

Measurement and Stylized Facts in Growth and Development

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January 2024

Data sources: Acemoglus (2009), Aghion-Howitt (2009), Jones (1998, 2015)

B. The Big Picture

1. Long Term Development of the World Economy

- **Five ancient empires:**

| | | |
|--|---|---|
| Greek empire (2000-300BC) | | Chinese empire (2852BC-1911) |
| | Babylonian empire (1696-539BC) | |
| Egyptian empire (4000-30BC) | | Indian empire (3300BC-1818) |

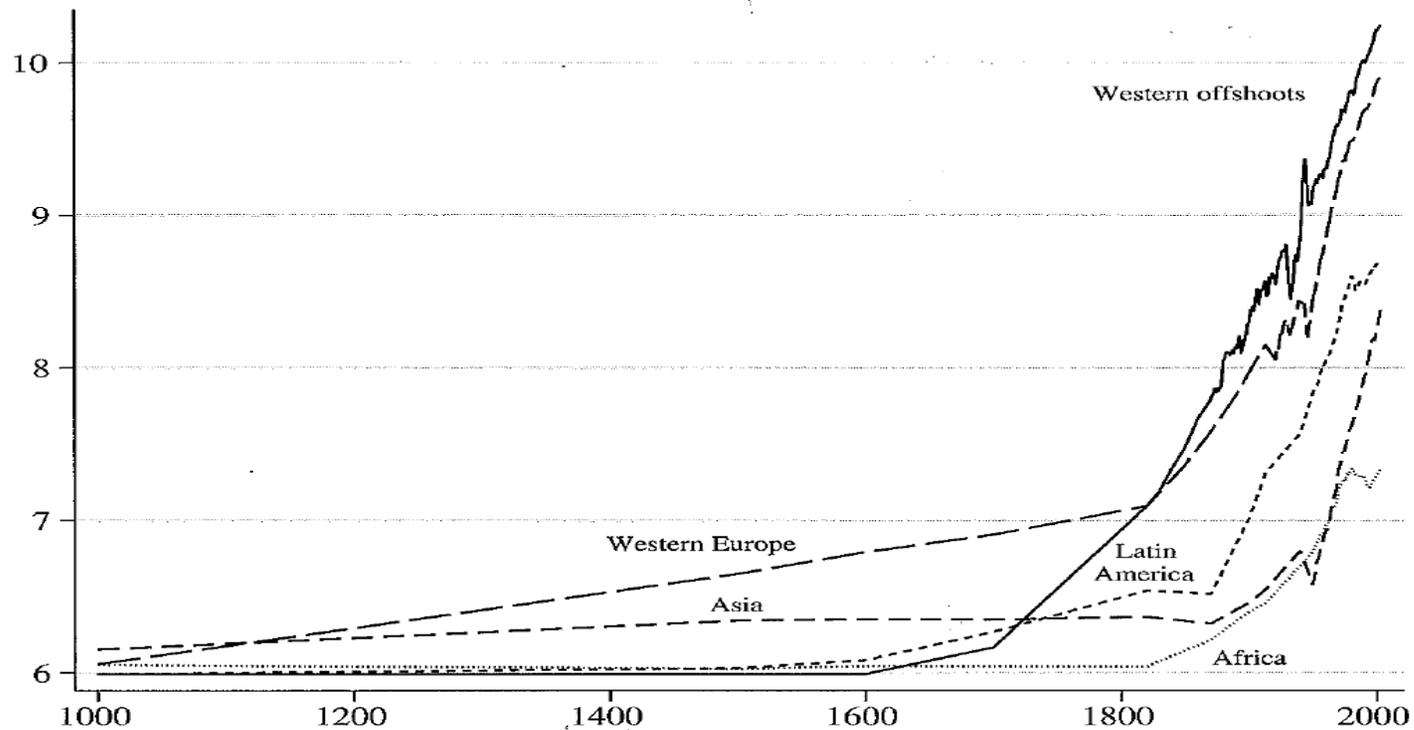
- **The rise of Europe:**

- **Roman empire (27BC-1461)**
- **Spanish empire (1519-1898)**
- **Dutch empire (1579-1795)**
- **British empire (1689-1997)**
- **German empire (1871-1918)**

- **The rise of America (1776-now)**

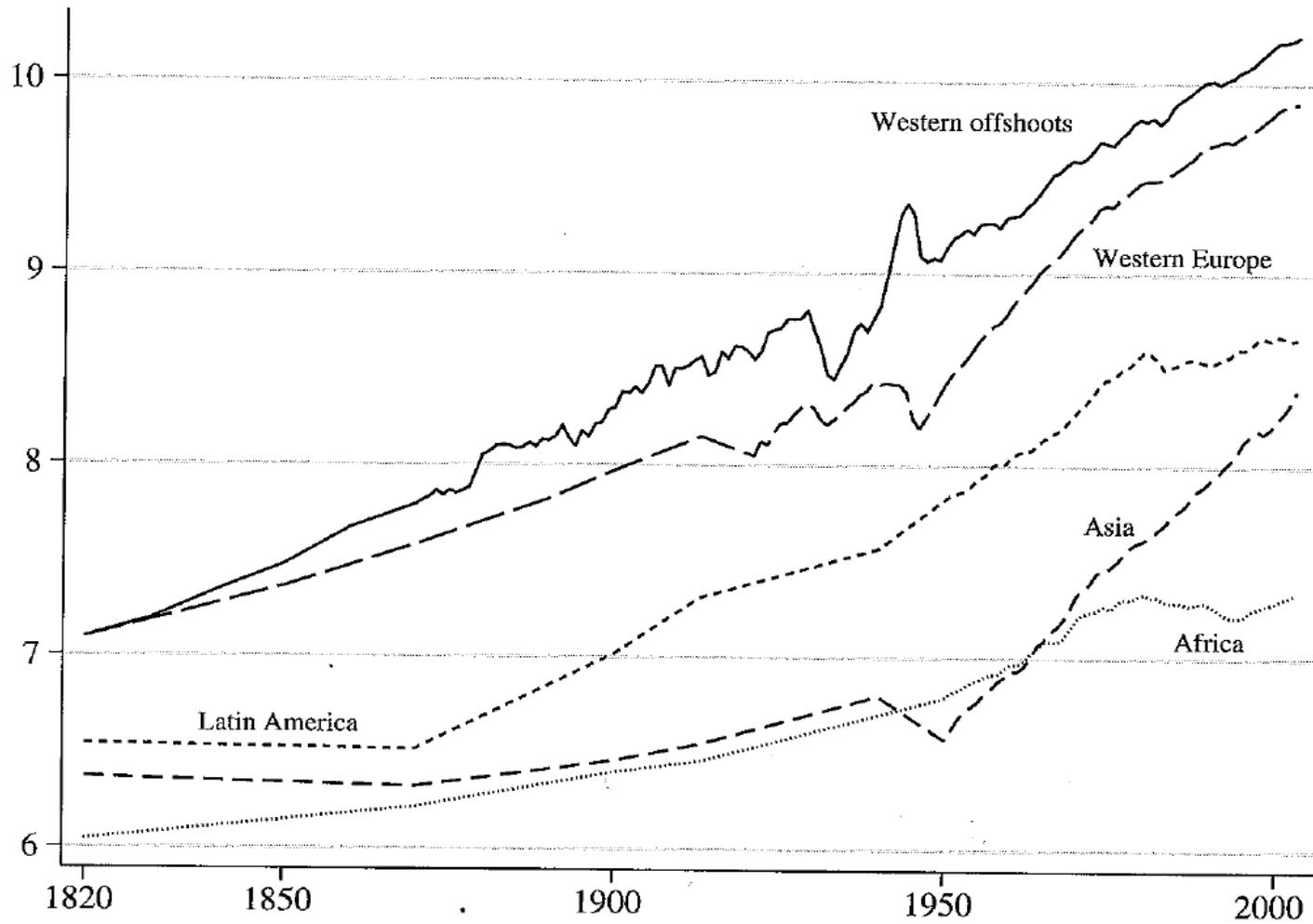
- **World development since 1000: Overtaking of Western Offshoots**
 - Maddison data (scarce prior to 1820)
 - **Western offshoots (former colonies of Western Europe)**
 - **Asia (historically China + India)**

Log GDP per capita

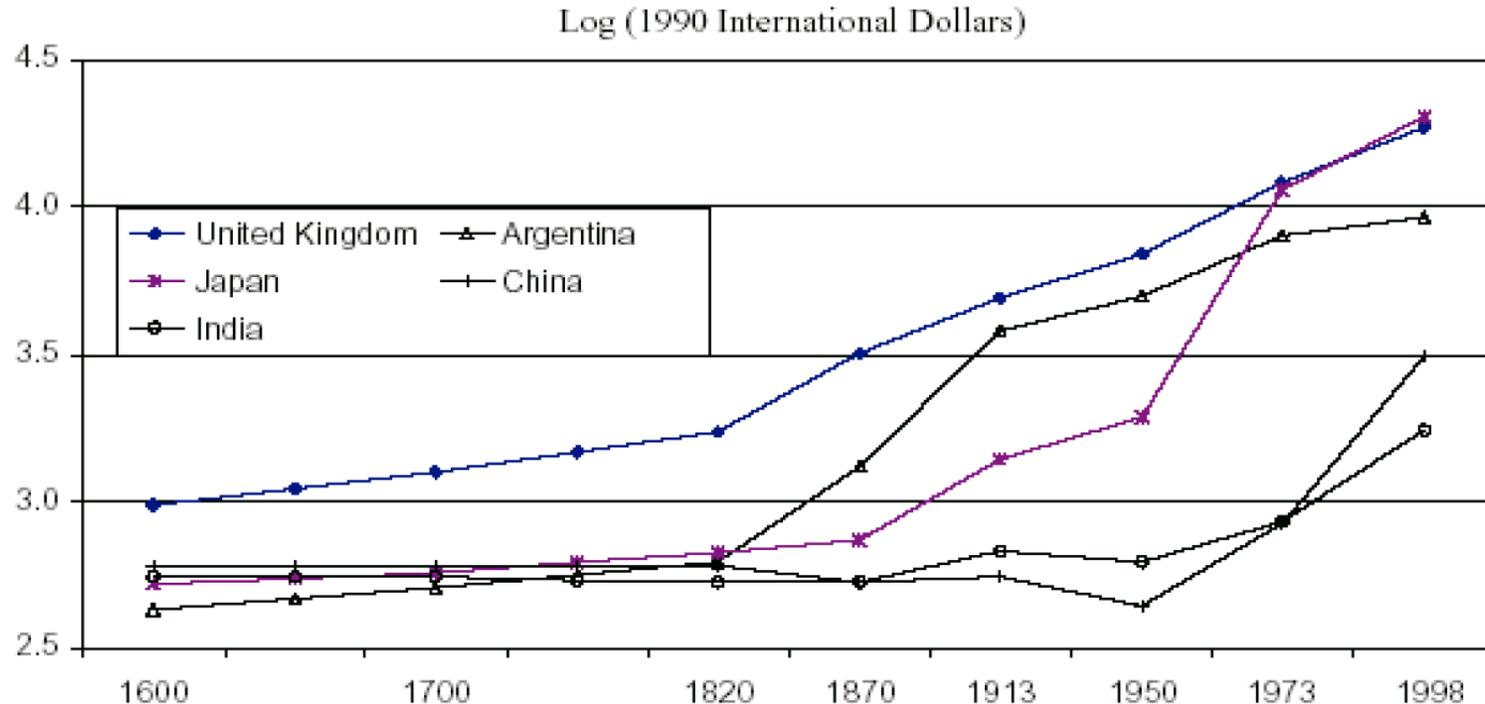


- **World development since mid-19th century:**

Log GDP per capita



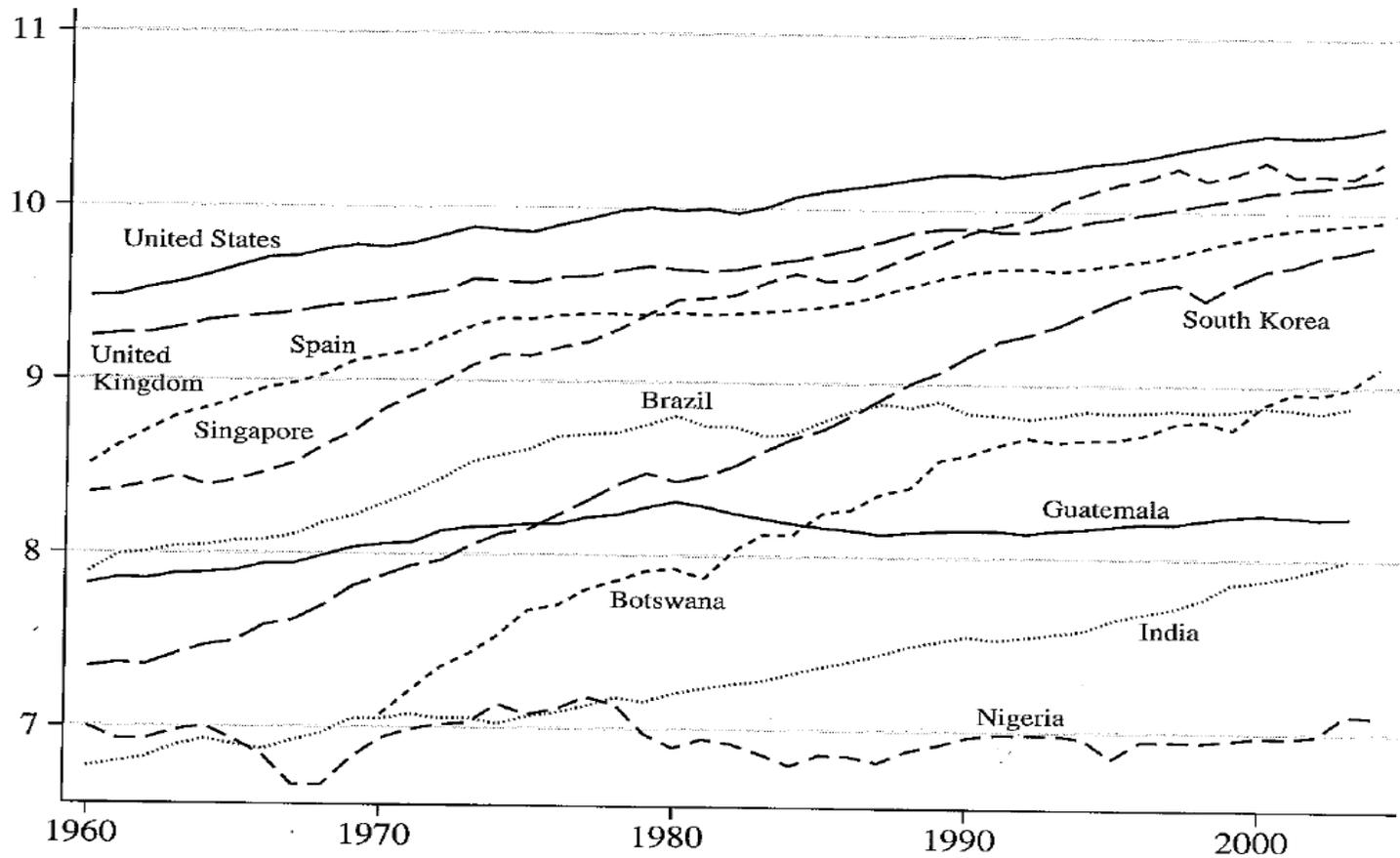
- **A closer look at 5 representative economies since 1600 (Ngai 2004):**



- **Sustainable growth in real income per capita only started 1780**
- **Argentina: post-independent federation since 1861**
- **Japan: Meiji Restoration in 1868; lost decade(s) since 1991**
- **China: wars; great leap forward; cultural revolution; post-1979 open-door policy (market/trade) + 1992 Southern Tour (FDI)**
- **India: 1980's reform by Indira Gandhi; 1990's reform by Manmohan Singh**

2. The Post-WWII Era

Log GDP per capita

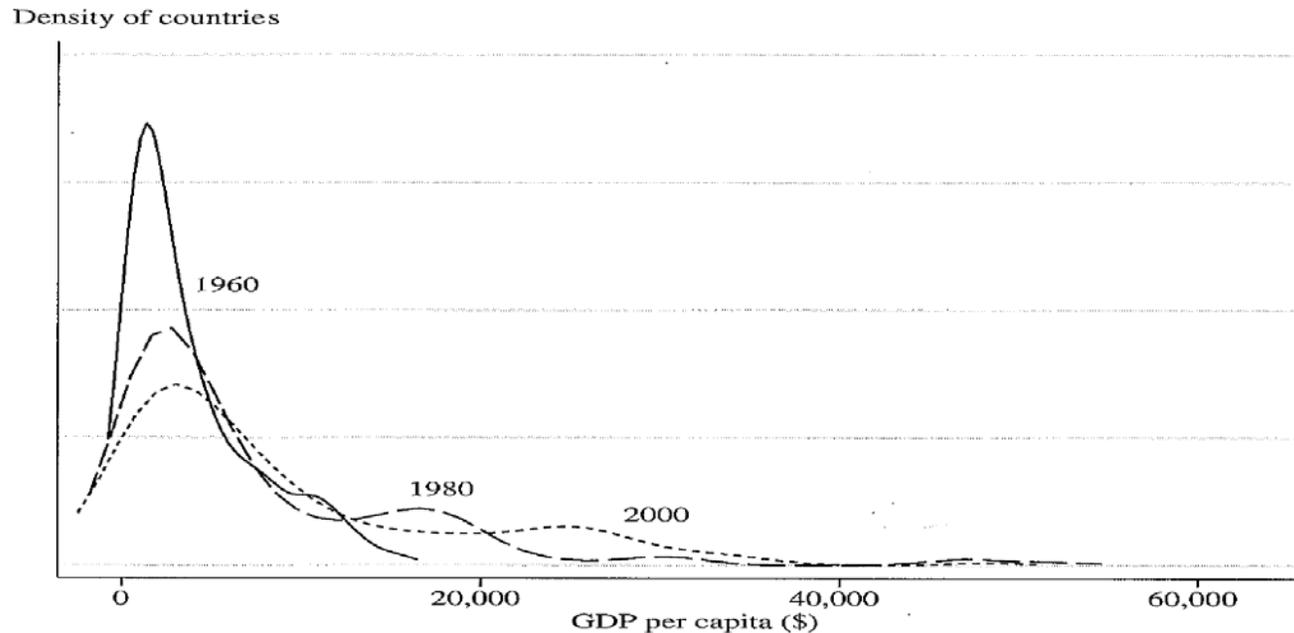


- **East Asian Miracles (Asian Tigers)**
- **African Miracle (Botswana)**
- **Poverty Traps (Nigeria and many Sub-Saharan)**

