

# **Measurement and Stylized Facts in Growth and Development**

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**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:**

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

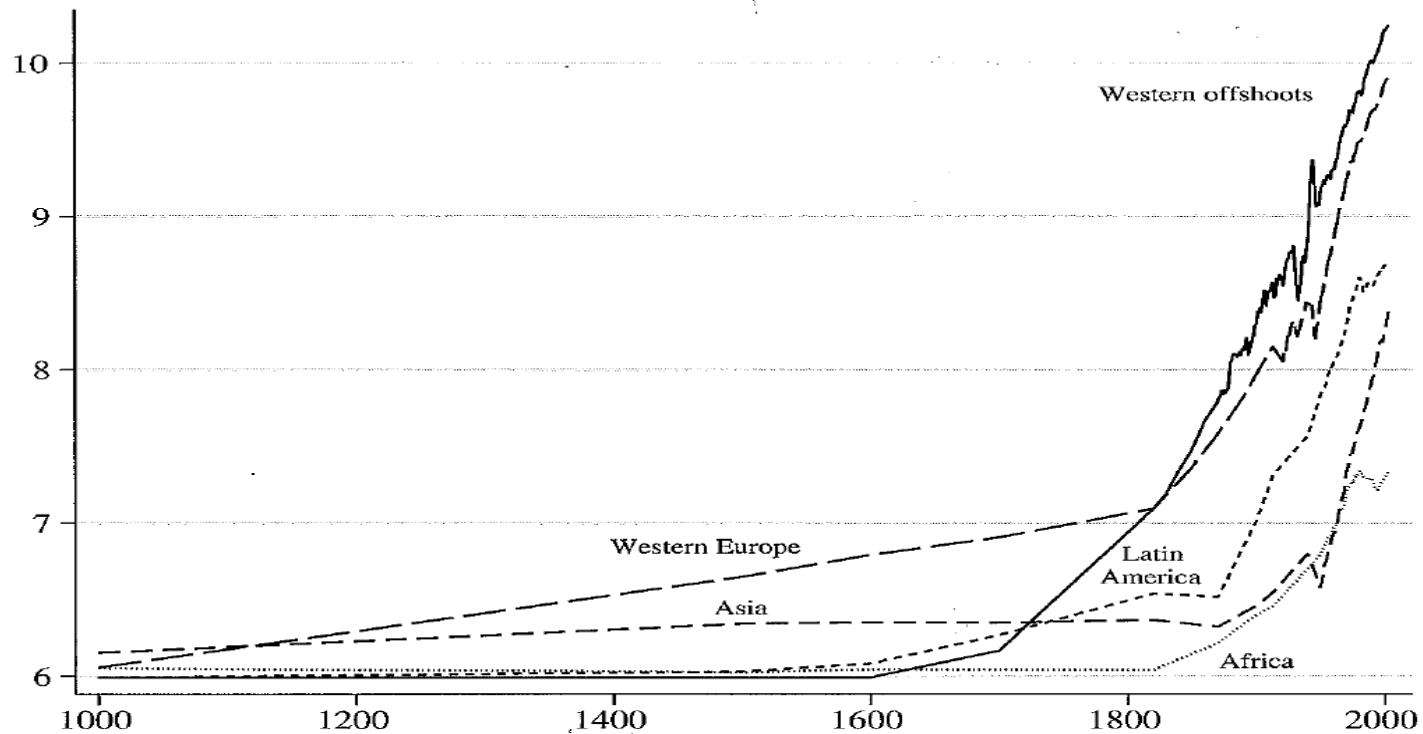
- **The rise of Europe:**

- **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)**

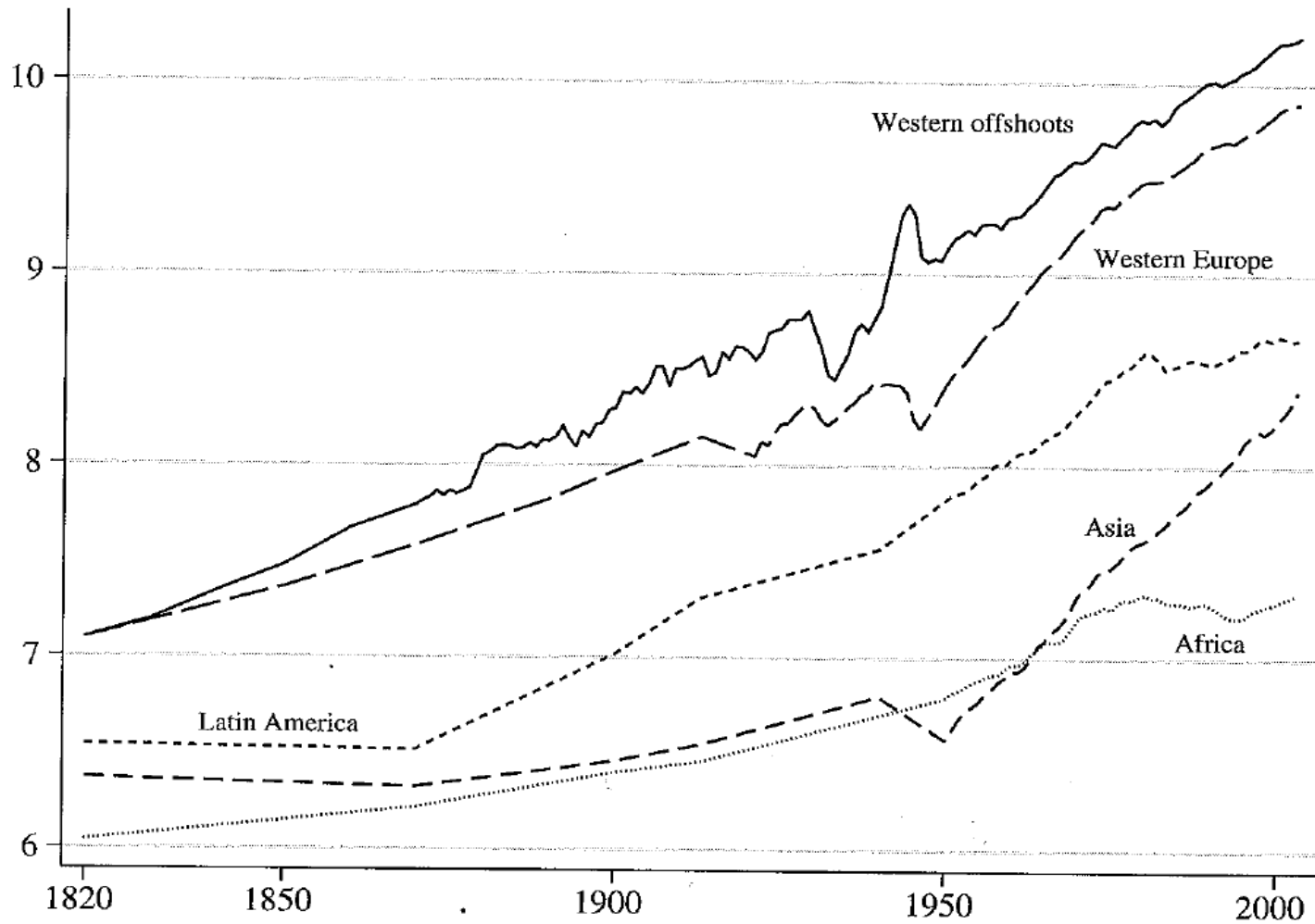
- **World development since 1000: Overtaking of Western Offshoots**
  - Maddison data (scarce prior to 1820)
  - **Western offshoots** (former colonies of Western Europe)
  - **Asia** (historically China + India)

Log GDP per capita

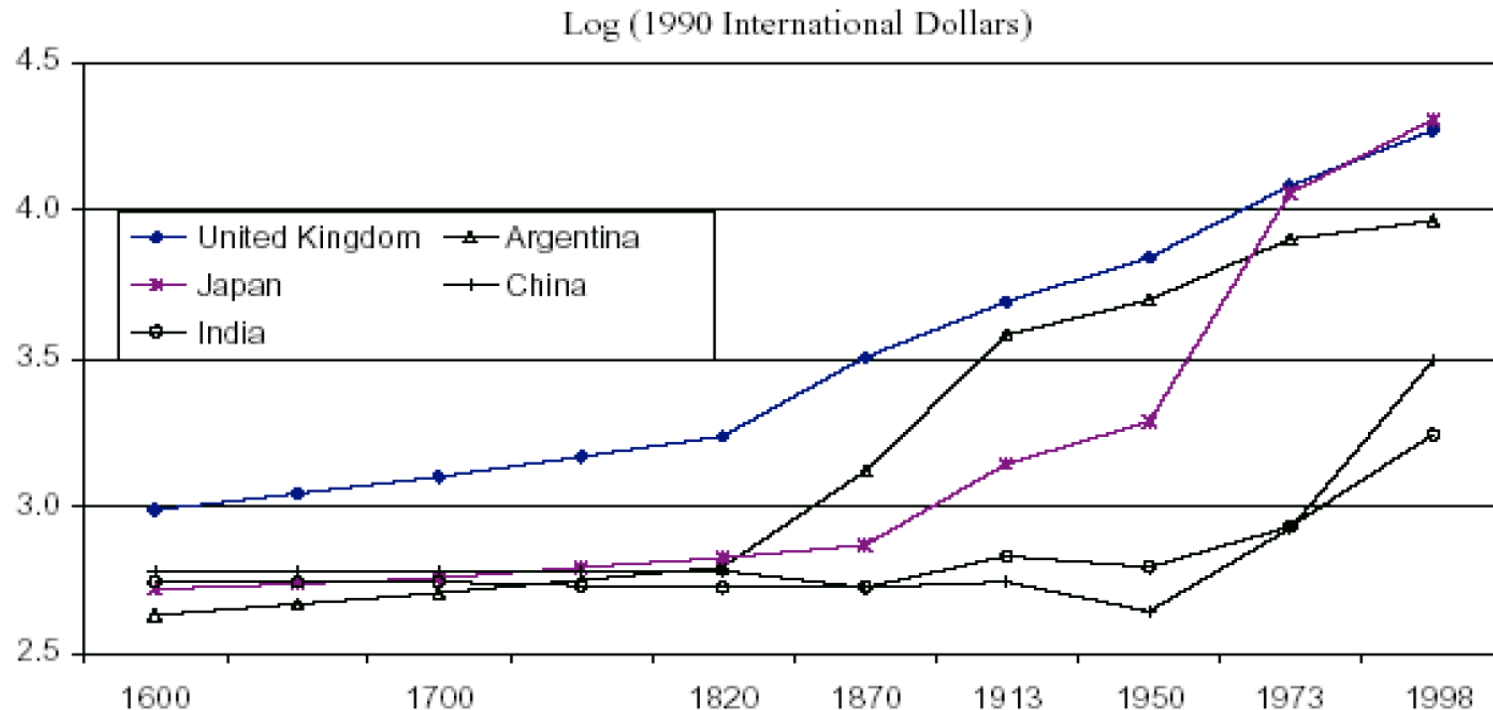


- **World development since mid-19<sup>th</sup> century:**

Log GDP per capita



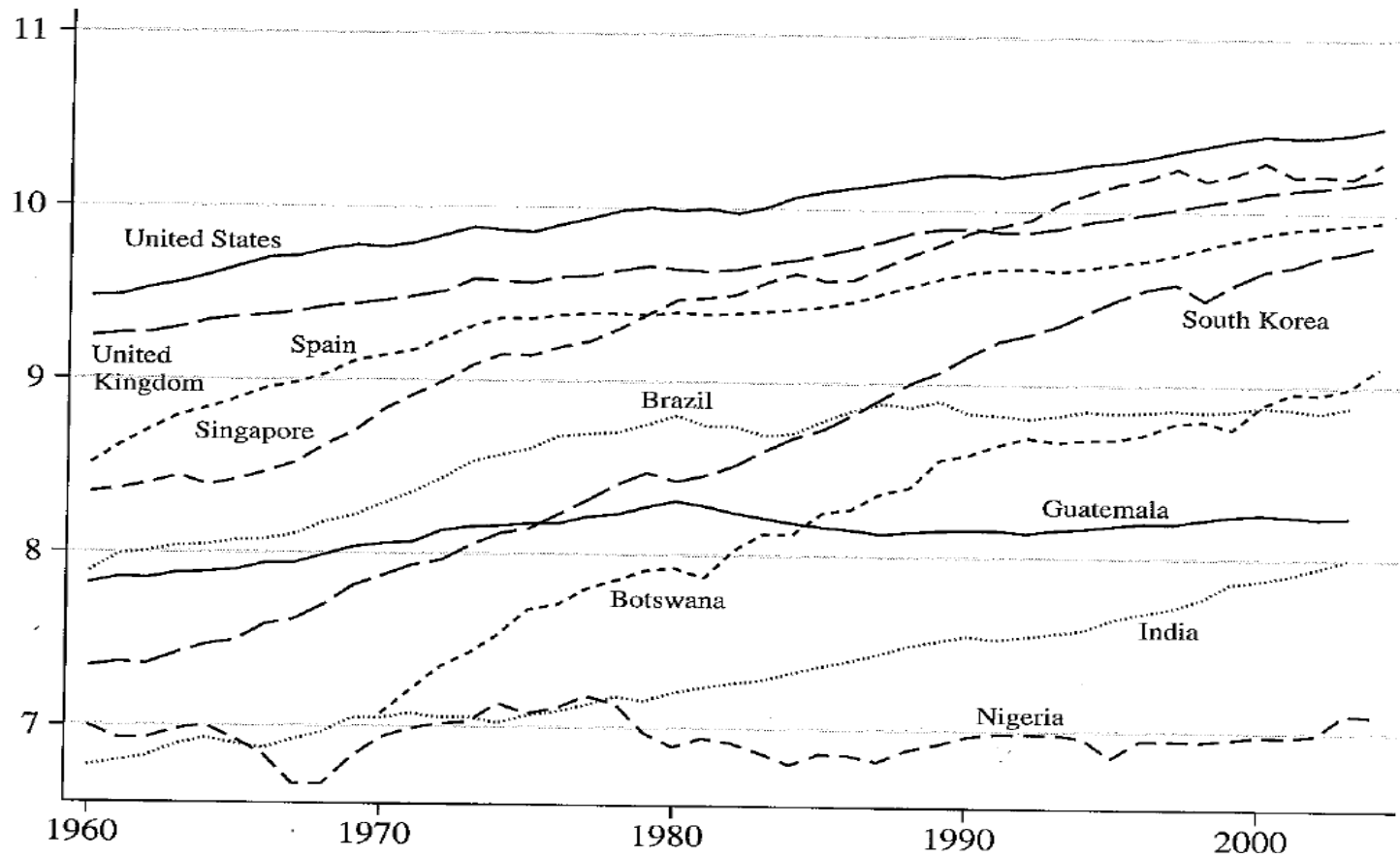
- **A closer look at 5 representative economies since 1600 (Ngai 2004):**



- 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

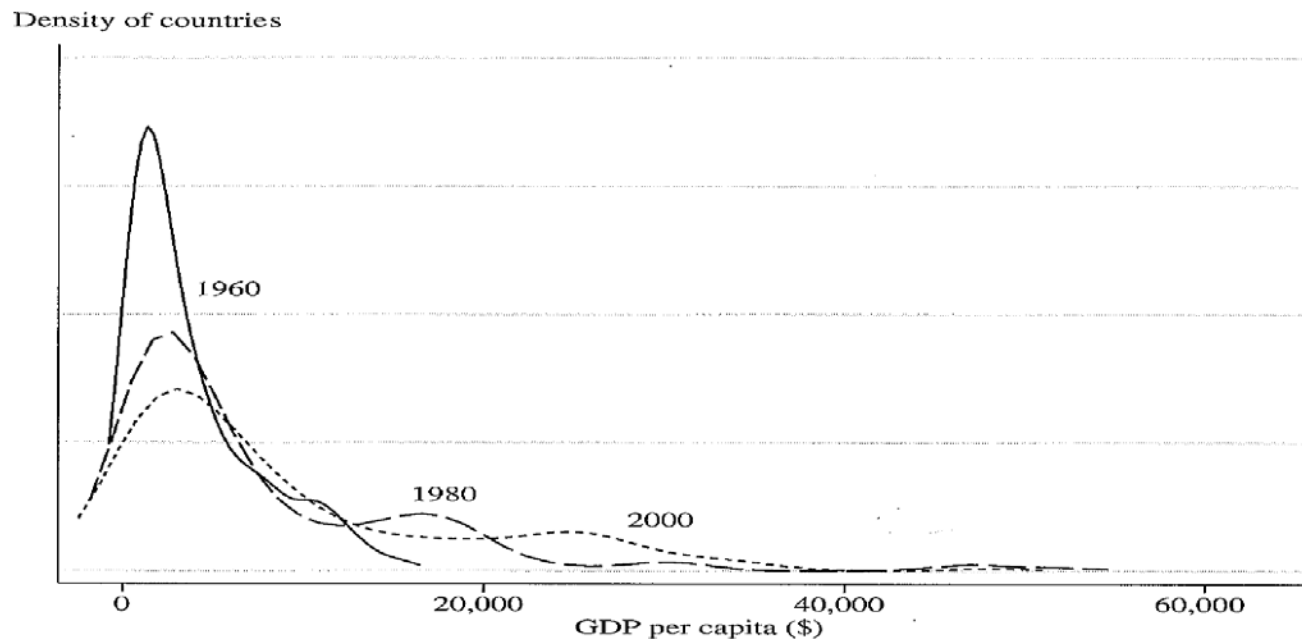


- East Asian Miracles (Asian Tigers)
- African Miracle (Botswana)
- Poverty Traps (Nigeria and many Sub-Saharan)

