Human Capital and the Nature of Technological Progress

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Outline

- Direct effects of human capital.
- The importance of technological progress.
- Human capital and the rate of aggregate technological progress.
- Human capital and the direction of technological progress.
- Institutions, human capital and technology.

The Wealth of Nations

- Tremendous growth in income per capita in many parts of the world over the past 200 years.
  - E.g.: income per capita in the U.S. rose from $1200 in 1990 dollars in 1820 almost $30,000 today.
  - Average income in Western Europe during the same time arose from $1200 to over $18,000.
- But changes not uniform; large disparities across countries.
  - Average income per capita in Africa is around $1300.
  - And much less in some countries; around $550 in Tanzania, Sierra Leone, Niger, and less in Zaire.

Why?

- "Fundamental" answers: institutions, geographic, culture, luck---to be discussed later.
- "Proximate" answers (channels and mechanics):
  1. Physical capital
  2. Human capital
  3. "Efficiency"
- Growth accompanied with more physical and human capital, and greater efficiency.
- Poor countries have less physical capital, human capital and lower efficiency.

Human Capital

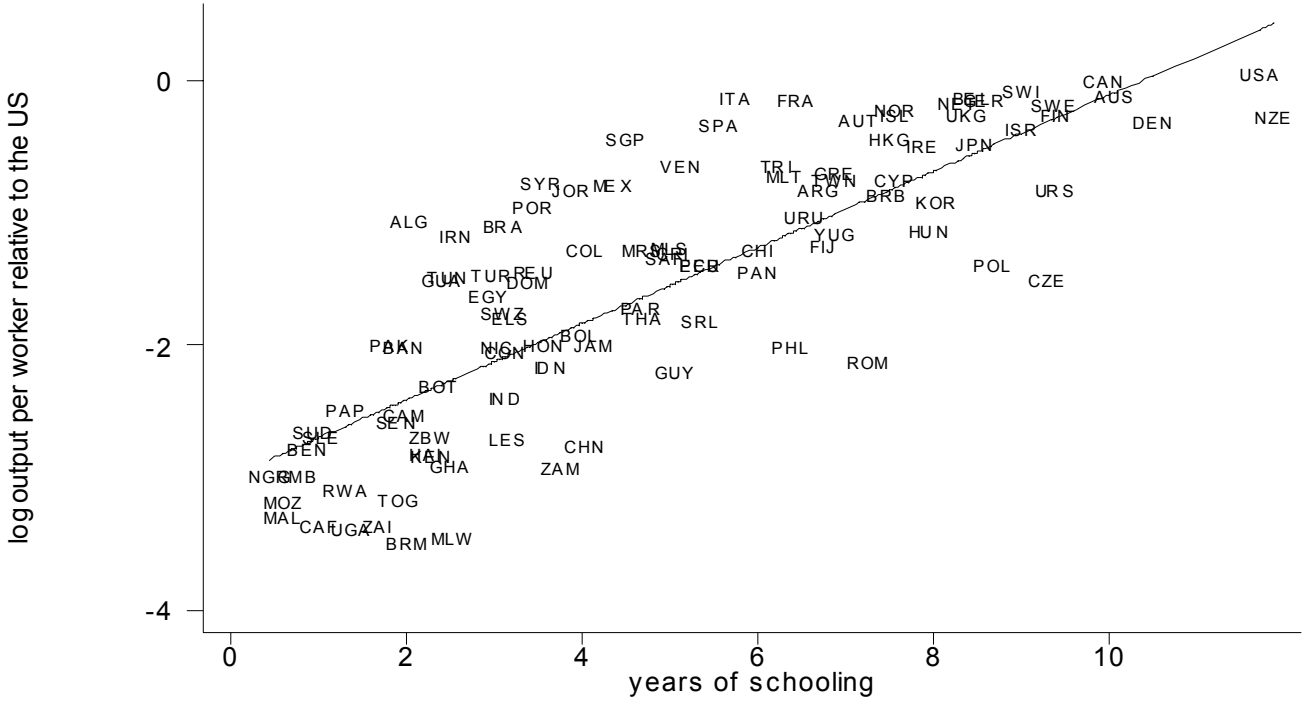
- Skills and competencies of workers.
  - Analogy to physical capital: in the same way as firms investing their machinery and build up human capital, workers invest in their skills to build up human capital.
- A major component: education.
  - Though large part of human capital not in schooling.
- Why do workers invest in human capital?
  - Gary Becker: for market reward (similar two firms investing in new machinery…)
  - greater education → greater market wage.

Human Capital and Growth (1)

- Two types of effects of human capital:
  1. Private returns: workers become more productive and hence are rewarded in the marketplace
  2. External returns: other workers become more productive
     - E.g.: educated workers generate ideas that others can use.
     - Question: if I generate ideas for my colleagues at MIT, it this an external return?
- Both private and external returns contribute to growth. But how much? Engine of growth?
  - Can we account for long-run growth and cross-country differences with human capital differences?

Human Capital and Growth (2)

Figure 1



Human Capital and Growth (3)

- Does the above figure show the causal effect of education on income per capita?
  - Log (income pc)=TR*years of schooling
  - TR around 0.35-0.4 → one more year of schooling associated with 35-40% more income per capita
- Private plus external returns?
- Measuring the private returns:
  - Mincer regressions (Jacob Mincer, Gary Becker):
  - Log(wage)= PR*years of schooling + controls
  - Estimates: PR between 6% and 10%
- So need external returns of 25-35%

Human Capital and Growth (4)

- Measuring external returns
  - Log(wage)= PR*years of schooling
    ER*average schooling + controls
  - Average schooling in the labor market (hence, estimates of local external returns).
  - Estimates using differences across U.S. states: ER of about 7-10%. Still too small.
  - But are these the correct estimates? Higher wages in New York relative to Alabama attract more educated workers (reverse causality) or because of other factors (omitted variables)

Human Capital and Growth (5)

- To estimate ER, need to exploit exogenous variation in state average schooling.
- Acemoglu and Angrist (2000): use past changes in compulsory schooling and child labor laws.
  - When laws tighten, schooling increases (less dropping out from high school)
- Estimates of ER considerably smaller: between 1 and 2%.
- Total returns to schooling between 6-12%.

Human Capital and Growth (6)

- Total returns between 6-12%: Substantial.
- But only sufficient to be part of the major proximate channel for cross-country differences.
- In practice, there is more to human capital than years of schooling;
  - perhaps differences in quality of schooling or on the job training more important.
  - but existing evidence suggests limited effects from these sources.
- These conclusions consistent with Solow accounting for sources of growth over time.

Human Capital and Growth (7)

- Solow accounting: with constant returns to scale prod. function and competitive factor markets:

  Output pc growth= a*human capital pc growth

  + (1-a)*physical capital pc growth

  + total factor productivity growth

  - Where a is the share of labor in GDP (e.g. 0.66%)
  - Total Factor Productivity (TFP) measure of efficiency with which factors are used. Determined by (1) technology; (2) organization of production.
- Results: human capital important, but only part of the story for growth in the long run.
- TFP growth important.

