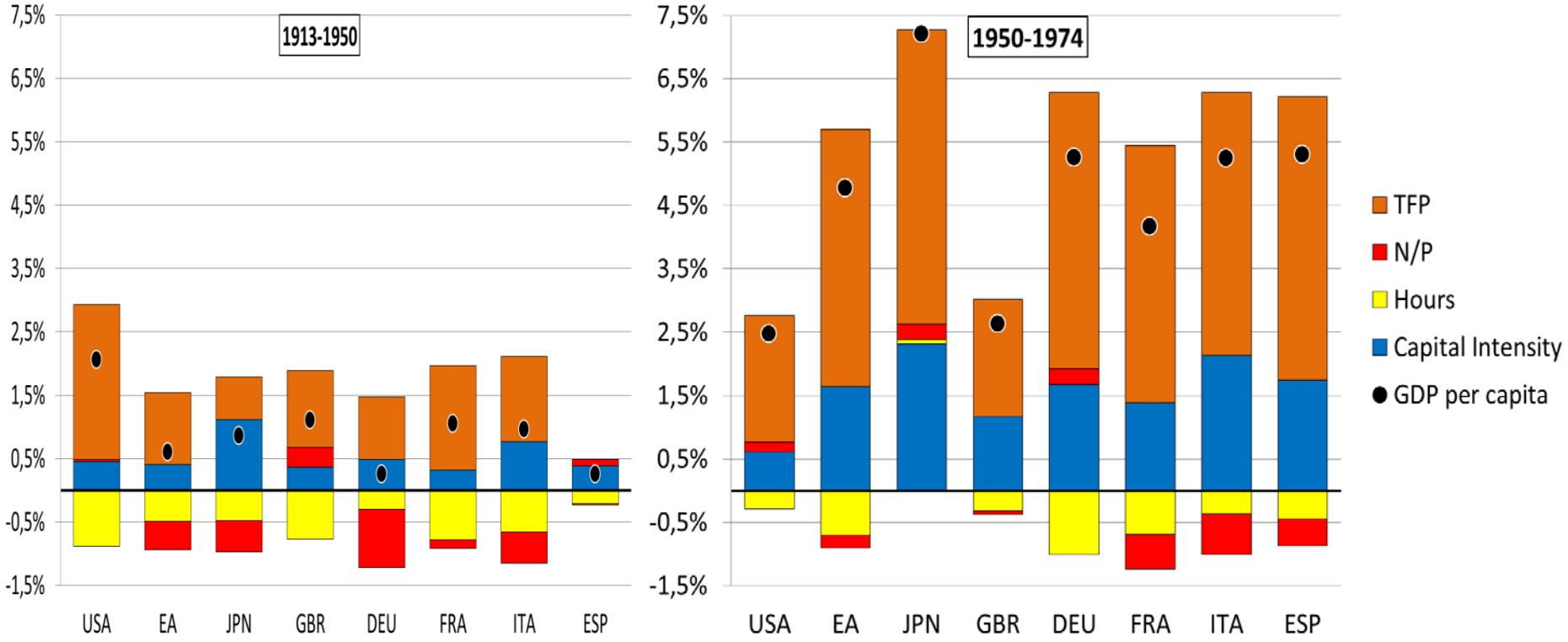
1895-2013
GDP per capita growth relying on TFP and capital intensity

Decomposition of GDP per capita growth for 17 countries and the Euro Area
Percentage points



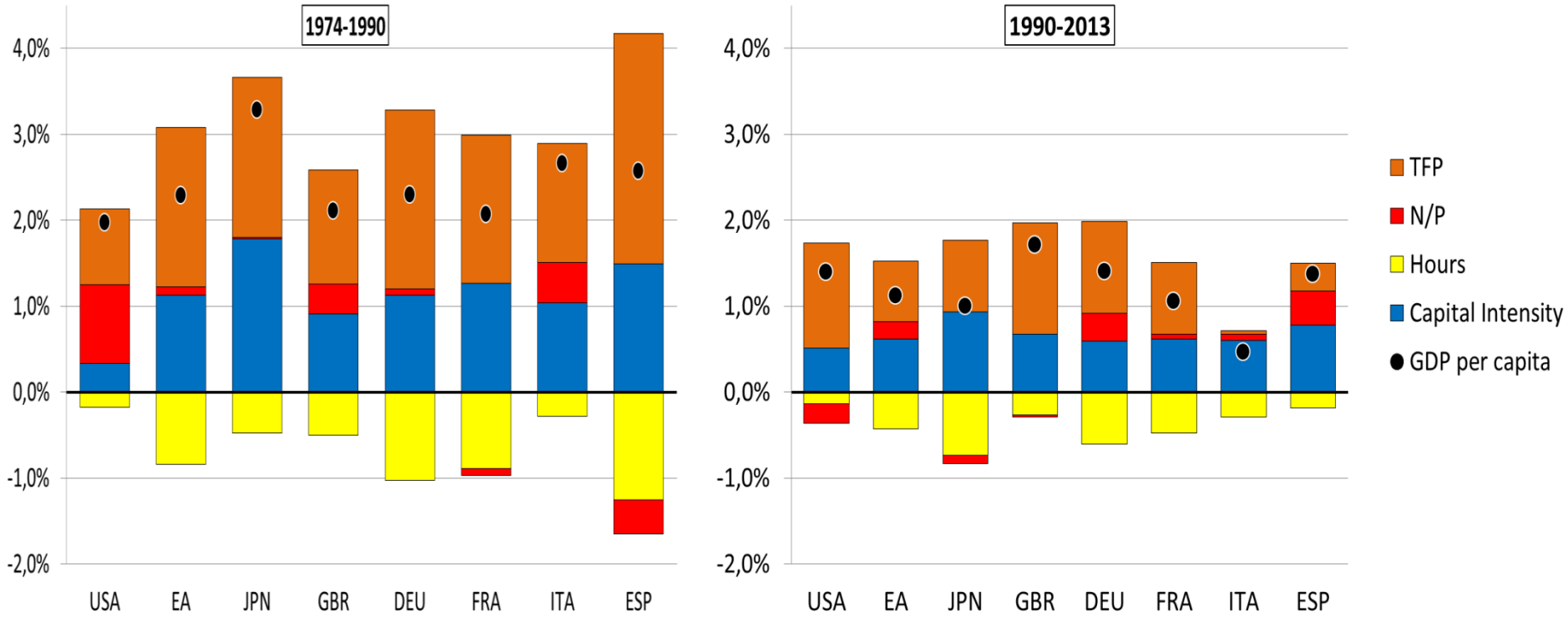
1913-1974
One large TFP wave
before 1950 in the US, afterwards elsewhere

Decomposition of GDP per capita growth for 17 countries and the Euro Area
Percentage points



1974-2013
TFP acceleration in the US and UK, deceleration elsewhere

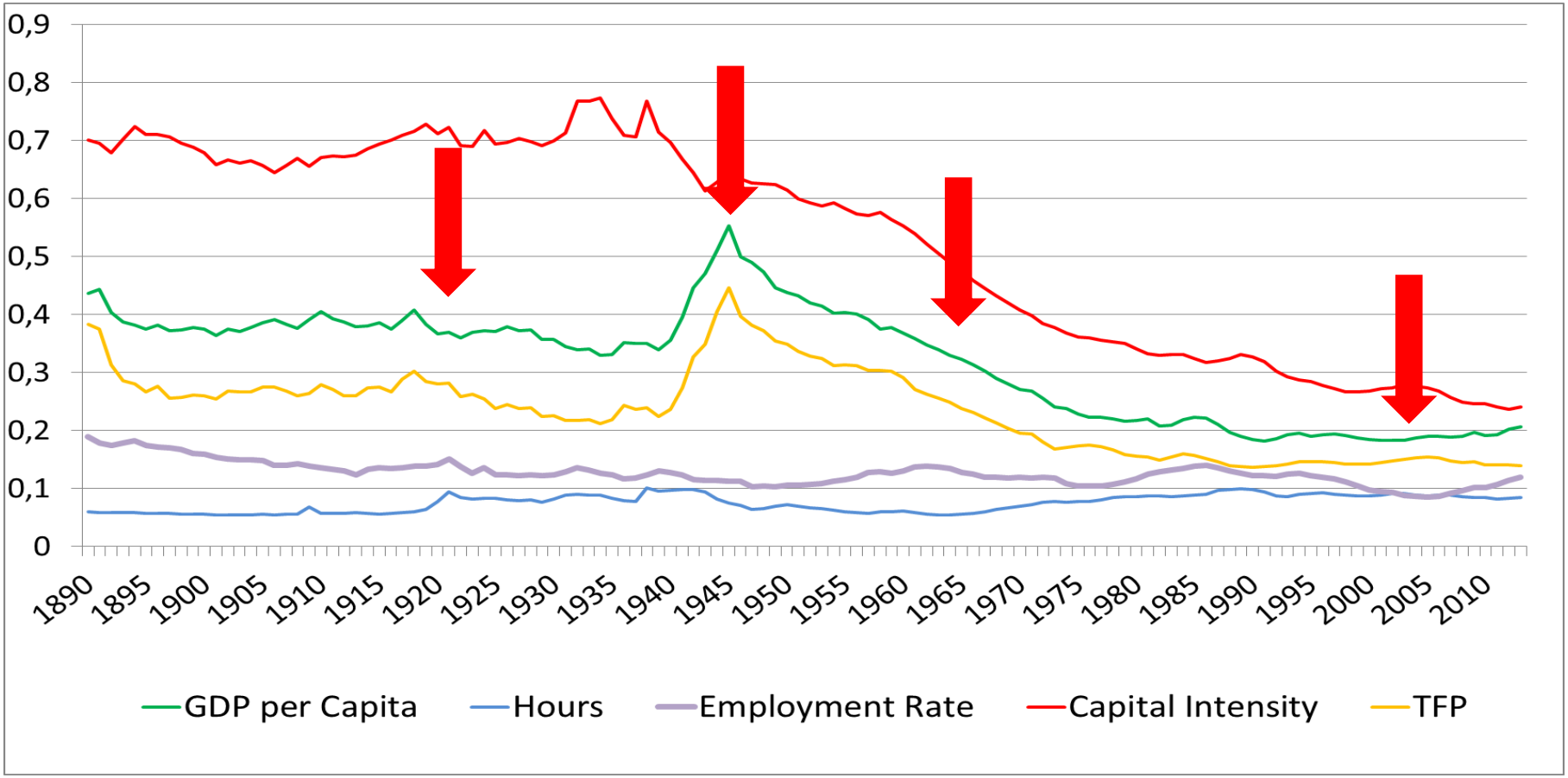
Decomposition of GDP per capita growth for 17 countries and the Euro Area
Percentage points