B. Cross-Country Study of Economic Growth

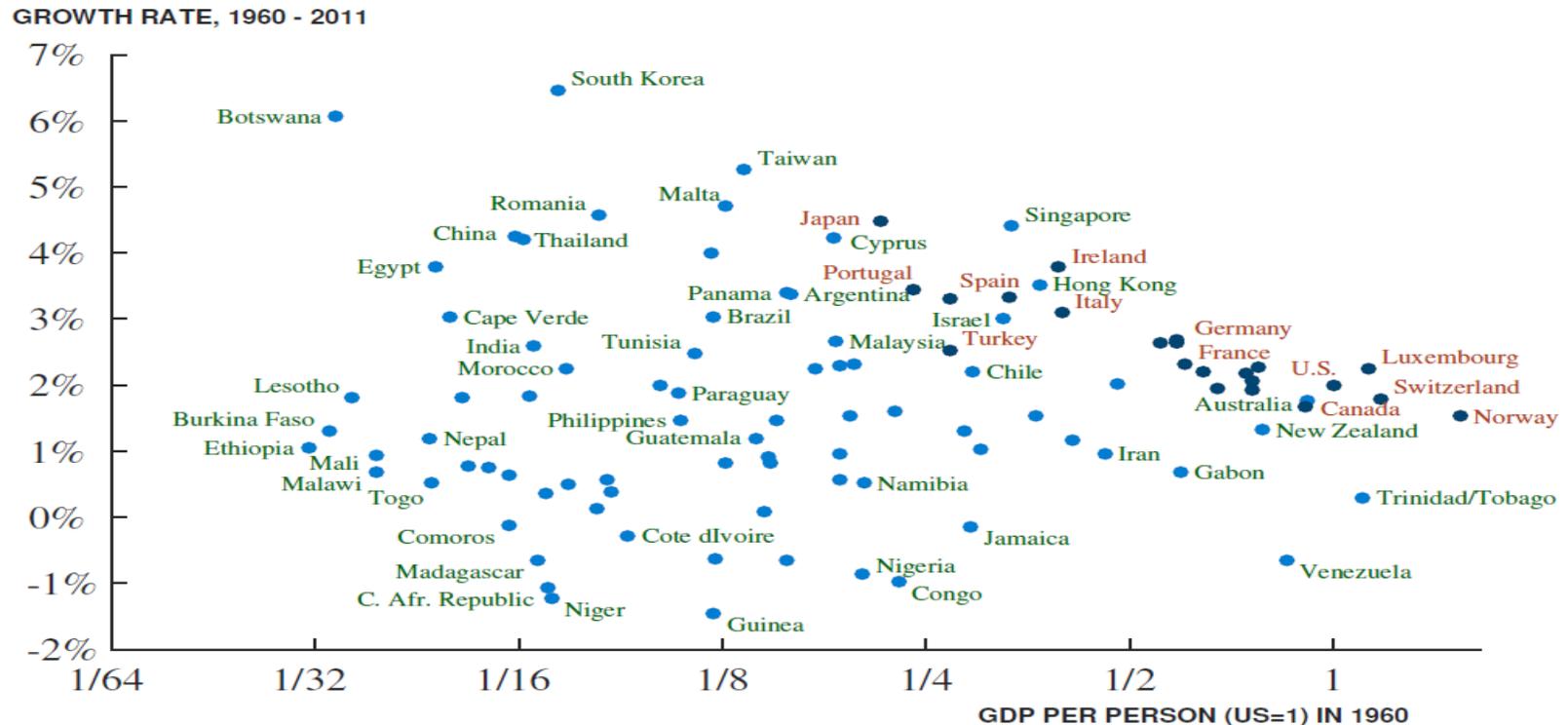
1. Overview

- **Distribution of world real GDP per capita**



- **Widened world income distribution (cross-country inequalities)**
- **Rightward shift (upward economic development)**
- **Twin Peaks (Quah): poverty + middle income traps**

- **Cross-country growth experiences compared (relative income to US)**



- **OECD frontier**
- **Asian miracles**
- **Development laggards: high initial relative income/low growth**
- **Poverty traps (1/10 of US): Sub-Saharan & others**
- **Convergence of the first 2 groups**

- **Growth miracles and disasters (1969-1990)**

| Miracles | Growth | Disasters | Growth |
|------------|--------|------------|--------|
| Korea | 6.1 | Ghana | -0.3 |
| Botswana | 5.9 | Venezuela | -0.5 |
| Hong Kong | 5.8 | Mozambique | -0.7 |
| Taiwan | 5.8 | Nicaragua | -0.7 |
| Singapore | 5.4 | Mauritania | -0.8 |
| Japan | 5.2 | Zambia | -0.8 |
| Malta | 4.8 | Mali | -1.0 |
| Cyprus | 4.4 | Madagascar | -1.3 |
| Seychelles | 4.4 | Chad | -1.7 |
| Lesotho | 4.4 | Guyana | -2.1 |

2. Determinants of Economic Growth:

- **Using neoclassical theory as an organizing framework, Jones-Manuelli (1997), Boldrin-Chen-Wang (2004) and Jones (2015) provided comprehensive surveys on the sources of per capita real GDP growth**
- **The determinants of economic growth:**
 - **Organizing framework: aggregate production: $Y = A * F(K, H * L)$**
 - **K: physical capital accumulation: saving, investment**
 - **L: labor force growth (labor participation); population growth – a negative factor (fertility choice)**
 - **H: human capital enhancement: education (years of schooling), learning by doing, job training**
 - **A: total factor productivity (TFP): R&D and technology invention, imitation, and adoption**
 - **other factors:**
 - **trade (final goods, intermediate goods)**
 - **institutions/infrastructures**
 - **finance/geography/urbanization**
 - **policy (monetary, fiscal, patent, population, others)**

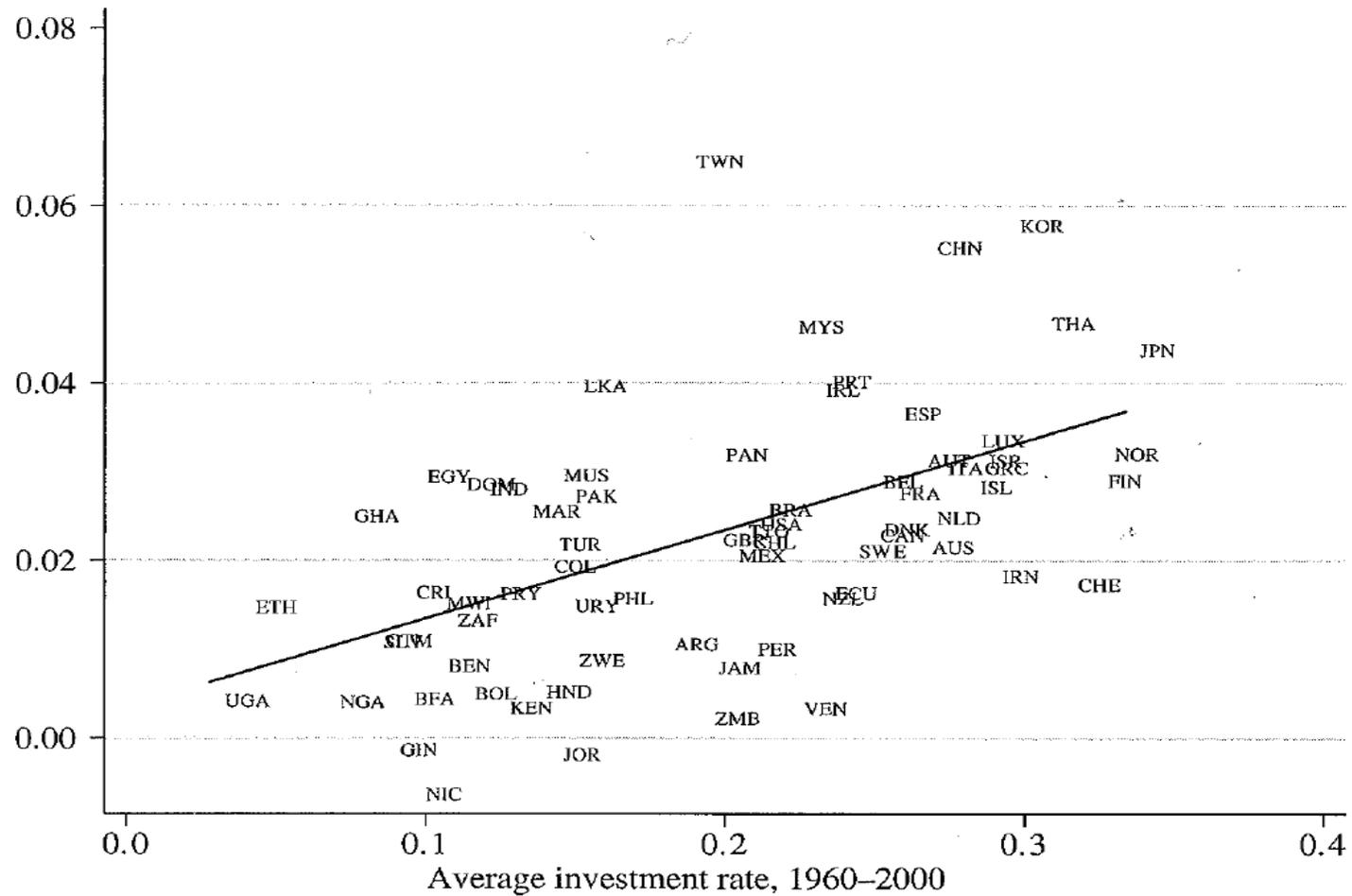
- **Physical/Human Capital Accumulation and Growth**

- **I/Y: investment rate**
- **H: human capital index (year of schooling or PWT index)**

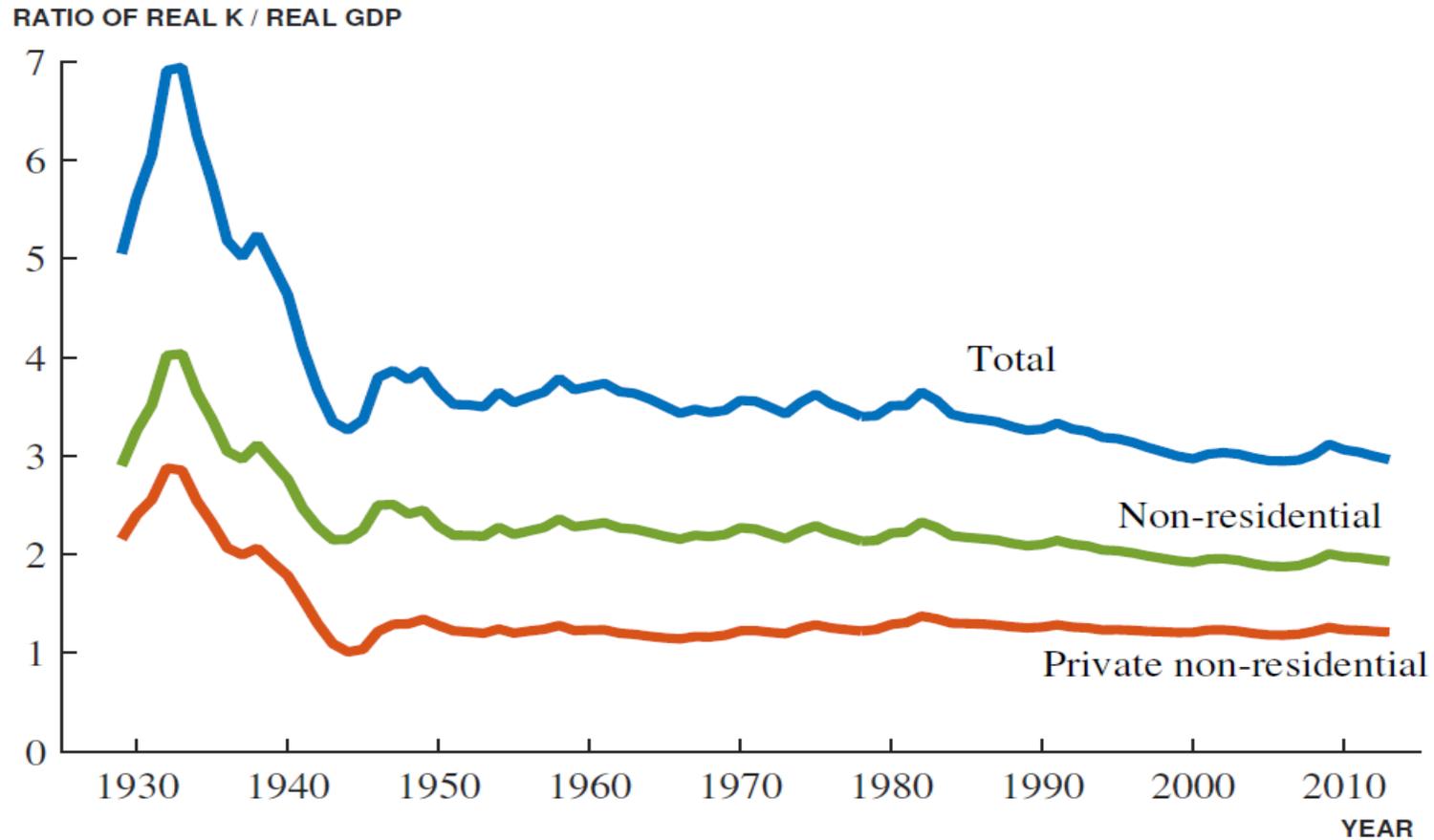
| Country | I/Y (%) | Y _i /Y _{US} *100 (1990) | ΔY _i /Y _i (%) | Country | H Index | Y _i /Y _{US} *100 (1990) | ΔY _i /Y _i (%) |
|-----------|---------|---|-------------------------------------|-------------|---------|---|-------------------------------------|
| U.S. | 24.0 | 100 | 2.1 | U.S. | 11.8 | 100 | 2.1 |
| Algeria | 23.3 | 14 | 2.2 | Argentina | 6.7 | 19 | 0.7 |
| Zambia | 27.9 | 4 | -0.8 | Philippines | 6.7 | 14 | 1.3 |
| Guyana | 25.1 | 7 | -0.9 | Korea | 9.2 | 45 | 6.3 |
| Japan | 36.6 | 80 | 5.6 | New Zealand | 12.3 | 63 | 1.4 |
| Singapore | 32.6 | 60 | 6.4 | Norway | 10.6 | 81 | 3.7 |

- **Physical capital:**

Average growth rate of GDP per capita, 1960–2000



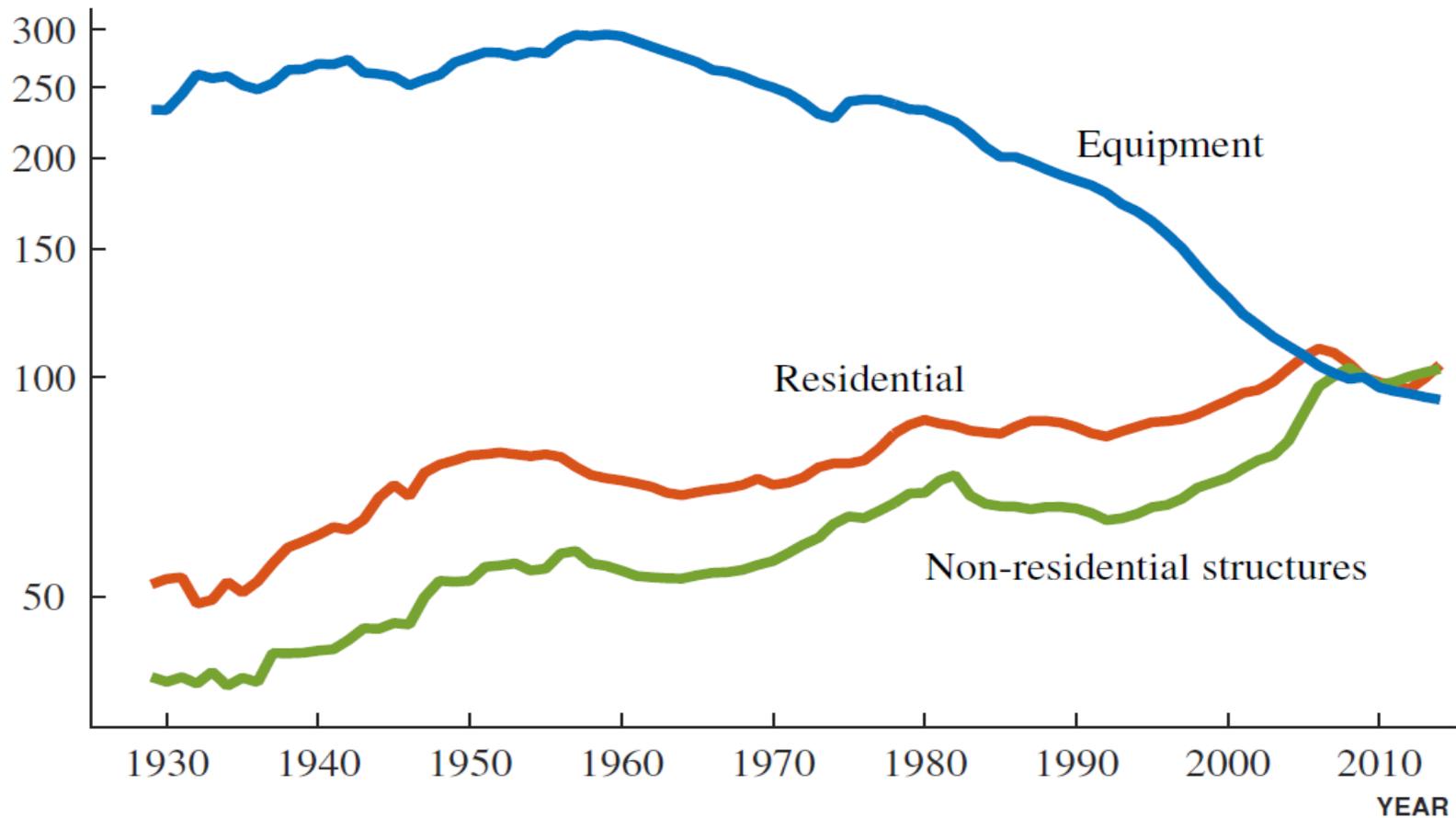
U.S. Capital-Output Ratio



- Destruction of physical capital by wars
- Rising service sector

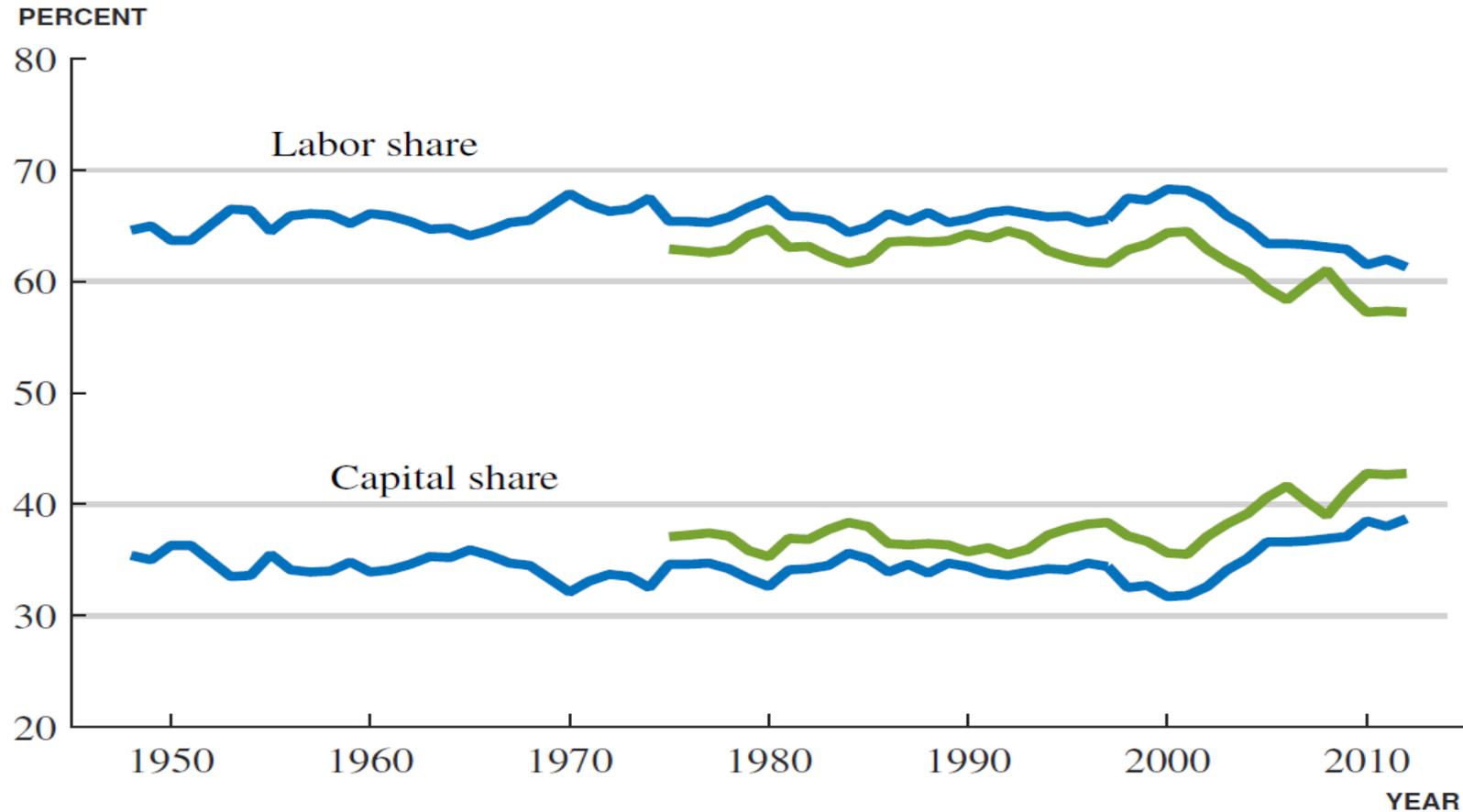
U.S. Relative Price of Investment

INDEX (2009 VALUE = 100, LOG SCALE)