TABLE 10.8
Growth accounting for a sample of 19 countries

	(1) Growth rate of GDP	(2) Contribution from capital	(3) Contribution from labor	(4) TFP growth rate
PANEL A: OECD Countries, 1947–1973				
Canada ($\alpha = 0.44$)	0.0517	0.0254 (49.2%)	0.0088 (17.0%)	0.0175 (33.9%)
France[a] ($\alpha = 0.40$)	0.0542	0.0225 (41.5%)	0.0021 (3.9%)	0.0296 (54.5%)
Germany[a] ($\alpha = 0.39$)	0.0661	0.0269 (40.6%)	0.0018 (2.8%)	0.0374 (56.6%)
Italy[b] ($\alpha = 0.39$)	0.0527	0.0180 (34.0%)	0.0011 (2.0%)	0.0337 (63.5%)
Japan[b] ($\alpha = 0.39$)	0.0951	0.0328 (34.5%)	0.0221 (23.3%)	0.0402 (42.3%)
Netherlands[c] ($\alpha = 0.45$)	0.0536	0.0247 (46.0%)	0.0042 (7.8%)	0.0248 (46.2%)
U.K.[d] ($\alpha = 0.38$)	0.0373	0.0176 (47.2%)	0.0003 (0.9%)	0.0193 (51.9%)
U.S. ($\alpha = 0.40$)	0.0402	0.0171 (42.7%)	0.0095 (23.7%)	0.0135 (33.6%)
PANEL B: G-7 Countries, 1960–1990				
Canada ($\alpha = 0.45$)	0.0410	0.0229 (55.9%)	0.0135 (32.8%)	0.0046 (11.3%)
France ($\alpha = 0.42$)	0.0350	0.0203 (58.1%)	0.0002 (0.5%)	0.0145 (41.4%)
Germany ($\alpha = 0.40$)	0.0320	0.0188 (58.7%)	−0.0025 (−8.1%)	0.0158 (49.4%)
Italy ($\alpha = 0.38$)	0.0410	0.0202 (49.3%)	0.0011 (2.8%)	0.0197 (47.9%)
Japan ($\alpha = 0.42$)	0.0681	0.0387 (56.9%)	0.0097 (14.3%)	0.0196 (28.8%)
U.K. ($\alpha = 0.39$)	0.0249	0.0131 (52.3%)	−0.0010 (−4.2%)	0.0130 (51.9%)
U.S. ($\alpha = 0.41$)	0.0310	0.0140 (45.2%)	0.0129 (41.5%)	0.0041 (13.2%)

(continued)

TABLE 10.8 *(continued)*

	(1) Growth rate of GDP	(2) Contribution from capital	(3) Contribution from labor	(4) TFP growth rate
PANEL C: Latin American Countries, 1940–1980				
Argentina ($\alpha = 0.54$)	0.0360	0.0155 (43.1%)	0.0095 (26.4%)	0.0110 (30.5%)
Brazil ($\alpha = 0.45$)	0.0640	0.0325 (50.8%)	0.0130 (20.3%)	0.0185 (28.9%)
Chile ($\alpha = 0.52$)	0.0380	0.0130 (34.2%)	0.0100 (26.3%)	0.0150 (39.5%)
Colombia ($\alpha = 0.63$)	0.0480	0.0205 (42.7%)	0.0155 (32.3%)	0.0120 (25.0%)
Mexico ($\alpha = 0.69$)	0.0630	0.0255 (40.5%)	0.0145 (23.0%)	0.0230 (36.5%)
Peru ($\alpha = 0.66$)	0.0420	0.0285 (67.9%)	0.0135 (32.1%)	0.0000 (0.0%)
Venezuela ($\alpha = 0.55$)	0.0520	0.0295 (56.7%)	0.0175 (33.7%)	0.0050 (9.6%)
PANEL D: East Asian Countries, 1966–1990				
Hong Kong ($\alpha = 0.37$)	0.0730	0.0309 (42.3%)	0.0200 (27.6%)	0.0220 (30.1%)
Singapore ($\alpha = 0.53$)	0.0850	0.0620 (73.1%)	0.0268 (31.6%)	−0.0040 (−4.7%)
South Korea ($\alpha = 0.32$)	0.1032	0.0477 (46.2%)	0.0435 (42.2%)	0.0120 (11.6%)
Taiwan ($\alpha = 0.29$)	0.0910	0.0368 (40.5%)	0.0362 (39.8%)	0.0180 (19.8%)

Column (1) reports the annualized growth rate of real GDP.

Column (2) is the product of the capital share, α, and the growth rate of quality-adjusted capital input. The number in parentheses is the percentage of the GDP growth rate that is explained by the growth of capital input. The average value of the capital share is reported in parentheses beneath the name of the country.

Column (3) is the product of the labor share, $1 - \alpha$, and the growth rate of quality-adjusted labor input. The number in parentheses is the percentage of the GDP growth rate that is explained by the growth of labor input.

Column (4) shows the growth rate of total factor productivity (TFP). The number in parentheses is the percentage of the GDP growth rate that is explained by TFP growth.

[a] 1950–1973

[b] 1952–1973

[c] 1951–1973

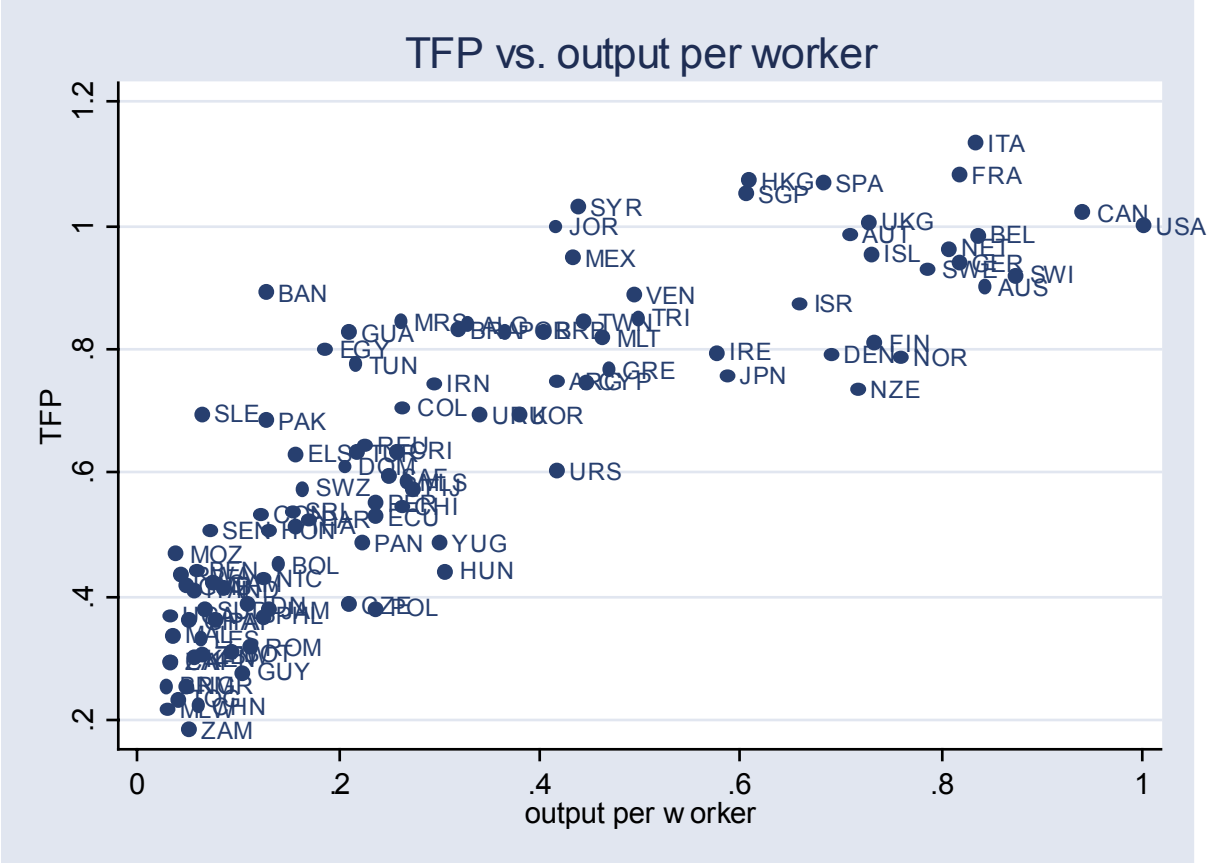
[d] 1955–1973

Source: Panel A: Christenson, Cummings, and Jorgenson (1980); panel B: Dougherty (1991); panel C: Elias (1990); panel D: Young (1994).