Convergence

Convergence after the 1940s
mainly based on TFP and capital intensity

Coefficients of variation (standard deviation / mean) for the 17 countries sample



Test of convergence (Phillips et Sul, 2007)

$$h_{i,t} = \frac{log\, y_{i,t}}{\frac{1}{N}\sum_{j=1}^{N} log\, y_{j,t}}$$

$h_{i,t}$: measures the divergent behavior of a country *i* and its distance to a common steady state.

Convergence if: $H_t = \frac{1}{N}\sum_{i=1}^{N}(h_{i,t} - 1)^2 \underset{t\to\infty}{\longrightarrow} 0.$

$$log\frac{H_1}{H_t} - log\, log\, t = a + \beta\, log\, t + \varepsilon_t \quad for\ t > rT$$

r =0.2: first part of the time series not taken into account in the regression.

H_0 hypothesis of convergence : $\beta > 0$

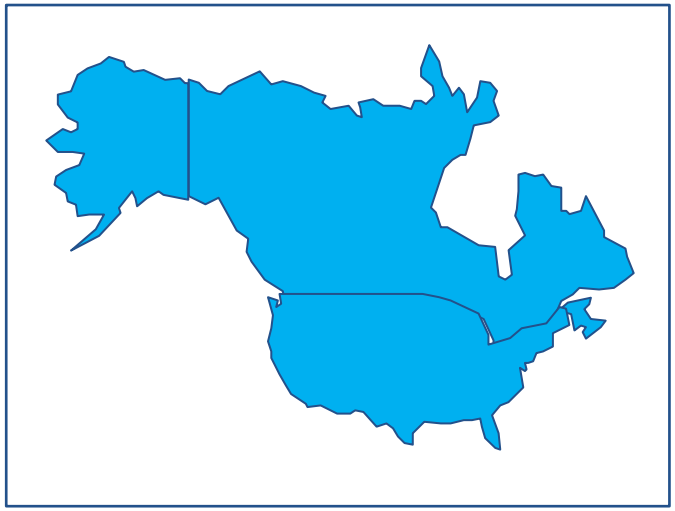
β: convergence if H_0 not rejected (t-stat>-1,65)

$\beta > 2$: convergence in level

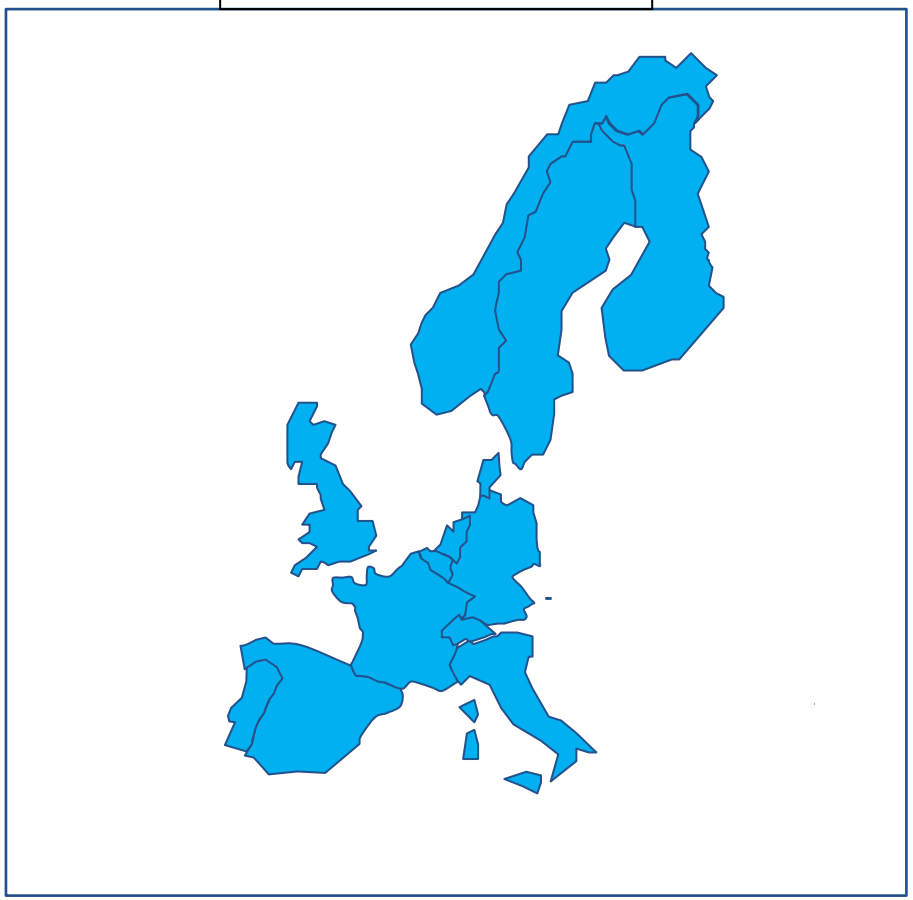
$2 > \beta > 0$: convergence in growth rate

Convergence test :1895-2013

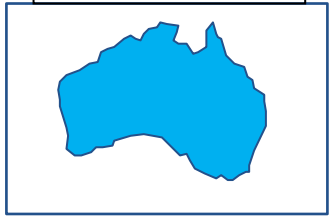
North America



Europe



Australia

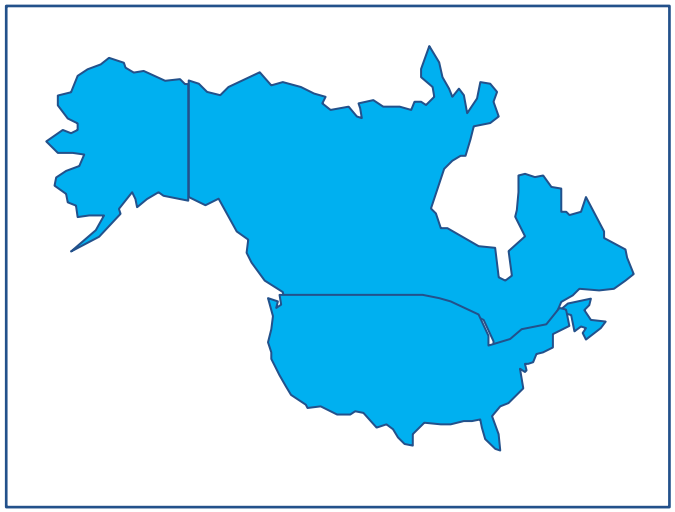


Japan

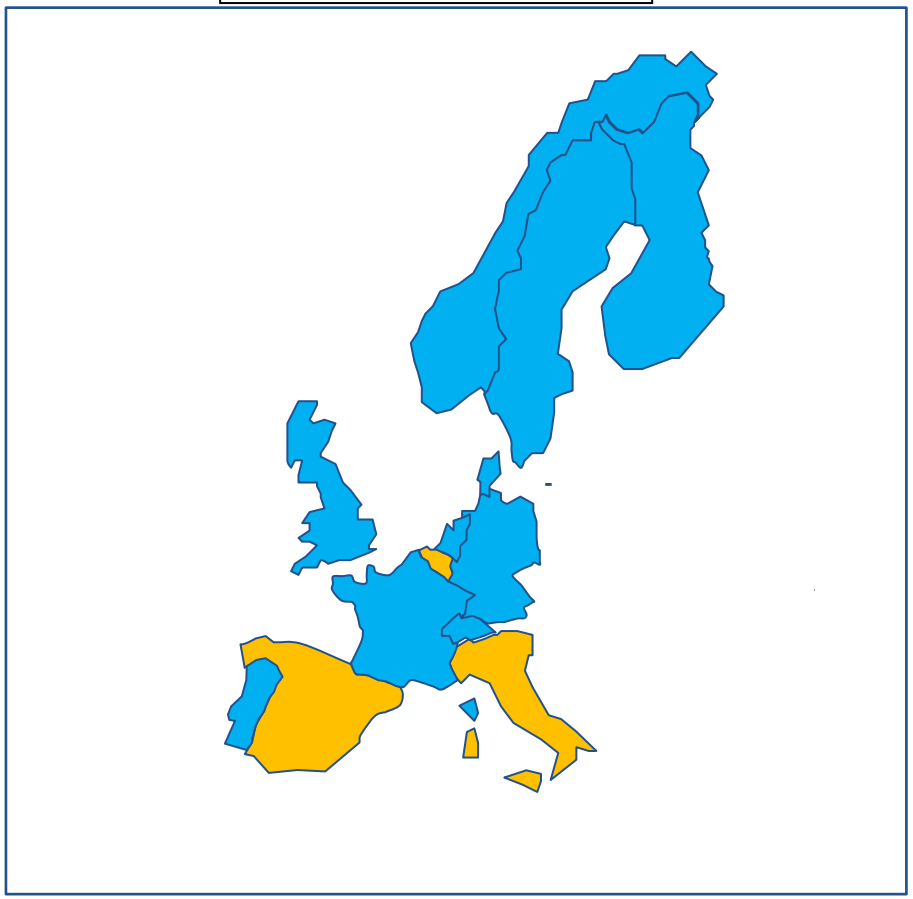
GDP per Capita : β=1,2 **Capital intensity : β=2,8** **TFP : β=2,0**