## B. Cross-Country Study of Economic Growth

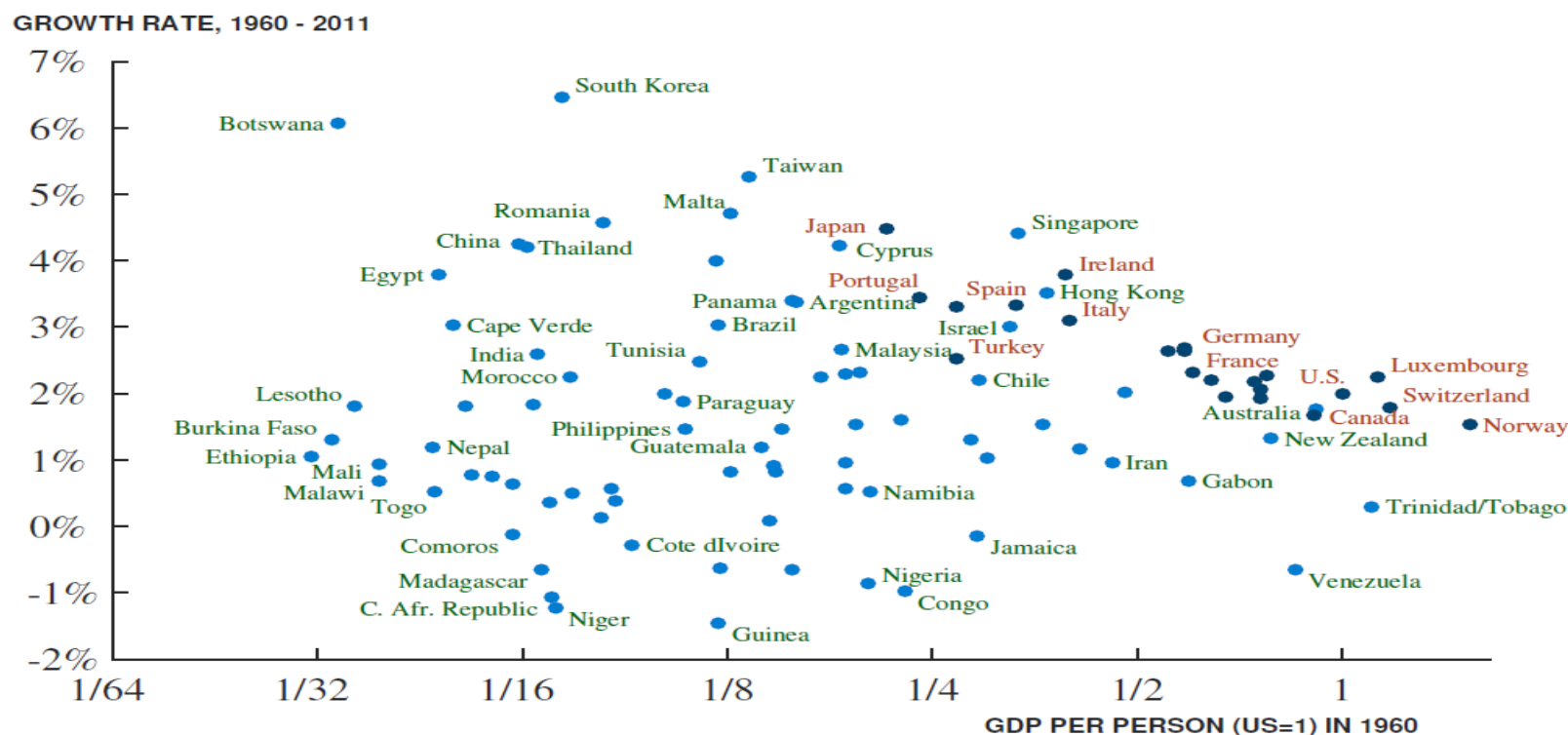
### 1. Overview

- **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)**

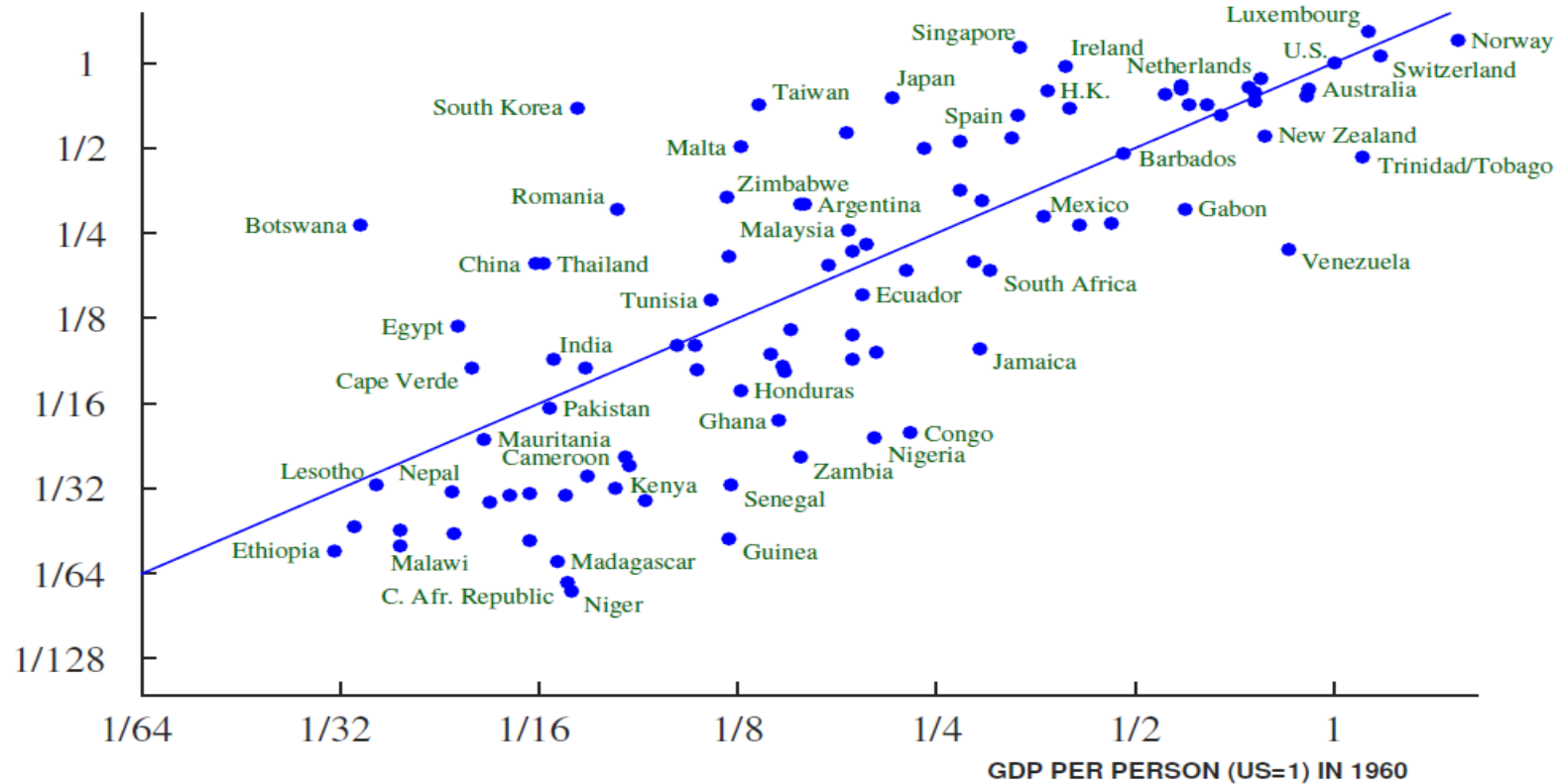


- **OECD frontier**
- **Asian miracles**
- **Development laggards: high initial relative income/low growth**
- **Poverty traps (1/10 of US): Sub-Saharan & others**
- **Convergence of the first 2 groups**



- **Cross-country income mobility:**

GDP PER PERSON (US=1) IN 2011



- **Great divergence:**

- Upward/downward mobility: miracles/laggards
- Persistently high/low: developed/poverty traps

- **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)**

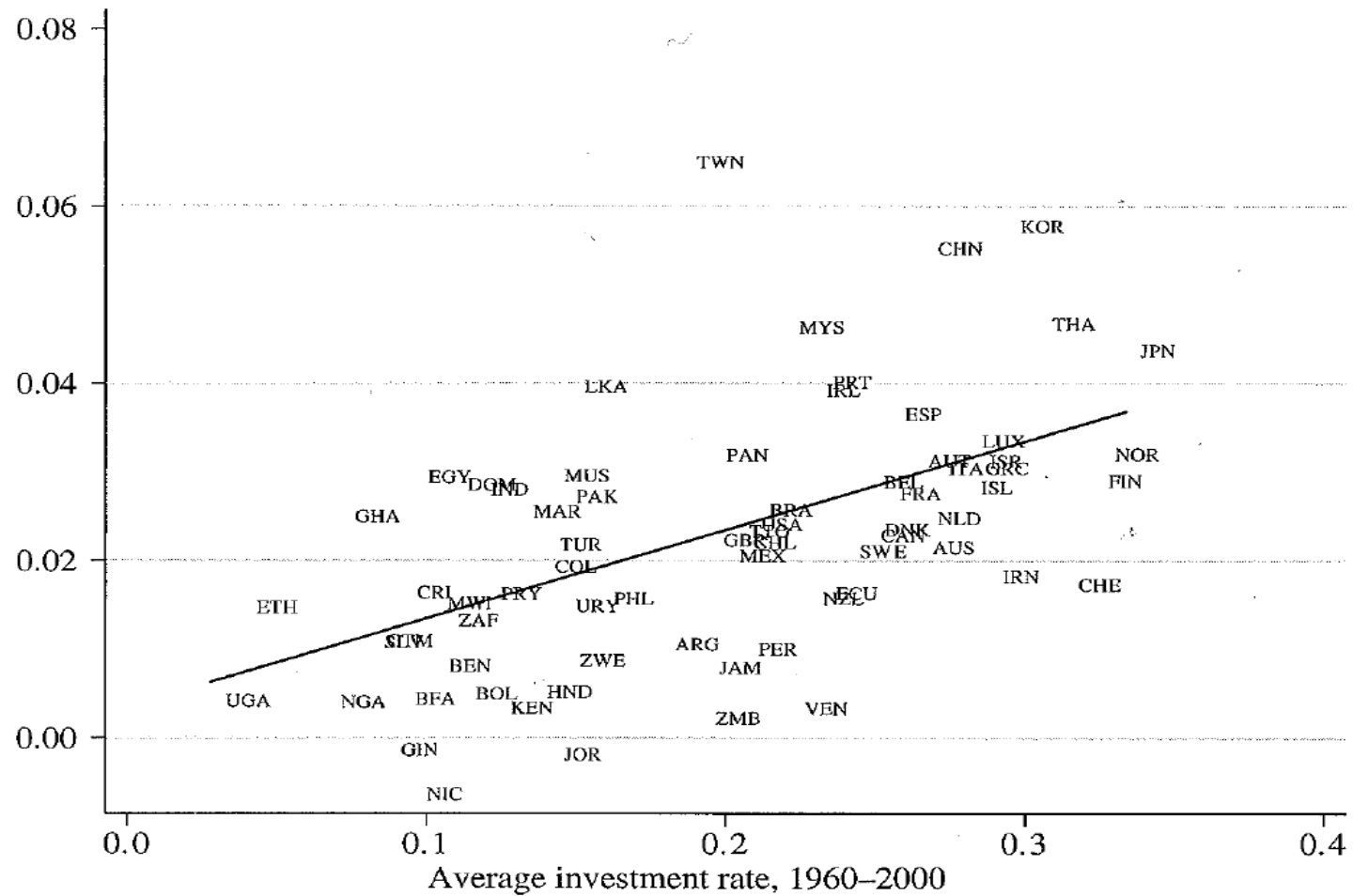
- **Physical/Human Capital Accumulation and Growth**

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

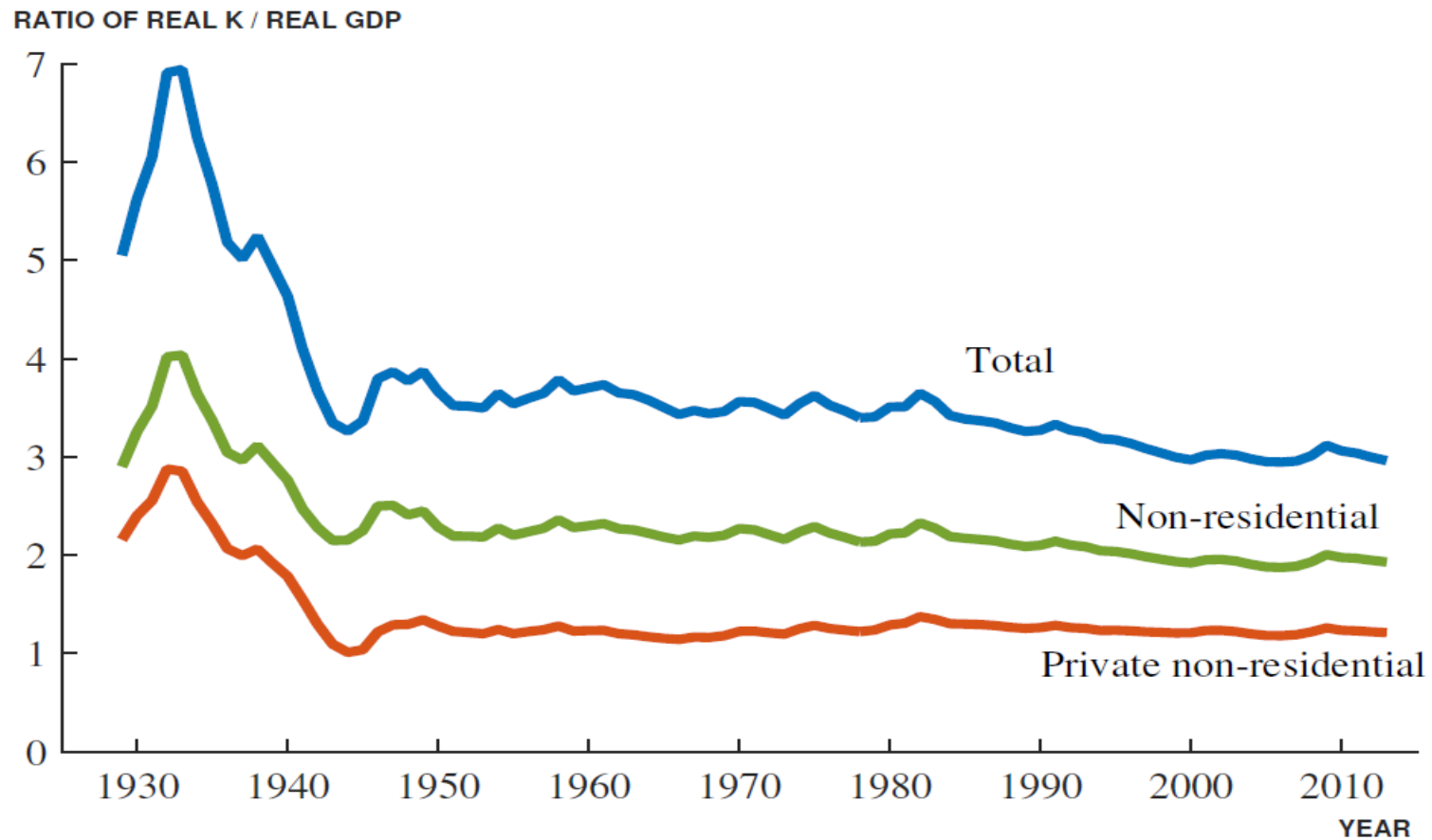
<b>Country</b>	<b>I/Y (%)</b>	<b>Y<sub>i</sub>/Y<sub>US</sub>*100 (1990)</b>	<b>ΔY<sub>i</sub>/Y<sub>i</sub> (%)</b>	<b>Country</b>	<b>H Index</b>	<b>Y<sub>i</sub>/Y<sub>US</sub>*100 (1990)</b>	<b>ΔY<sub>i</sub>/Y<sub>i</sub> (%)</b>
<b>U.S.</b>	<b>24.0</b>	<b>100</b>	<b>2.1</b>	<b>U.S.</b>	<b>11.8</b>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

- Physical capital:

Average growth rate of GDP per capita, 1960–2000



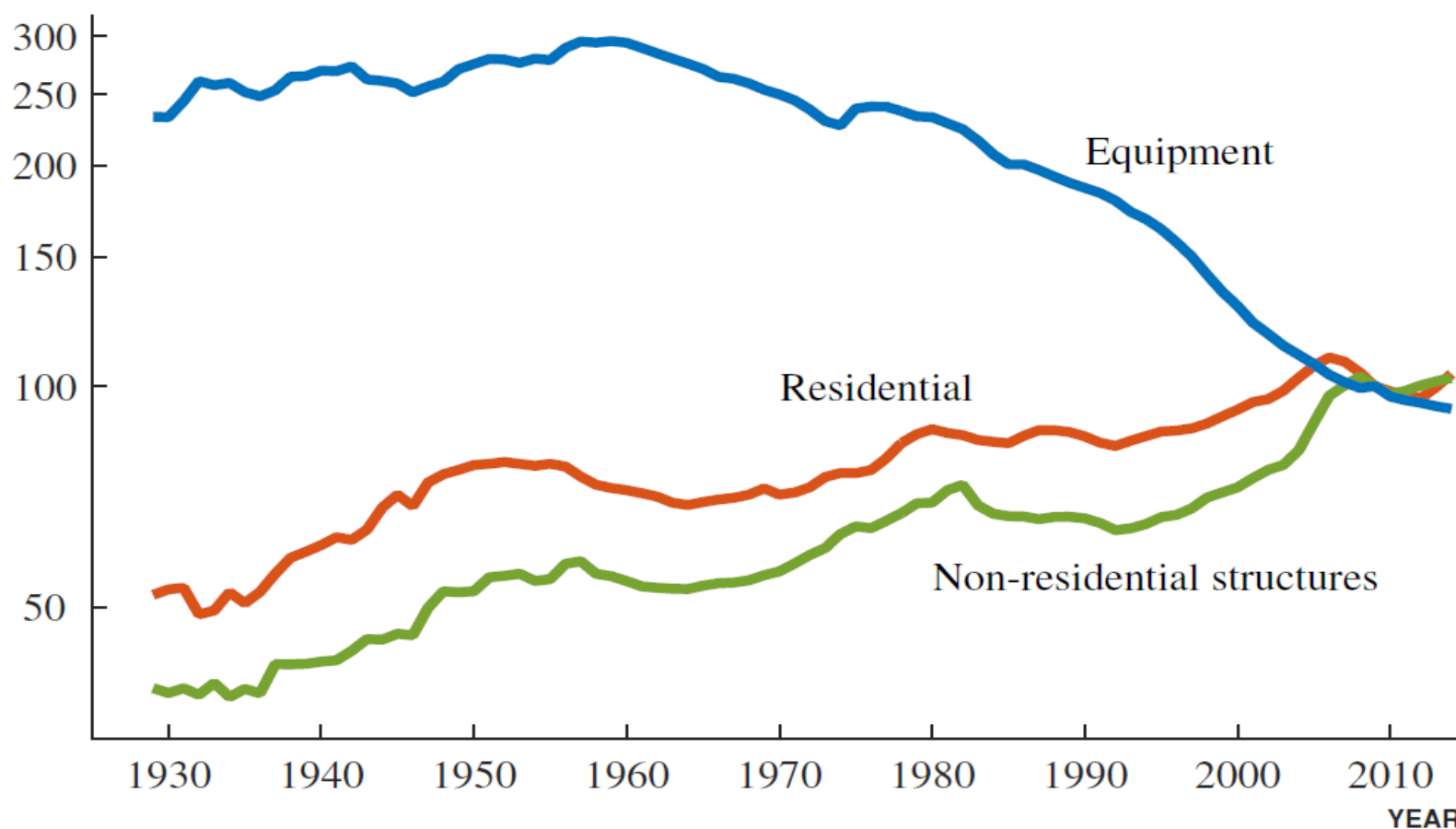
## U.S. Capital-Output Ratio



- Destruction of physical capital by wars
- Rising service sector

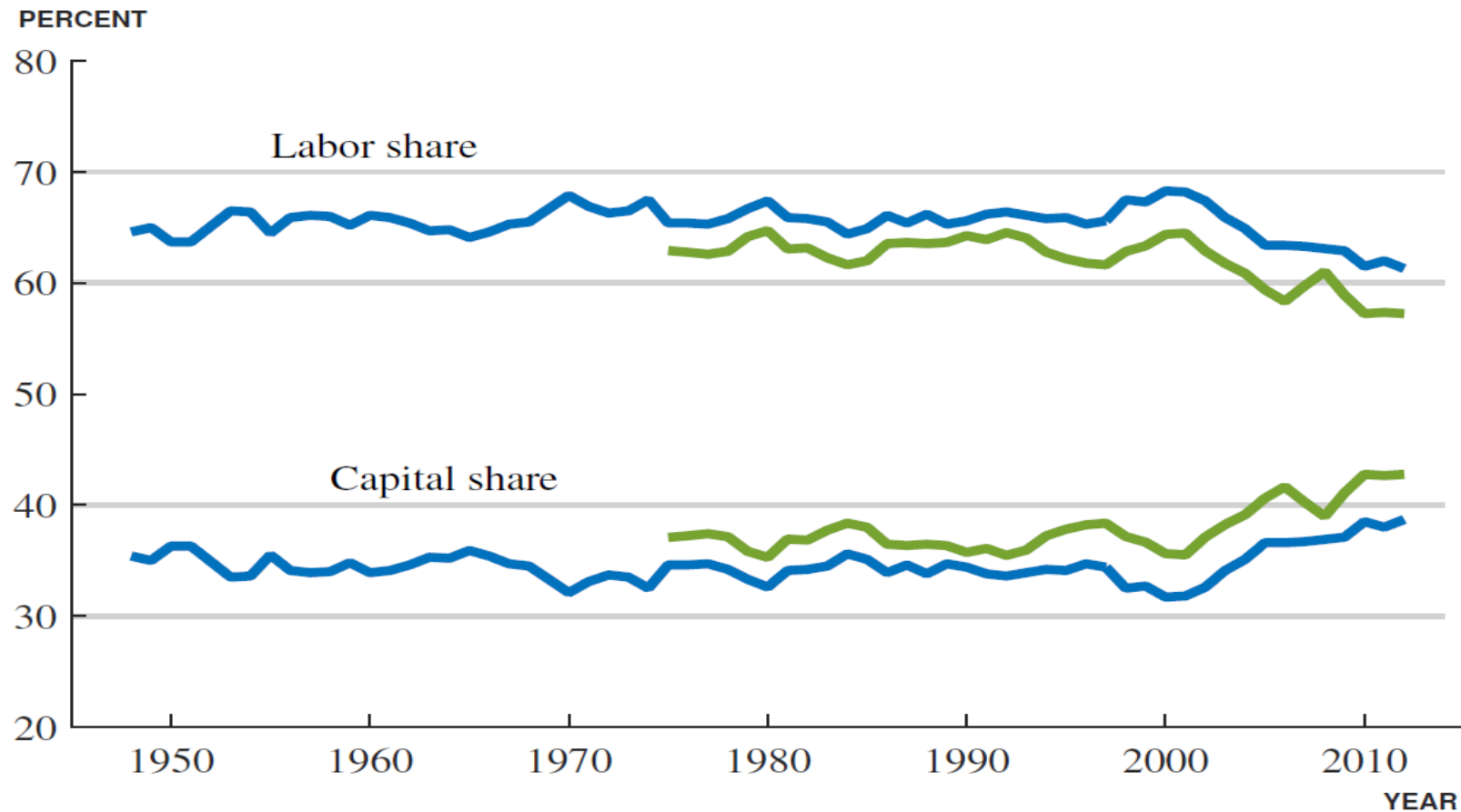
## U.S. Relative Price of Investment

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



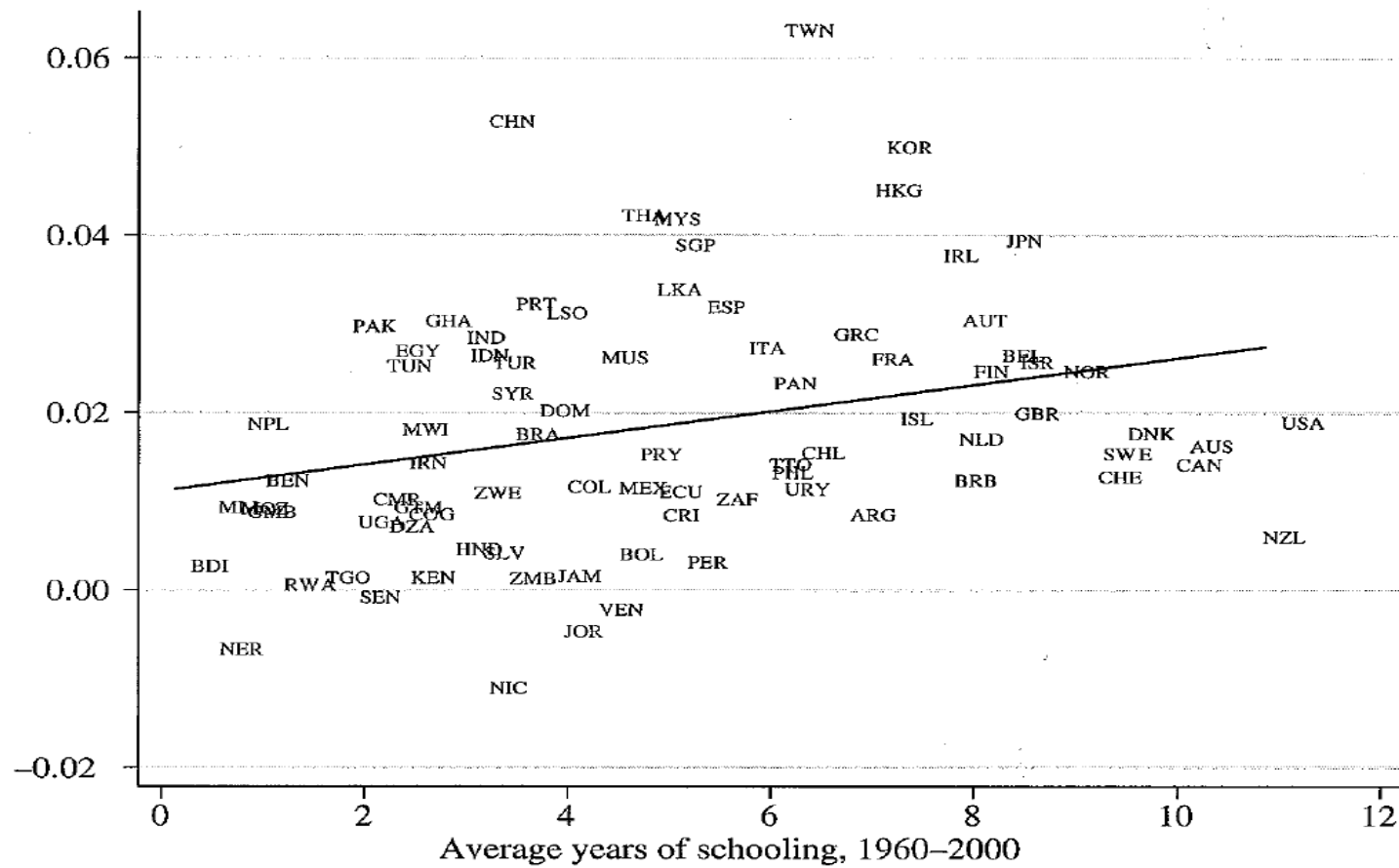
- Declined labor share:

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

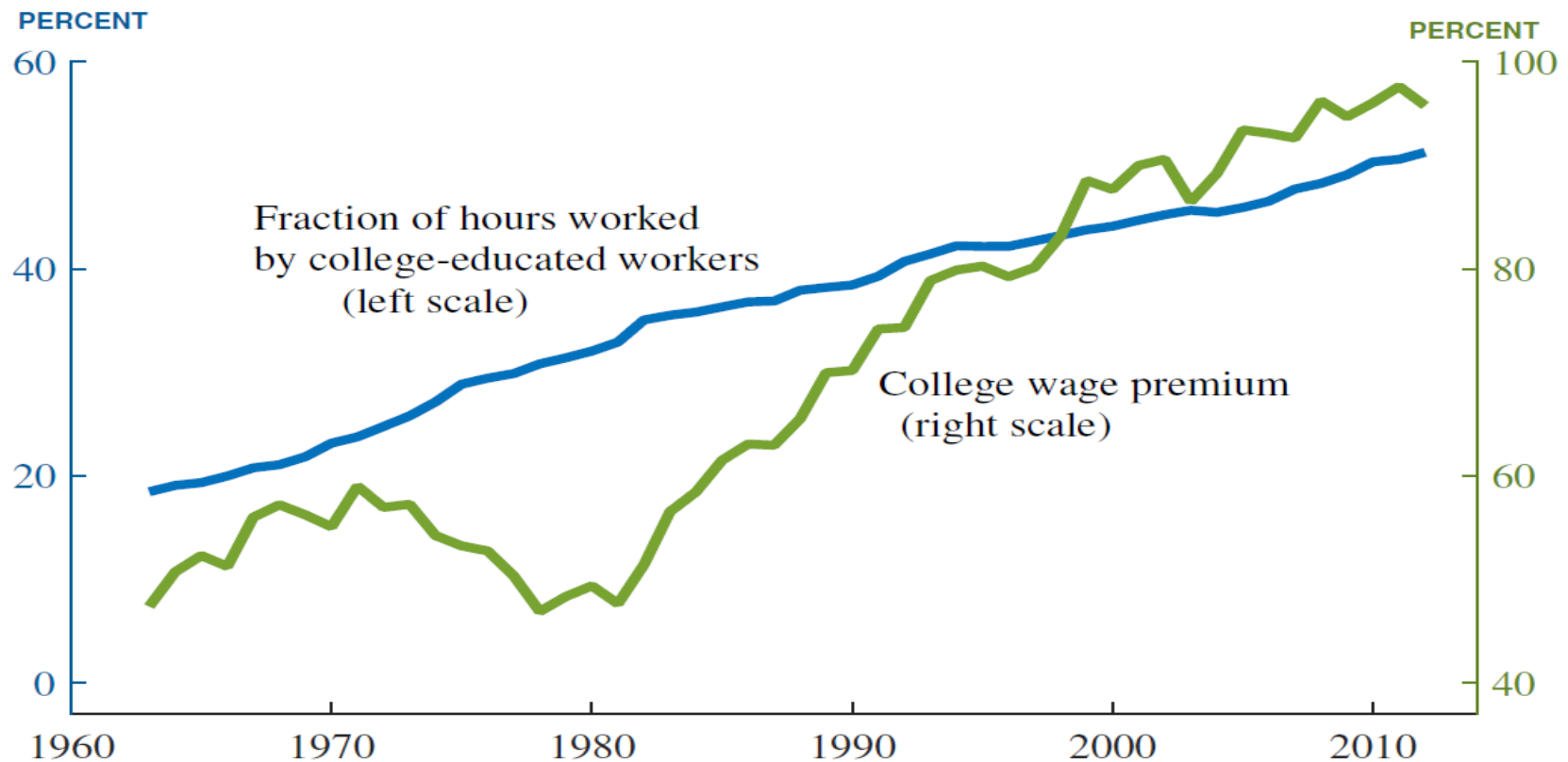


- Human capital:

Average growth rate of GDP per capita, 1960–2000

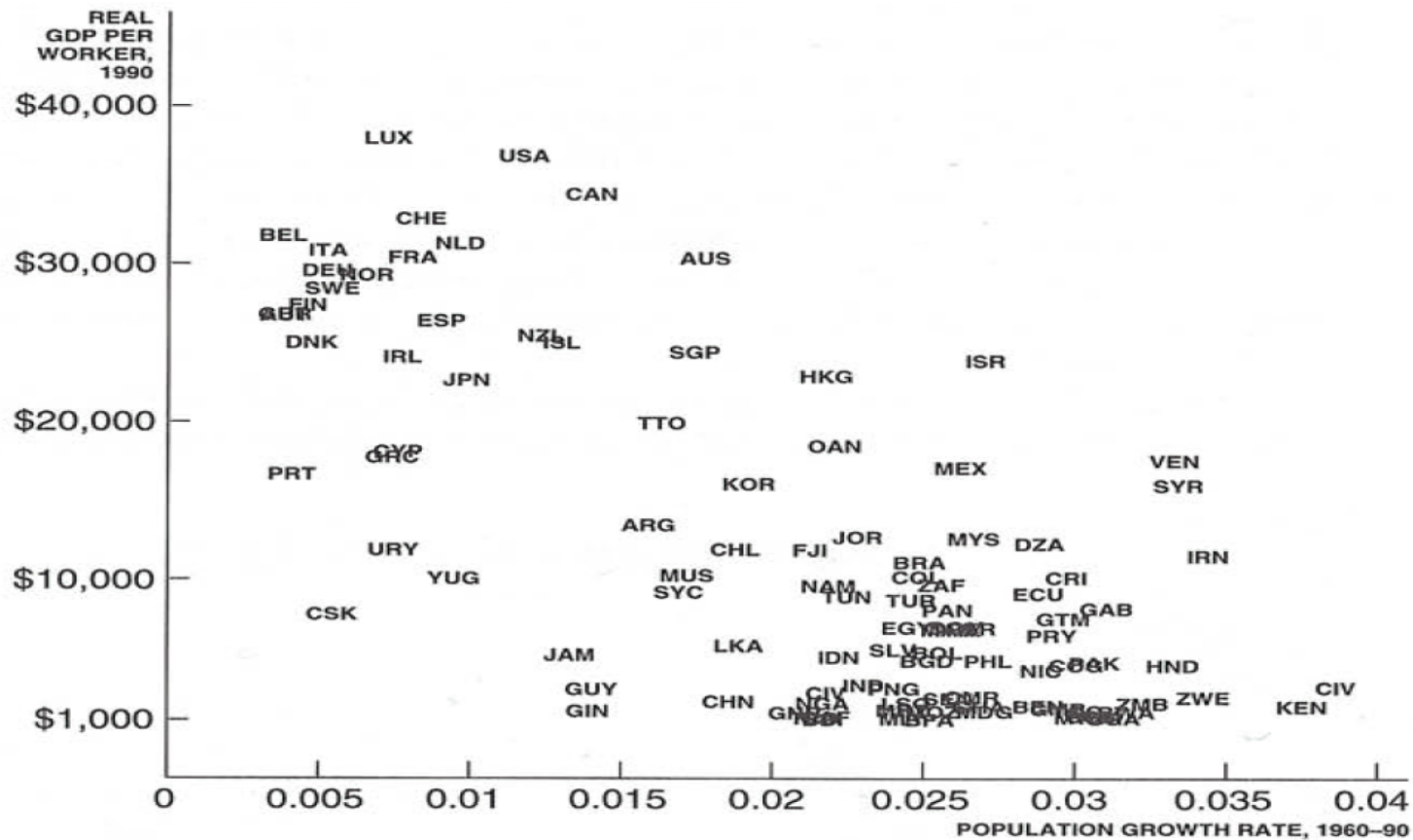


## U.S. Skilled Labor Growth and Skill Premium



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

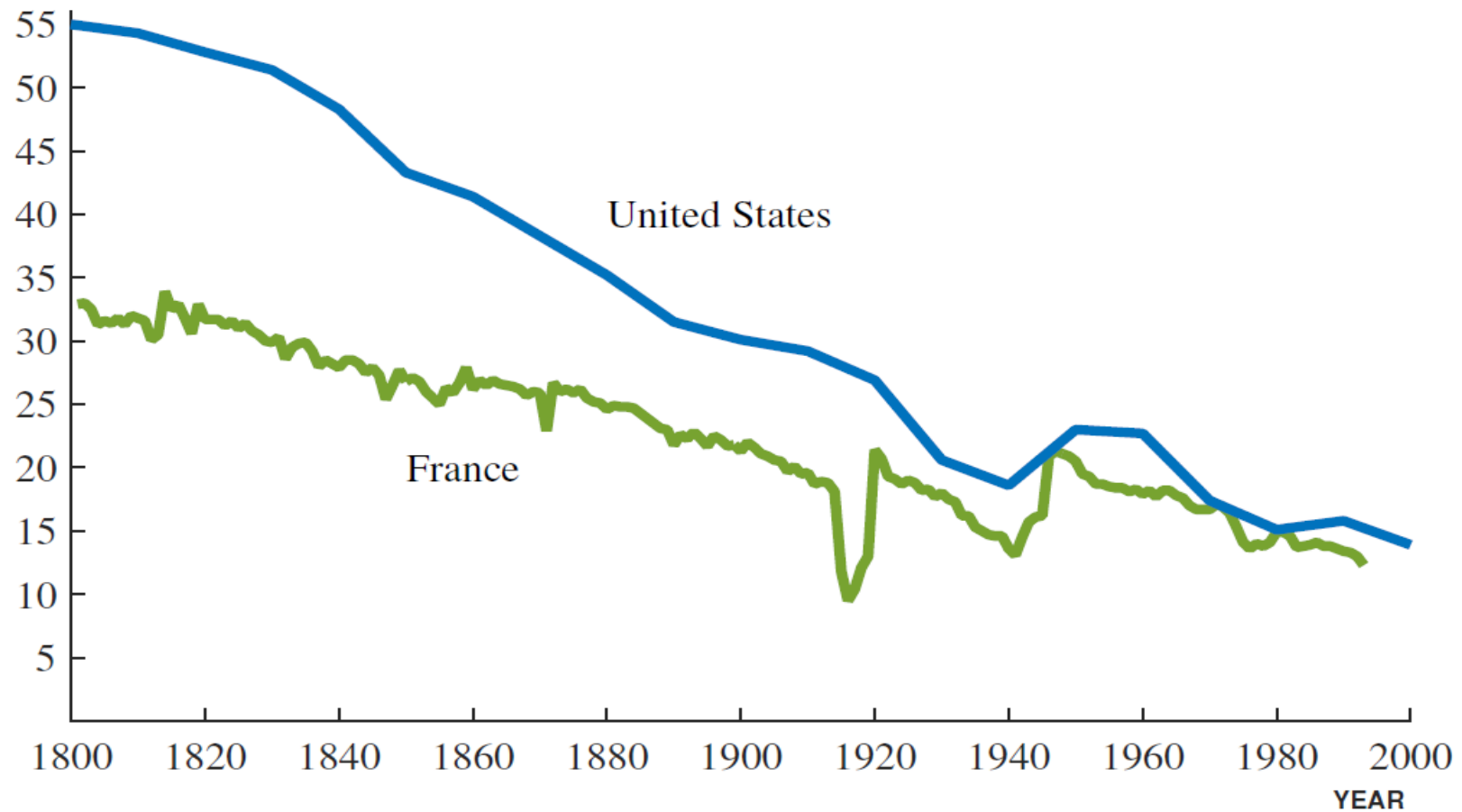
- **Population growth:**



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

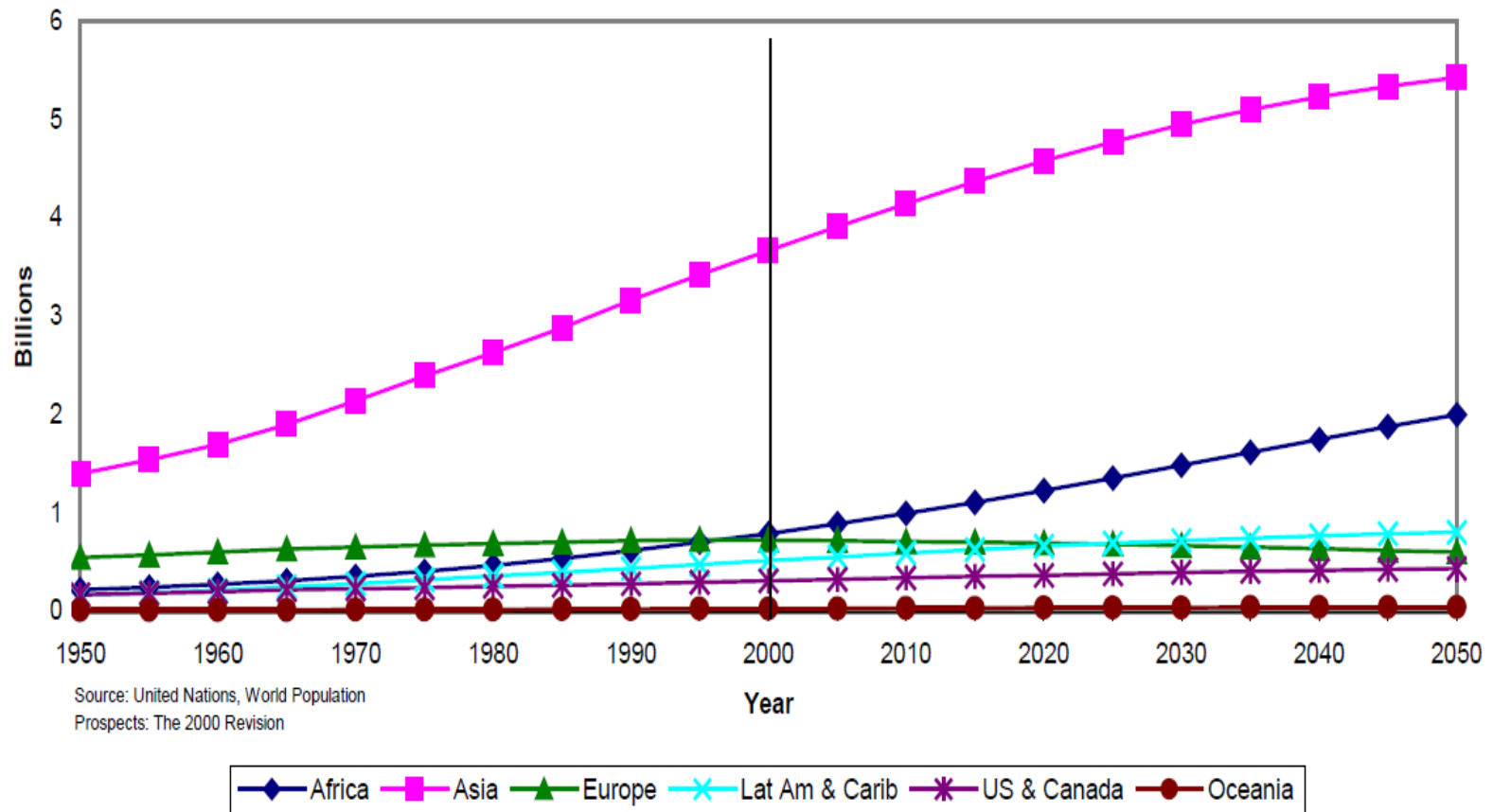
## ○ Fertility of Advanced Countries: US vs. France

ANNUAL BIRTHS PER 1000 POPULATION



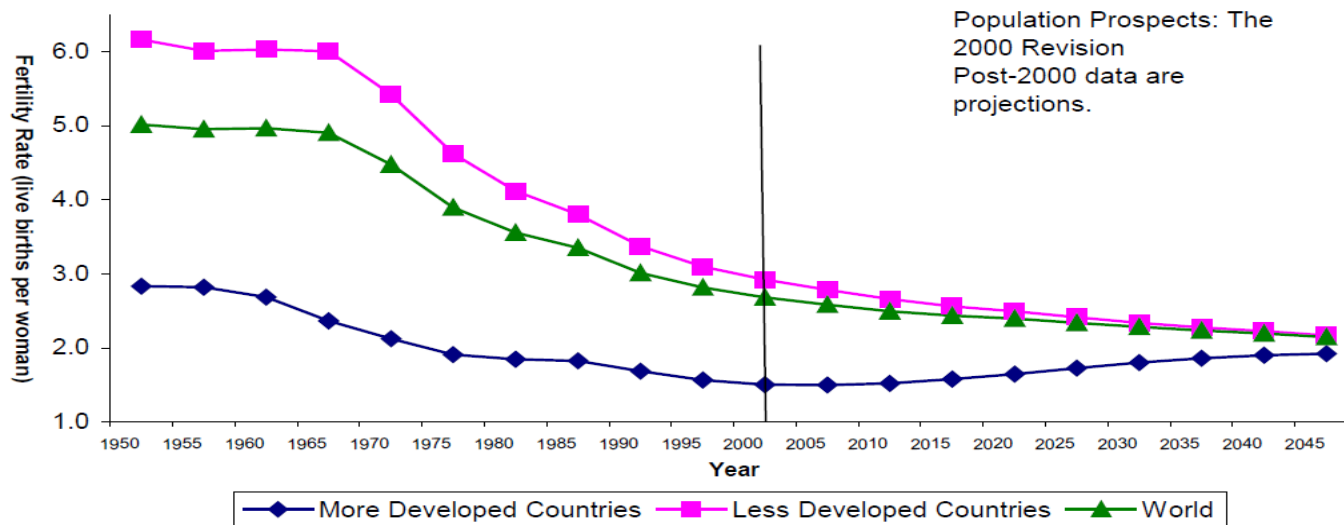
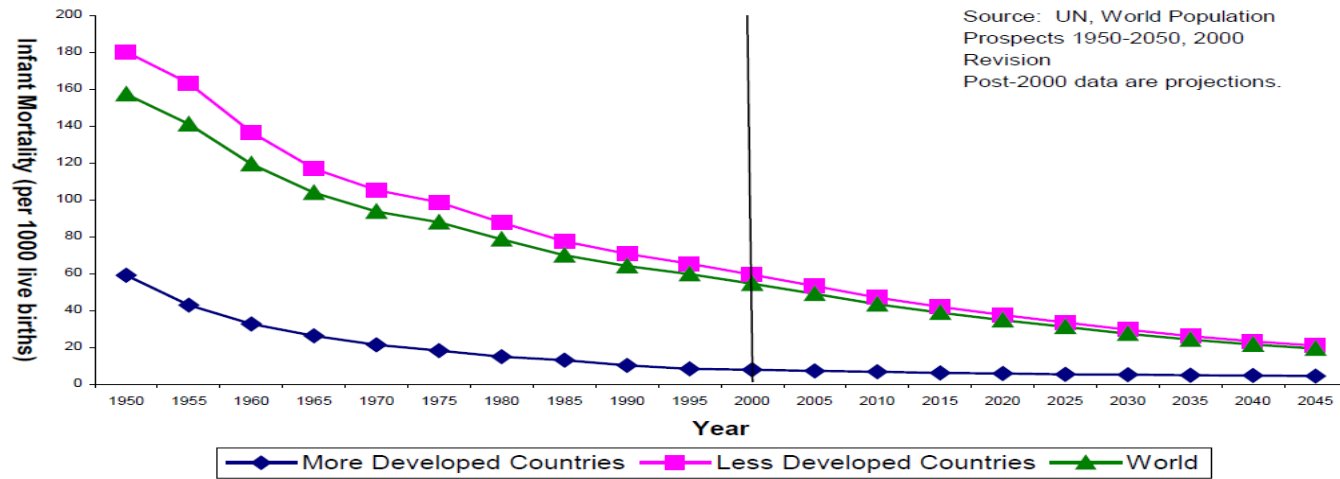
- **France: socialism/high welfare toward poor & children => more moderate decline in total fertility**

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

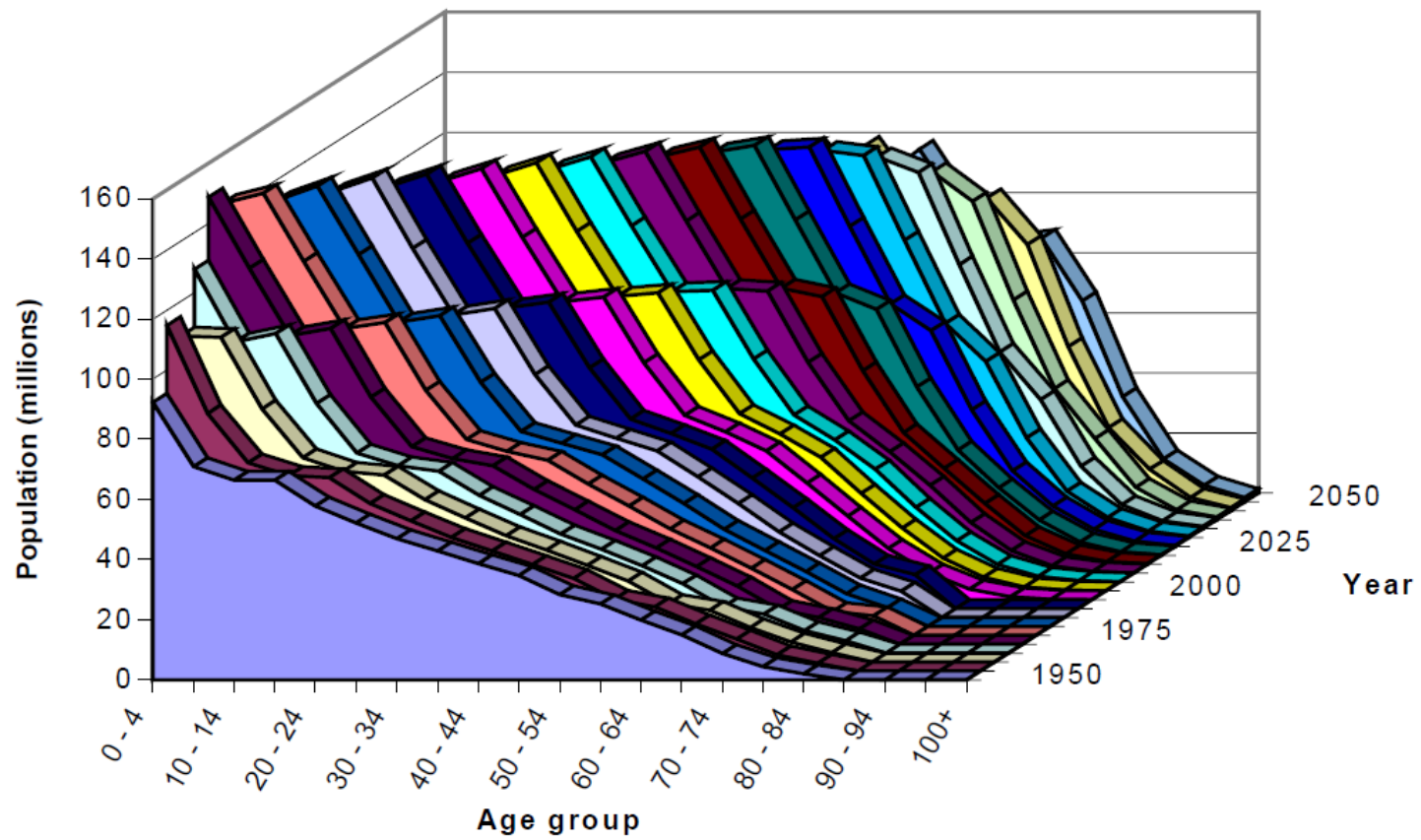


# ○ World fertility/infant mortality project by UN

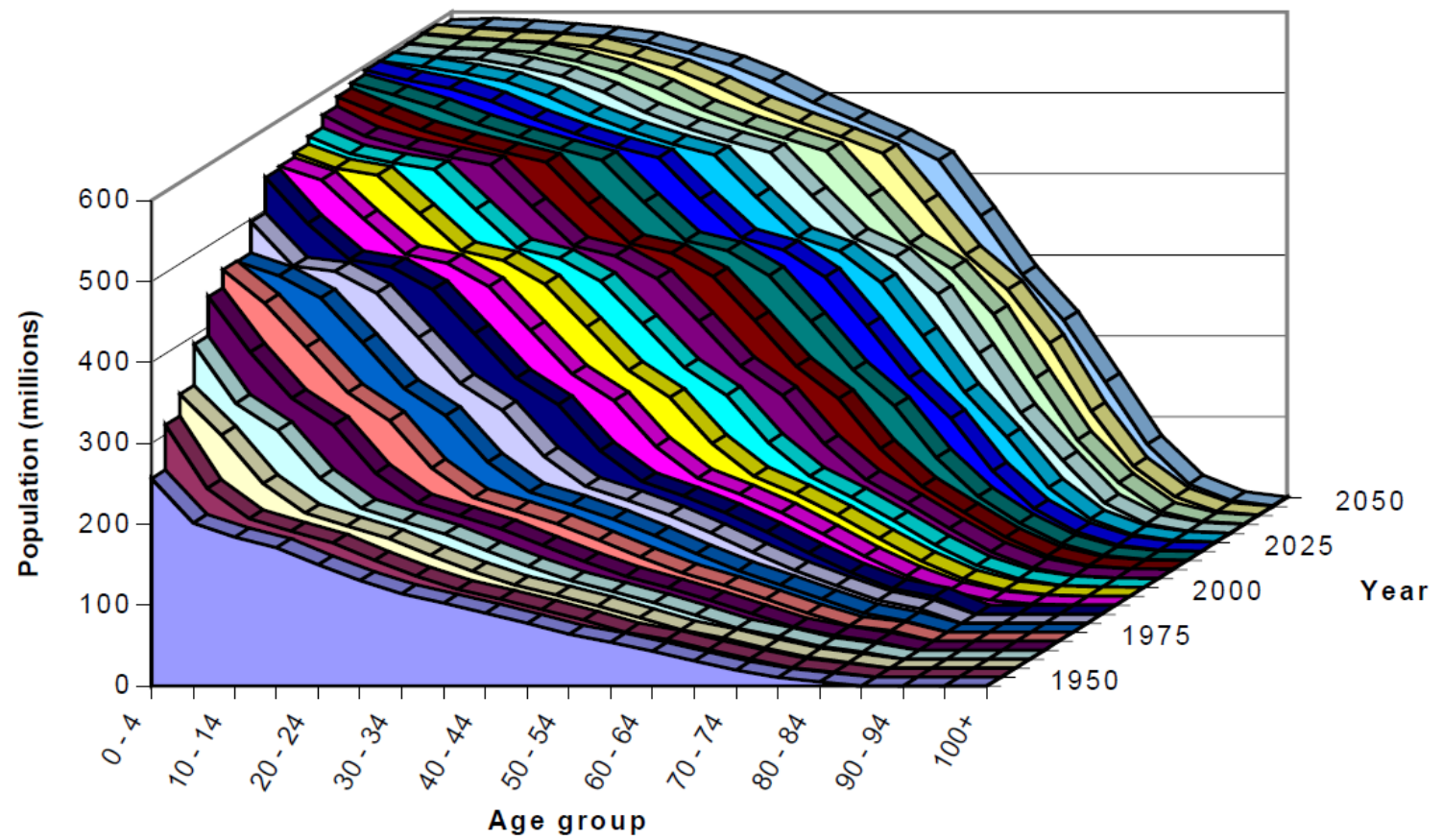
## Infant Mortality Rate at Different Levels of Development