Human Capital and Growth (8)

- Hall and Jones: Apply Solow accounting across countries.
- Similar conclusions to over-time growth decompositions:
  - Human capital, physical capital and TFP important
  - Without TFP, much remains unexplained.

Human Capital and Growth (9)



Human Capital and Growth (10)

- Also consistent with experience of African countries; large increases in education with slow growth.
- Pritchett: faster growth in supply of educated workers in many sub-Saharan African countries than growth in wage employment.
  - Little return from education if no jobs or no technology.
- Conclusion: substantial returns to education in general, but no magic bullet; TFP and physical capital growth also necessary.

TABLE 4. Growth of Enrollments and of Wage Employment in Selected Sub-Saharan African Countries

Country	Change in enrollments (thousands)	Change in wage employment (thousands)	Ratio, expansion of enrollment to wage employment	Wage employment as percentage of total labor force
Enrollment growth positive, wage employment falling				
Zambia	446	–4.3	—	13.1
Côte d'Ivoire	323	–7.7	—	9
Enrollment growth exceeds wage employment growth by an order of magnitude				
Sierra Leone	257	8.9	29	4.9
Uganda	225	13.2	17	4.7
Ghana	1312	80	16	3.8
Burkina Faso	351	35.4	10	3.8
Lesotho	142	14.9	10	5.4
Enrollment growth higher by factor of 4				
Senegal	180	45.4	4.0	5.5
Kenya	1709	436	3.9	14.1
Malawi	546	143	3.8	13.7
Rough equality of enrollment and wage sector growth				
Botswana	157	122	1.3	50.4
Zimbabwe	135	111.1	1.2	36.6

Note: Growth rates of enrollments and wage sector growth are calculated from the beginning date of the study estimating Mincerian return to 1990 (or the most recent data).

Source: Bennell (1996), table 5.

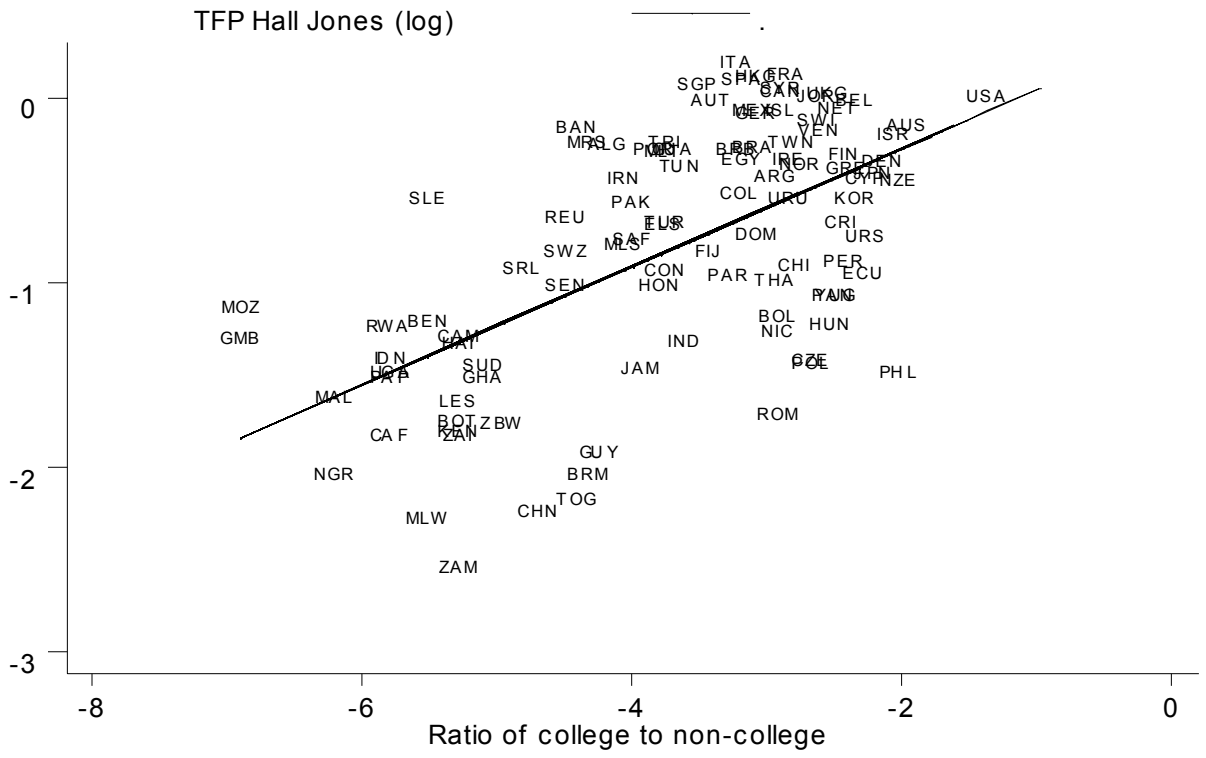
Human Capital and Technology

- Missing link: human capital and technology.
- Traditional role of human capital: increase efficiency of labor.
  - Additional channel: faster technological progress from more skilled scientists (global not local spillovers)
  - Human capital → TFP
- Shultz, Nelson-Phelps: new role of human capital:
  - Increase adaptability, increase ability to deal with new technologies.
  - Human capital → TFP.
  - Foster-Rozensweig: relationship between education and Green Revolution in India.

Technology-Skill Mismatch

- Acemoglu-Zilibotti:
- Less developed countries (LDCs) import technologies designed in the OECD to be used operated by skilled/educated workers.
- Loss of efficiency if workers lack skills.
  - Example of Cummins motor factory in India and Japan.
  - Successful adaptation in Japan, but not in India because of lack of skilled managers and line workers.
- Also slow diffusion of new technologies in LDCs because of lack of skills
- Human capital → TFP for LDCs

Human Capital and TFP (1)