Convergence test :1895-2013
Employment rate

North America



Europe



Australia

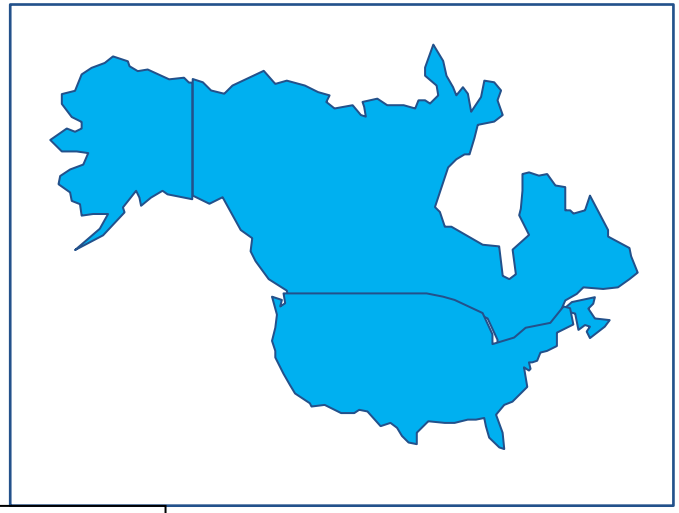
Japan

β=0,17

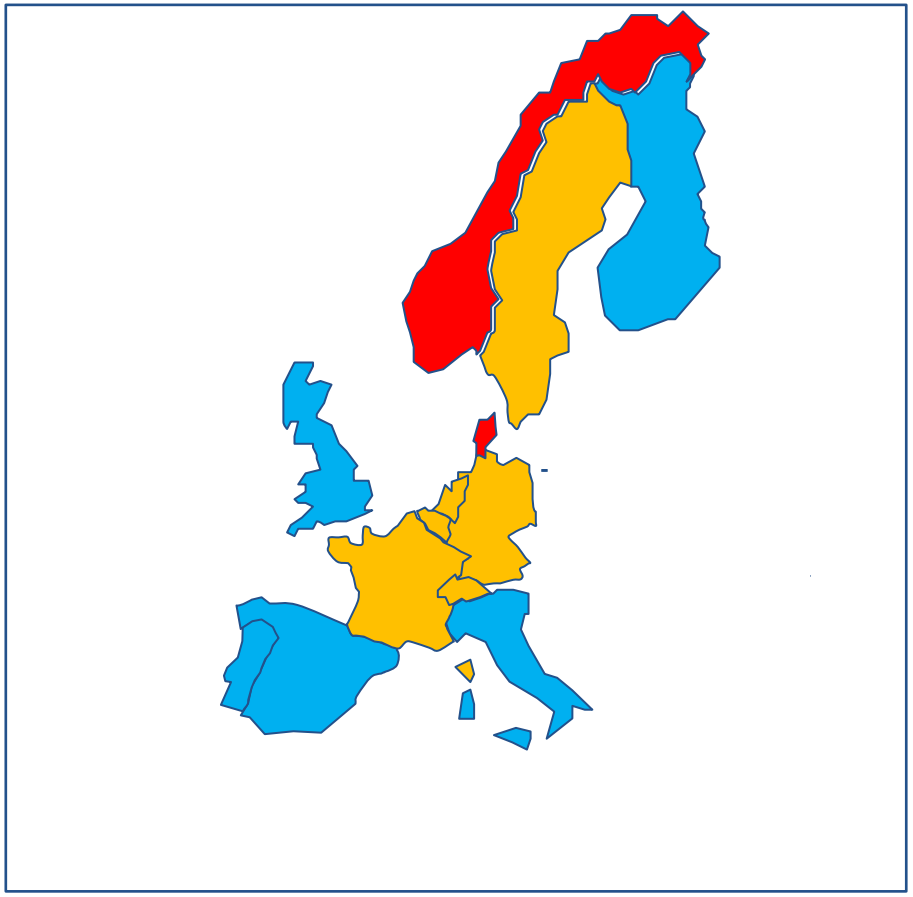
β=1,40

Convergence test :1895-2013
Hours per employee

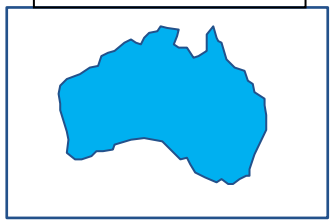
North America



Europe



Australia



Japan

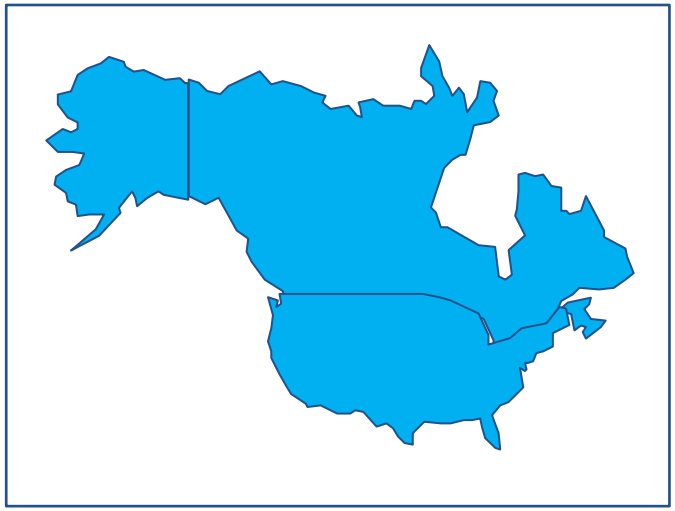
β=0,84

β=0,15

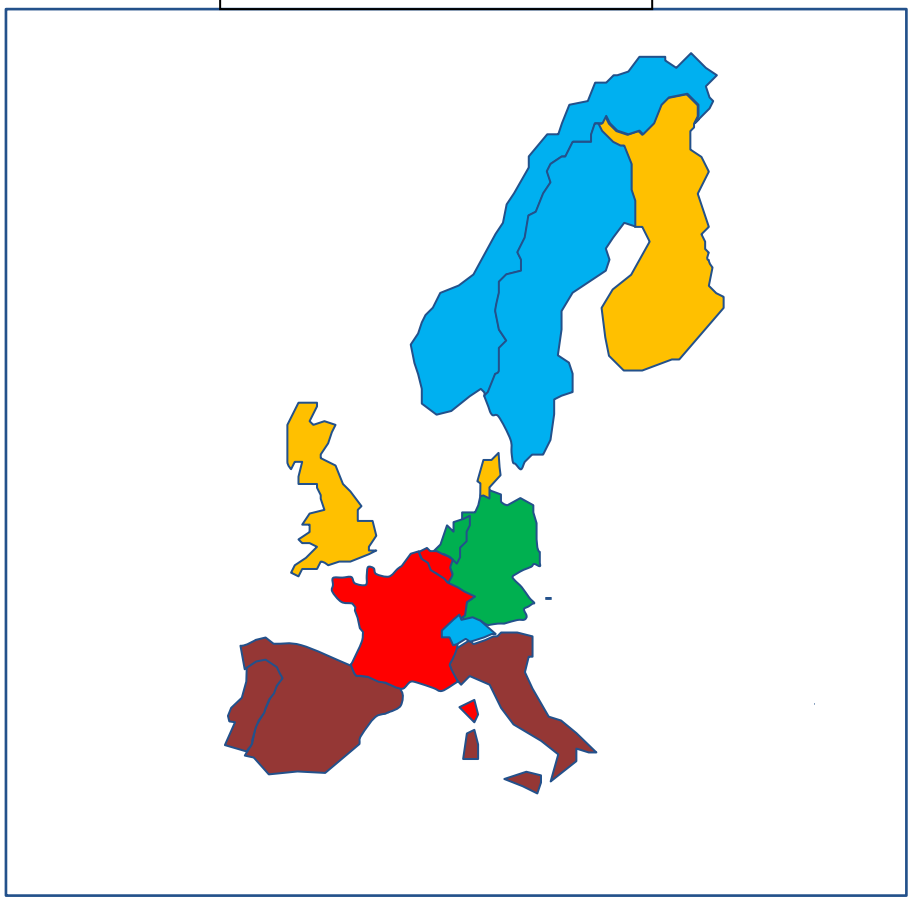
β=0,79

Convergence test : 1895-1950

North America



Europe



Australia

Japan

GDP per Capita

β=0,32 β=-0,18

β=0,25 β=-0,50

β=0,31

Capital intensity : all countries converge (0,37)