- **Fallen equipment price due to computerization and mass production**
- **Rising commercial structure and housing prices (land)**

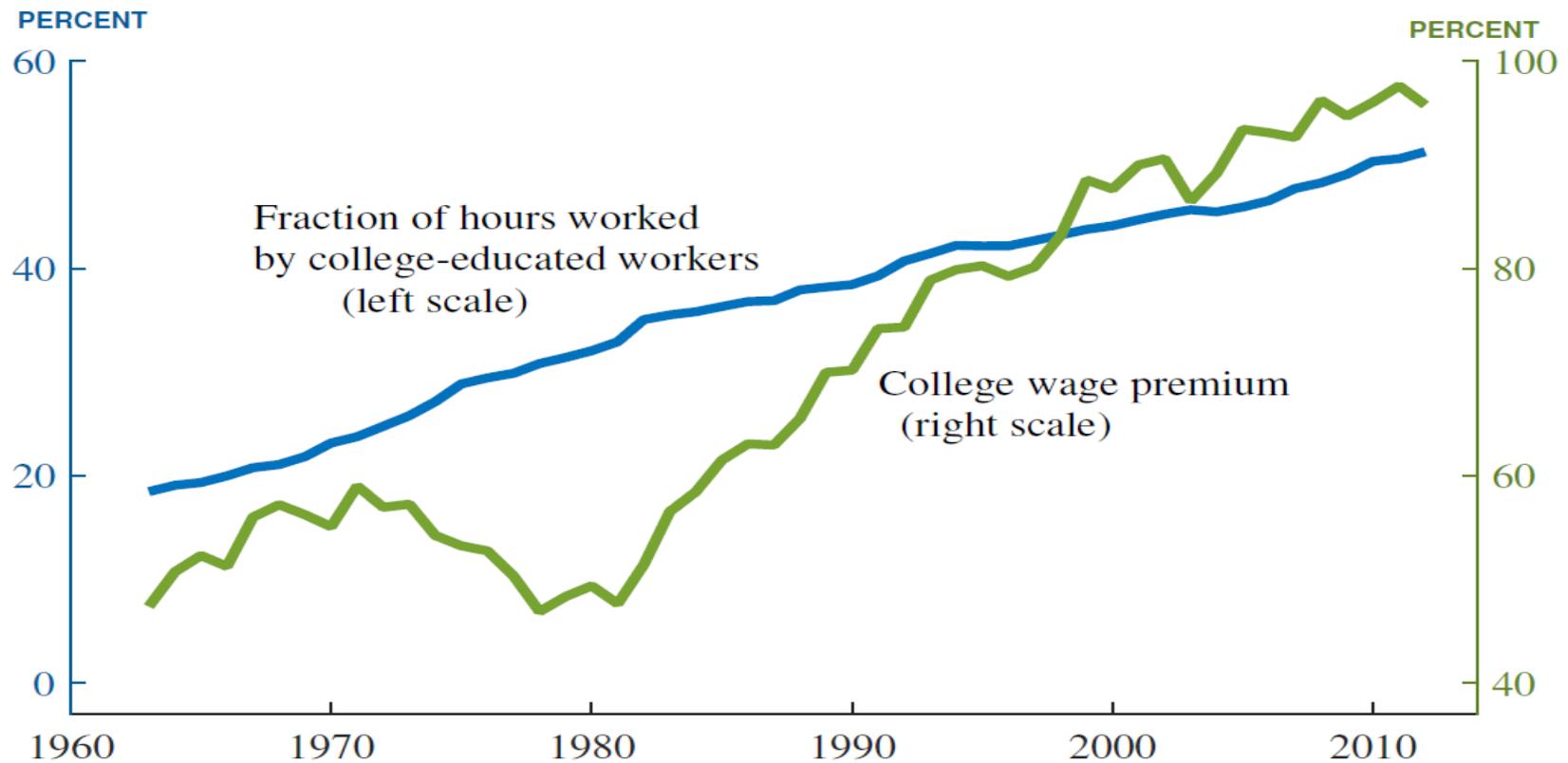
U.S. Capital Shares



○ **Declined labor share:**

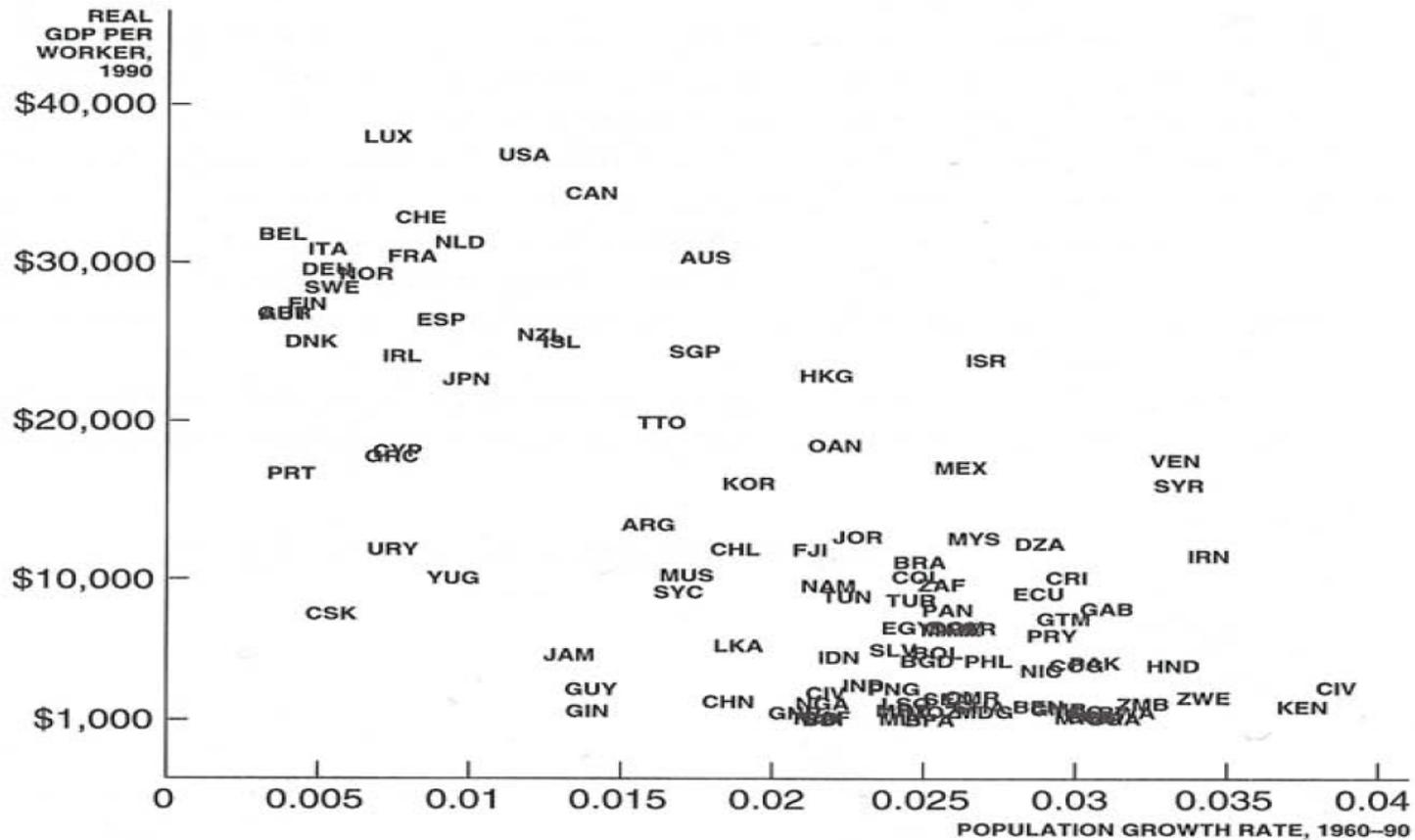
- **role played by automation**
- **implication for rising inequality, especially top inequality**

U.S. Skilled Labor Growth and Skill Premium



- **Skilled: 14 or 16 years of schooling (developing or developed)**
- **Rising skill premium (relative wage) since 1980**

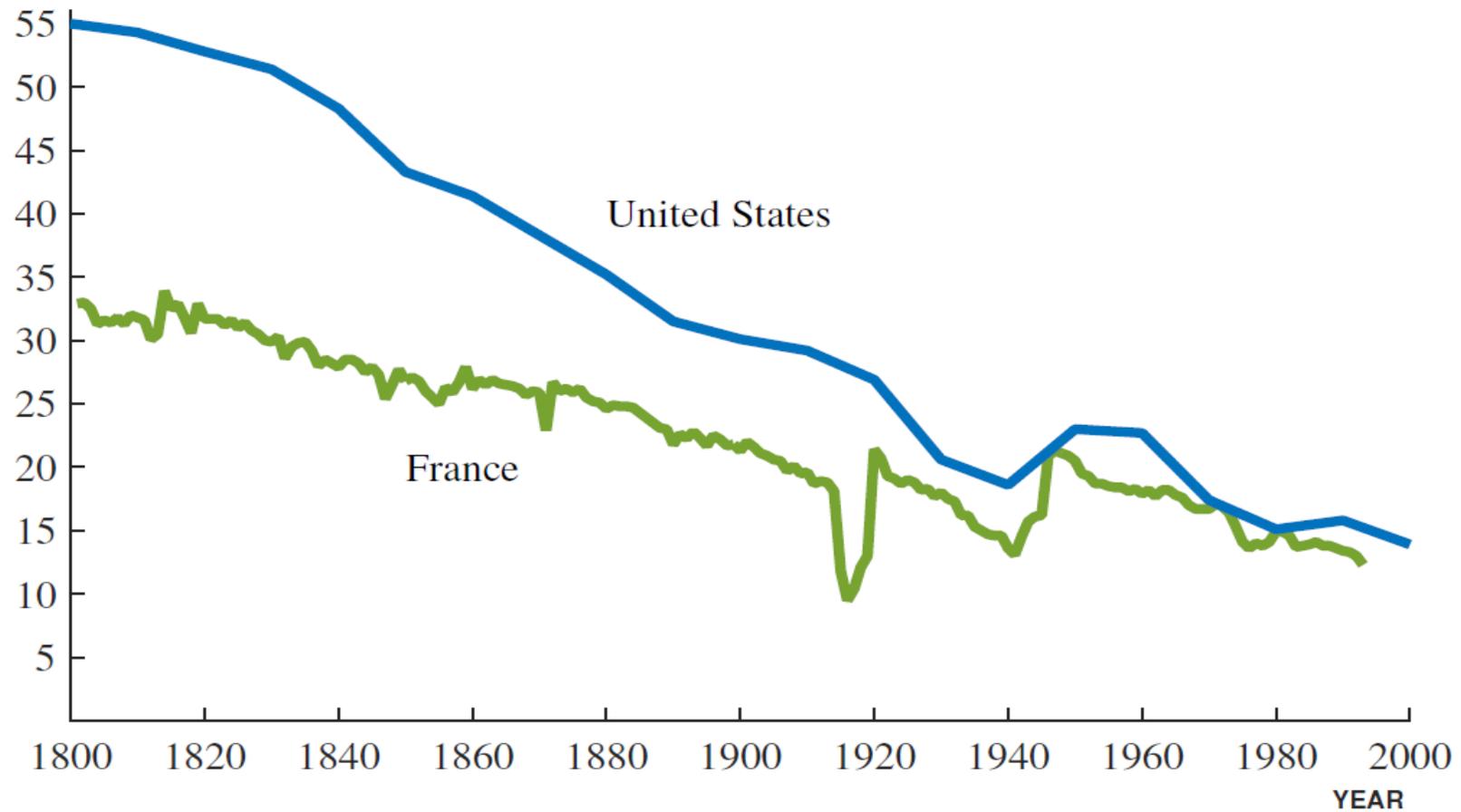
- **Population growth:**



- **Negative relationship: cake eating**
- **Quantity-quality tradeoff in fertility choice (Becker)**

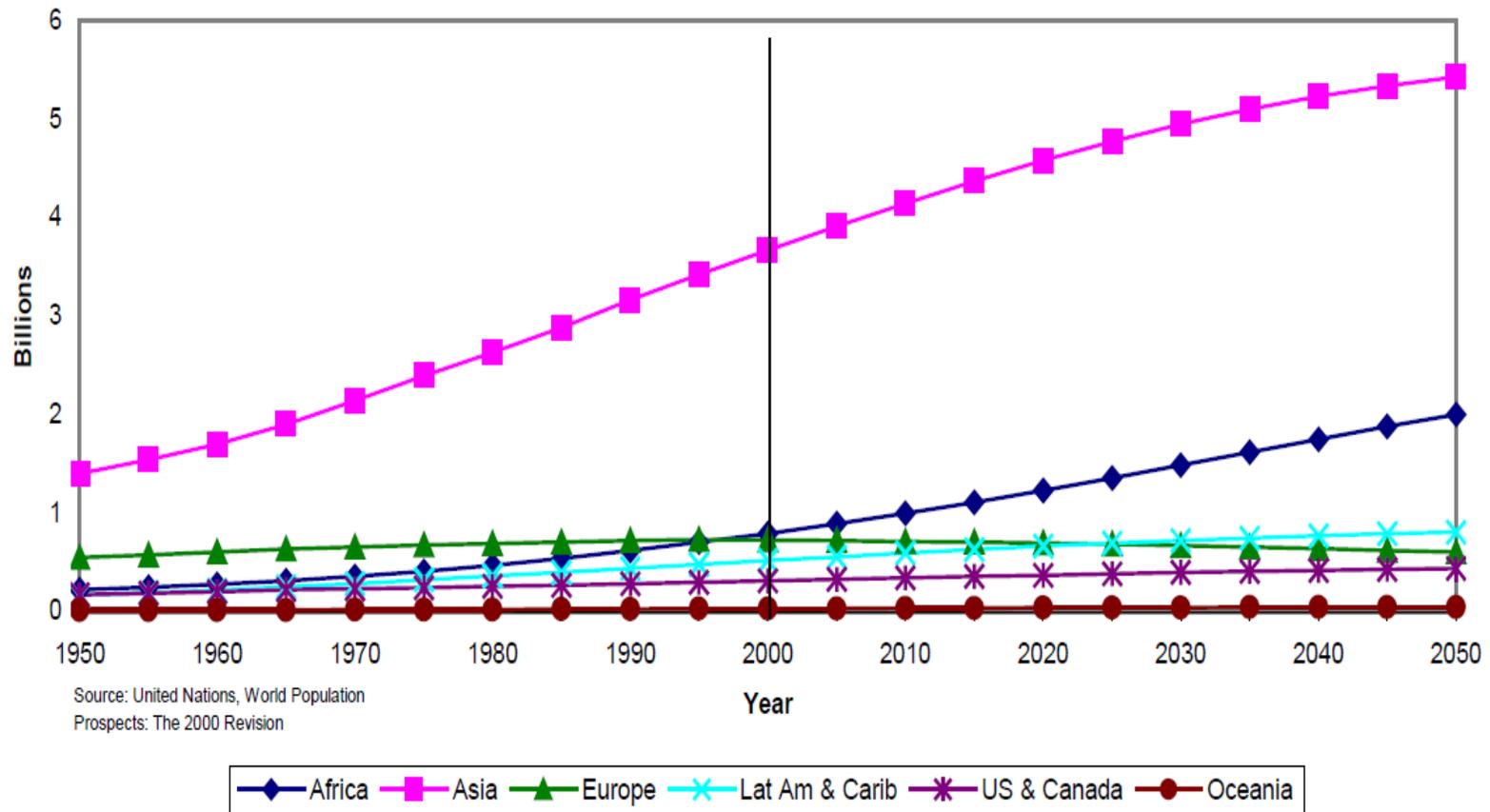
○ Fertility of Advanced Countries: US vs. France