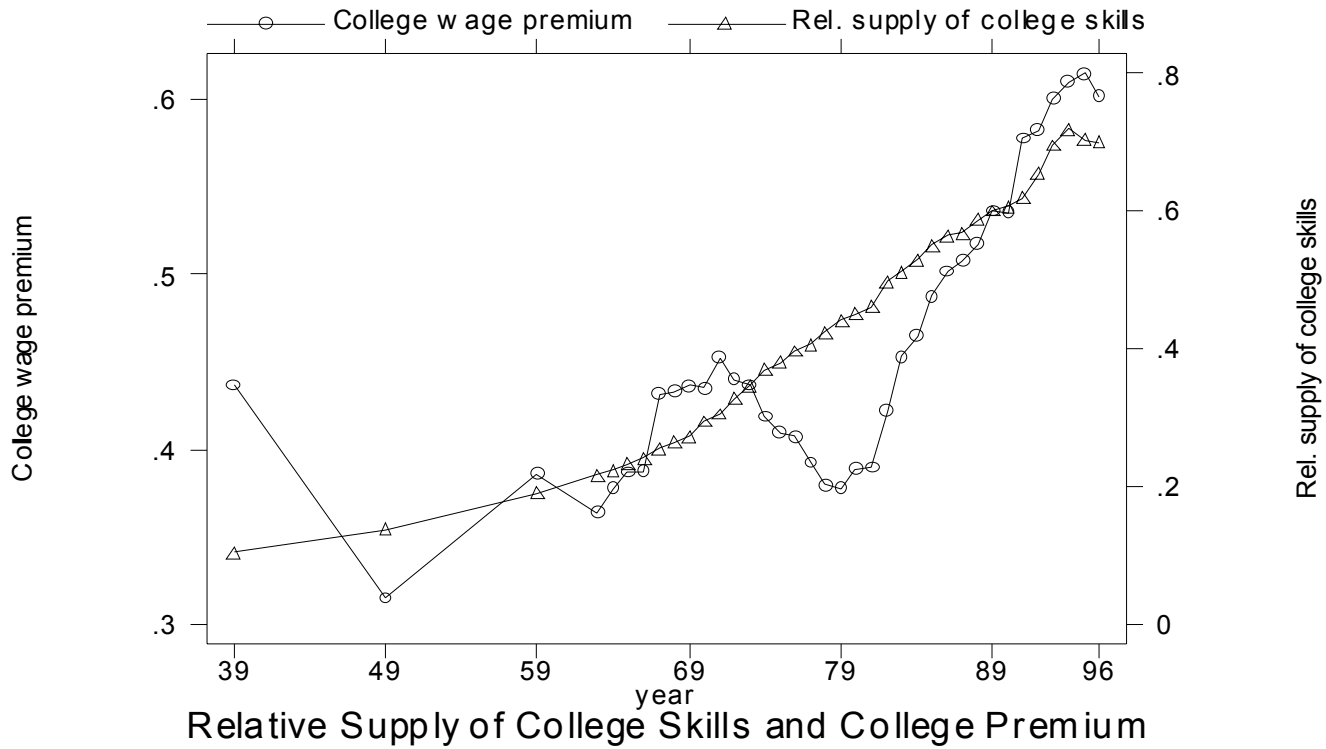
Human Capital and TFP (2)

- Conclusion: direct effect of human capital to economic growth substantial, but not the entire story.
- TFP (technology and efficiency) also important.
- Potential important links from human capital to TFP.
- Future research area: to assess the empirical importance of these links.

Nature of Technology

- Technology not neutral towards different individuals and factors of production.
  - Winners and losers
  - E.g.: British Industrial Revolution; introduction of weaving machines reduced wages of skilled weavers.
  - Technology for skilled and unskilled workers?
- Evidence from the last hundred years: Skill-Biased Technical Change (SBTC).
  - Large increase in supply of education, and a subsequent increase in returns to education.
  - New technologies displacing unskilled workers and increasing the employment of skilled workers.

SBTC



Relative Supply of College Skills and College Premium

Understanding SBTC

- Why has new technology been skill biased?
- Perhaps in the nature of technology?
  - New technologies replace routine tasks and require abstract skills.
  - Nelson-Phelps: introduction of new technologies favors skilled workers.
  - But many new technologies of the 19th century were skill-replacing…
- Perhaps the nature of technology adapts to circumstances…
- Directed Technical Change hypothesis (Acemoglu, 1998, 2001).

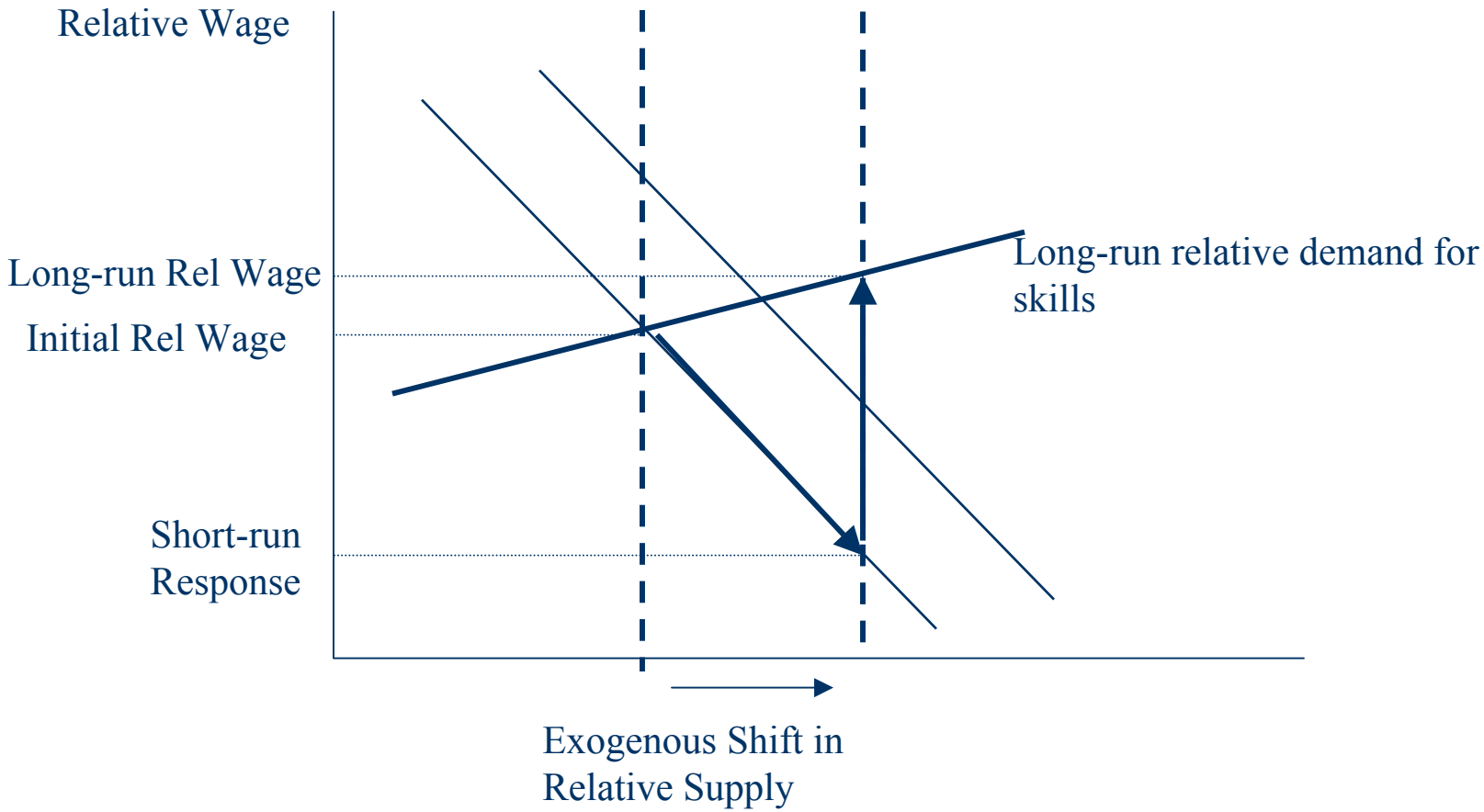
Directed Technical Change (1)

- The direction of technological progress endogenous and responds to profit incentives.
  - E.g.: introduce and develop personal computers rather than scanners if the former more profitable.
- Key determinant of profitability: market size.
  - When more workers use a particular technology, more profitable to develop, market and introduce it.
  - Personal computers more profitable than scanners if more workers to utilize them.