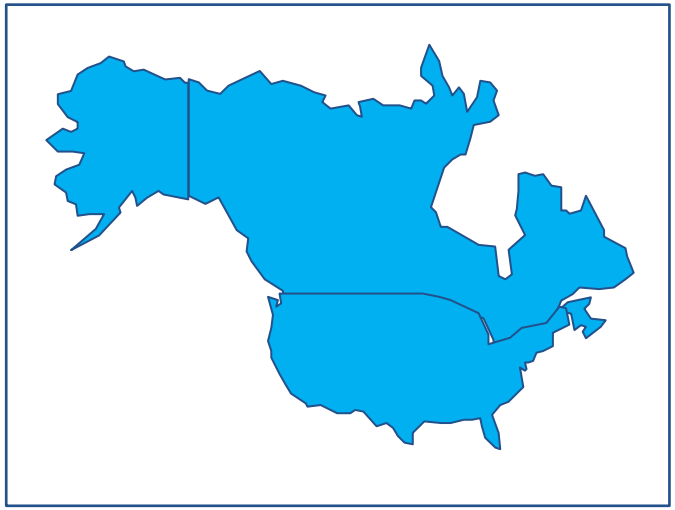
TFP : all countries converge (-0,069)

Employment rate : 2 convergence groups, no convergence (AU,ES,PT)

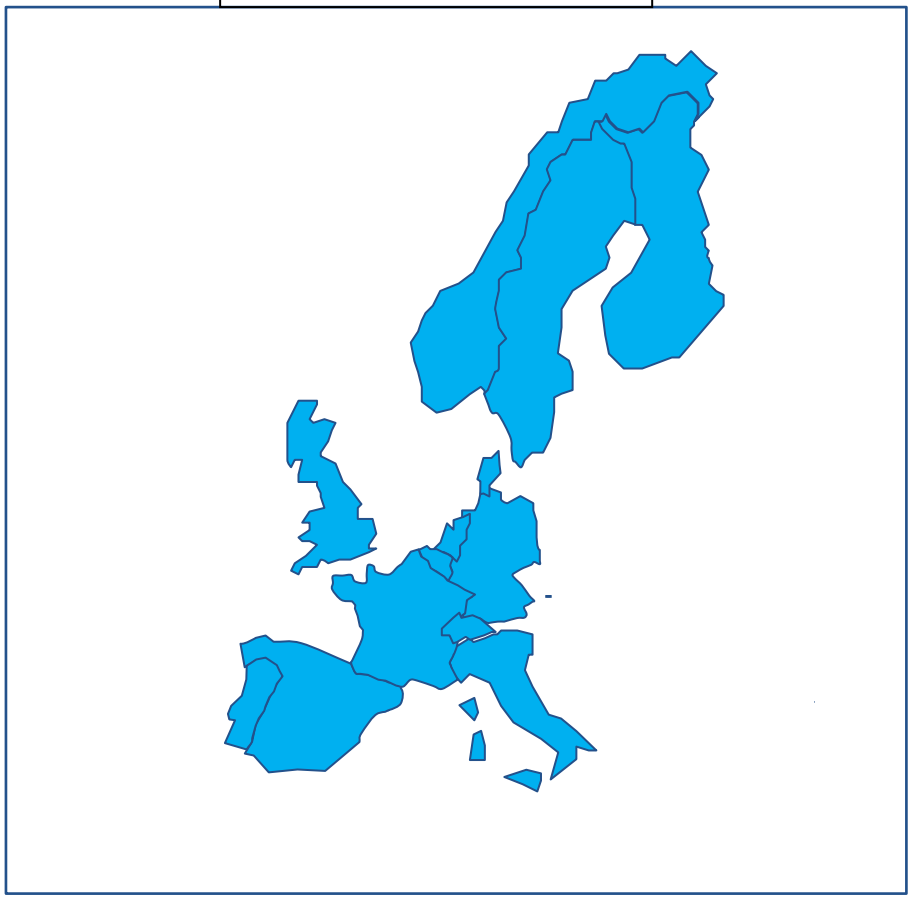
Hours : 2 convergence groups, no convergence (NO,SE,US)

Convergence test : 1950-2013

North America



Europe



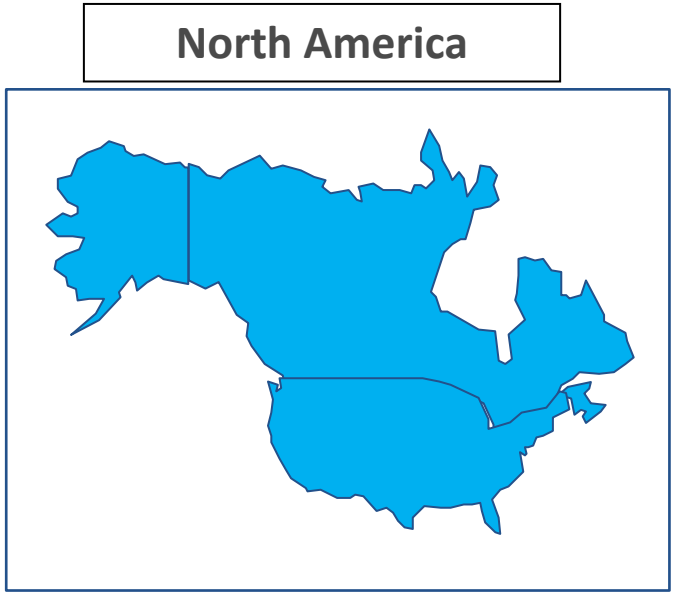
Australia

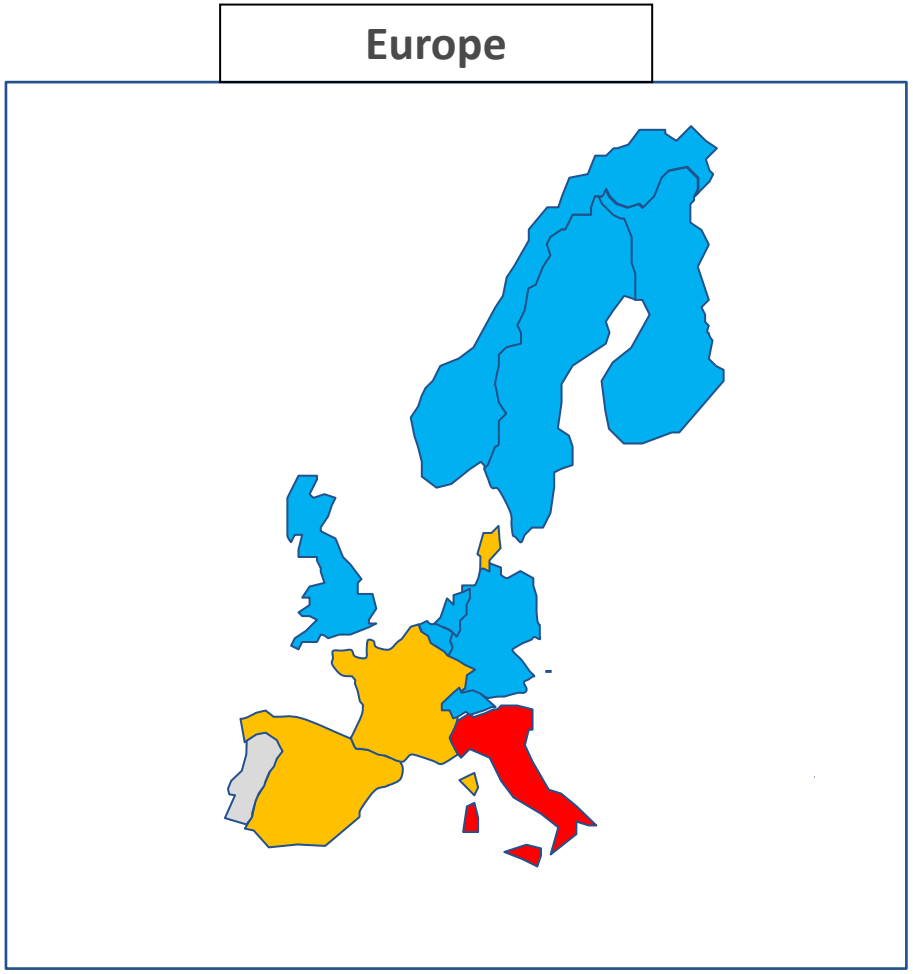
Japan

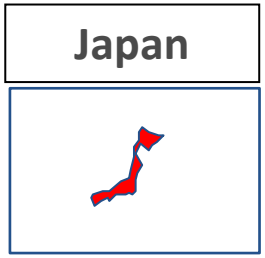
GDP per Capita
β=0,40

Capital intensity : all countries converge (1,1)
TFP : all countries converge (0,66)
Employment rate : 2 convergence groups
Hours : 3 convergence groups, no convergence (CH,GB,NO)

Convergence test : 1990-2013







GDP per Capita

β=0,046 β=0,098

β=-1,3

No convergence (PT)

Capital intensity : 3 convergence groups, no convergence (NO)

TFP : 2 convergence groups

Employment rate : 3 convergence groups, no convergence (NO)

Hours : 3 convergence groups

Robustness: change in dates

1987 - 2013	1990 - 2013	1993 - 2013
GDP per capita		
Gr1: AU, CA, CH, FI, GB, NL, NO, SE, US	**Gr1: AU, BE, CA, CH, DE, FI, GB, NL, NO, SE, US**	Gr1: AU, CA, CH, FI, NL, NO, SE, US
Gr2: BE, DE, DK, ES, FR, JP	**Gr2: DK, ES, FR**	Gr2: DE, GB
Gr3: IT, PT	**Gr3: IT, JP**	Gr3: BE, DK
	NOCV: PT	Gr4: ES, FR, IT, JP
		NOCV: PT
TFP		
Gr1: AU, BE, CH, DE, DK, FI, FR, GB, NL, NO, SE, US	**Gr1: AU, BE, CH, DE, DK, FI, FR, GB, NL, NO, SE, US**	Gr1: BE, DE, FR, GB, NL, NO, SE, US
Gr2: CA, ES, IT, JP, PT	**Gr2: CA, ES, IT, JP, PT**	Gr2: AU, CA, CH, DK, FI
		Gr3: ES, IT, JP, PT