ANNUAL BIRTHS PER 1000 POPULATION



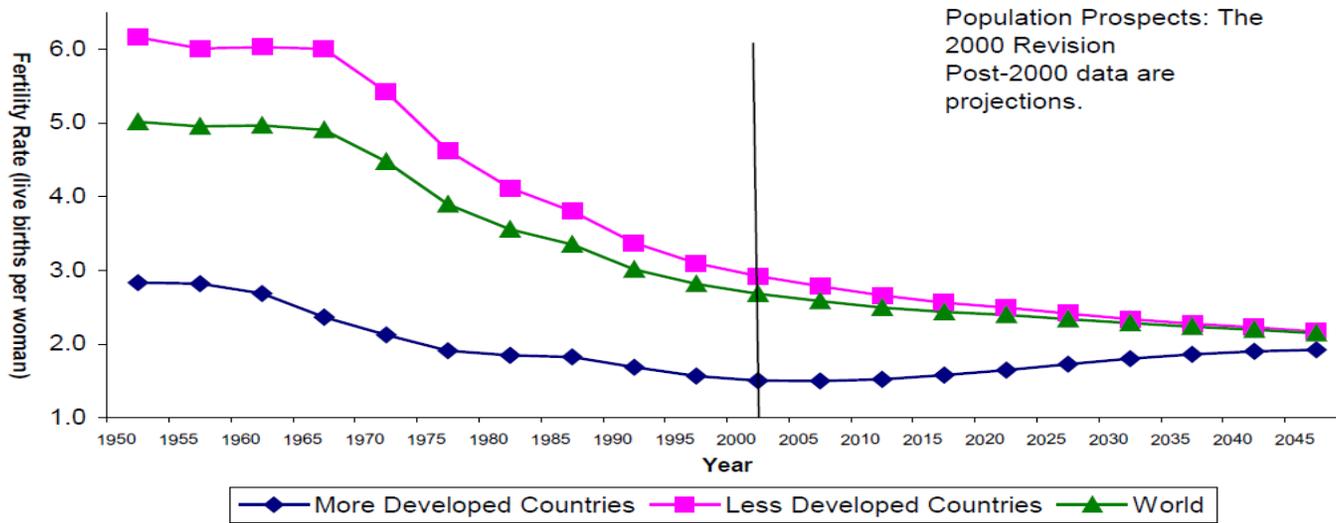
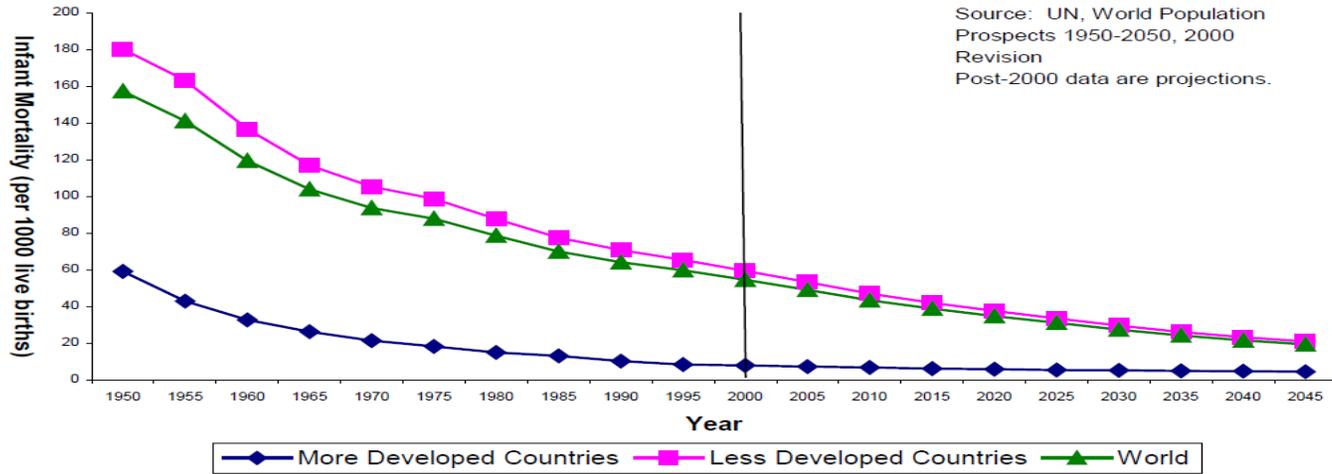
- **France: socialism/high welfare toward poor & children => more moderate decline in total fertility**

○ World population projection by UN (Bloom-Canning-Sevilla)

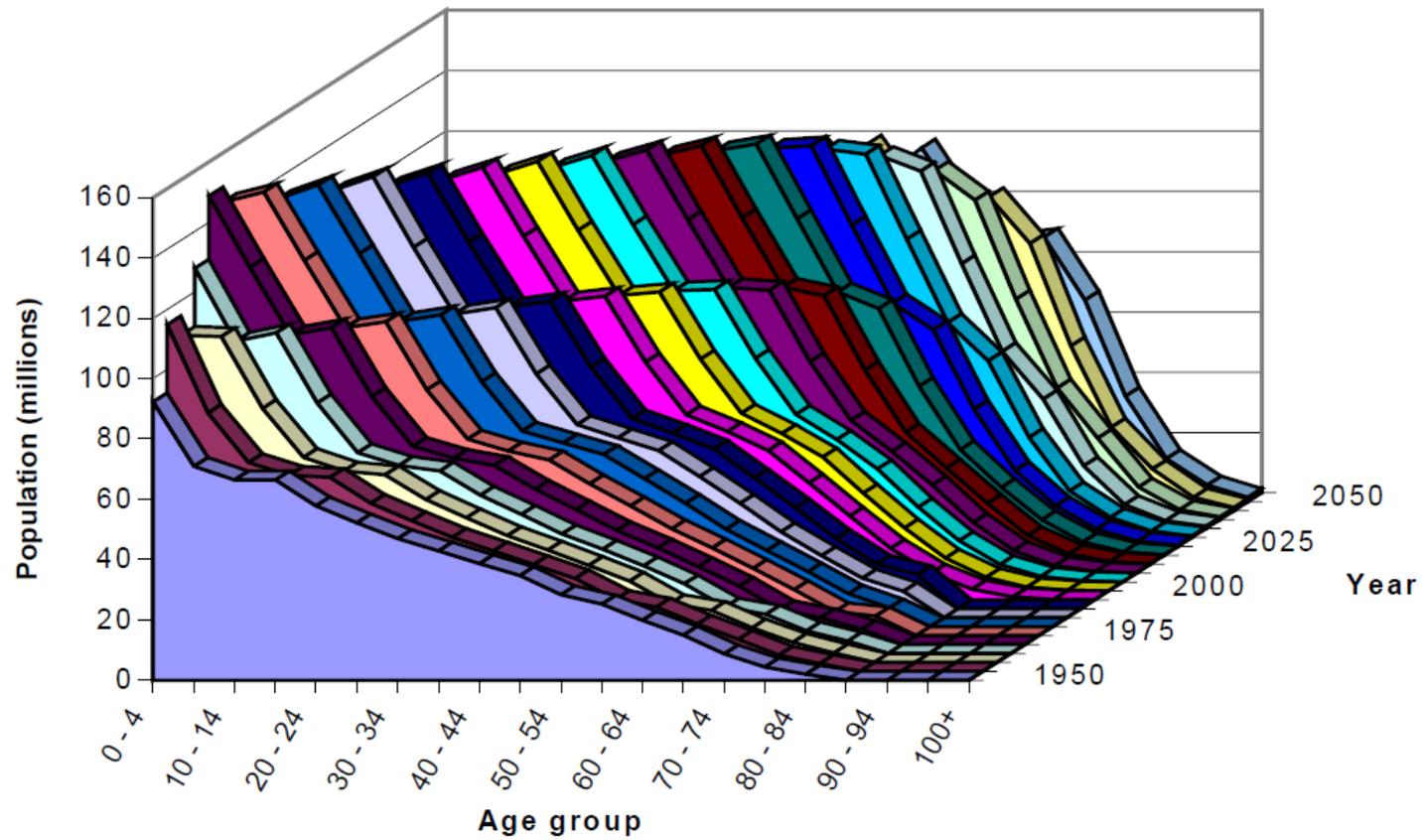


○ World fertility/infant mortality project by UN

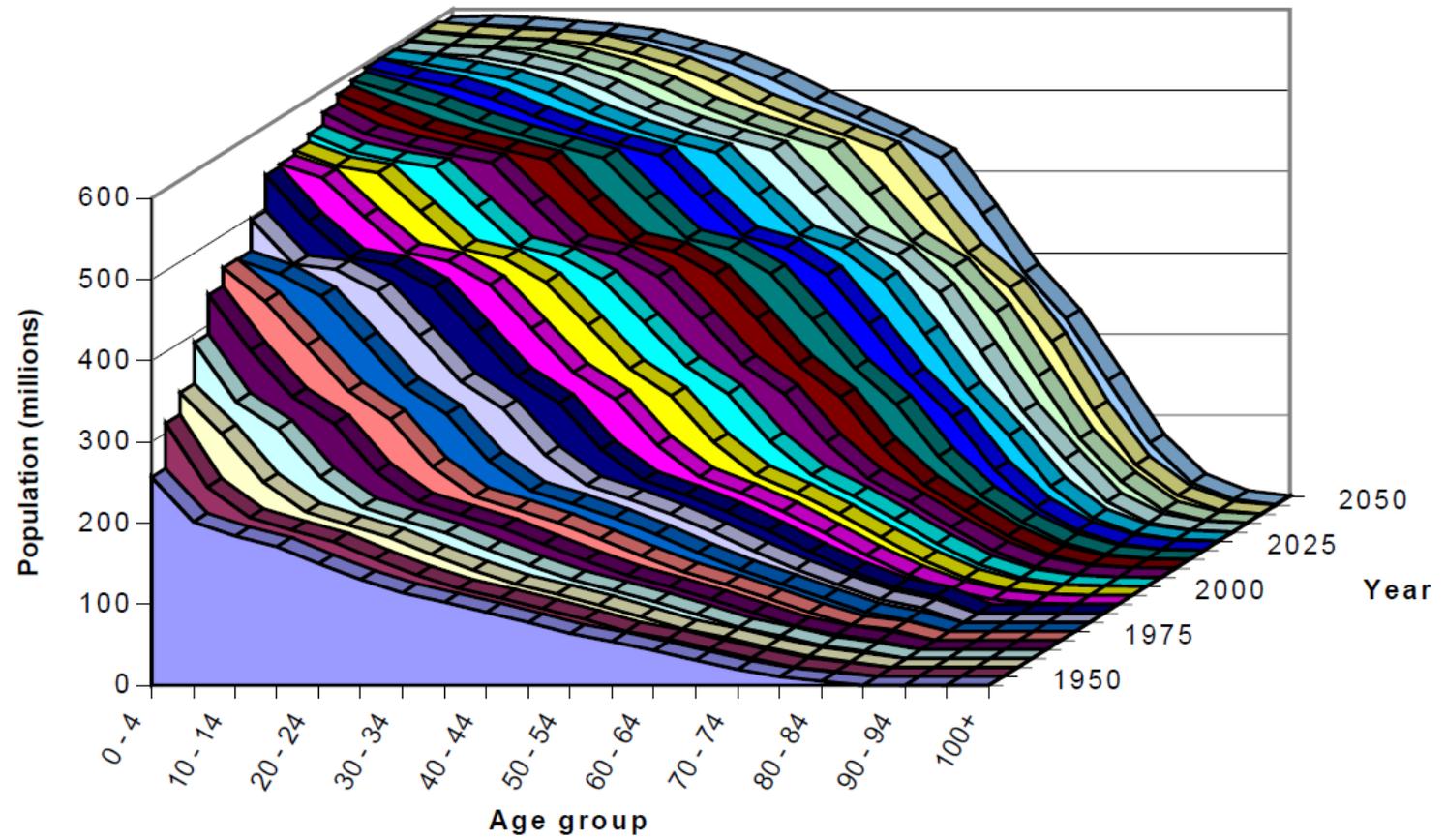
Infant Mortality Rate at Different Levels of Development



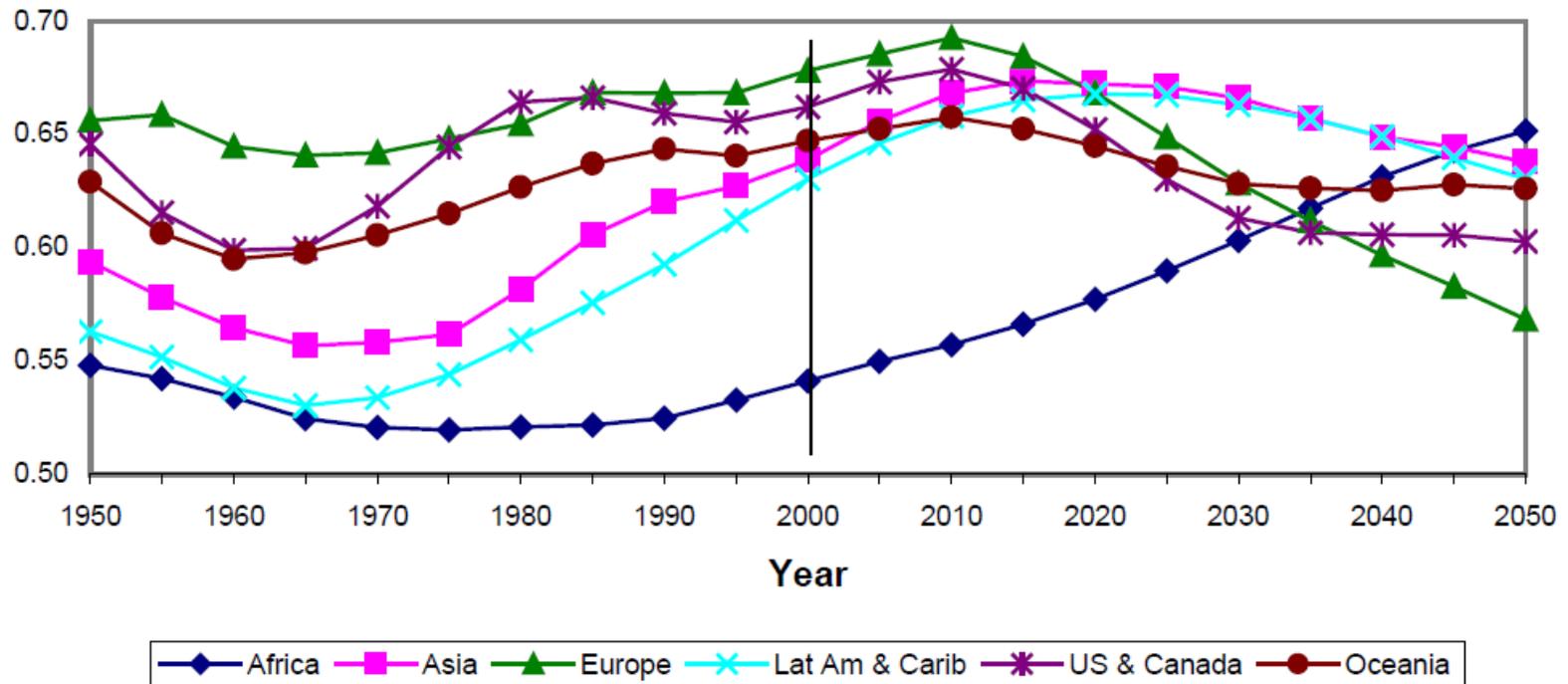
- Population ageing:
 - East Asia



■ LDCs

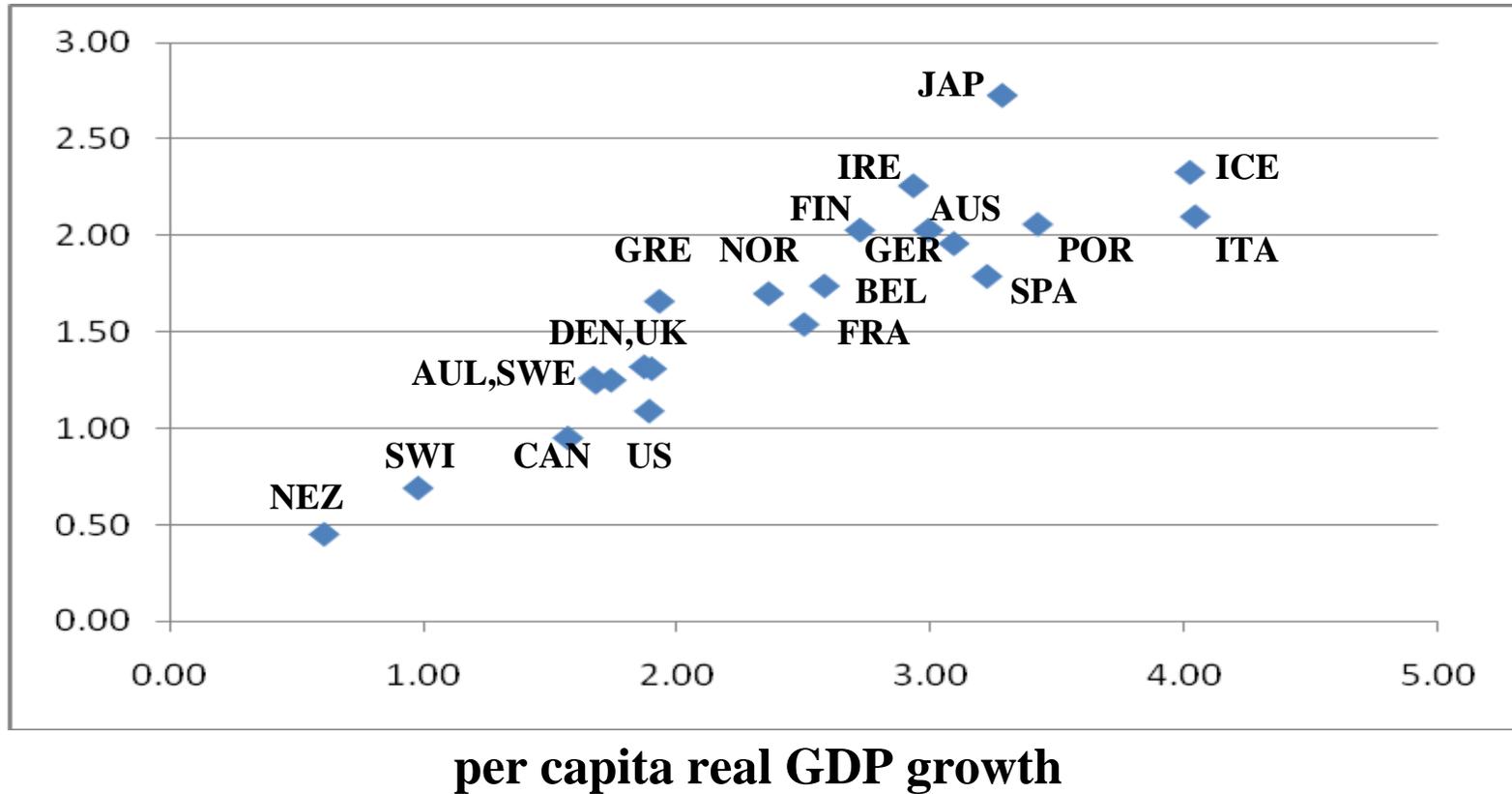


○ Share of working-age population:

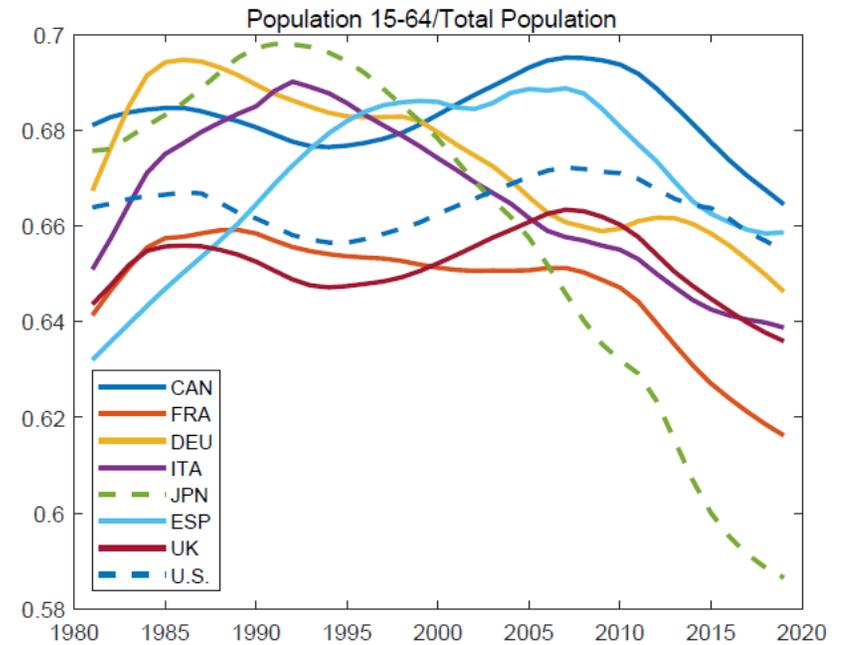
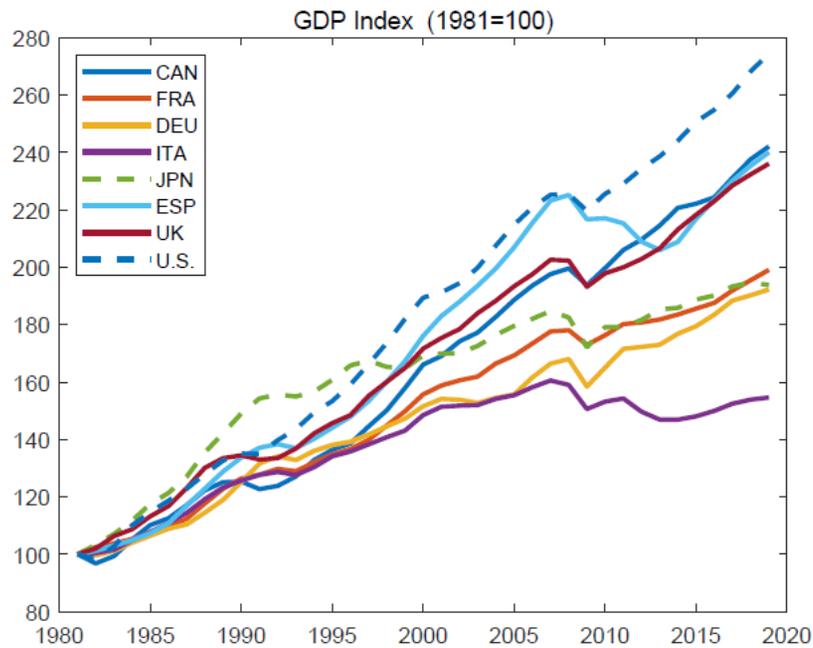


- **TFP growth: PWT TFP index**

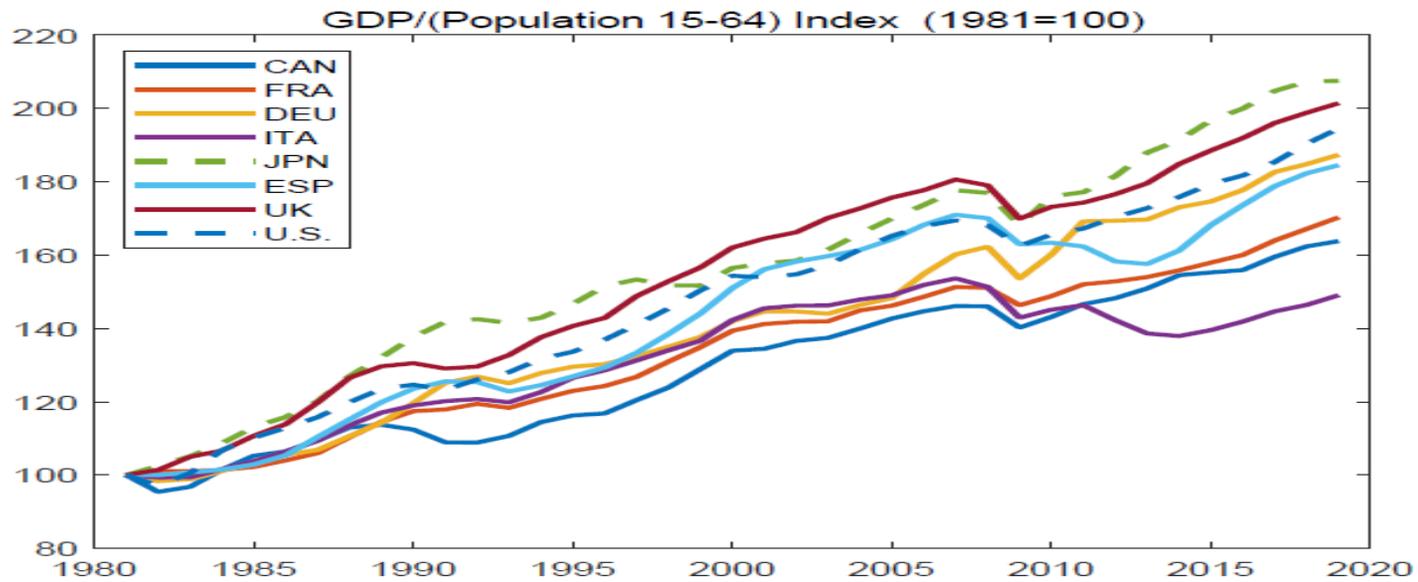
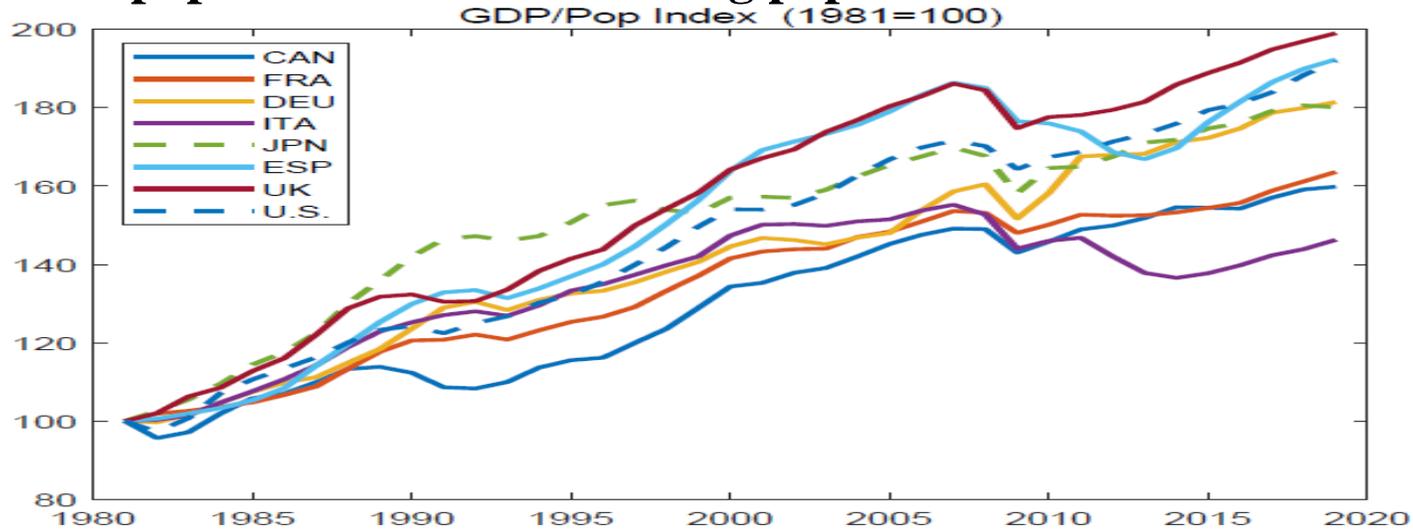
TFP growth versus per capita real GDP growth



- **GDP index and working pop (15-64) share: G7 + Spain (Fernandes Villaverde-Ventura-Yao 2023)**



- GDP/pop index vs. GDP/working pop index



- **GDP per capita measure can lead to sizable bias, especially since the Great Recession**

Table 4: G7 plus Spain: Basic Growth and Population Facts, 1981-2007

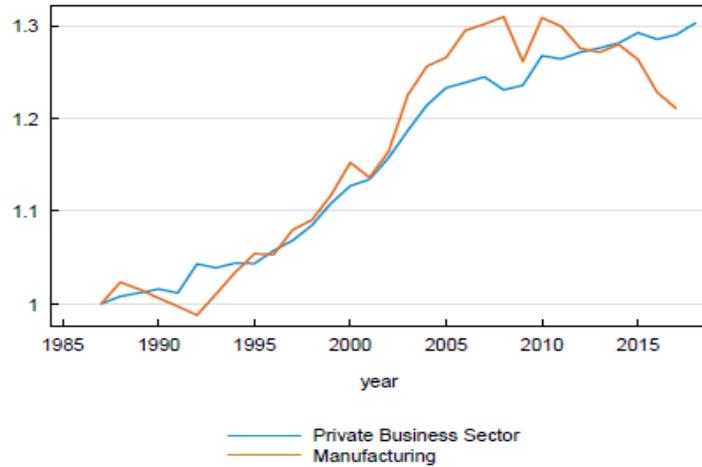
| 1981-2007 | Canada | France | Germany | Italy | Japan | Spain | UK | USA |
|---------------------------|--------|--------|---------|-------|-------|-------|------|------|
| GDP | 2.68 | 2.24 | 1.99 | 1.84 | 2.41 | 3.15 | 2.76 | 3.19 |
| GDP per Capita | 1.57 | 1.67 | 1.80 | 1.71 | 2.08 | 2.44 | 2.43 | 2.11 |
| Population | 1.09 | 0.56 | 0.19 | 0.13 | 0.32 | 0.70 | 0.33 | 1.05 |
| GDP per Working-age Adult | 1.49 | 1.61 | 1.84 | 1.67 | 2.25 | 2.10 | 2.31 | 2.06 |
| Working-age Population | 1.17 | 0.62 | 0.15 | 0.17 | 0.15 | 1.03 | 0.44 | 1.10 |
| Working-age Pop. Ratio | 0.68 | 0.65 | 0.68 | 0.67 | 0.68 | 0.67 | 0.65 | 0.66 |

Table 5: G7 plus Spain: Basic Growth and Population Facts, 2008-2019

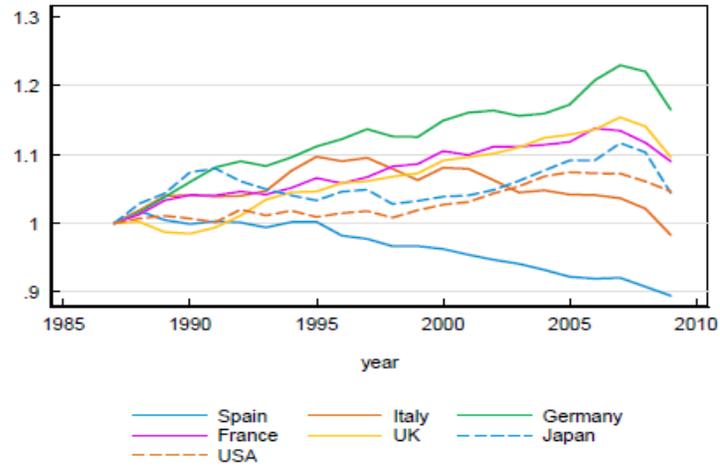
| 2008-2019 | Canada | France | Germany | Italy | Japan | Spain | UK | USA |
|---------------------------|--------|--------|---------|-------|-------|-------|------|------|
| GDP | 1.79 | 1.03 | 1.27 | -0.23 | 0.58 | 0.61 | 1.43 | 1.81 |
| GDP per Capita | 0.65 | 0.61 | 1.16 | -0.36 | 0.68 | 0.38 | 0.71 | 1.11 |
| Population | 1.13 | 0.42 | 0.11 | 0.14 | -0.10 | 0.23 | 0.71 | 0.70 |
| GDP per Working-age Adult | 1.07 | 1.11 | 1.35 | -0.11 | 1.49 | 0.78 | 1.10 | 1.34 |
| Working-age Population | 0.71 | -0.07 | -0.08 | -0.12 | -0.90 | -0.16 | 0.33 | 0.46 |
| Working-age Pop. Ratio | 0.68 | 0.63 | 0.66 | 0.65 | 0.61 | 0.67 | 0.65 | 0.66 |

• Sectoral composition effect: Acemoglu-Autor-Patterson (2023)

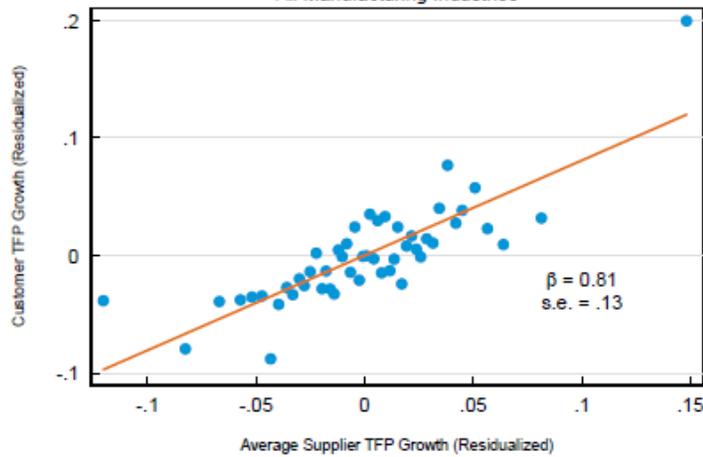
(a) United States



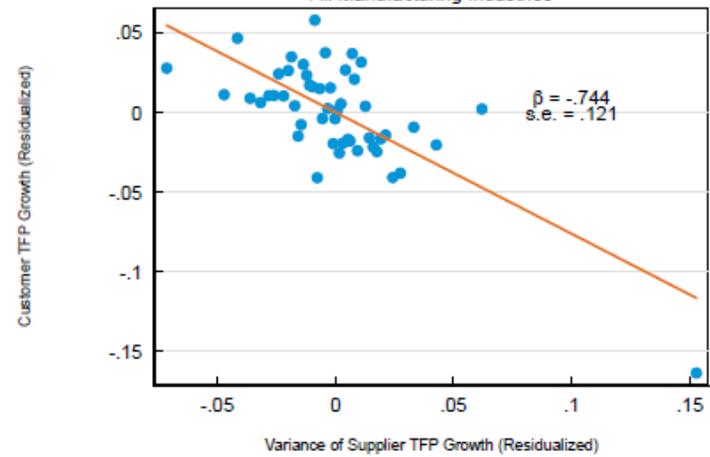
(b) Select OECD Countries



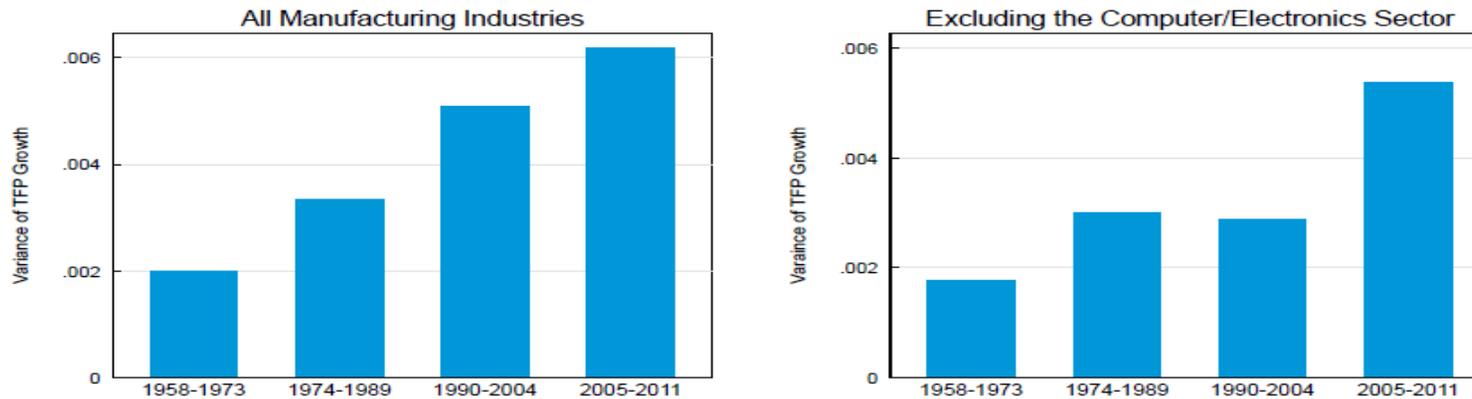
TFP growth vs. Average Supplier TFP Growth
All Manufacturing Industries



TFP growth vs. Variance of Supplier TFP Growth
All Manufacturing Industries



○ Upstream suppliers matter



| | Downstream | | Upstream Average | | Upstream Variance | |
|--|-------------|------|------------------|------|-------------------|------|
| | Mean | SD | Mean | SD | Mean | SD |
| Panel A: Manufacturing Industries | | | | | | |
| Growth in log(TFP) | .018 | .152 | .033 | .075 | .022 | .048 |
| Growth in log(Patents) | .132 | .19 | .085 | .119 | .015 | .012 |
| Growth in Price Index | .134 | .178 | .125 | .172 | .033 | .059 |
| Growth in log(Employment) | -.08 | .258 | -.087 | .115 | .027 | .021 |
| Panel B: All Industries | | | | | | |
| Growth in log(TFP) | .015 | .155 | .034 | .079 | .028 | .057 |
| Growth in Price Index | .095 | .147 | .081 | .145 | .04 | .069 |
| Growth in log(Employment) | -.079 | .266 | -.084 | .123 | .025 | .023 |
| Panel C: International panel | | | | | | |
| Growth in log(TFP) | .046 | 0.16 | .041 | .068 | .018 | .023 |

○ The ups and downs of industries

Panel A: List of Fastest-Growing Industries that Drive Rising TFP Variance
1997–2002 Industries *2002–2007 Industries*

| | |
|---|--|
| Semiconductor and Related Devices | Semiconductor and Related Devices |
| Electronic Computers | Electronic Computers |
| Paper (except Newsprint) Mills | Computer Storage Devices |
| Other Animal Foods | Sawmills |
| Iron and Steel Mills | Biological Products (except Diagnostic) |
| All Other Plastics Products | Other Basic Inorganic Chemicals |
| Motor Vehicle Electrical and Electronic Equipment | Other Plastics Products |
| Soybean Processing | Motor vehicle transmission and power train parts |
| Gas engine and engine parts | Motor vehicle metal stamping |
| Motor Vehicle Metal Stamping | Petrochemicals |