Directed Technical Change (2)

- More skilled/educated workers around, market size for skill-biased technologies larger.
- Technology becomes more skill biased endogenously.
  - The large increase in college-educated work force leading to faster skill-biased technical change.
  - Implications for the relationship between supply of skills and returns to education.

Directed Technical Change (3)



Directed Technical Change (4)

- Human capital determines the nature of technology
- Potential explanation for the nature of technological progress
  - Recent past and during the entire 20th century, increase in the supply of skills → skill-biased technologies
  - During the industrial revolution, increase in the supply of unskilled workers → skill-replacing technologies
- Potential problems:
  - Low-skill workers potentially excluded from benefits of new technologies → greater inequality
  - For LDCs: new technologies becoming more and more skilled, and thus less and less appropriate for their needs.

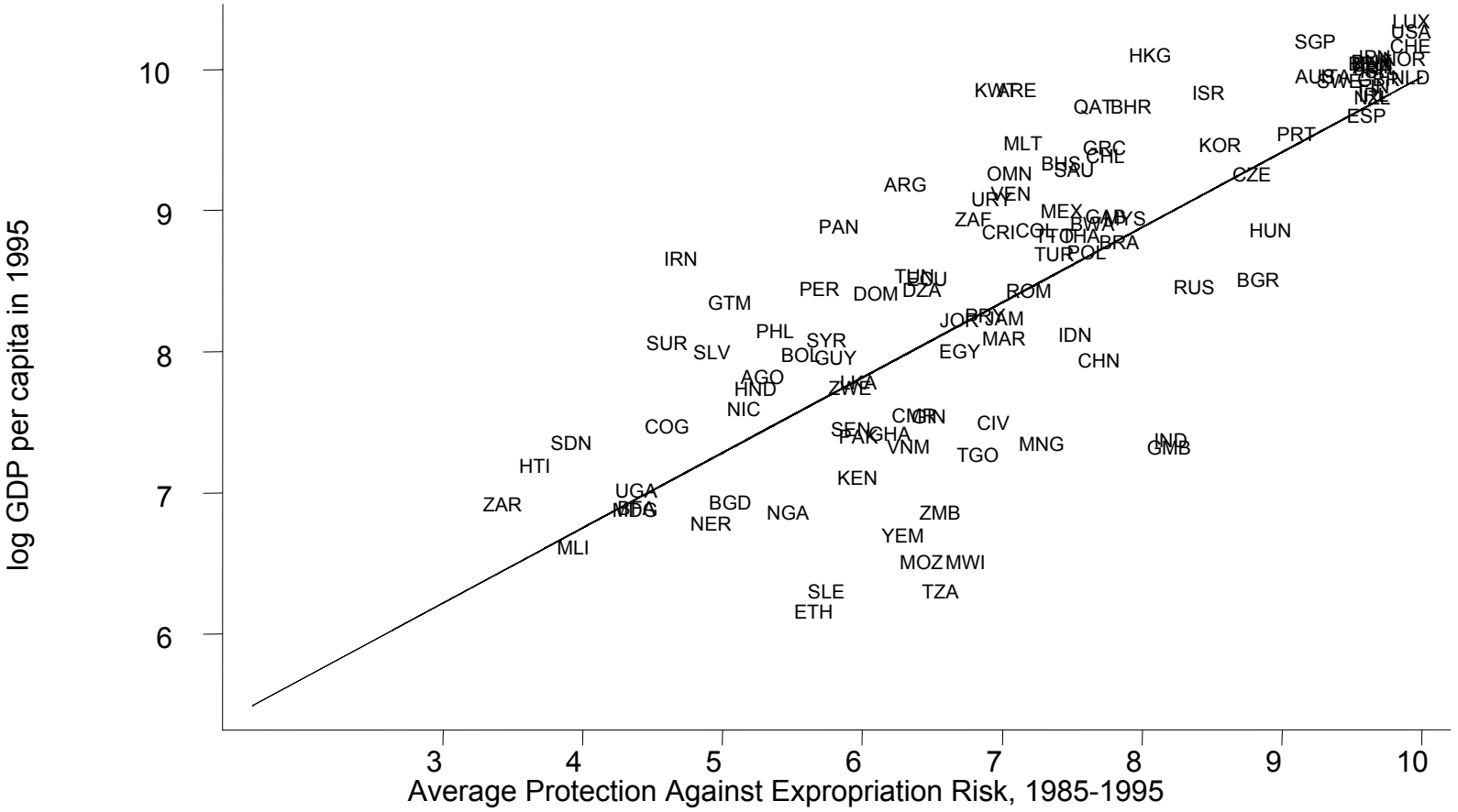
Institutional Background

- Human capital, physical capital and technology are proximate causes of economic growth.
- Why do some countries invest more in human capital, physical capital and technology?
- Fundamental cause: Incentives determined by institutions (rules of the game of society).
- Institutions have to provide:
  - Secure property rights for investors.
  - Level playing field.
- Alternative factors: geography or culture, outside the (direct) control of society

Institutional Variation

- Big differences in institutions across countries.
  - Democracy vs. dictatorship.
  - Enforcement of property rights.
  - Legal systems.
  - Entry barriers (e.g., DLLS: cost of opening a new business over 60 times in the Dominican Republic compared to the U.S.).