Other robustness tests

- α = 0.25 / 0.35 instead of 0.3
- Depreciation rates:
  - Equipment: 0.05 / 0.15 instead of 0.1
  - Buildings: 0.015 / 0.05 instead of 0.025
- Value of trimming coefficient r / country order
- No significant changes; global convergence hold

Concluding remarks

- **A long mourning for the "one big wave"**
  - "One big wave" based on technology diffusion through TFP and capital intensity
  - …first in the US, then convergence process after war in most advanced countries
  - …unmatched by the ICT technology shock

- **A new divergence era?**
  - Divergence in the past due to world wars and staggered diffusion of innovation
  - Large role of economic policy since 1974 through employment rate and hours worked…
  - …and reaction to financial crisis…
  - …but also through the disparate impact of the ICT technology shock…
  - …emphasizing a stronger role of institutions and education as countries come closer to the frontier

APPENDIX

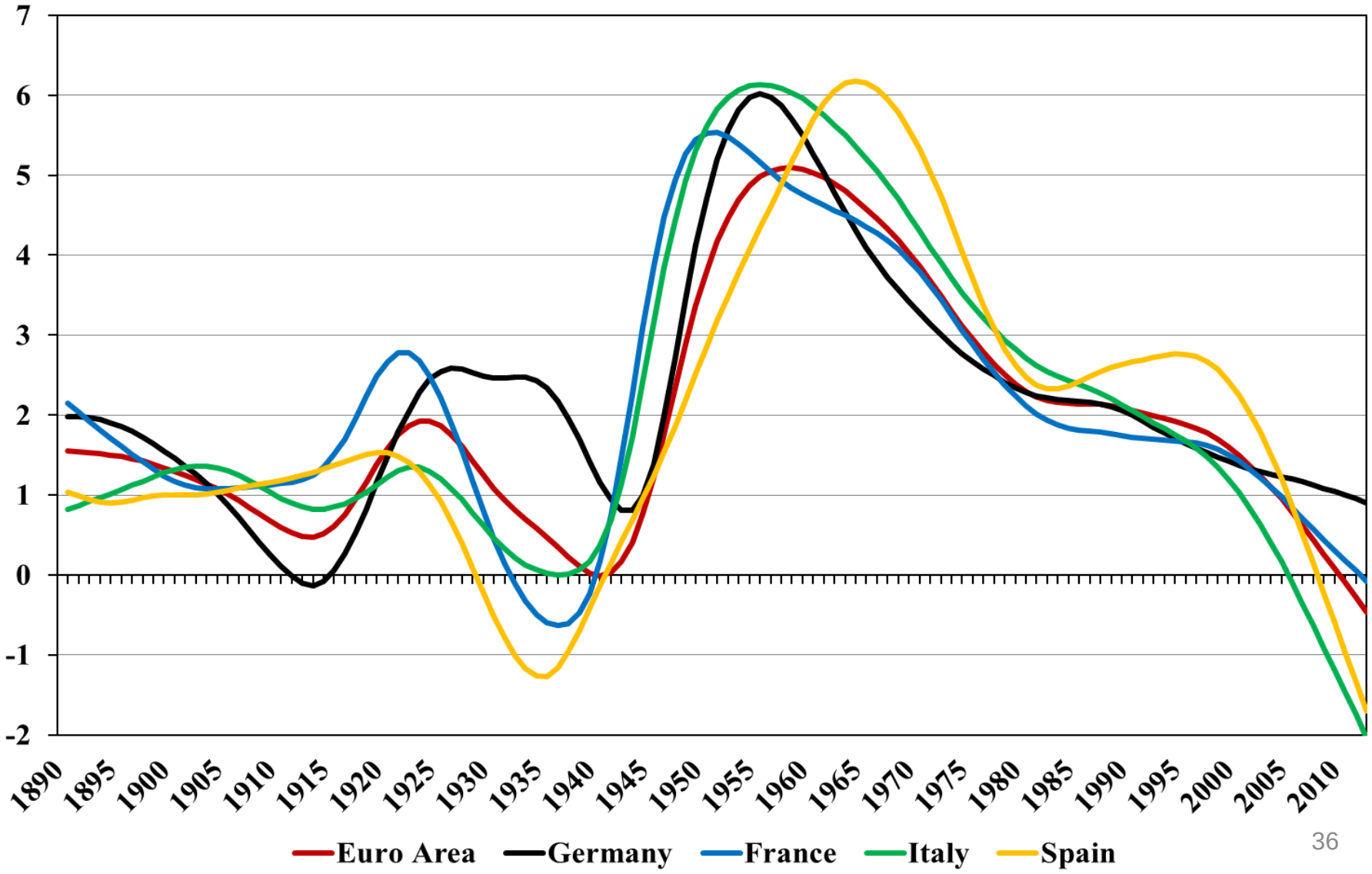
Results when the Phillips-Sul Club Convergence test is used on the set of 17 countries in different sub-periods for TFP and Capital Intensity and for different values of parameters α and δ

	TFP				Capital Intensity	
	High value of α	Low value of α	High value of δ	Low value of δ	High value of δ	Low value of δ
1895 – 2013	- (2.0)	- (2.1)	- (1.9)	- (2.2)	- (3.0)	- (2.6)
1895 – 1950	Gr1: AU, BE, CA, CH, DE, DK, FI, FR, GB, IT, JP, NL, SE, US (0.14) Gr2: ES, PT (3.6)	- (-0.0039)*	Gr1: AU, BE, CA, CH, DE, DK, FI, FR, GB, NL, SE, US (0.29) Gr2: ES, IT, JP, PT (0.39)	- (0.023)*	- (0.54)	- (0.26)
1950 – 2013	- (0.69)	- (0.63)	- (0.67)	- (0.65)	- (1.2)	- (1.2)
Original Values	TFP				Capital Intensity	
1895 – 2013	- (2.0)				- (2.87)	
1895 – 1950	- (-0.069)*				- (0.37)	
1950 – 2013	- (0.66)				- (1.1)	

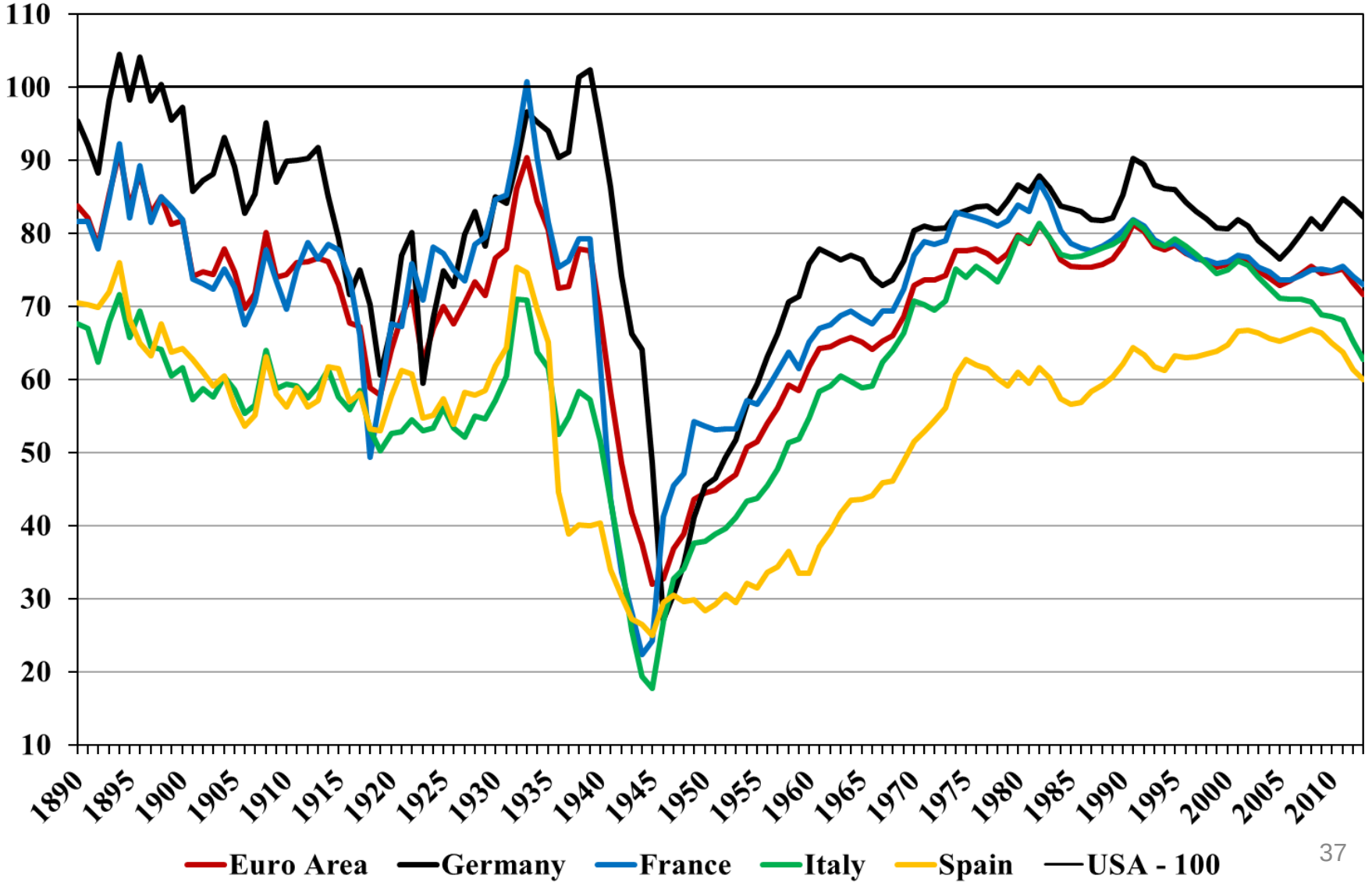
Results when the Phillips-Sul Club Convergence test is used on the set of 17 countries in different sub-periods for TFP and Capital Intensity and for different values of parameters α and δ (quarterly data)