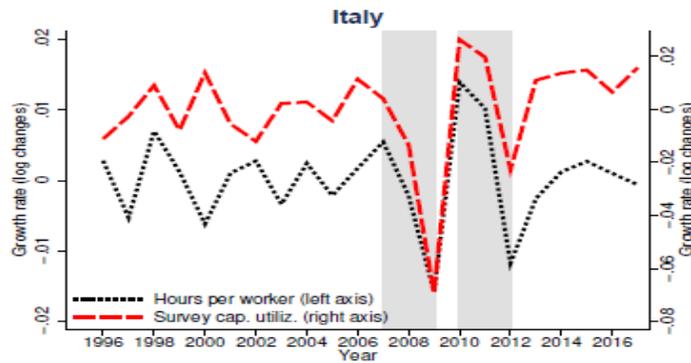
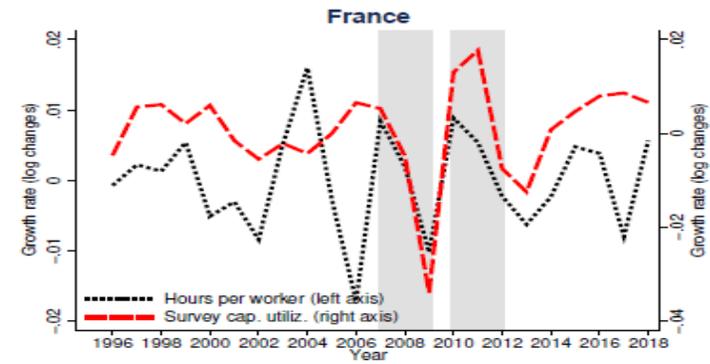
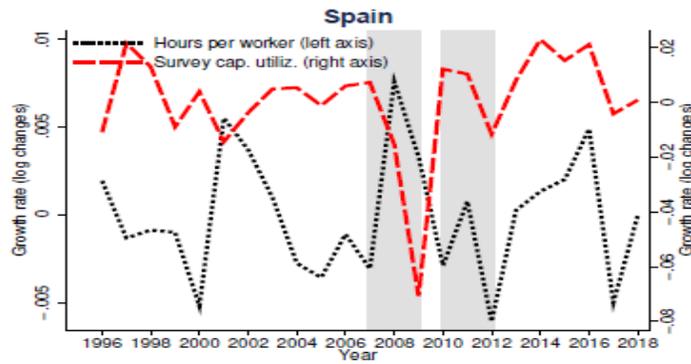
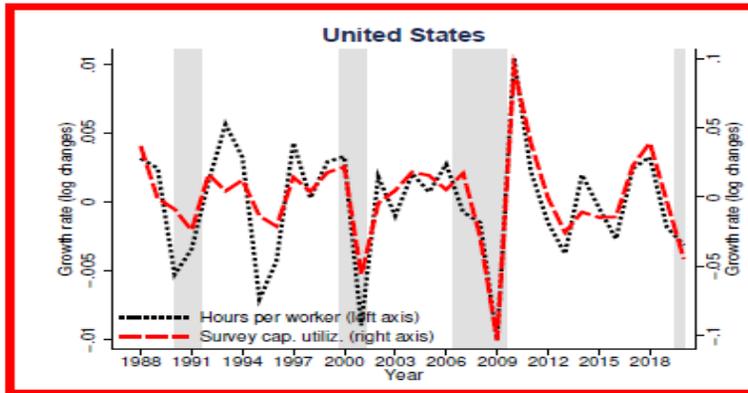
Panel B: List of Bottleneck Industries

| <i>1997–2002 Industries</i> | <i>2002–2007 Industries</i> |
|--|---|
| Commercial Lithographic Printing | Petroleum Refineries |
| All Other Basic Organic Chemical | Pharmaceutical Preparation |
| Printed Circuit Assembly (Electronic Assembly) | Other Communication and Energy Wires |
| Corrugated and Solid Fiber Boxes | Manifold Business Forms Printing |
| Petrochemicals | Corrugated and Solid Fiber Boxes |
| Radio/TV Broadcasting | Rolled Steel Shape Manufacturing |
| Bare Printed Circuit Boards | Turbine and Turbine Generator Set Units |
| Electronic Connectors | Medicinal and Botanical Manufacturing |
| Other Electronic Components | Motor Vehicle Electrical and Electronic Equipment |
| Electronic Capacitors | Unsupported Plastics Film and Sheets |

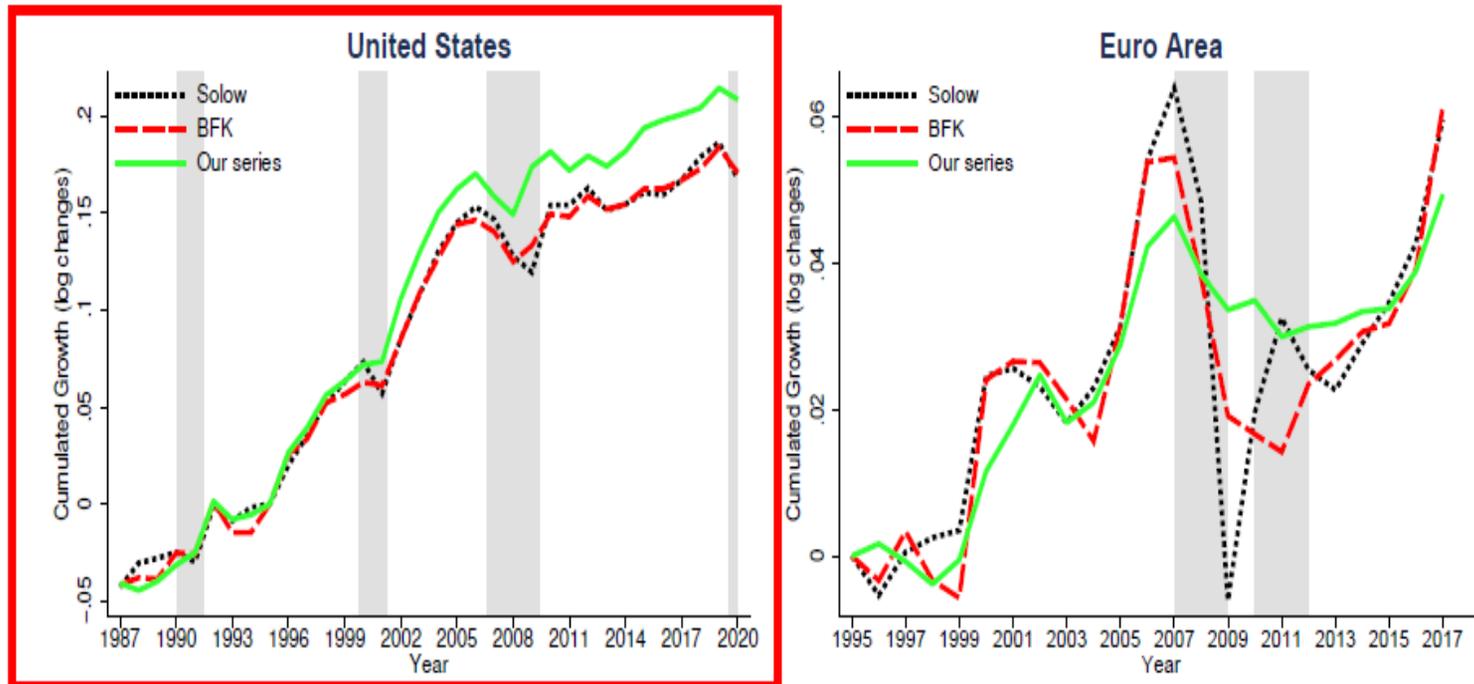
- **Factor utilization and TFP: Comin-Quintana-Schmitz-Trigari (2023)**
 - **Average output elasticities**

| | USA | Germany | Spain | France | Italy | UK |
|----------------------|------|---------|-------|--------|-------|------|
| <i>Materials</i> | | | | | | |
| Our elasticity | 0.43 | 0.54 | 0.55 | 0.56 | 0.59 | 0.53 |
| Solow-BFK elasticity | 0.41 | 0.52 | 0.52 | 0.53 | 0.56 | 0.50 |
| <i>Labour</i> | | | | | | |
| Our elasticity | 0.41 | 0.34 | 0.33 | 0.35 | 0.31 | 0.37 |
| Solow-BFK elasticity | 0.39 | 0.33 | 0.32 | 0.34 | 0.29 | 0.35 |
| <i>Capital</i> | | | | | | |
| Our elasticity | 0.17 | 0.12 | 0.12 | 0.09 | 0.10 | 0.09 |
| Solow-BFK elasticity | 0.20 | 0.14 | 0.16 | 0.13 | 0.15 | 0.15 |

○ labor utilization (hours worked) and capital utilization



○ cumulated TFP growth



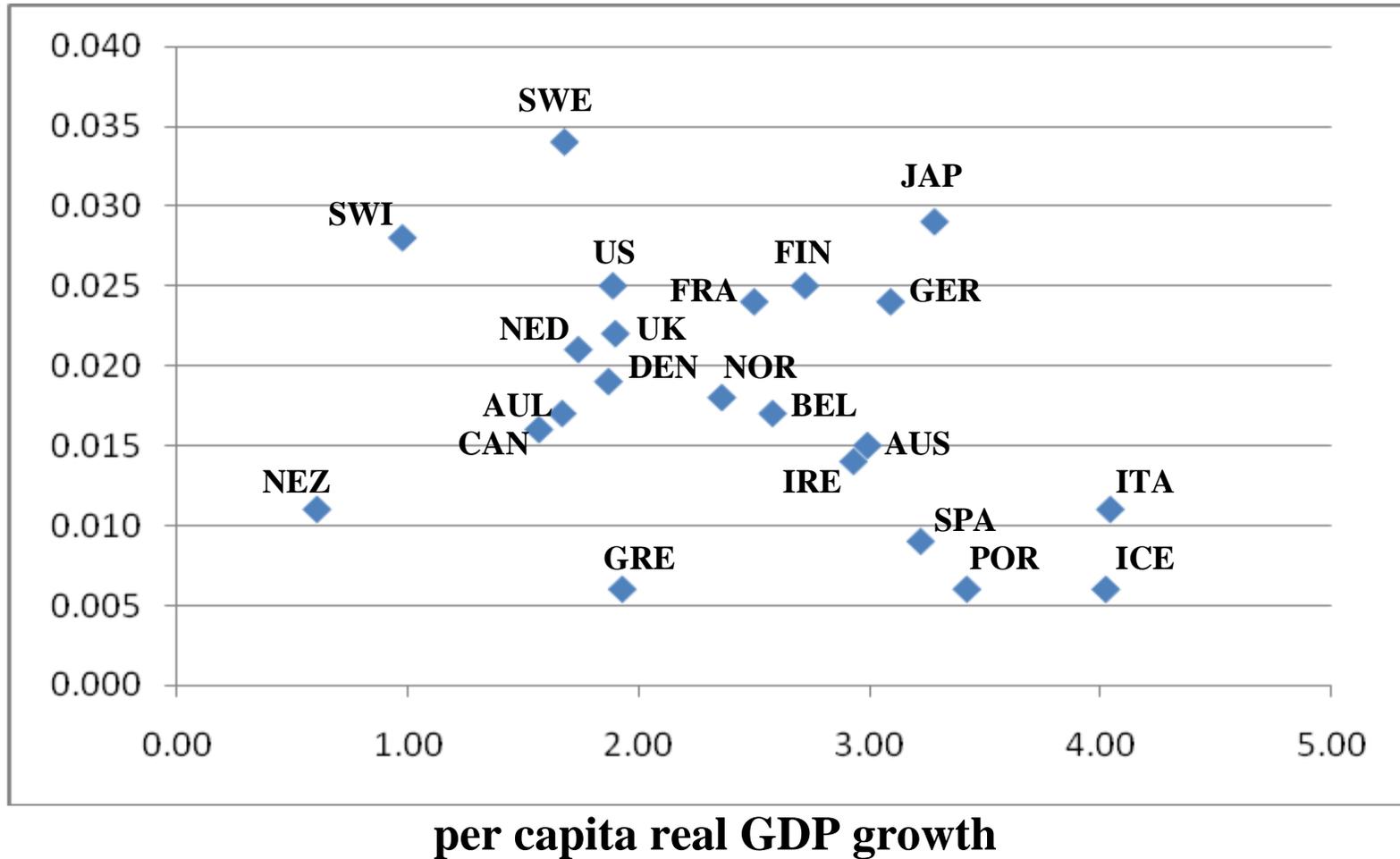
Notes: BFK = Basu-Fernald-Kimball (AER 2006)

○ **average TFP growth rates**

| | USA | EA | Germany | Spain | France | Italy | UK |
|-------------------------------|-------------|------|---------|-------|--------|-------|------|
| <i>Overall sample</i> | | | | | | | |
| Solow residual | 0.64 | 0.27 | 0.73 | -0.33 | 0.28 | -0.30 | 0.91 |
| BFK method | 0.64 | 0.28 | 0.76 | -0.33 | 0.26 | -0.33 | 0.92 |
| Our method | 0.76 | 0.22 | 0.61 | -0.40 | 0.25 | -0.27 | 1.11 |
| <i>Subperiods, our method</i> | | | | | | | |
| 1988-2004 | 1.13 | . | . | . | . | . | . |
| 2004-2009 | 0.47 | . | . | . | . | . | . |
| 2009-2020 | 0.32 | . | . | . | . | . | . |
| 1995-2007 | . | 0.39 | 0.82 | -0.72 | 0.88 | -0.26 | 1.73 |
| 2008-2018 | . | 0.03 | 0.38 | -0.06 | -0.43 | -0.28 | 0.44 |

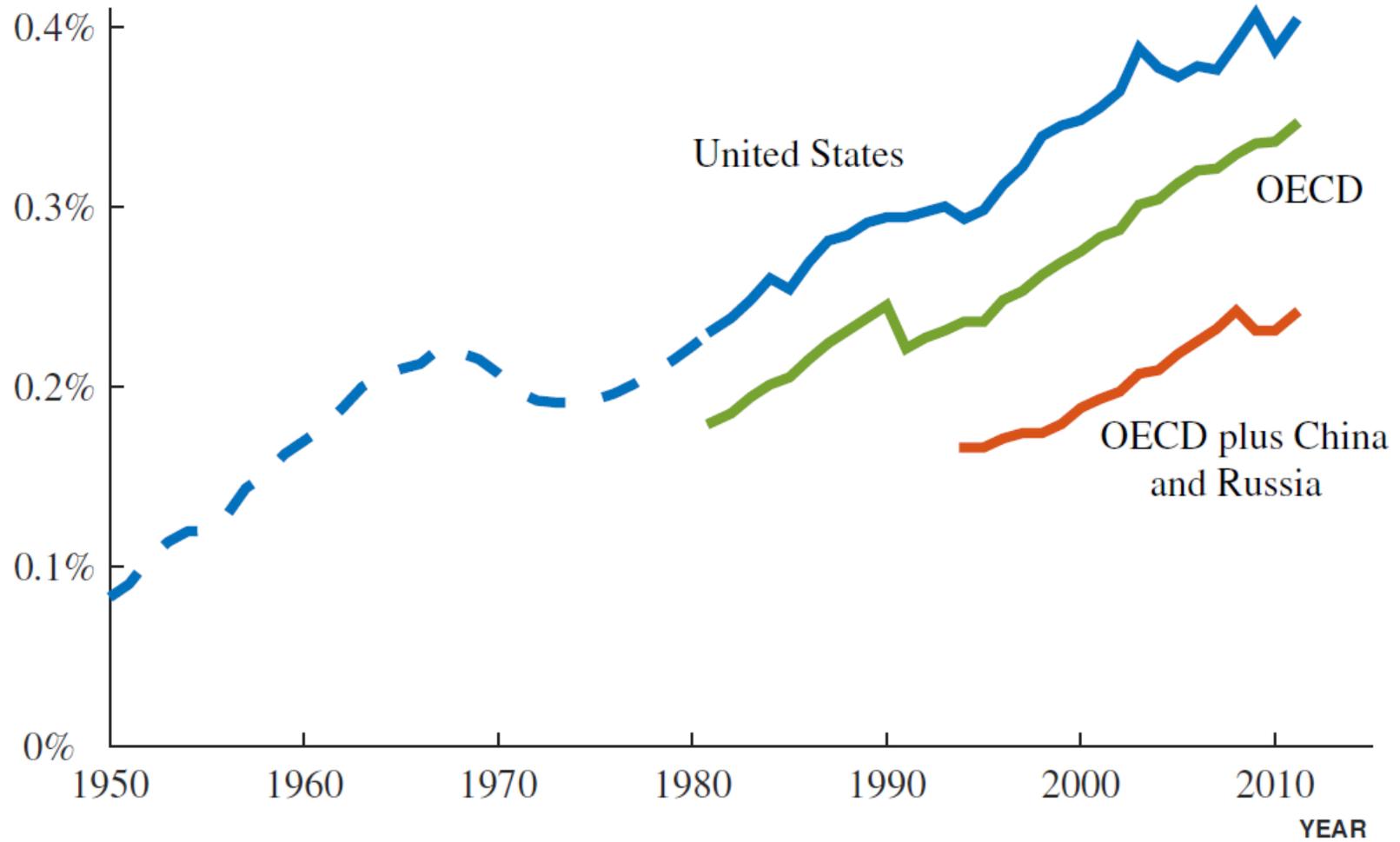
- **R&D: other forms of technical progress (licensing, imitation, technology spillovers, technology assimilation)**