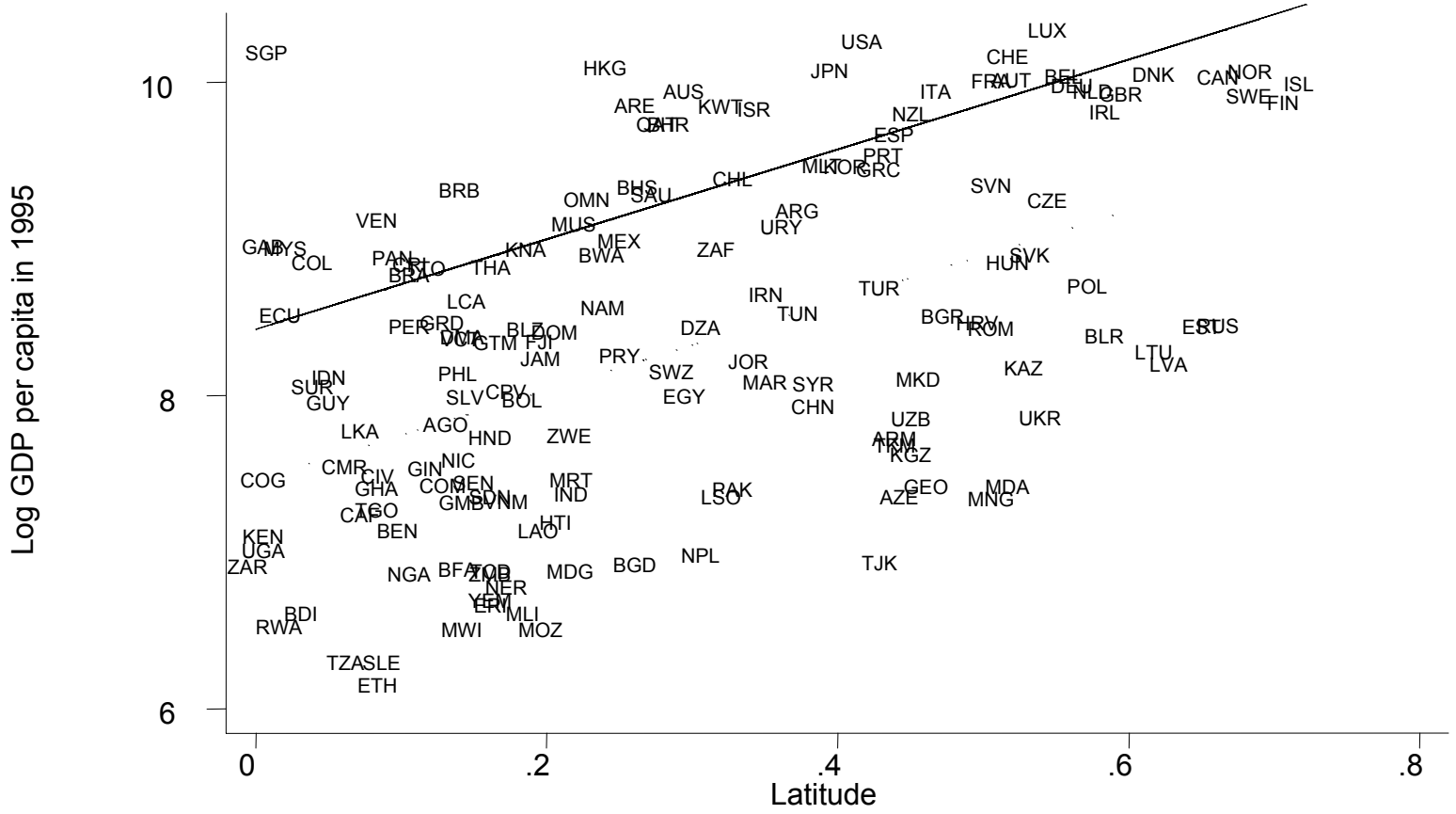
Institutions and GDP



But Institutions Endogenous

- Institutions could vary because underlying factors differ across countries.
- Montesquieu's story:
  - Geography determines "human attitudes"
  - Human attitudes determine both economic performance and political system.
- Identification problem
  - Correlation does not mean causation.
  - Similar identification problem to that of uncovering external returns to education.

Montesquieu's Story?



Need For Exogenous Variation

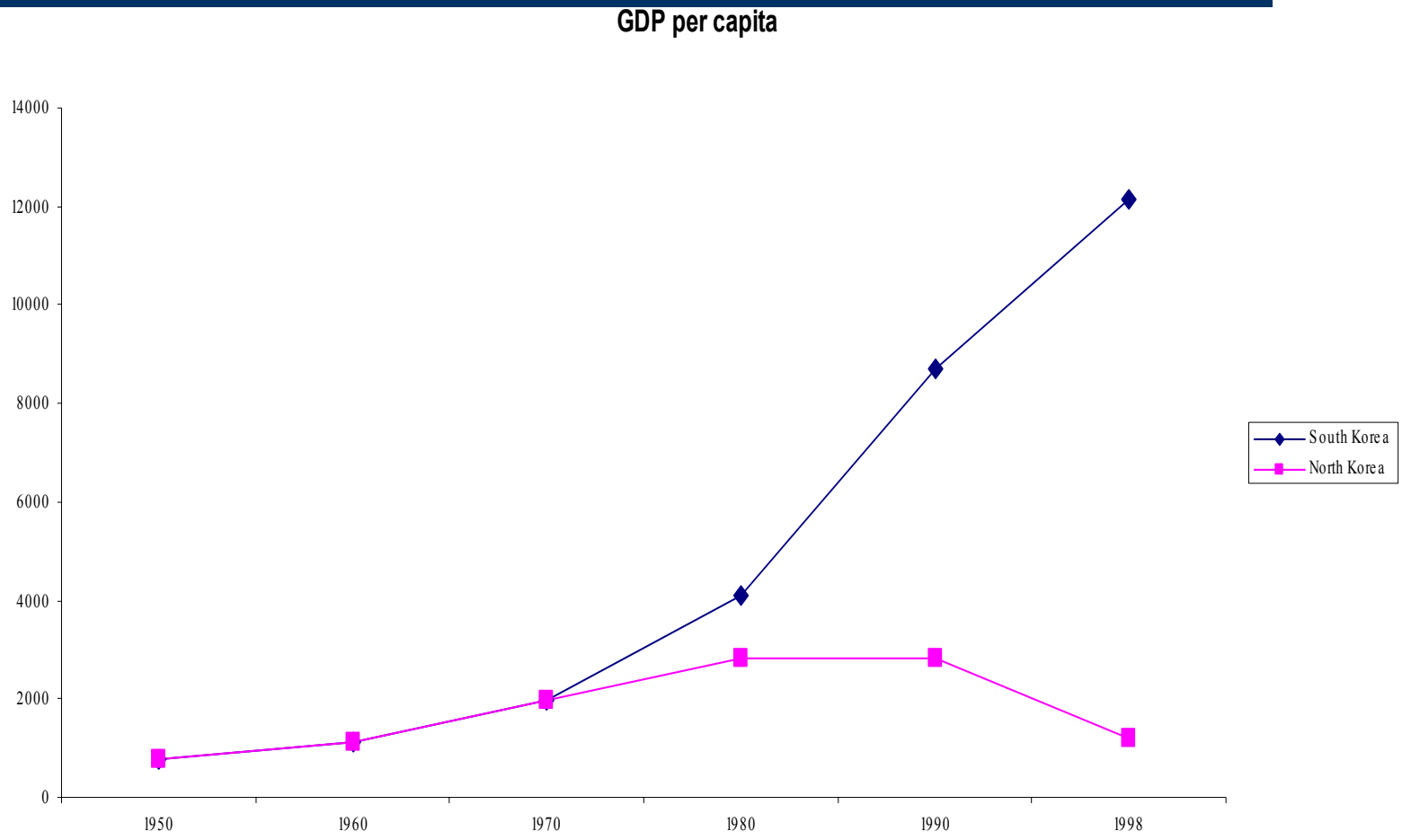
Exploit “natural experiments” of history to make further progress.

1. South versus North Korea
2. European colonization (Acemoglu, Johnson and Robinson)

The Korean Experiment

- Korea: economically, culturally and ethnically very homogeneous at the end of WWII.
- If anything, the North more industrialized.
- “Exogenous” separation of North and South, with very different political and economic institutions.
- Capitalism vs. planned economy.
- Big divergence
  - In physical capital, human capital and technology.