- Population ageing:
  - East Asia

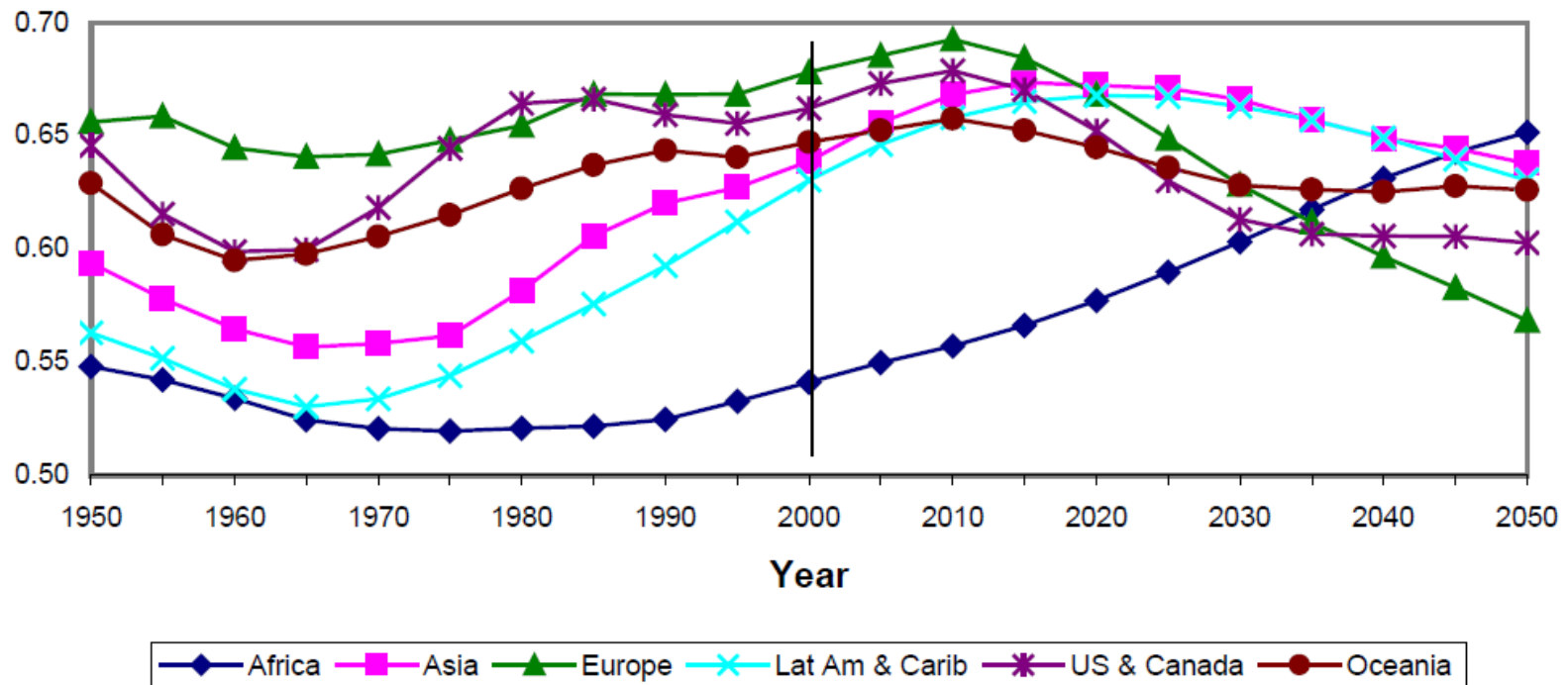


## ■ LDCs



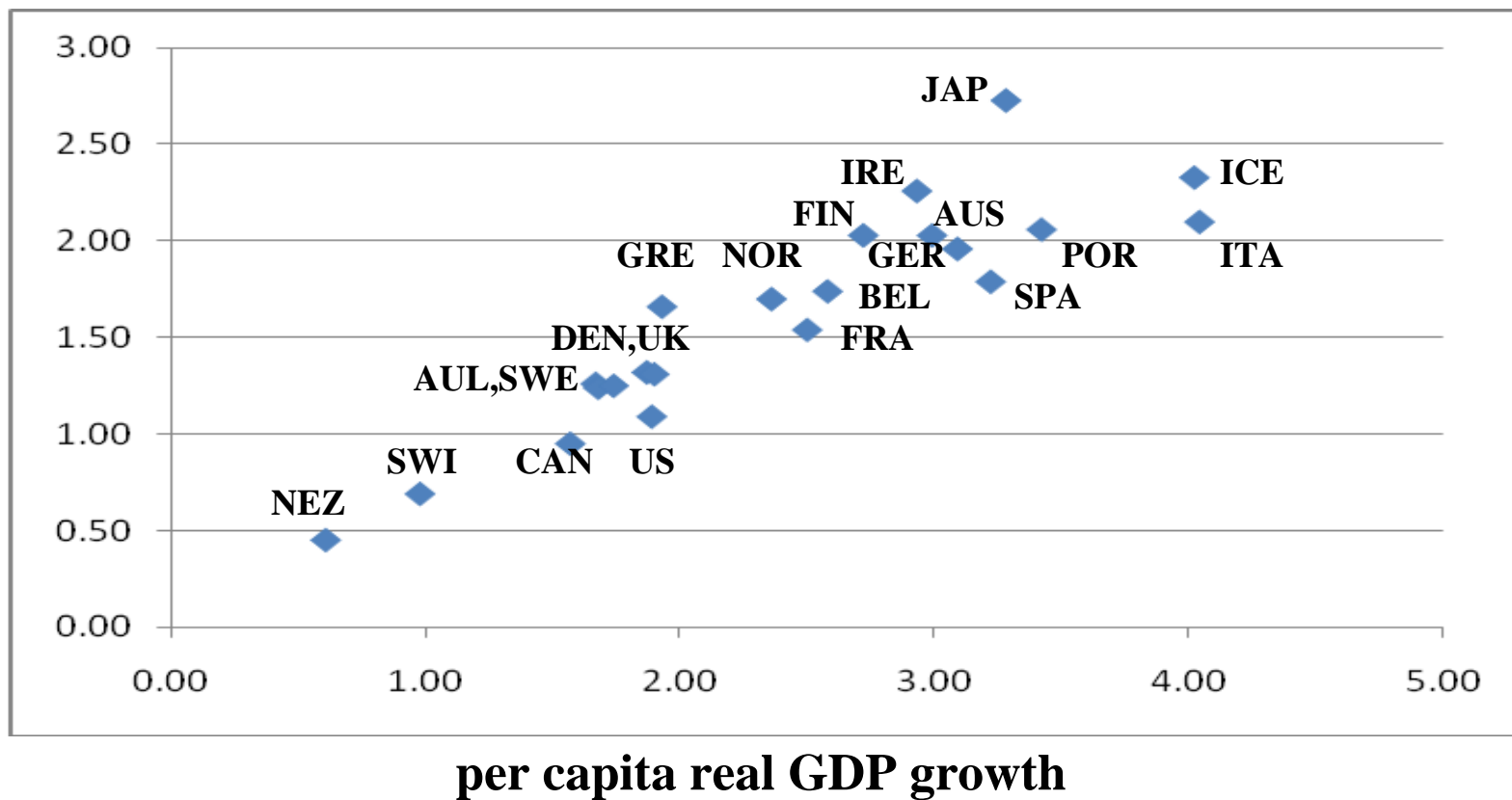


○ Share of working-age population:

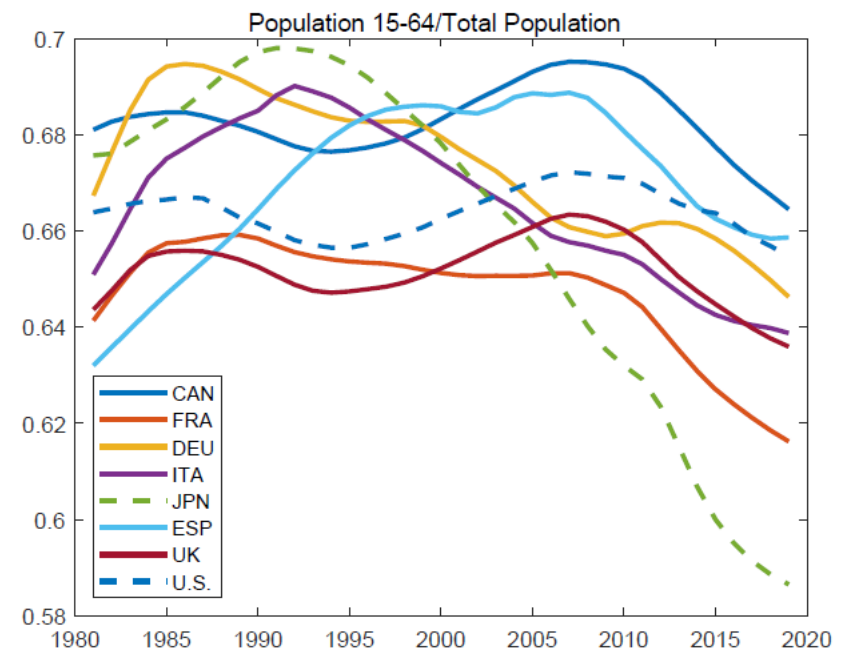
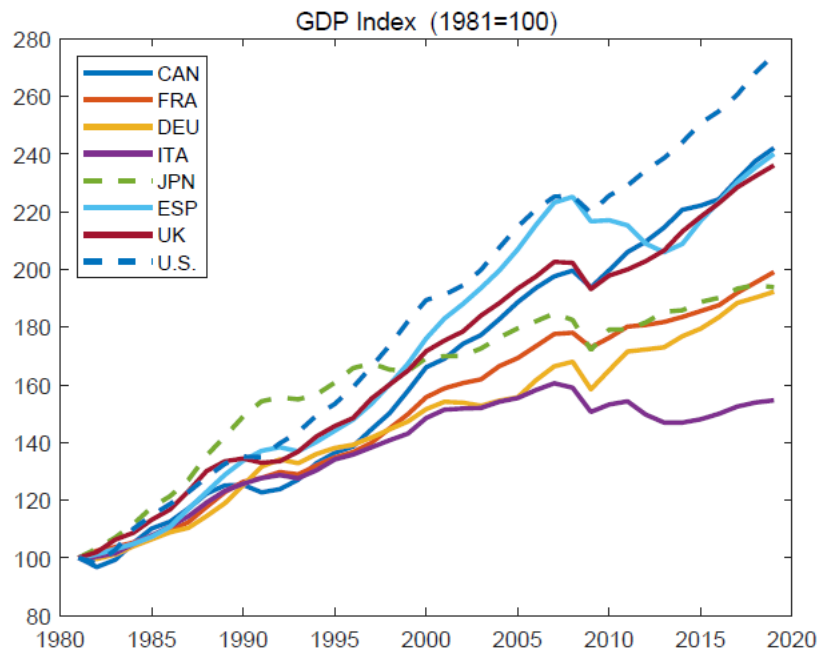


- TFP growth: PWT TFP index

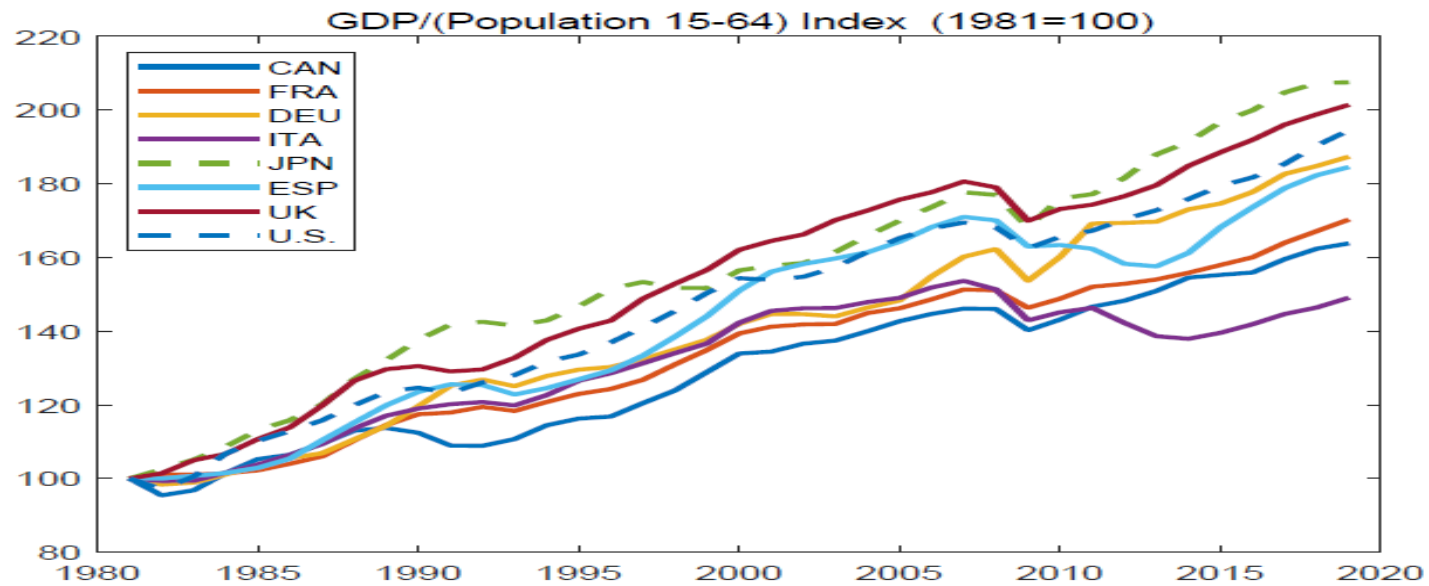
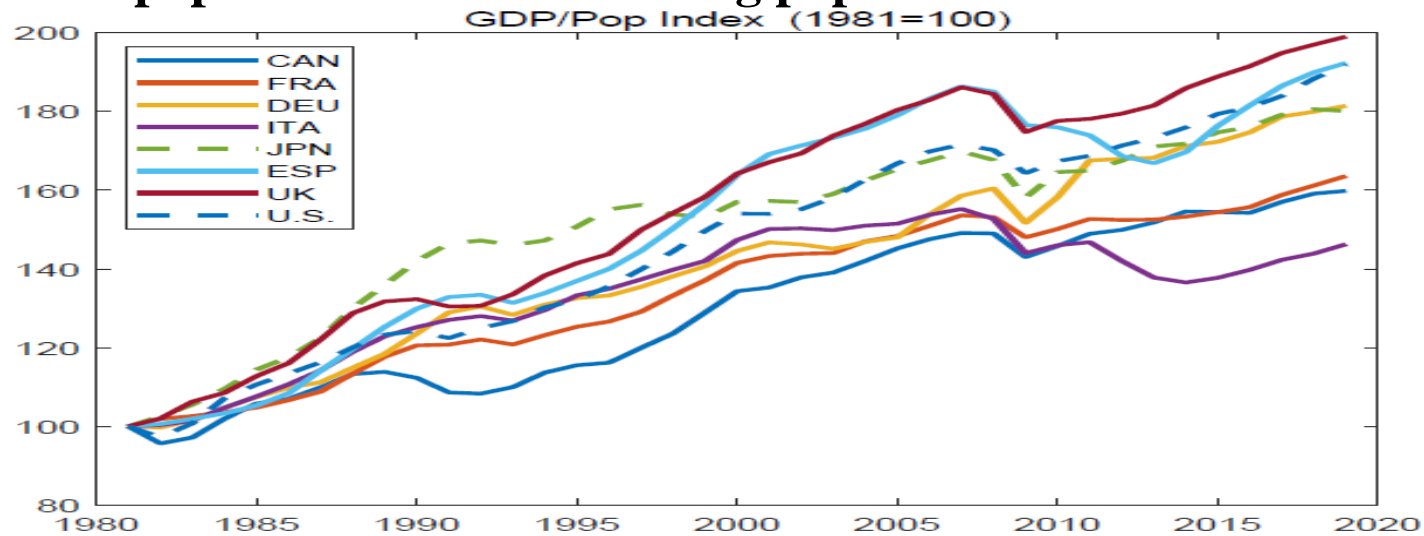
### TFP growth versus per capita real GDP growth



- **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

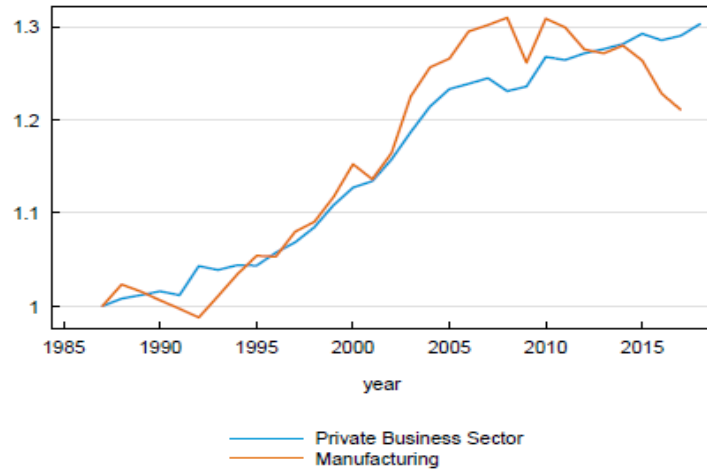
1981-2007	Canada	France	Germany	Italy	Japan	Spain	UK	USA
GDP	2.68	2.24	1.99	1.84	2.41	3.15	2.76	3.19
GDP per Capita	1.57	1.67	1.80	1.71	2.08	2.44	2.43	2.11
Population	1.09	0.56	0.19	0.13	0.32	0.70	0.33	1.05
GDP per Working-age Adult	1.49	1.61	1.84	1.67	2.25	2.10	2.31	2.06
Working-age Population	1.17	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

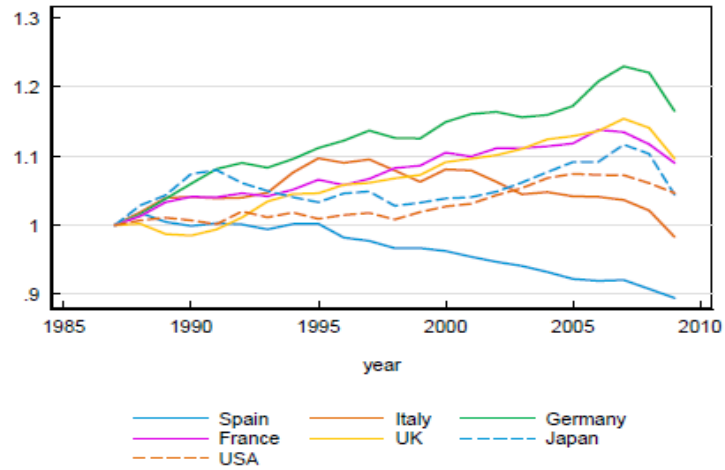
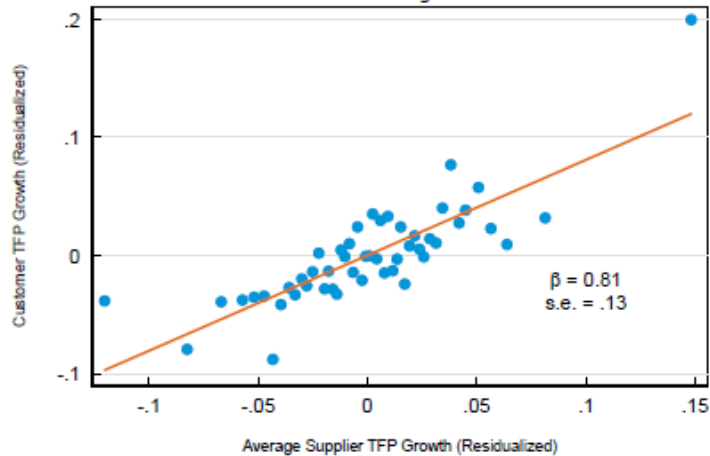
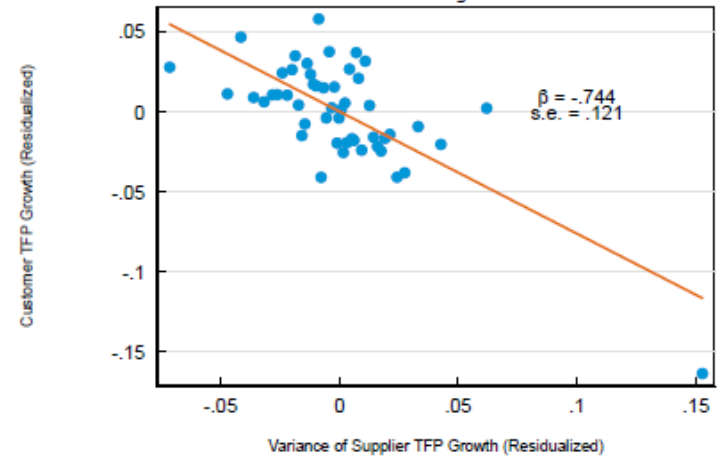
2008-2019	Canada	France	Germany	Italy	Japan	Spain	UK	USA
GDP	1.79	1.03	1.27	-0.23	0.58	0.61	1.43	1.81
GDP per Capita	0.65	0.61	1.16	-0.36	0.68	0.38	0.71	1.11
Population	1.13	0.42	0.11	0.14	-0.10	0.23	0.71	0.70
GDP per Working-age Adult	1.07	1.11	1.35	-0.11	1.49	0.78	1.10	1.34
Working-age Population	0.71	-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)

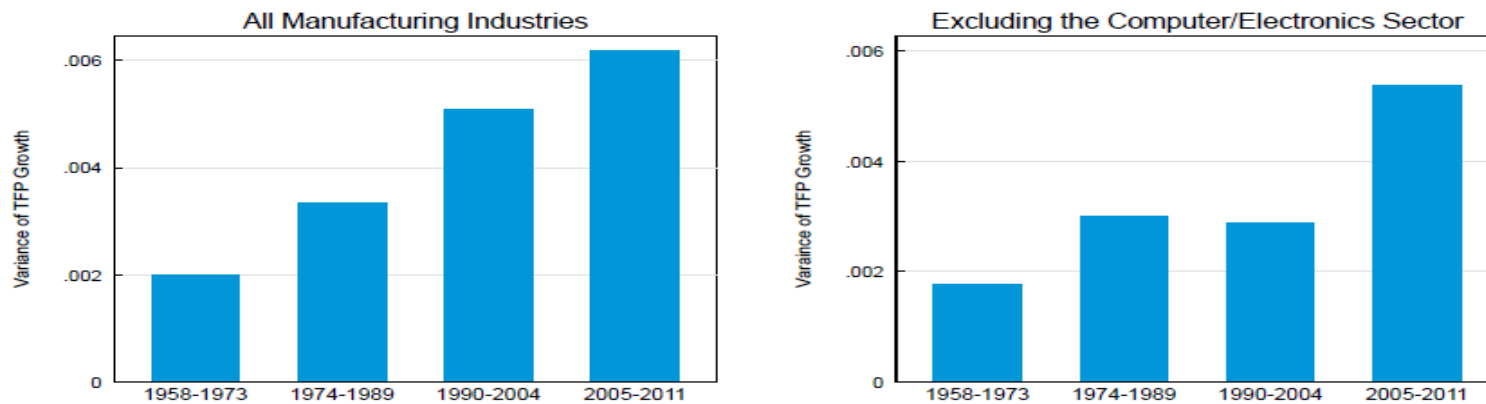
(a) United States



(b) Select OECD Countries

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

## ○ Upstream suppliers matter



	Downstream		Upstream Average		Upstream Variance	
	Mean	SD	Mean	SD	Mean	SD
<b>Panel A: Manufacturing Industries</b>						
Growth in log(TFP)	.018	.152	<b>.033</b>	.075	.022	.048
Growth in log(Patents)	<b>.132</b>	.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
<b>Panel B: All Industries</b>						
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
<b>Panel C: International panel</b>						
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