R&D-GDP Share

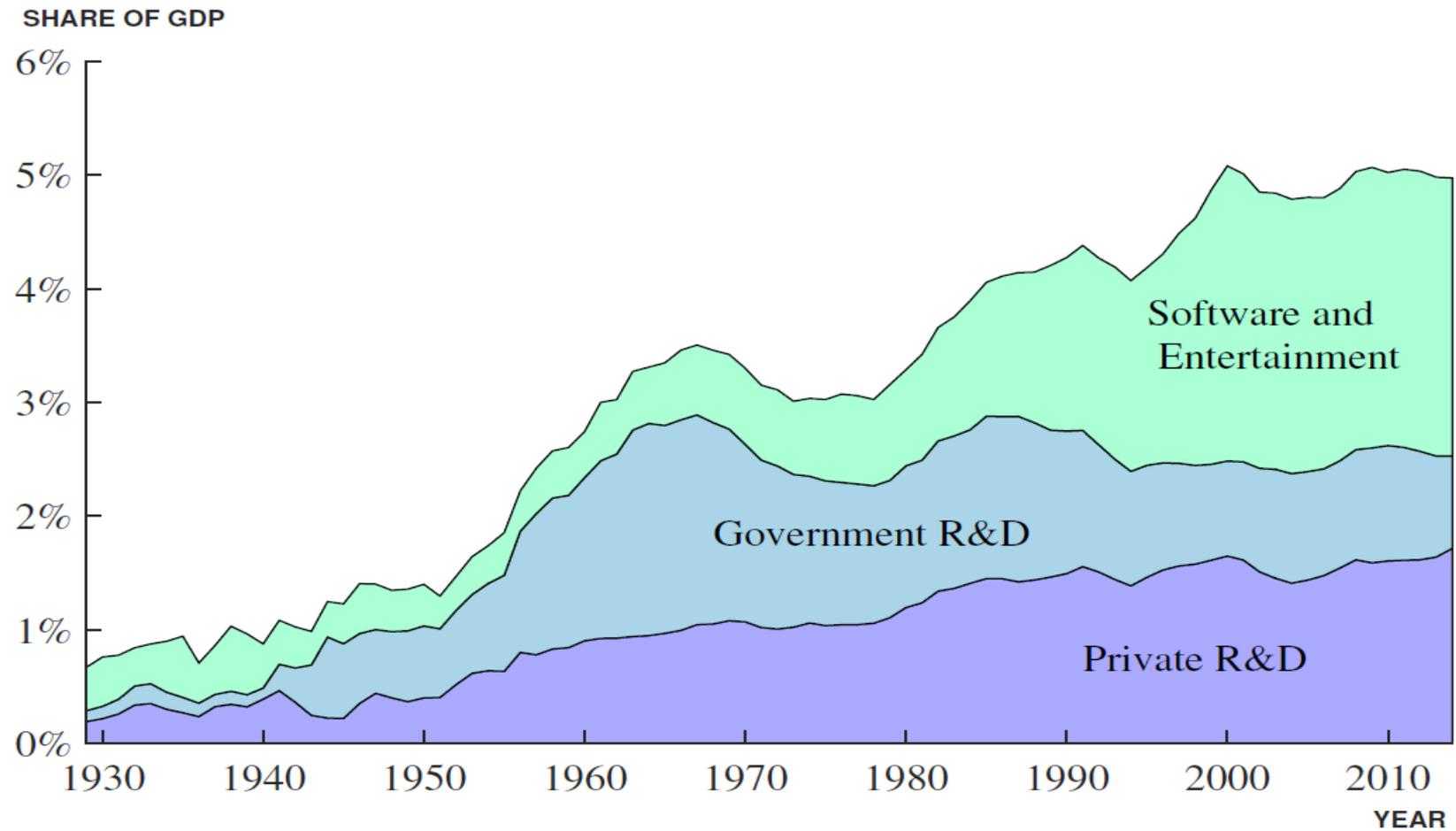


R&D Employment Share

SHARE OF THE POPULATION

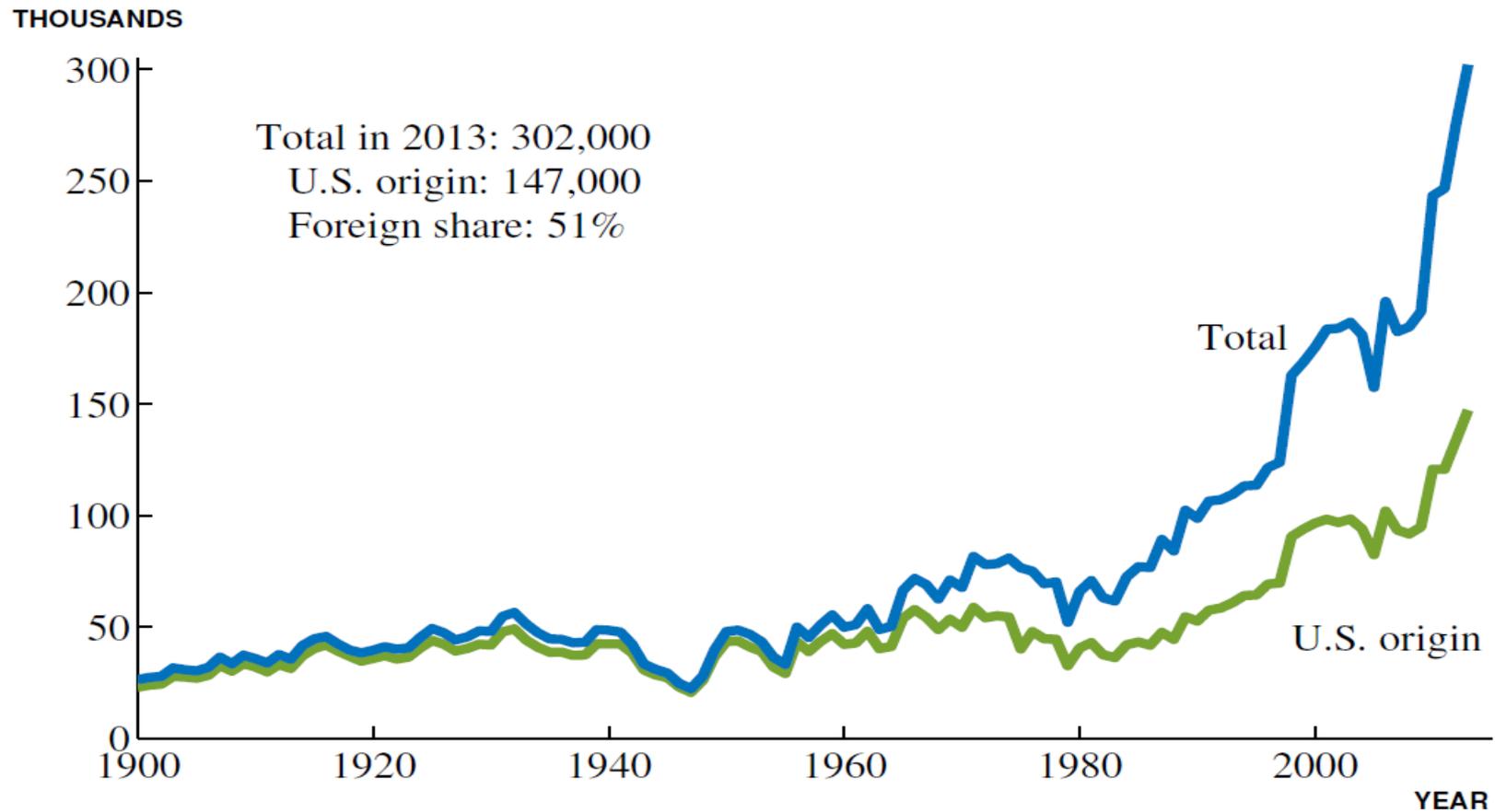


U.S. R&D Growth



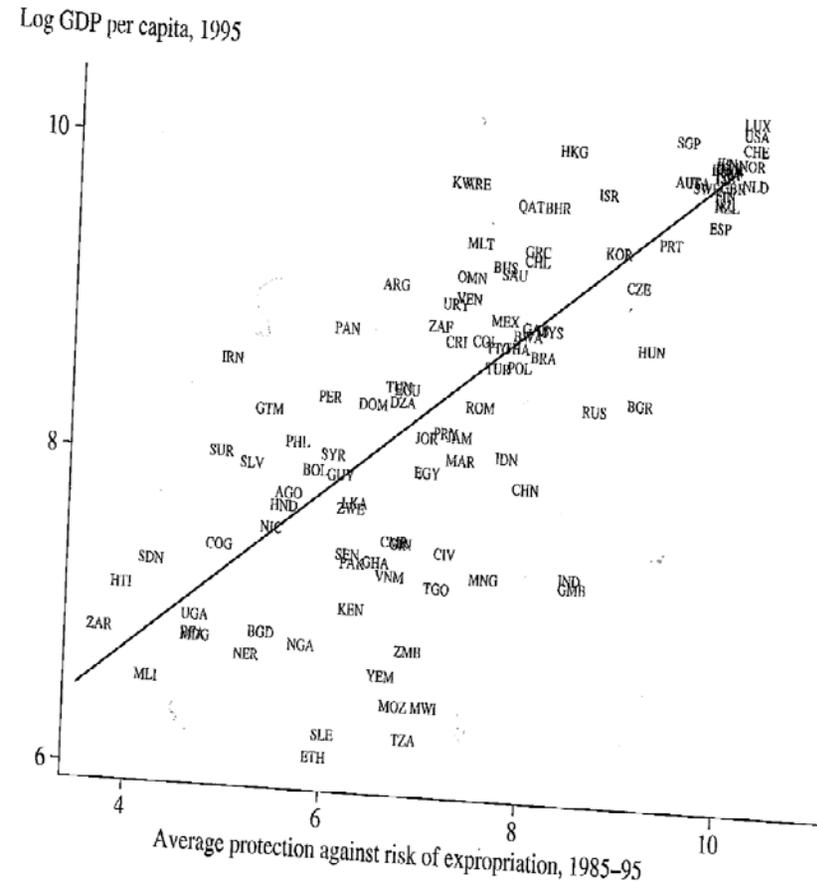
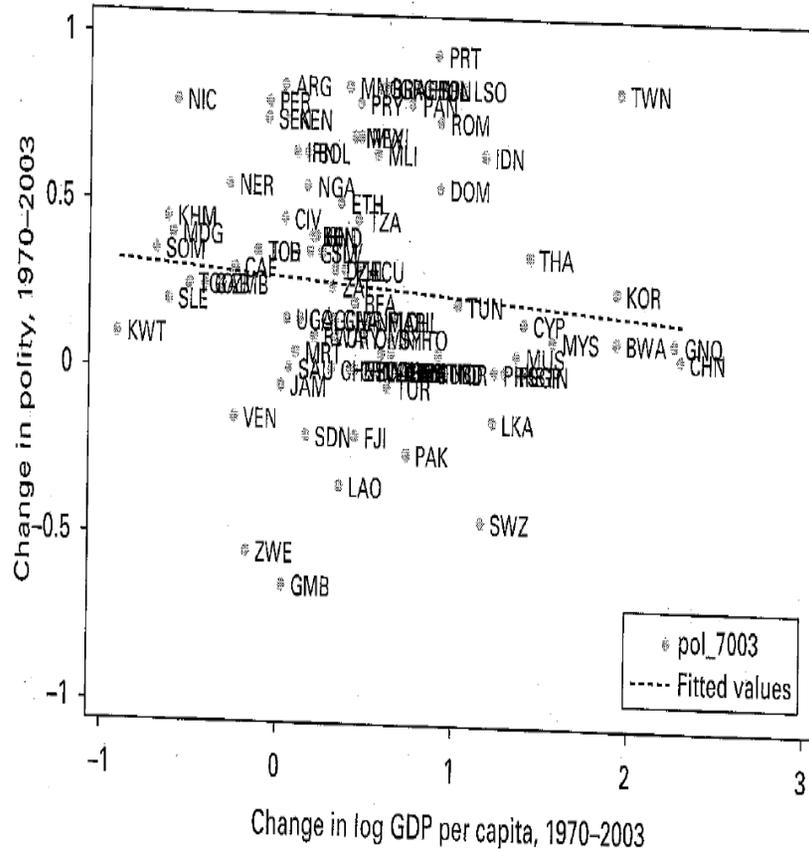
- **Government R&D expansion due to cold war**
- **Software R&D expansion since 1980**

Patents Growth (Granted by USPTO)



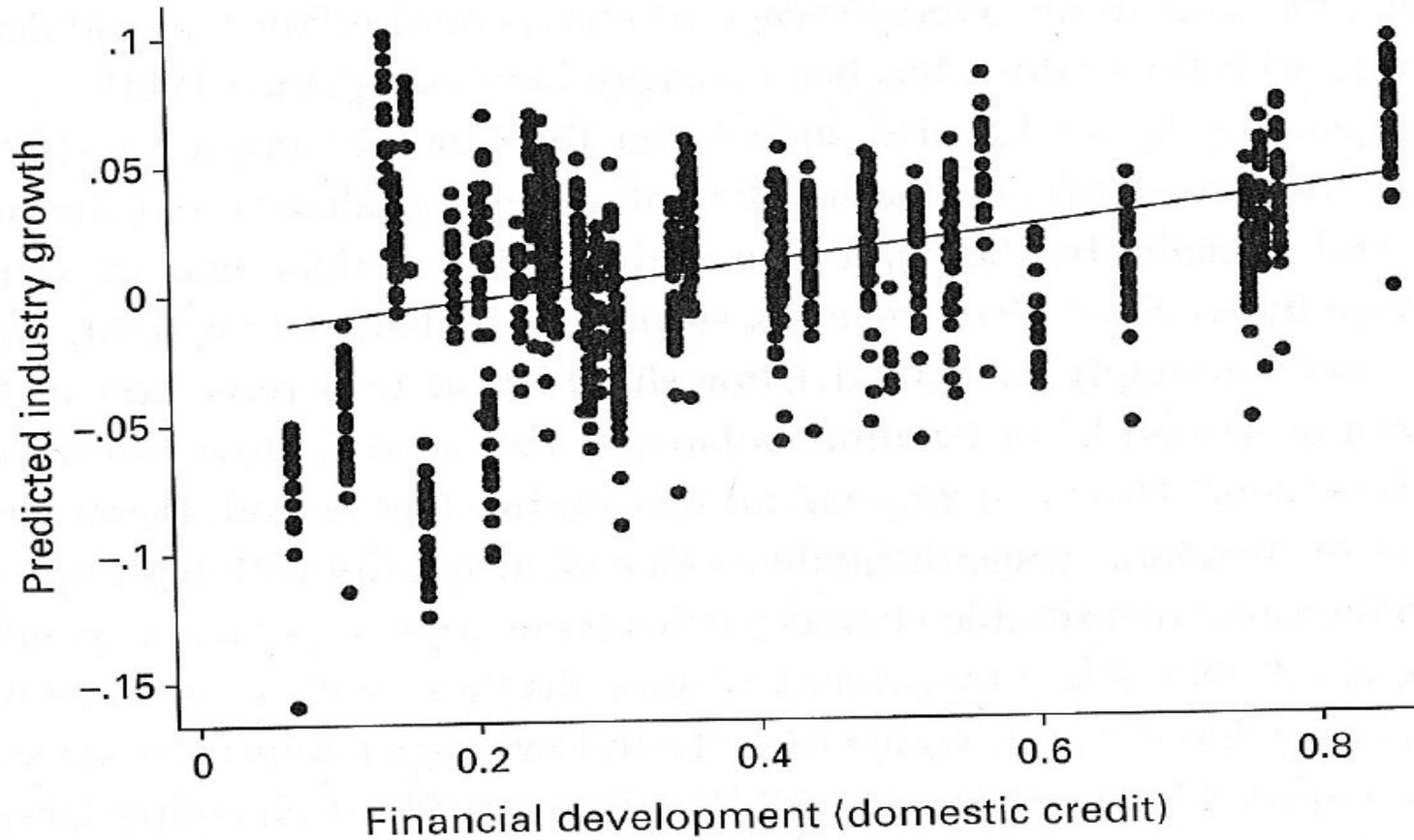
- Patents are highly concentrated geographically:
 - US accounts for half
 - US, UK, Taiwan, South Korea, Germany, Japan together > 80%

- **Institutions – democracy and IPR protection**



- **A tale of two systems: China vs. Taiwan (fast growth under different democracies)**
- **IPR protection promotes invention incentives**

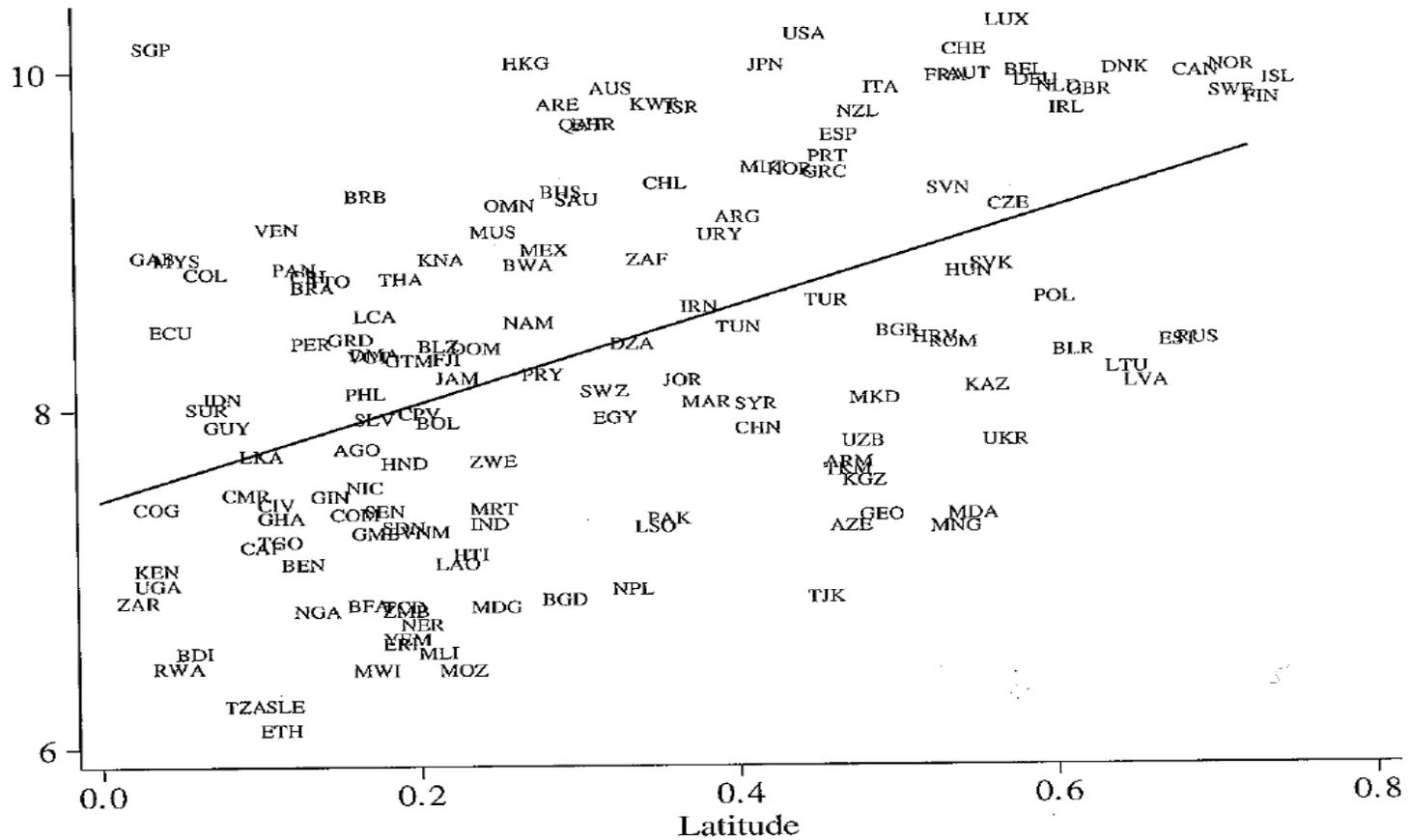
- Finance



- **Threshold effect of minimum financial development for investment purposes (at domestic credit/GDP = 0.2)**