North and South Korea



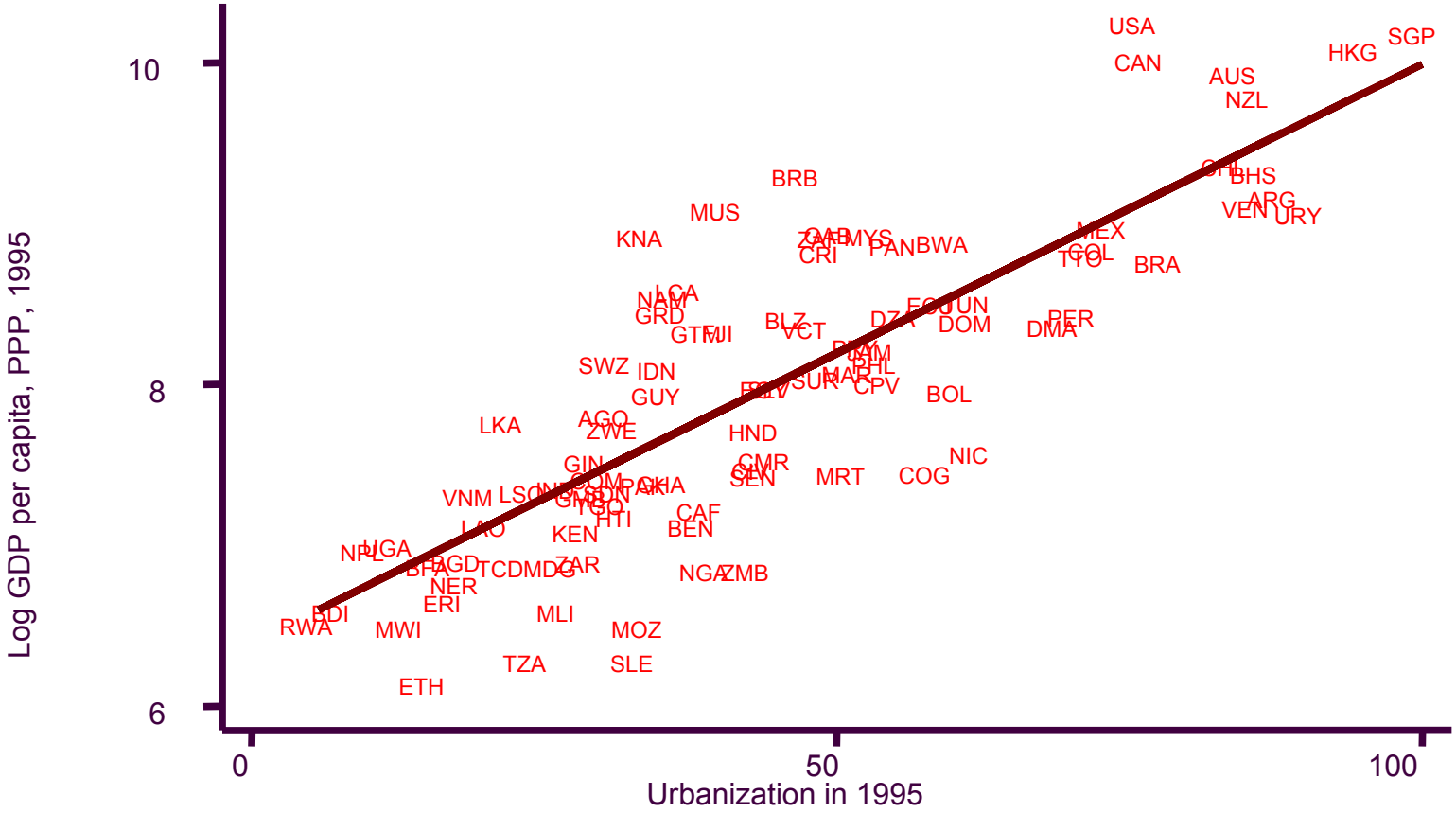
European Colonization as a "Natural" Experiment

- After the discovery of the New World and the rounding of the Cape of Good Hope, Europeans dominated many previously diverse societies, and fundamentally affected their social organizations (institutions).
- Many factors, including geographic, ecological and climatic ones, constant, while big changes in institutions.
- Consequences?
- Look at changes in prosperity from before colonization (circa 1500) to today.

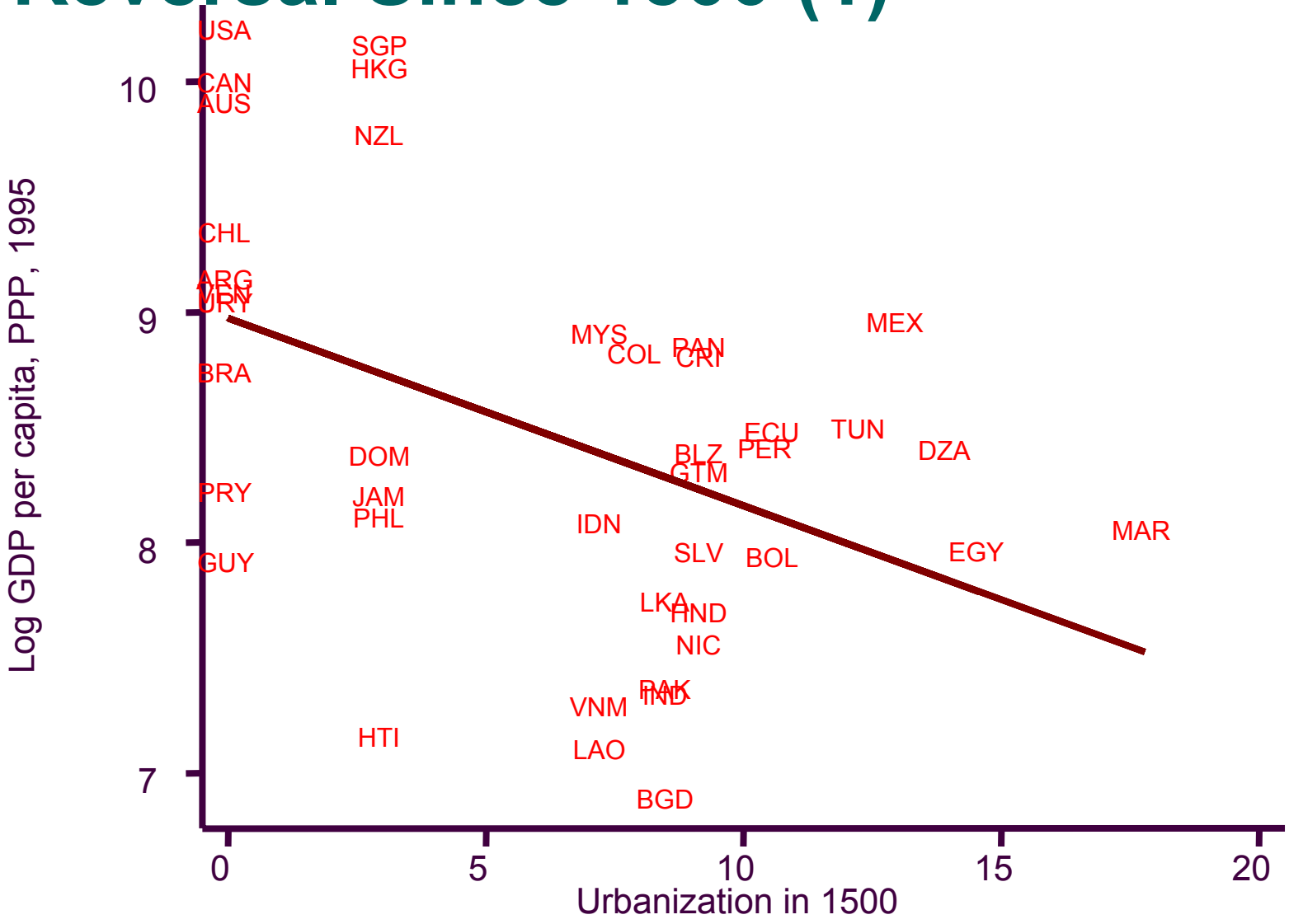
Measuring Prosperity

- To answer these questions, we need a measure of prosperity before the modern era.
- Urbanization is a good proxy for GDP per capita.
- Only societies with agricultural surplus and good transportation network can be urbanized.
- Urbanization is highly correlated with income per capita today and in the past.
- In addition, use population density as a check.