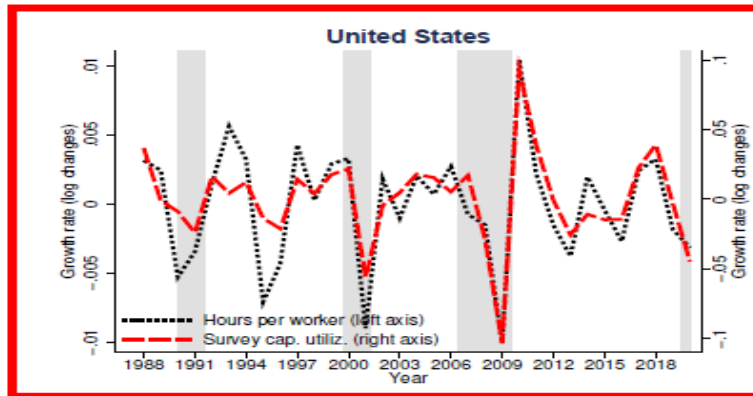
<u>1997–2002 Industries</u>	<u>2002–2007 Industries</u>
Commercial Lithographic Printing	Petroleum Refineries
All Other Basic Organic Chemical	Pharmaceutical Preparation
Printed Circuit Assembly (Electronic Assembly)	Other Communication and Energy Wires
Corrugated and Solid Fiber Boxes	Manifold Business 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



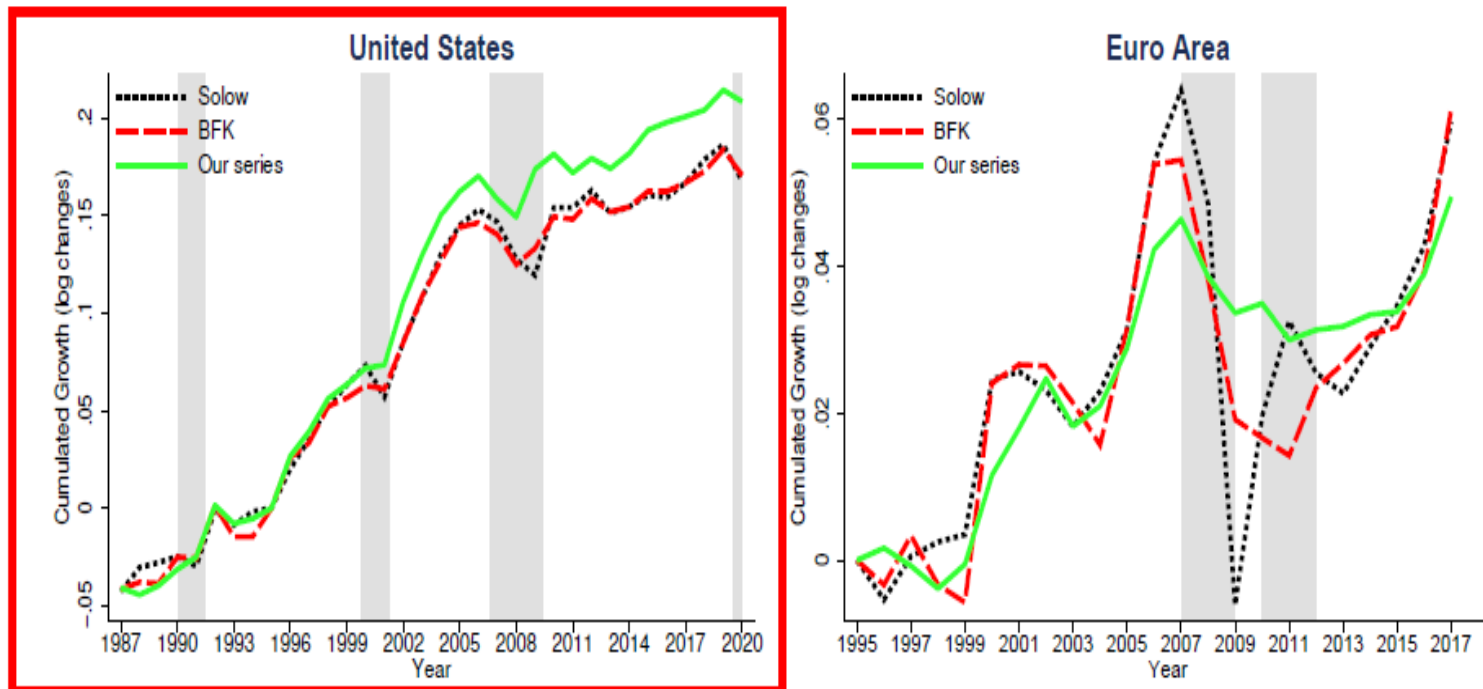
- **Factor utilization and TFP: Comin-Quintana-Schmitz-Trigari (2023)**
  - **Average output elasticities**

	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



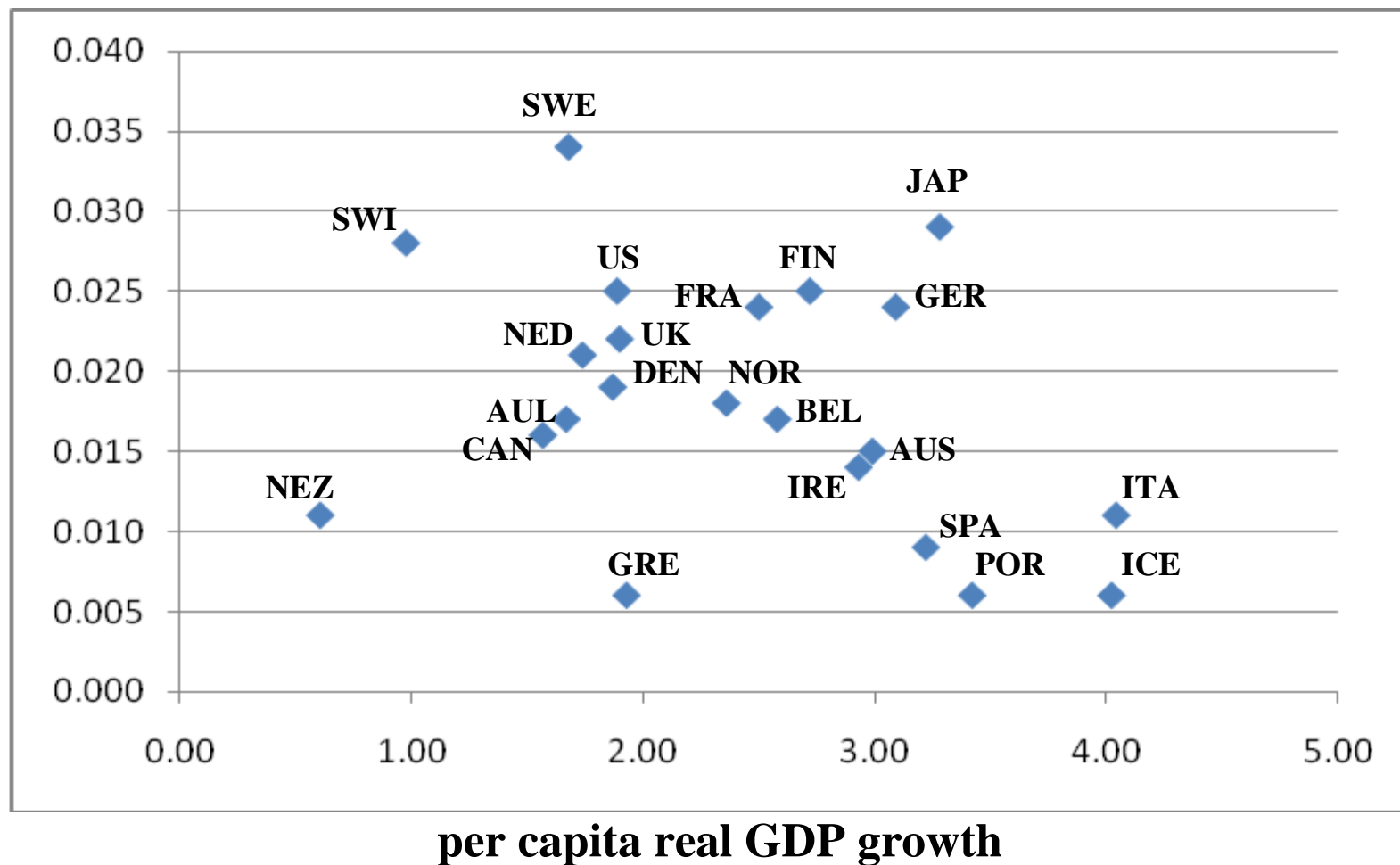
Notes: BFK = Basu-Fernald-Kimball (AER 2006)

○ **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

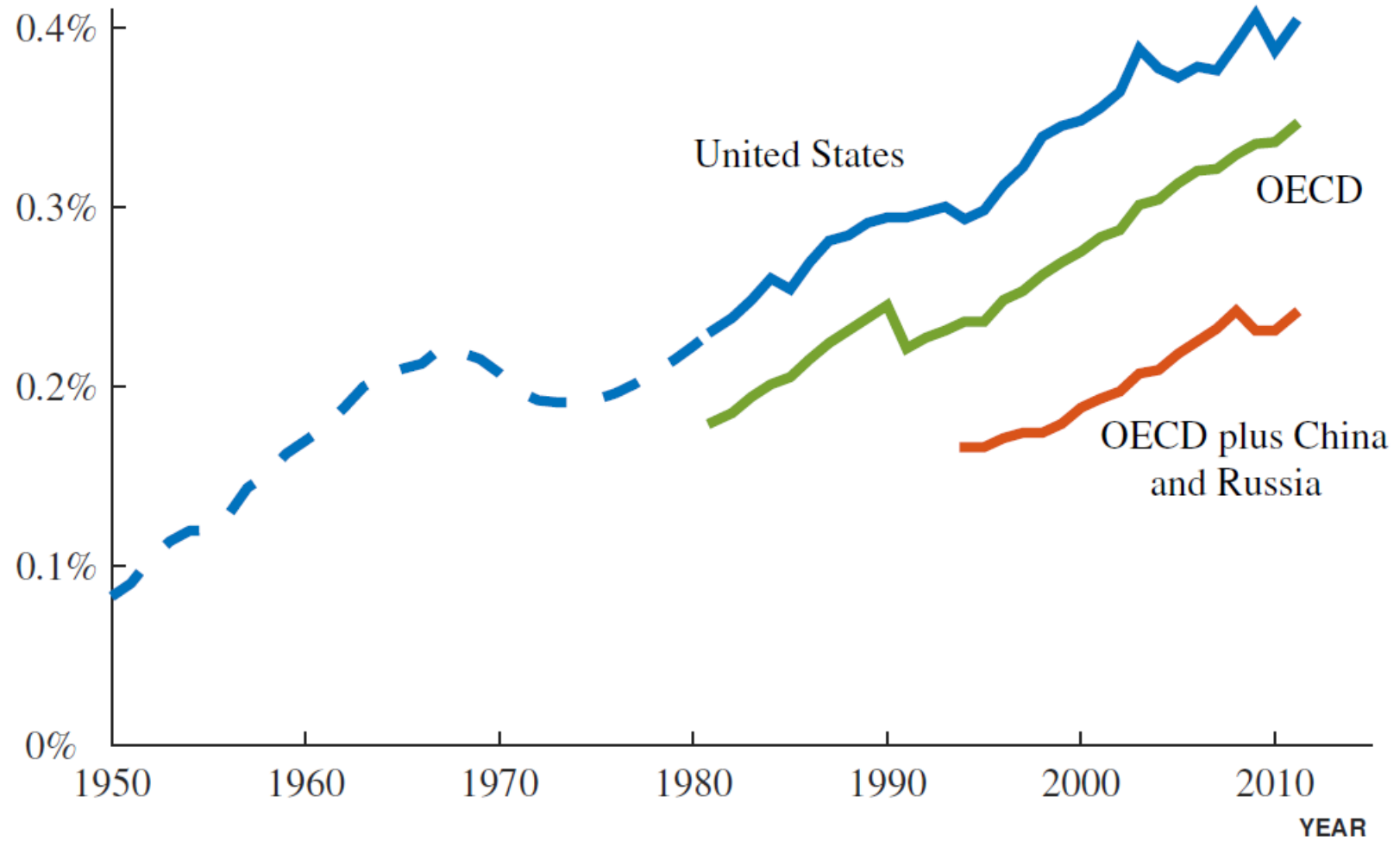
- **R&D: other forms of technical progress (licensing, imitation, technology spillovers, technology assimilation)**