	TFP				Capital Intensity	
	High value of α	Low value of α	High value of δ	Low value of δ	High value of δ	Low value of δ
1974 – 2013	- (0.41)	- (0.22)	- (0.27)	- (0.29)	- (0.27)	- (0.35)
1974 – 1990	- (0.094)	Gr1: BE, CH, DE, DK, ES, FI, FR, GB, JP, NL, NO (0.16) Gr2: AU, CA, IT, SE, US (0.13) NOCV: PT	- (-0.13)*	- (-0.017)*	Gr1: AU, BE, CA, CH, DE, DK, ES, FR, IT, JP, NL, SE, US (0.13) Gr2: FI, GB (-0.38)* NOCV: NO, PT	Gr1: AU, BE, CA, CH, DE, DK, ES, FI, FR, IT, JP, NL, SE, US (0.024) NOCV: GB, NO, PT
1990 – 2013	Gr1: AU, BE, DE, DK, FR, GB, NL, NO, SE, US (0.57) Gr2: ES, IT, JP, PT (0.25) NOCV: CA, CH	Gr1: AU, BE, CH, DE, DK, FI, FR, GB, NL, NO, SE, US (0.30) Gr2: CA, ES, IT, JP, PT (0.021)	Gr1: AU, BE, CH, DE, DK, FI, FR, GB, NL, NO, SE, US (0.38) Gr2: CA, ES, IT, JP, PT (0.068)	Gr1: AU, BE, CA, CH, DE, DK, FI, FR, GB, NL, NO, SE, US (0.27) Gr2: ES, IT, JP, PT (0.21)	Gr1: AU, ES, FR, NL, PT, US (0.046) Gr2: BE, CA, DE, DK, FI, GB, JP (0.12) Gr3: CH, IT, SE (0.50) NOCV: NO	Gr1: AU, BE, DE, DK, FR, JP, NL, PT, US (0.12) Gr2: CA, CH, ES, FI, GB, IT, SE (0.18) NOCV: NO
Original Values	TFP				Capital Intensity	
1974 – 2013	- (0.28)				- (0.29)	
1974 – 1990	Gr1: BE, CA, CH, ES, FI, FR, JP, NL, NO (0.27) Gr2: AU, DE, DK, GB, IT, US (0.83) Gr3: PT, SE (-0.13)*				Gr1: BE, CH, DE, DK, ES, FR, JP, NL, SE, US (0.11) Gr2: AU, CA, FI, IT (0.40) NOCV: GB, NO, PT	
1990 – 2013	Gr1: AU, BE, CH, DE, DK, FI, FR, GB, NL, NO, SE, US (0.39) Gr2: CA, ES, IT, JP, PT (0.006)*				Gr1: AU, BE, FR, JP, NL, PT, US (0.14) Gr2: DE, DK, ES, SE (0.39)* Gr3: CA, CH, FI, GB, IT (0.39) NOCV: NO	

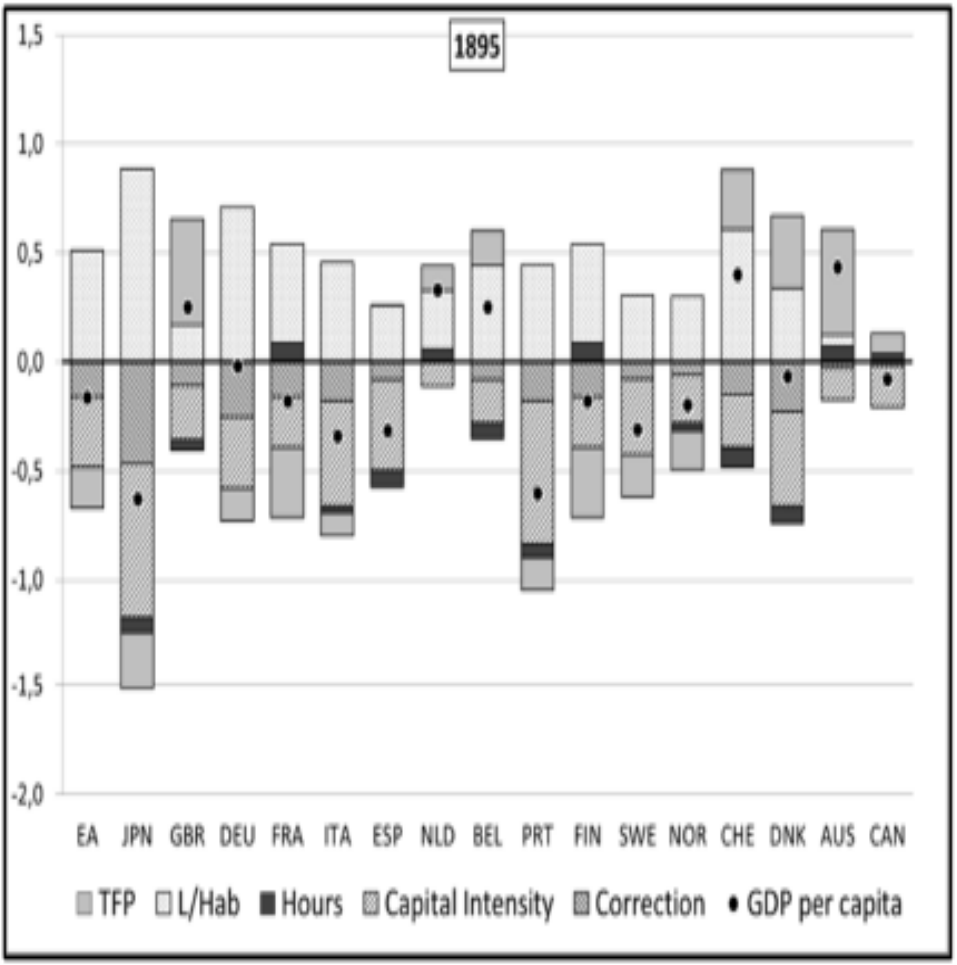
GDP per capita: growth waves for Euro Area