- **Geography**

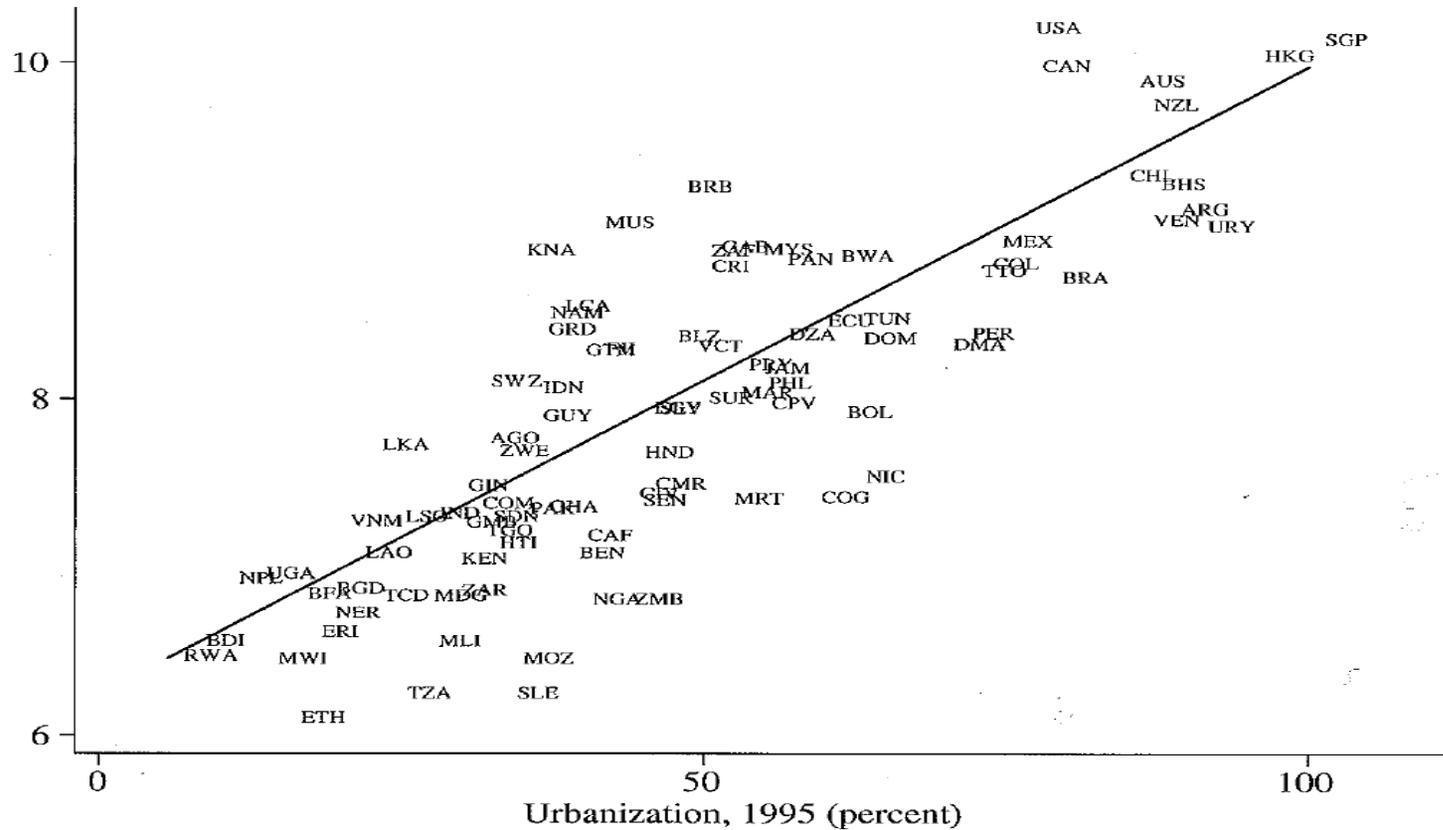
Log GDP per capita, 1995



- **Colonization and settlement of rulers**
- **Snow belt vs. sun belt**

• Urbanization

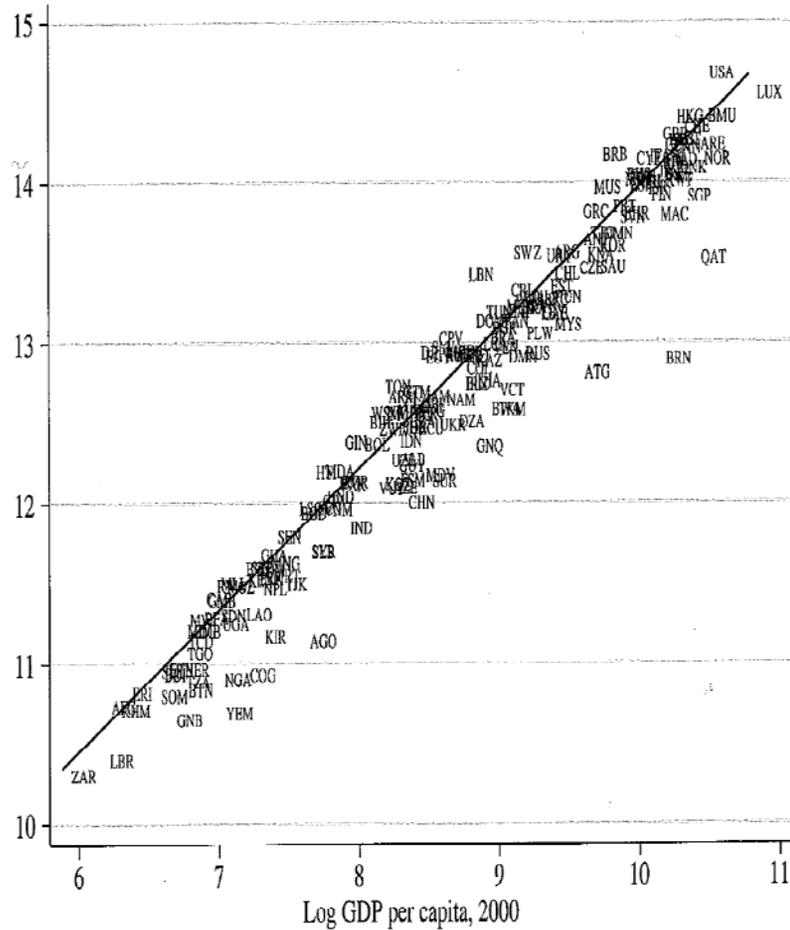
Log GDP per capita, 1995



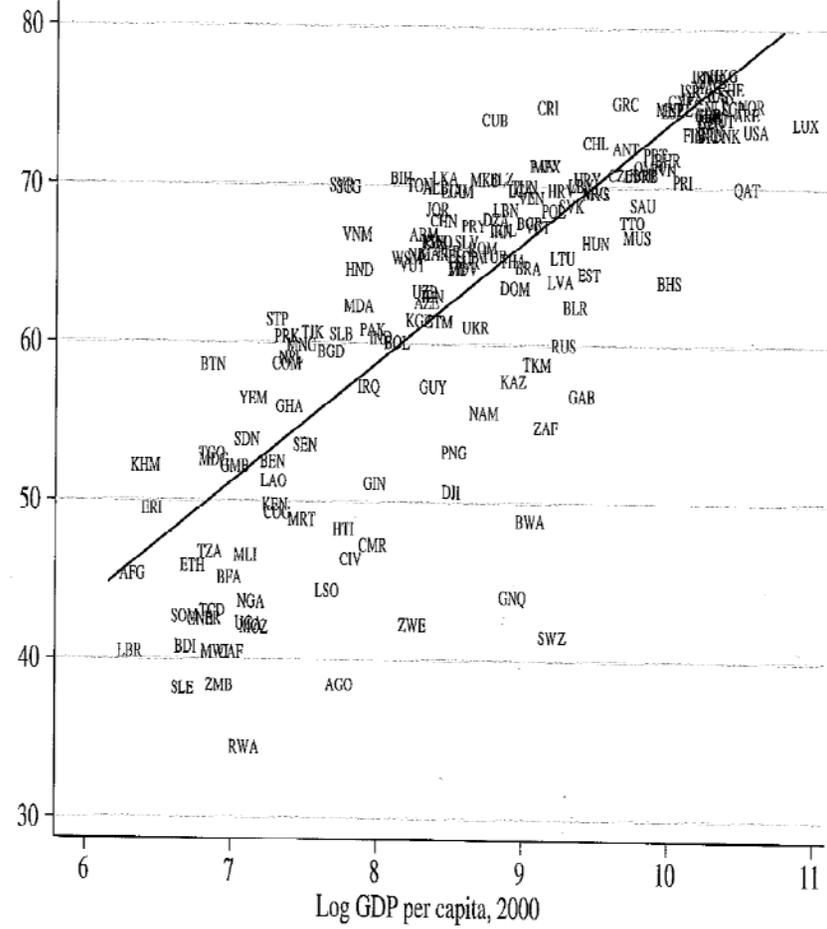
- Agglomeration economies
- Amenities and rise in services
- Reversal if using early urbanization

3. Economic growth, consumption and life expectancy

Log consumption per capita, 2000



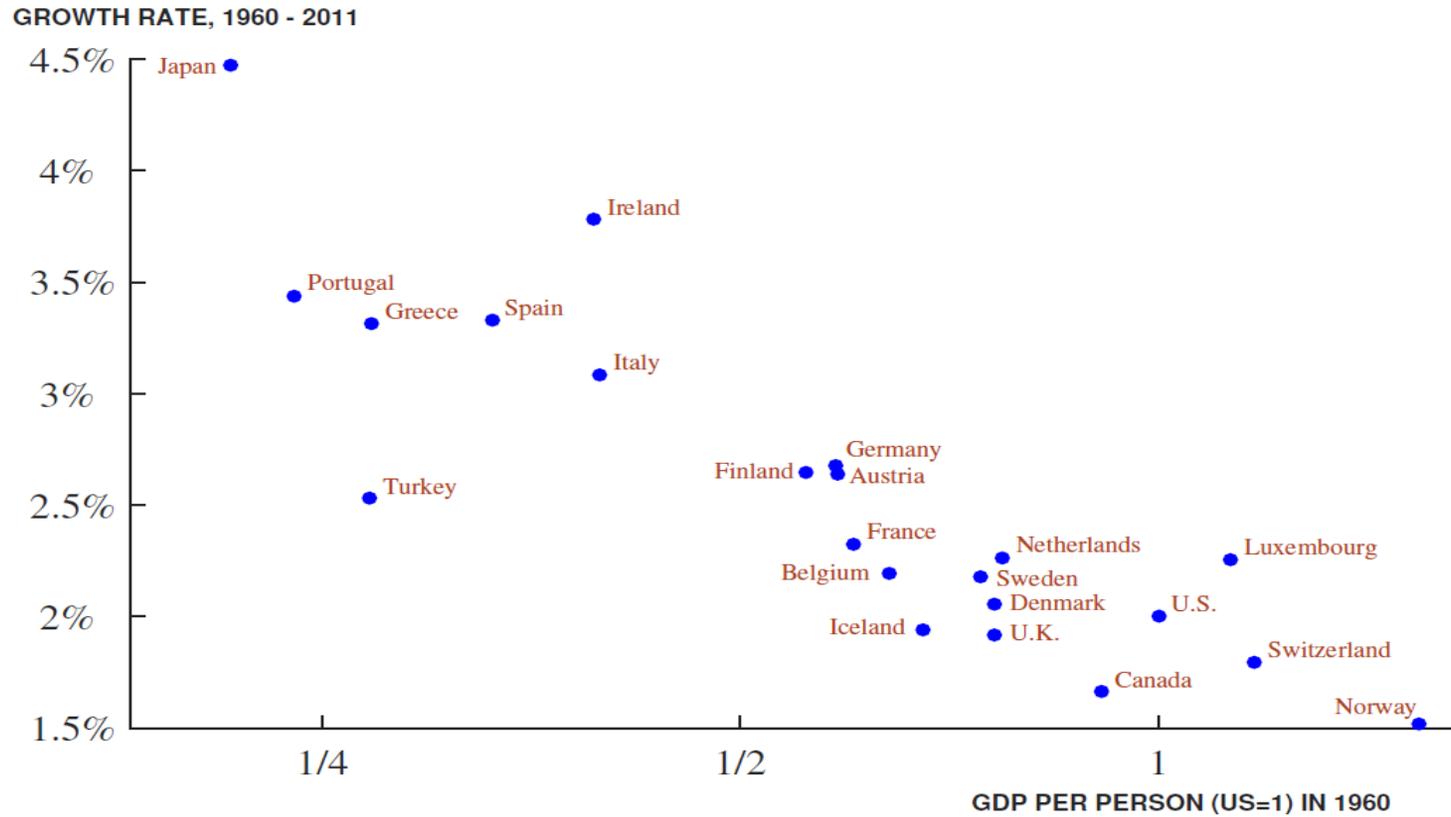
Life expectancy, 2000 (ycars)



4. Have rich countries suffered growth slowdown?

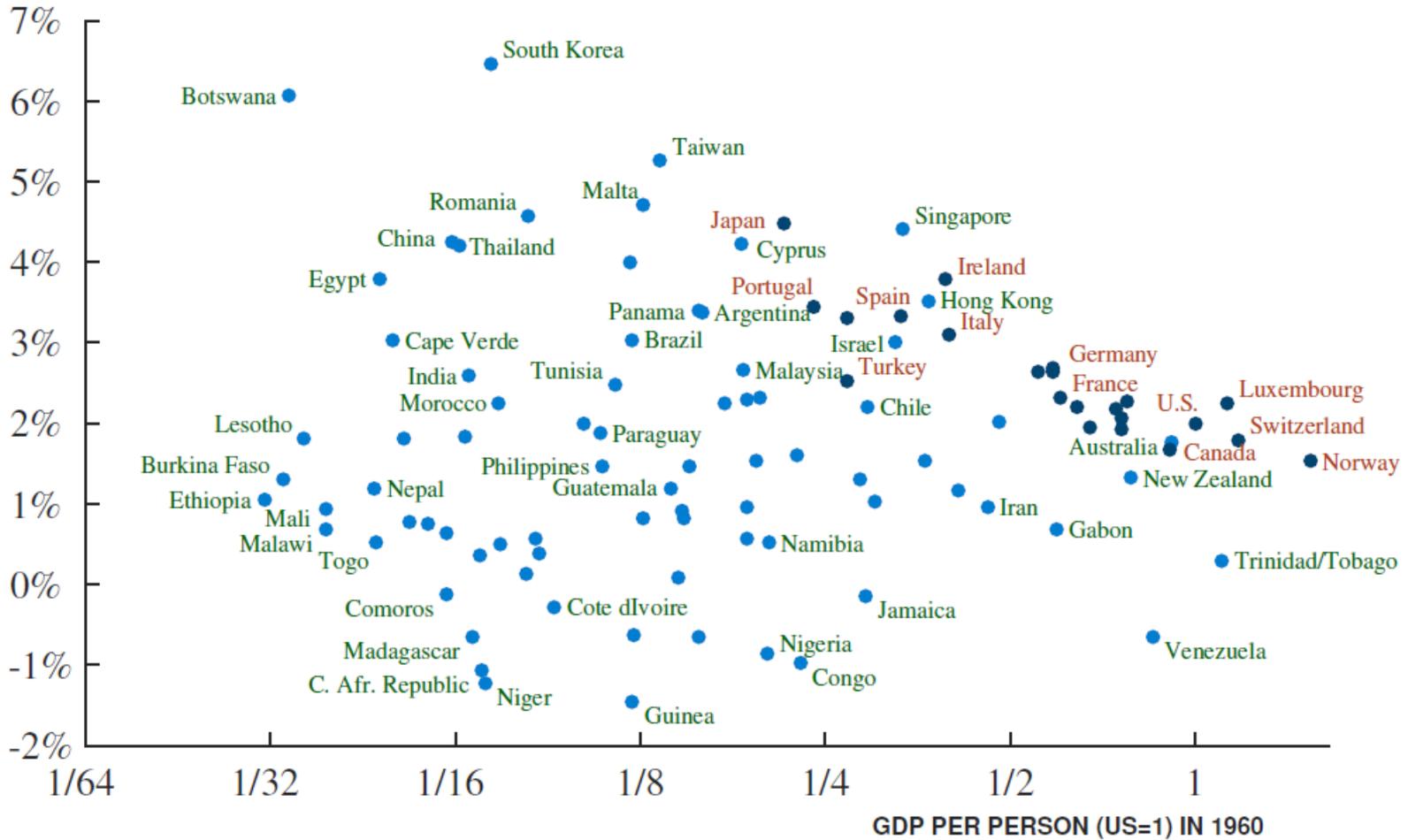
- Growth rate versus initial level of development

Convergence of the Rich (OECD)

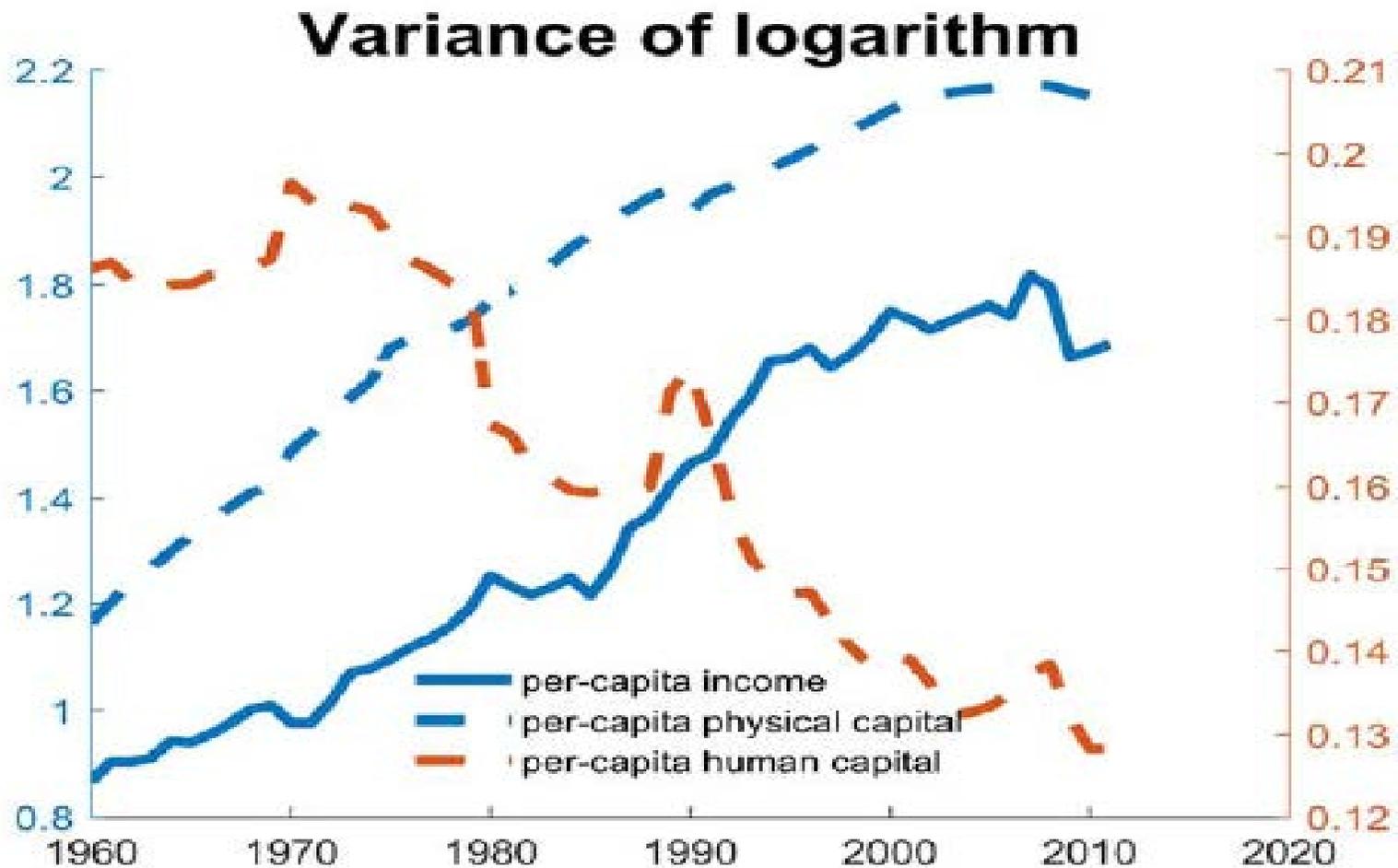


Nonconvergence of the Poor

GROWTH RATE, 1960 - 2011



Cross-Country Disparities in Income and Factor Inputs (Wang-Wong-Yip 2016)



- **The concept of convergence and conditional convergence**

Convergence in per capita real GDP (Baumol-Barro):

- **β -convergence: the higher the initial per capita real GDP is, the lower the per capita real GDP growth will be ($\beta < 0$)**

$$\beta\text{-convergence} - \frac{\dot{y}_i}{y_i} = \theta_i = \beta_0 + \beta y_i(0) + \dots$$

- **σ -convergence: the cross-country per capita real GDP is decreasing over time**

$$\sigma\text{-convergence} - \frac{d}{dt}[Var(y_i)] < 0$$

Problems:

- **Galton Fallacy (regression toward the mean)**
- **Twin-peak hypothesis (Quah 1996)**
- **Endogeneity problems**
- **Measurement errors**
- **Kitchen sink regressions**

C. Why Formal Theory Matters?

- **Albert Einstein: “[I]t is quite wrong to try founding a theory on observable magnitudes alone ... It is the theory which decides what we can observe.”**
- **Formal theory can help organizing the stylized facts observed, explaining causal relationships, offering economic predictions and drawing useful policy implications**

D. Basic Technical Tools

To build up formal dynamic general equilibrium theory, basic tools are:

- **calculus/matrix algebra, probability theory, mathematical statistics & stochastic process, basic real/functional analysis & measure theory**
- **constrained optimization methods (Lagrangian)**
- **optimal control (Maximum Principle) & stochastic control**
- **recursive methods and dynamic programming**
- **overlapping-generations (OLG) approach**
- **dynamic games**