### R&D-GDP Share

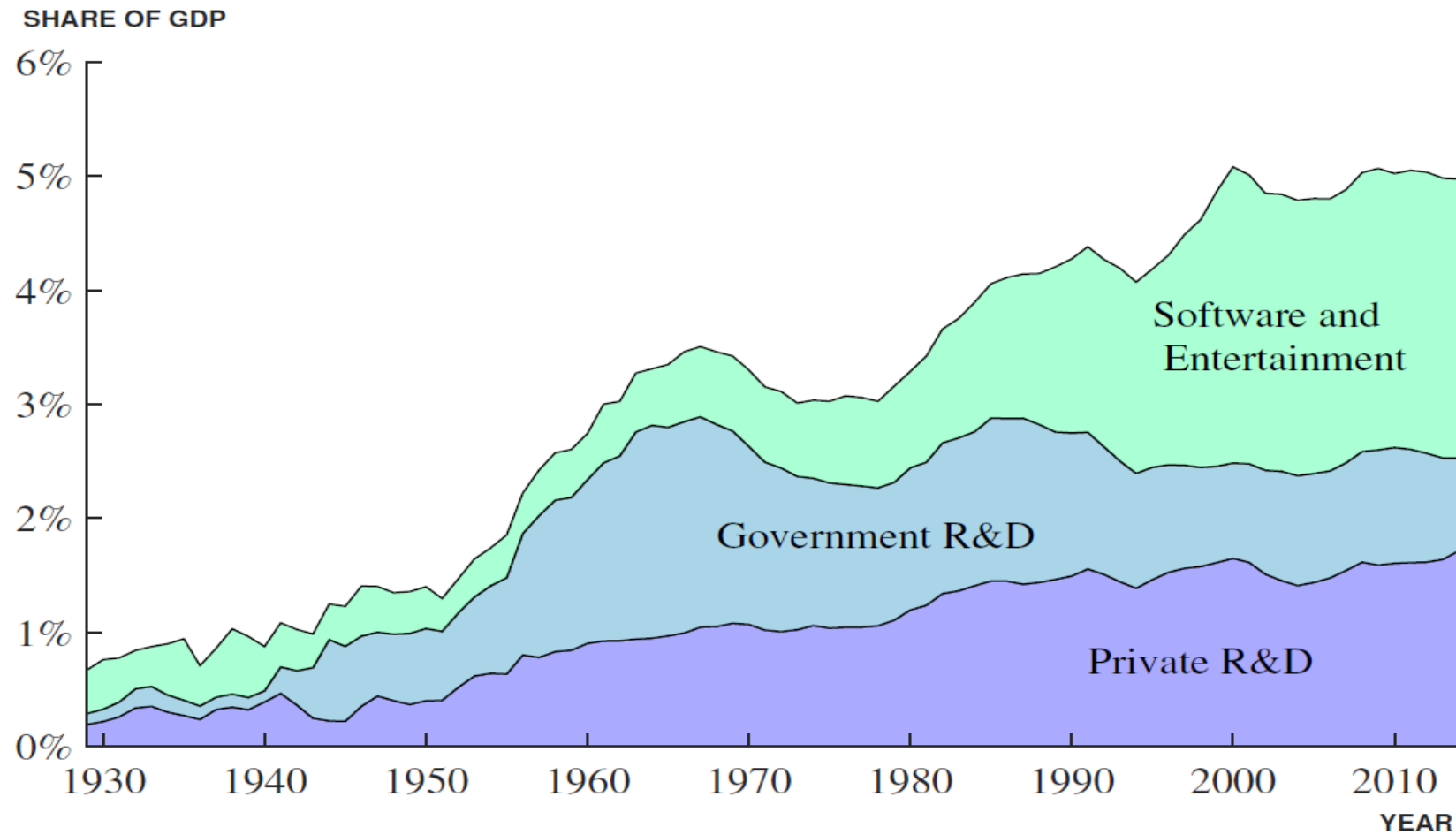


## R&D Employment Share

SHARE OF THE POPULATION

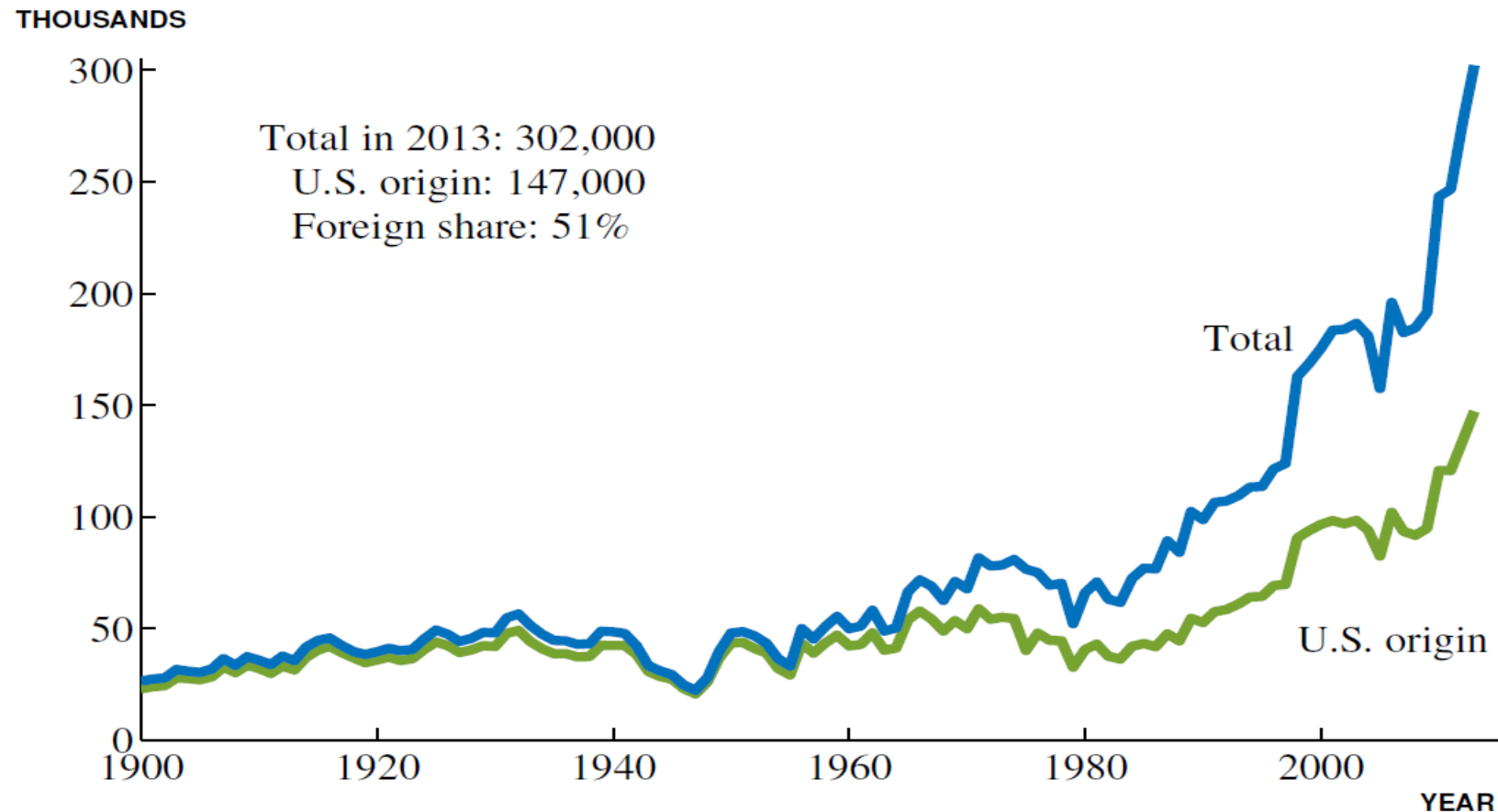


## U.S. R&D Growth



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

## Patents Growth (Granted by USPTO)

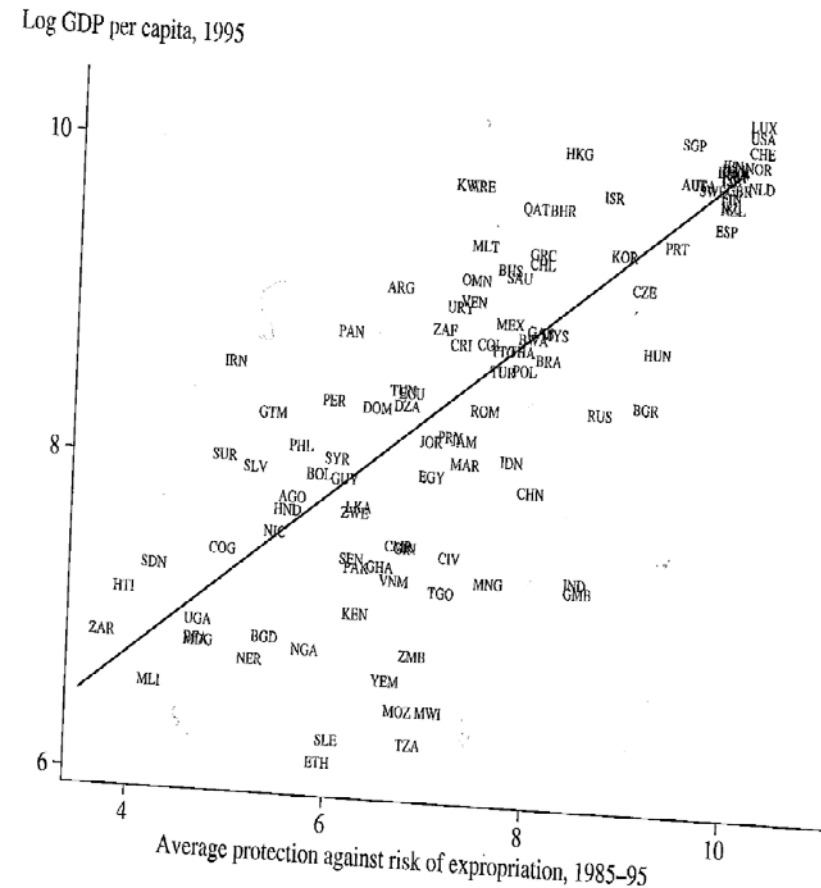
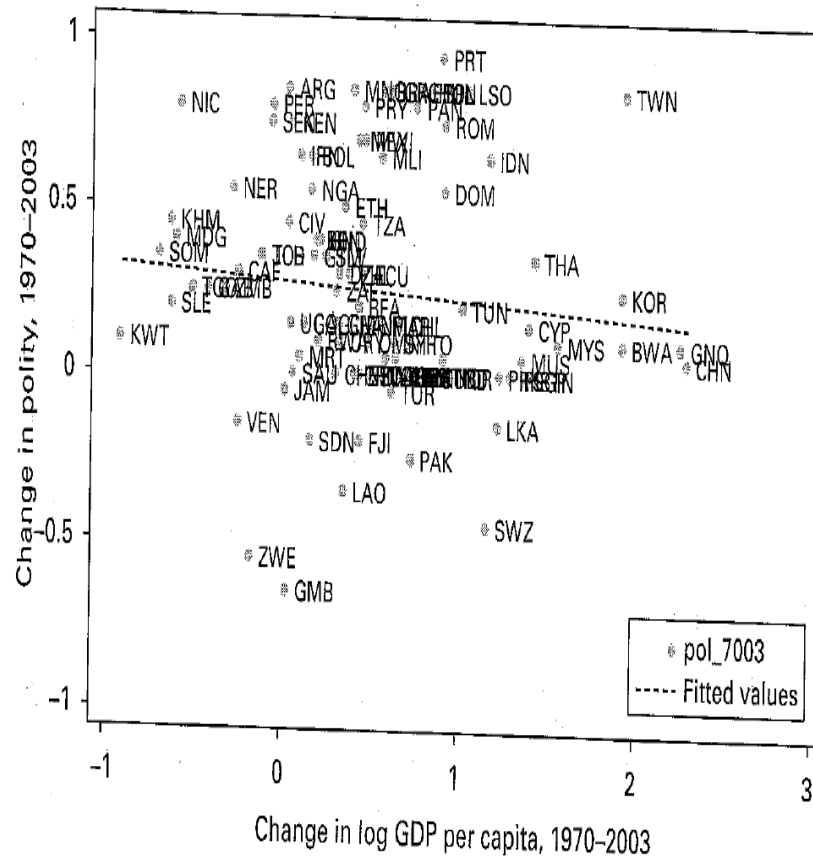


- Patents are highly concentrated geographically:
  - US accounts for half
  - US, UK, Taiwan, South Korea, Germany, Japan together > 80%