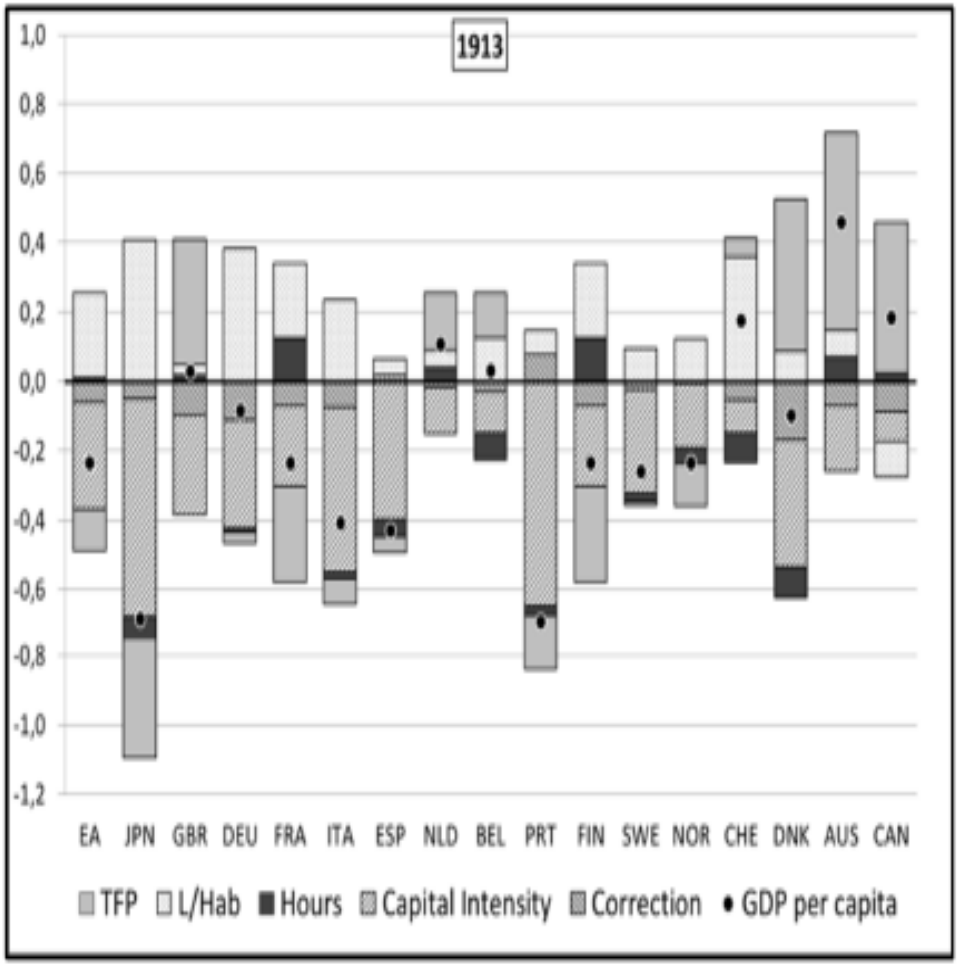


GDP per capita: Euro area countries level / US

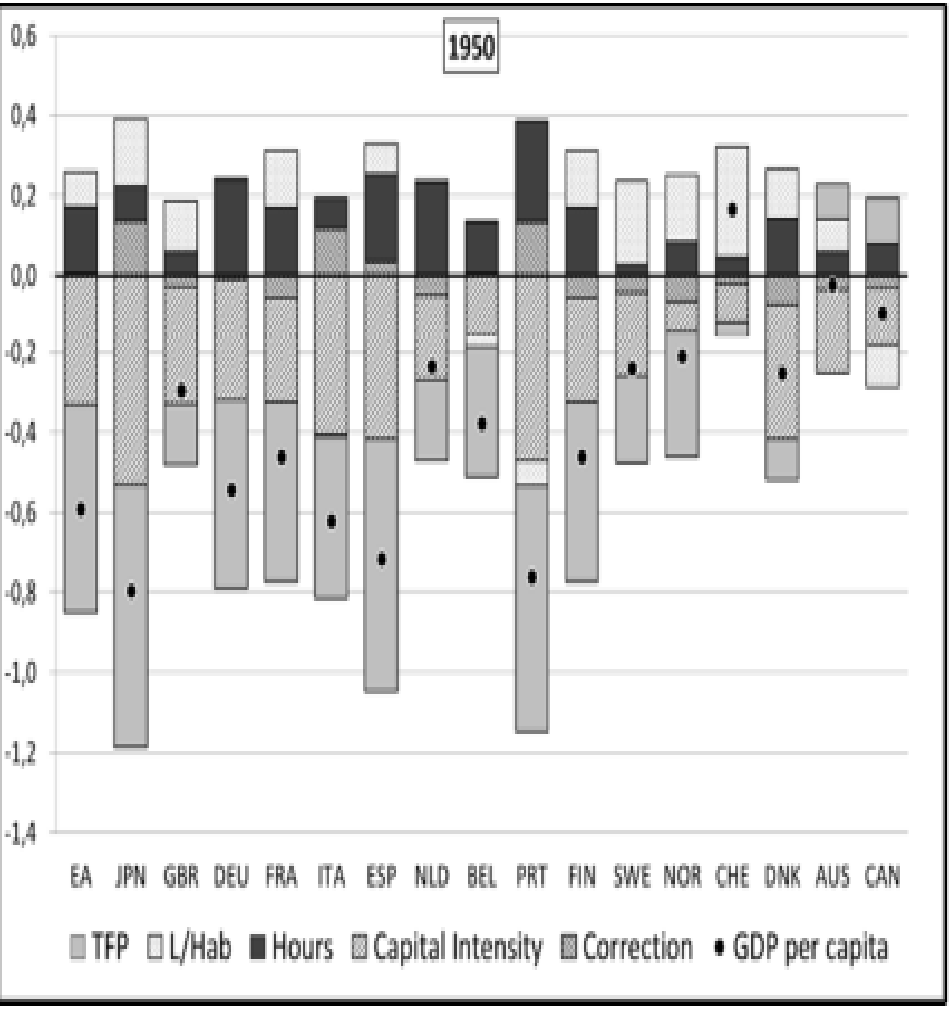


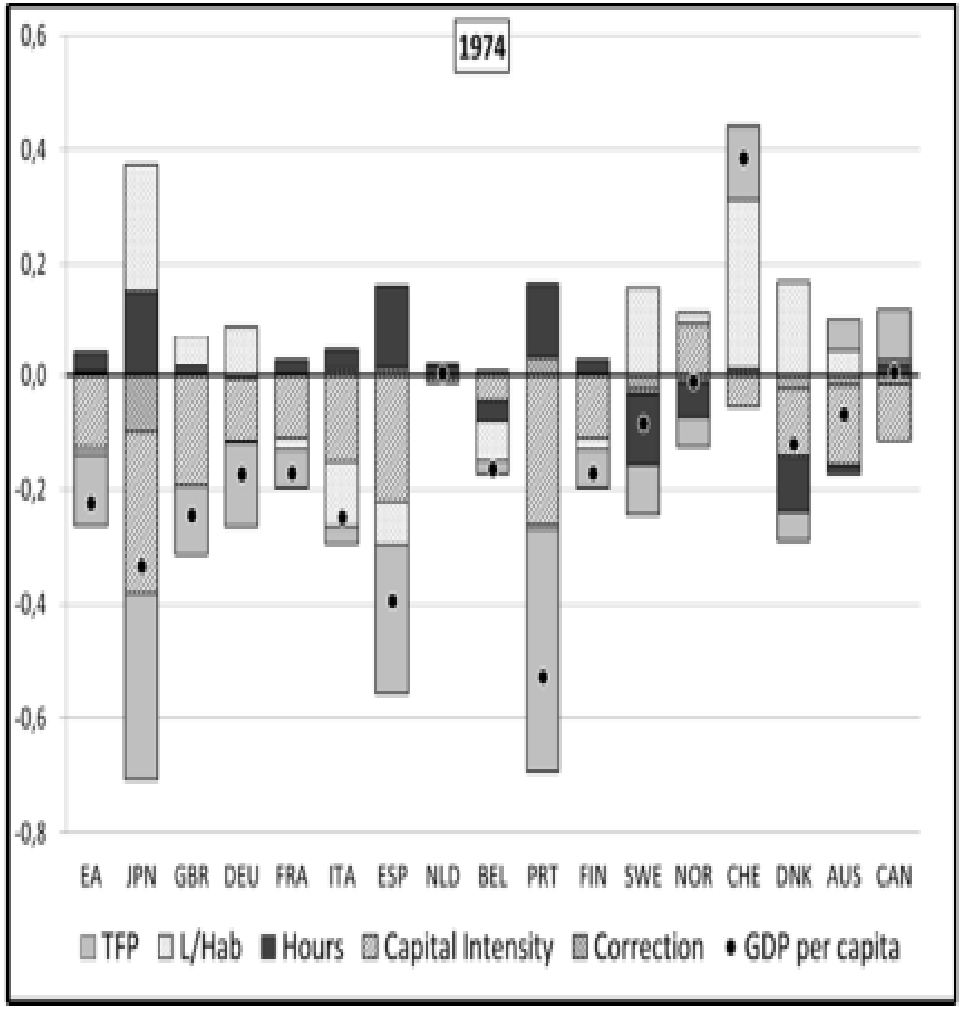
Decomposition of GDP per capita level with respect to the USA for 16 countries and the Euro Area