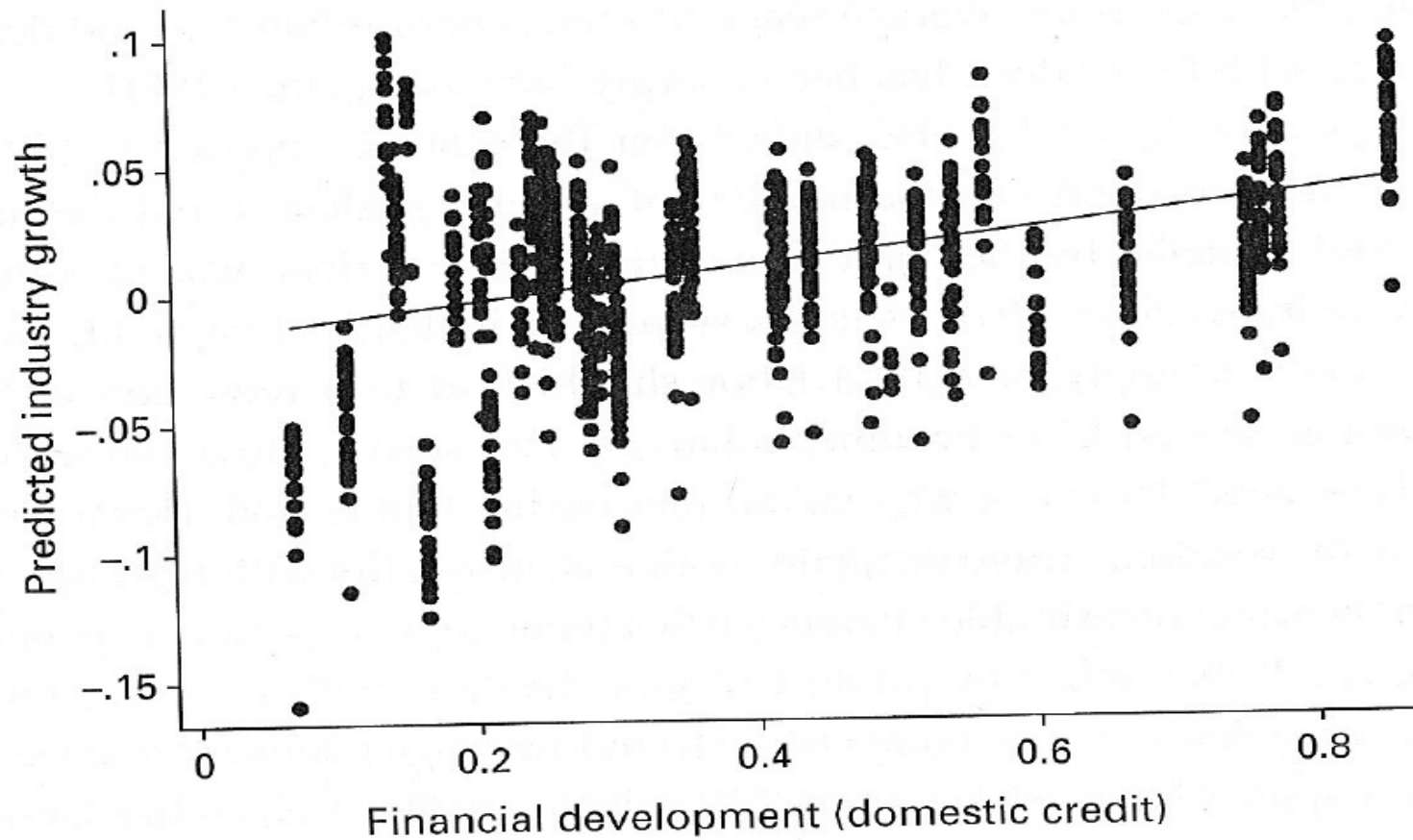


- **Institutions – democracy and IPR protection**



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

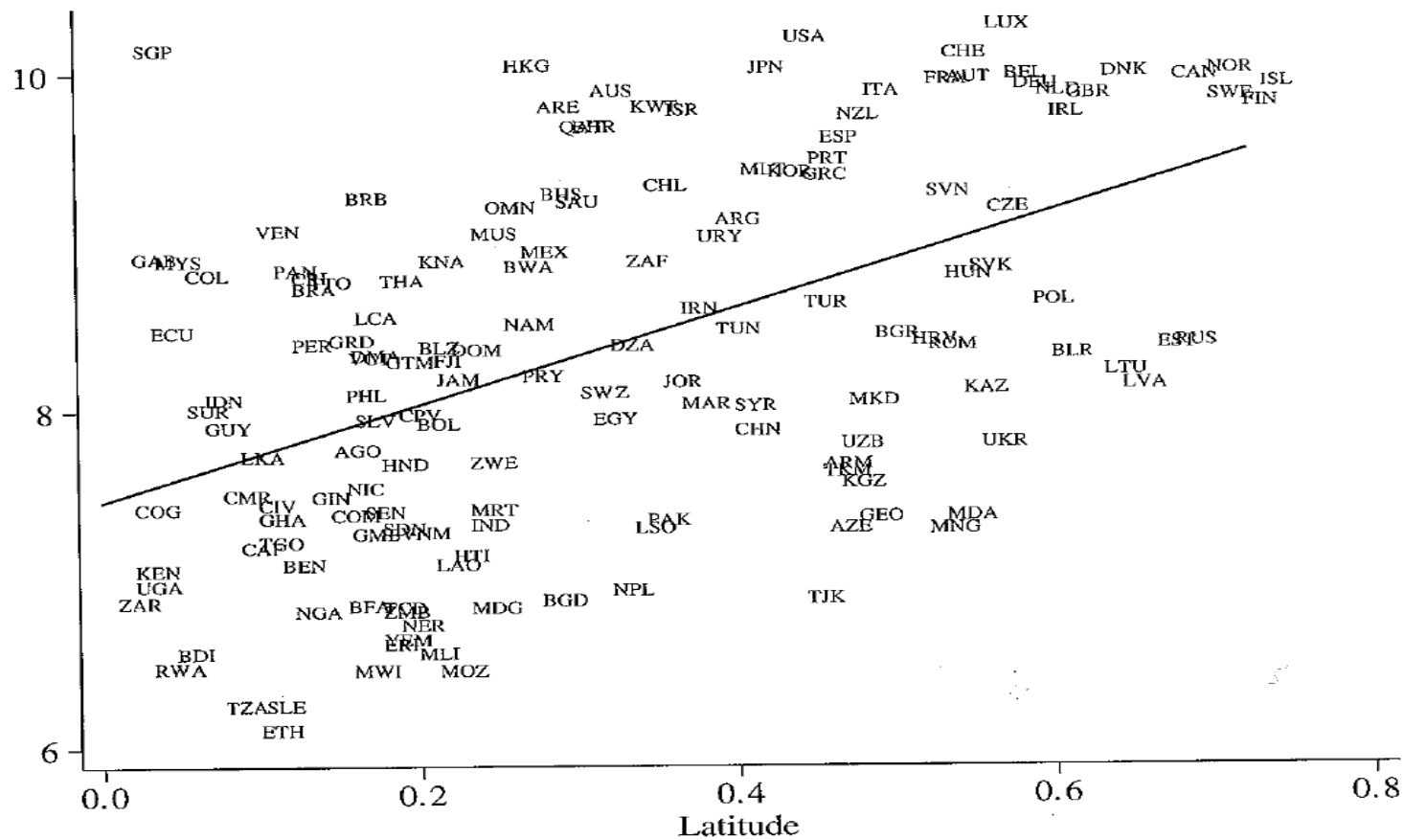
- Finance



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

## • Geography

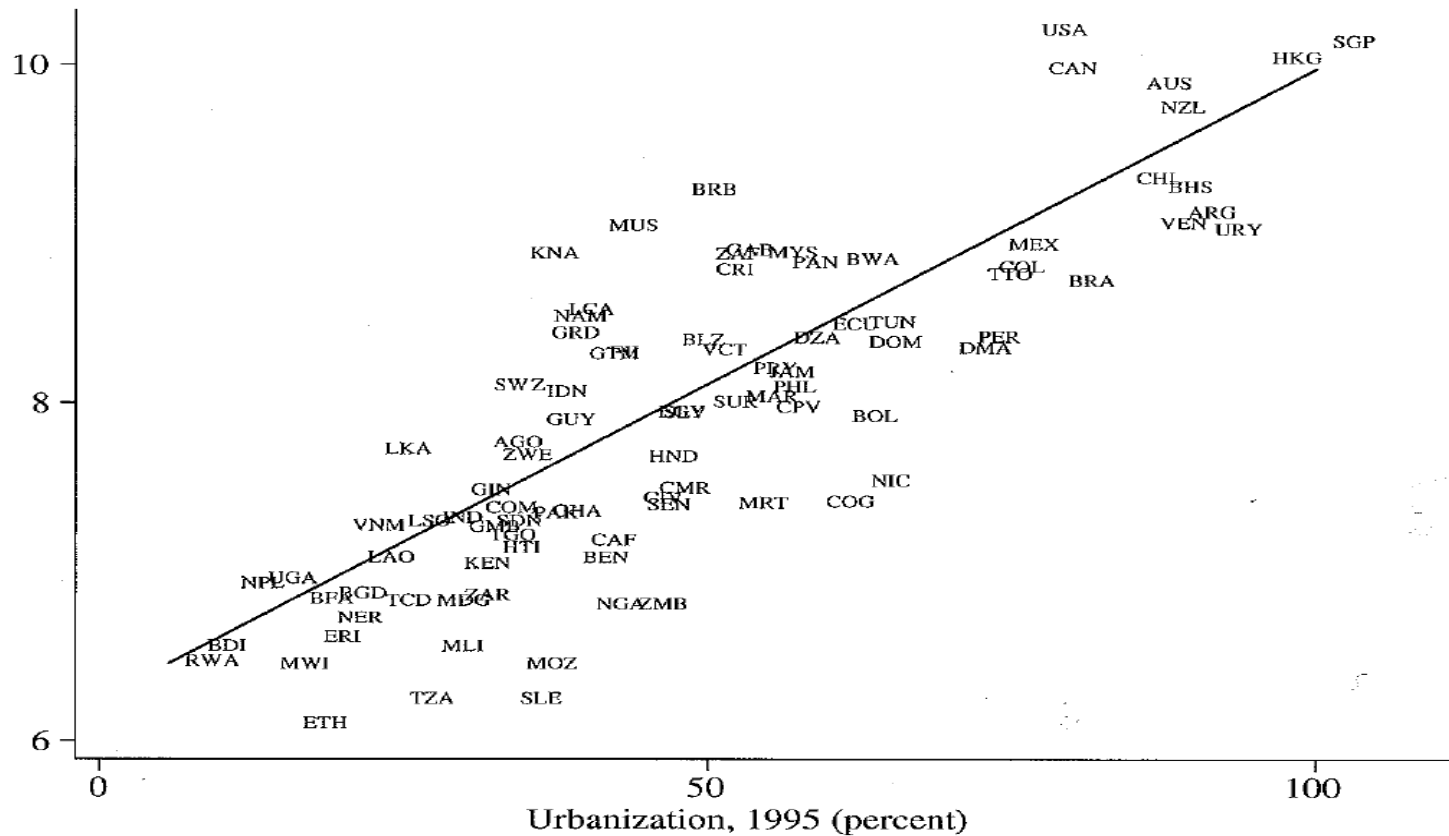
Log GDP per capita, 1995



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

## • Urbanization

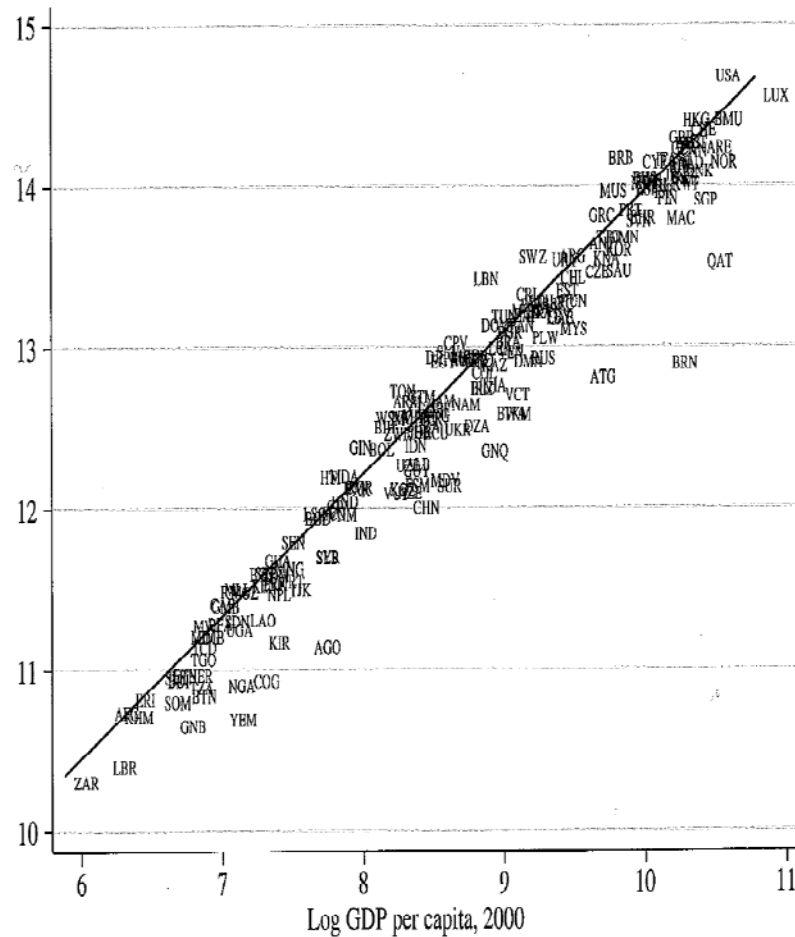
Log GDP per capita, 1995



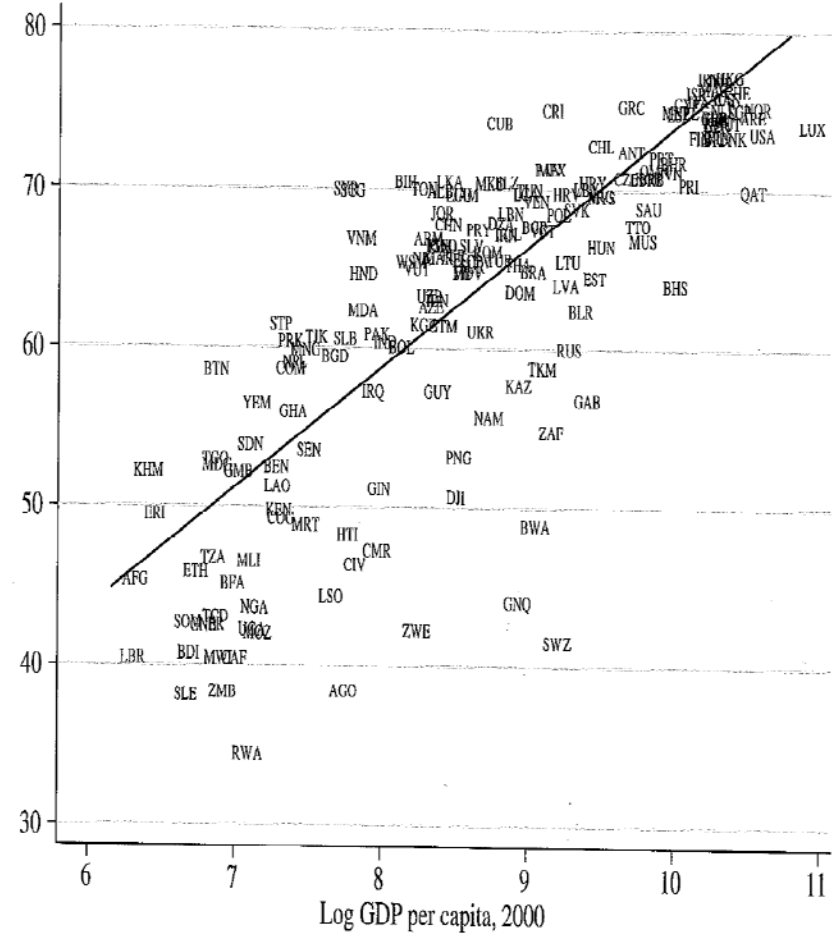
- Agglomeration economies
- Amenities and rise in services
- Reversal if using early urbanization

### 3. Economic growth, consumption and life expectancy

Log consumption per capita, 2000

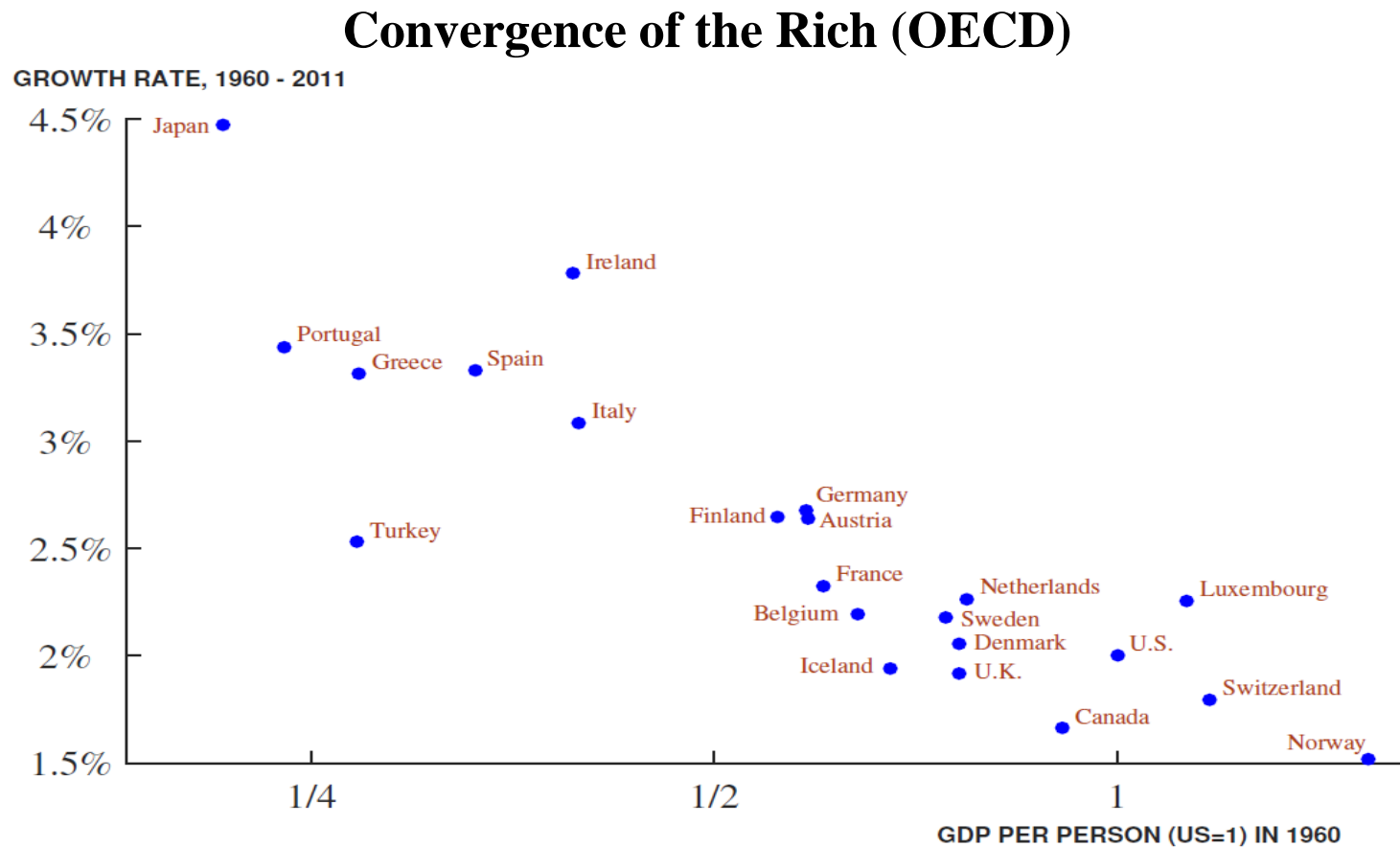


Life expectancy, 2000 (years)



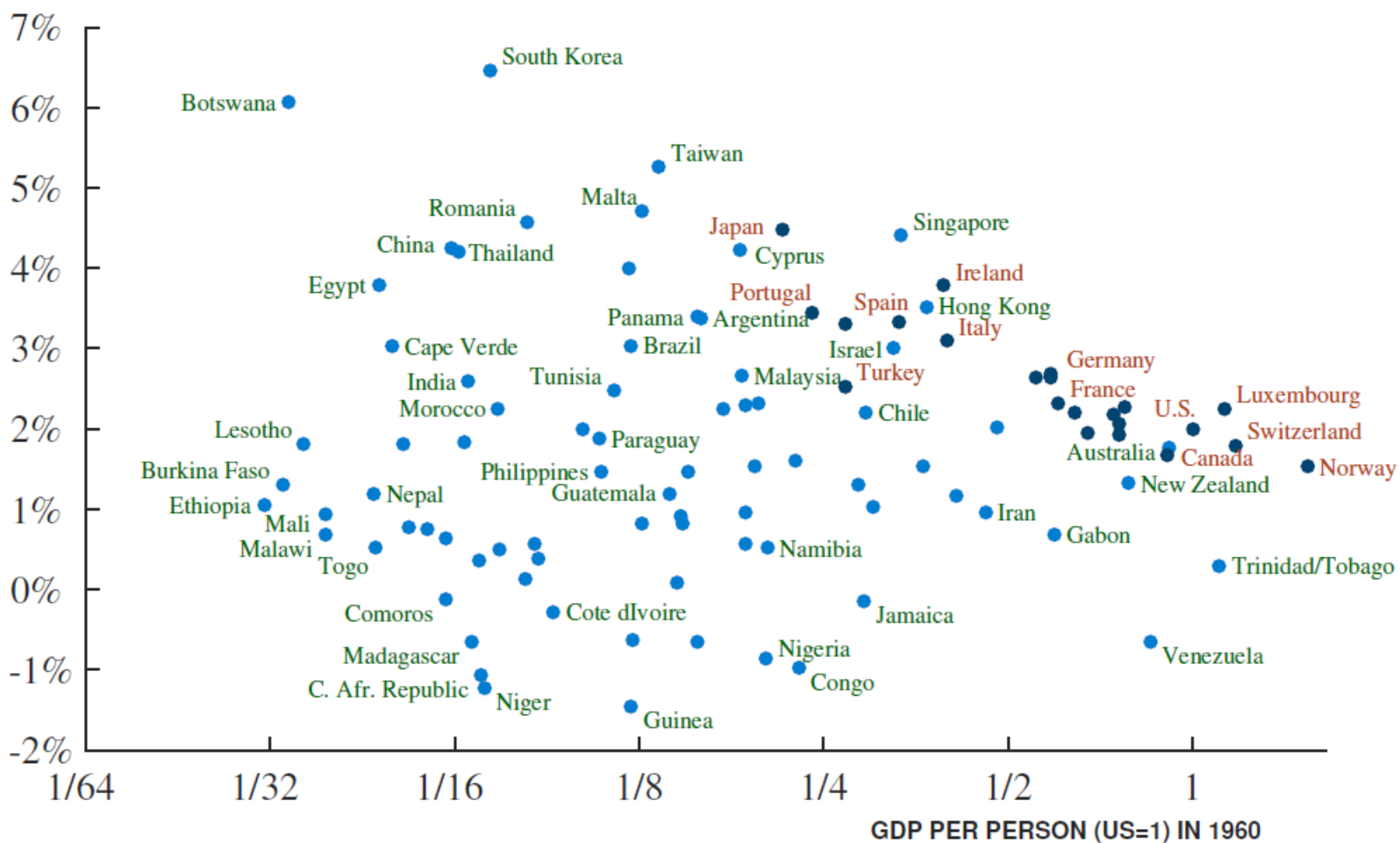
#### 4. Have rich countries suffered growth slowdown?

- Growth rate versus initial level of development



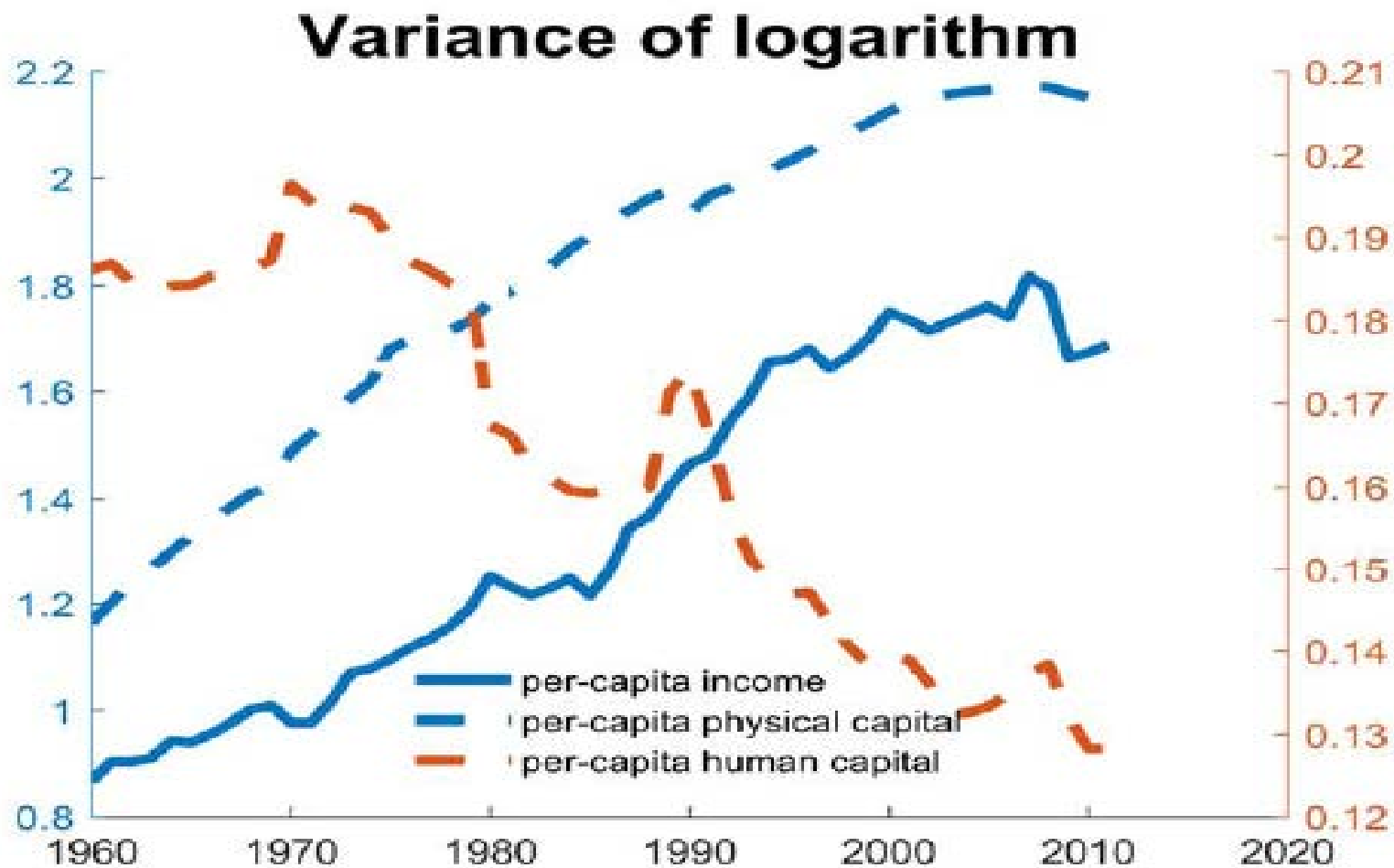
## Nonconvergence of the Poor

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):**

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

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

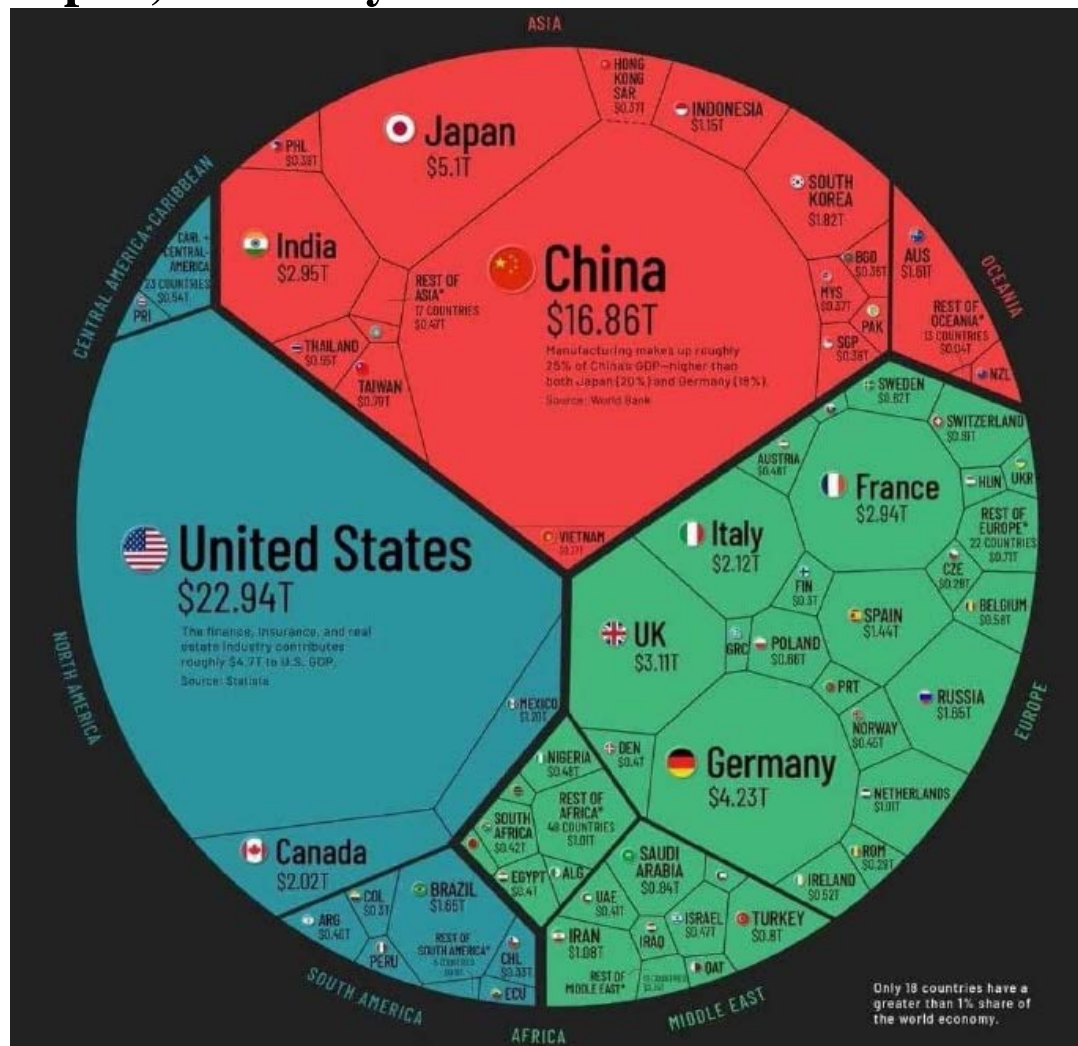
- **$\sigma$ -convergence:** the cross-country per capita real GDP is decreasing over time

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

**Problems:**

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

- World GDP by now: race to the top – only 18 countries have more than 1% share of world GDP, led by two giants, US and China, followed by Japan, Germany and UK



## **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**