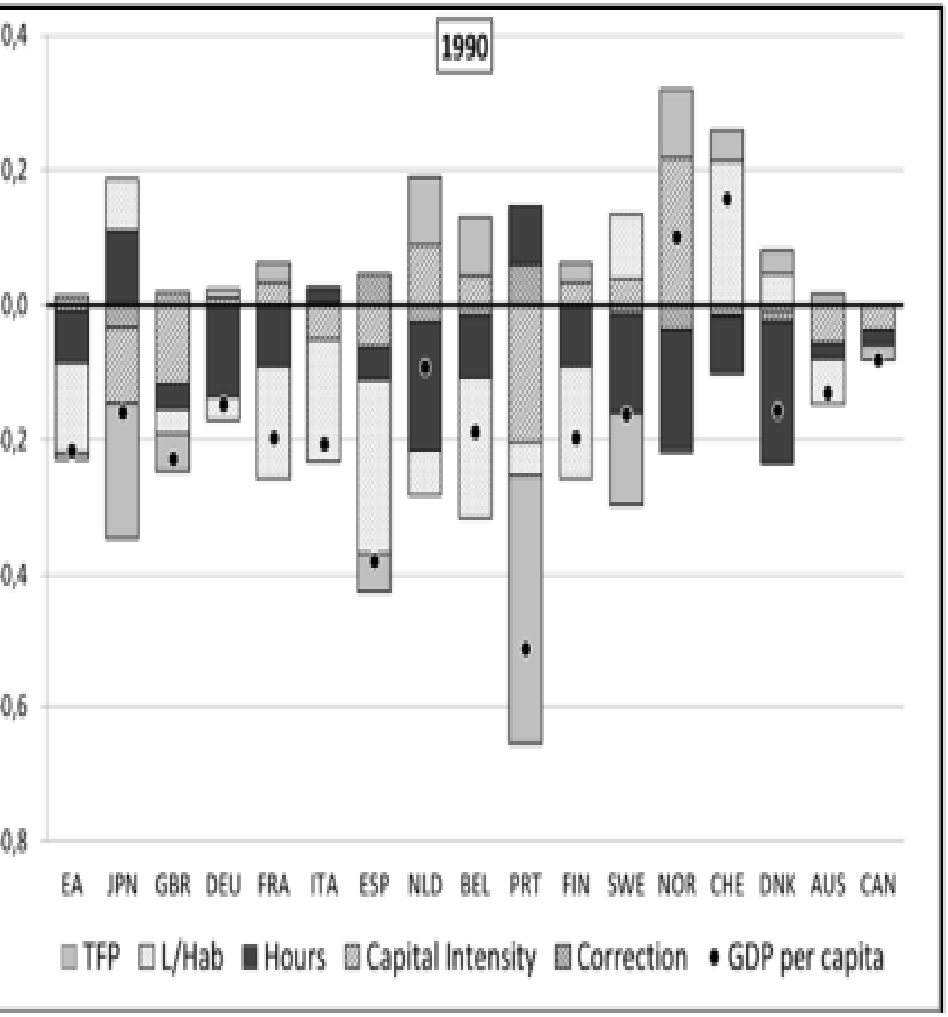


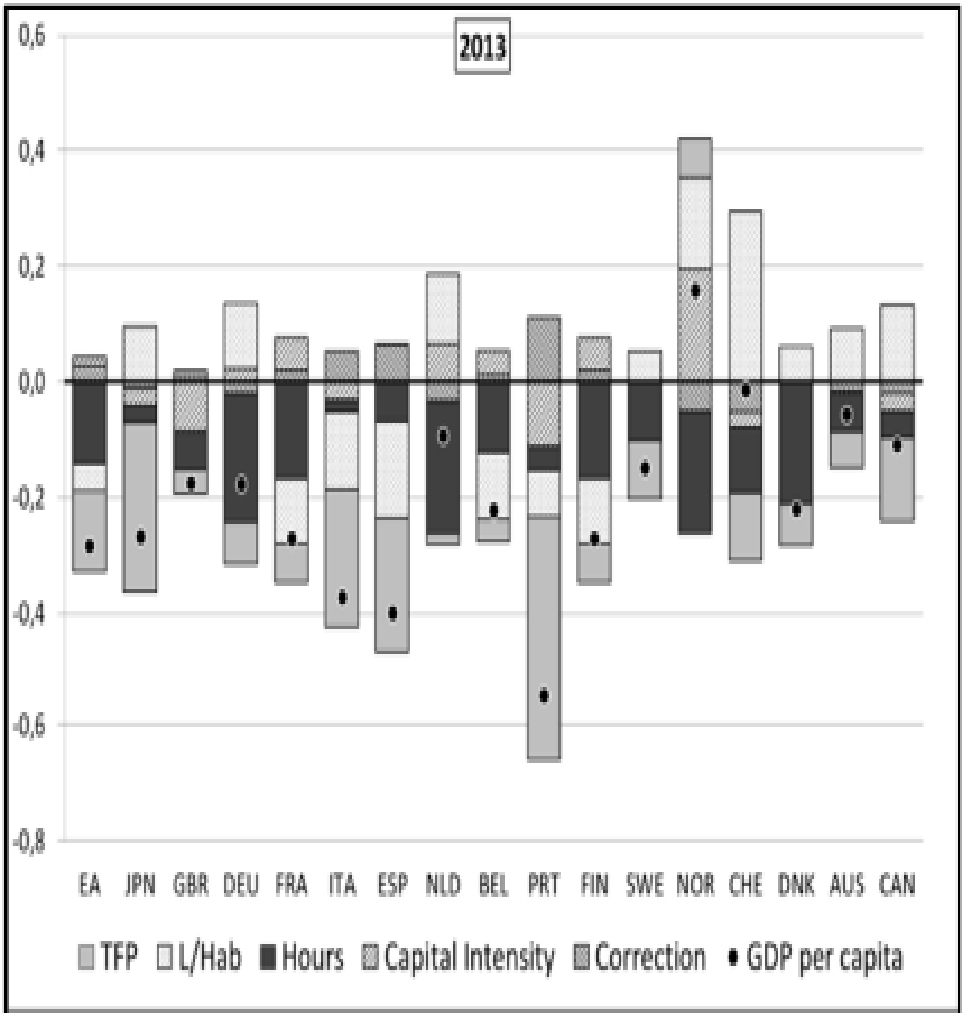
Decomposition of GDP per capita level with respect to the USA for 16 countries and the Euro Area



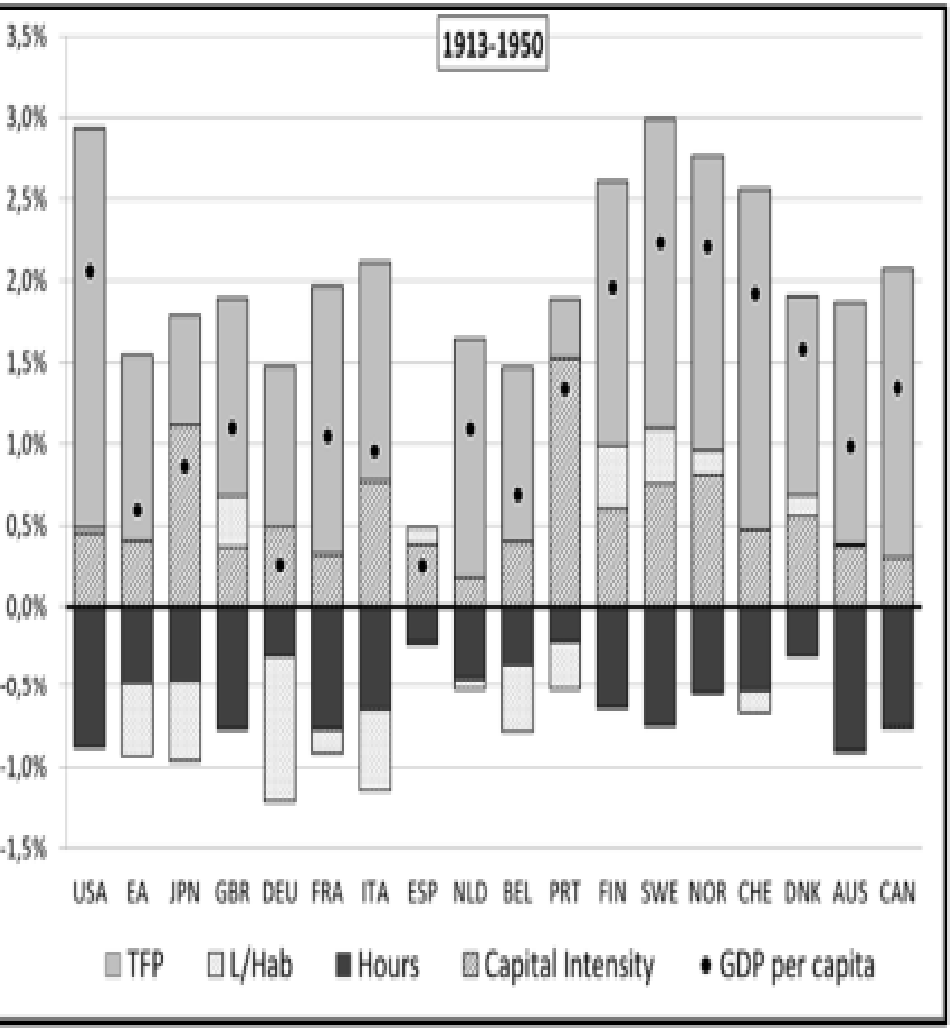


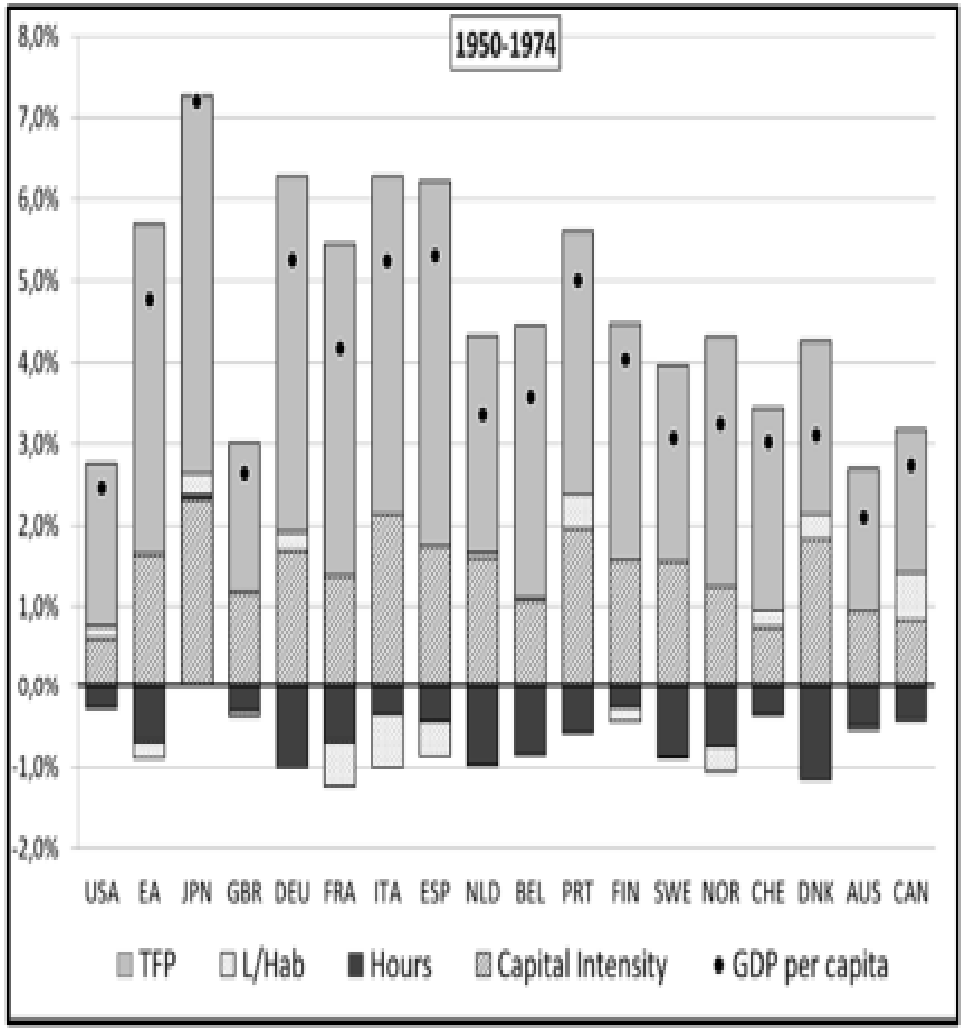
Decomposition of GDP per capita level with respect to the USA for 16 countries and the Euro Area





Decomposition of GDP per capita growth for 17 countries and the Euro Area
Percentage points





Decomposition of GDP per capita growth for 17 countries and the Euro Area
Percentage points