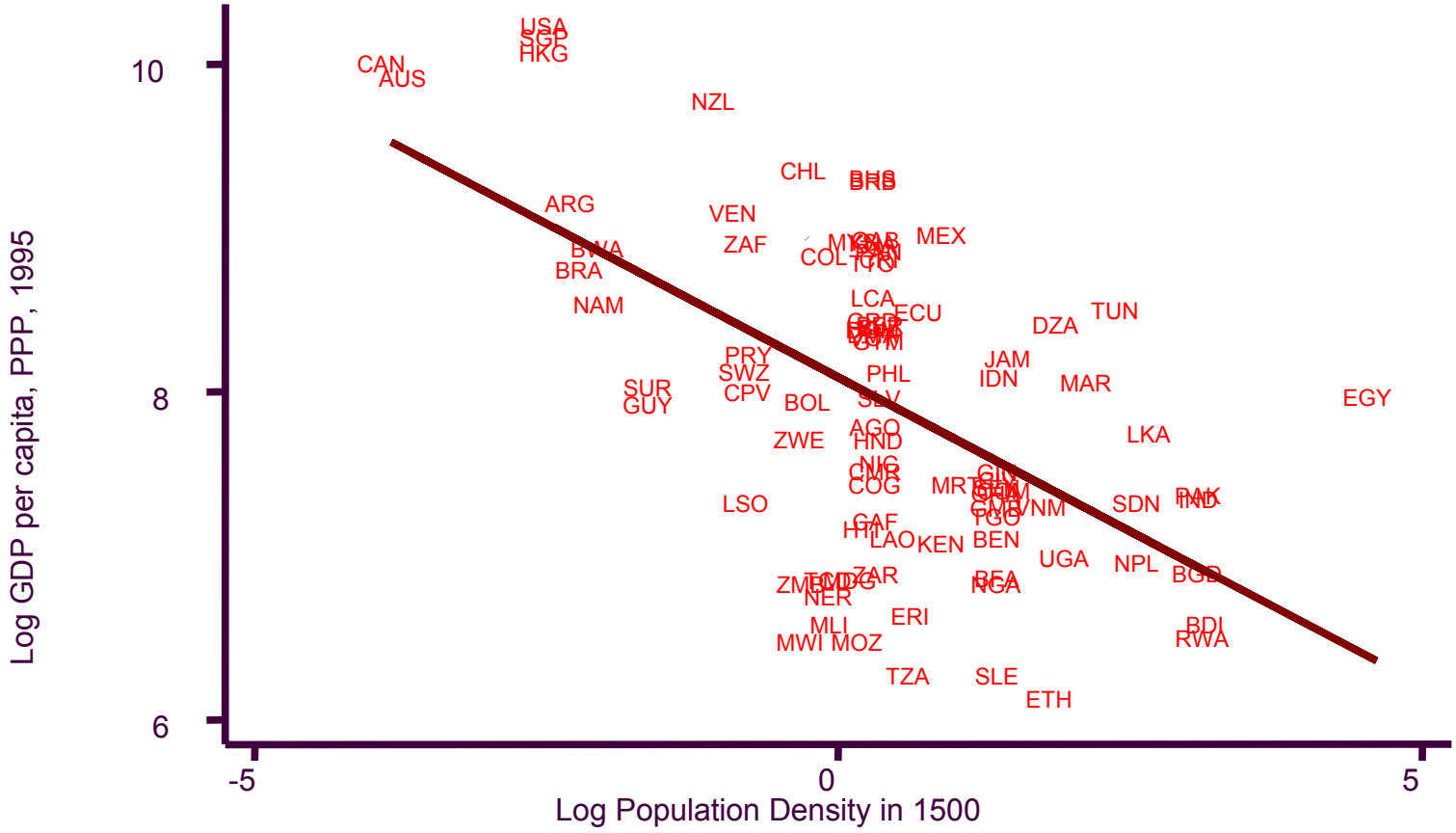
Urbanization and Income Today



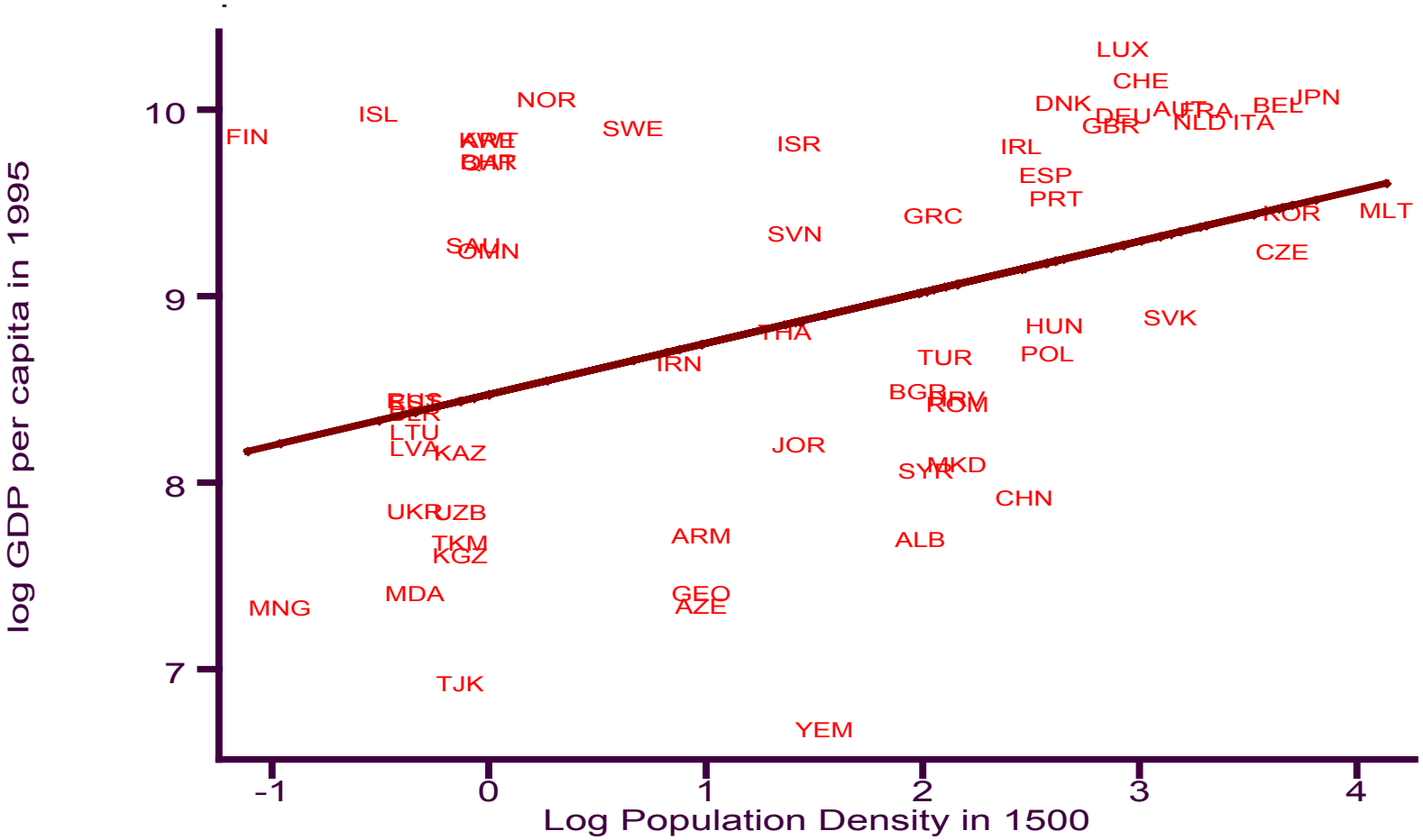
Reversal Since 1500 (1)



Reversal Since 1500 (2)



No Reversal Among the Non-Colonized



What's Happening? (1)

- It cannot be geographical differences
  - no change in geography
- Perhaps certain geographic characteristics that were good in 1500 are now harmful?
  - no evidence to support this view
  - other work with Johnson and Robinson: little direct effect of geography
- Reversal resulting from changes in social organization/institutions.
  - Reversal associated with human capital, physical capital and technology investments.
  - Formerly rich places little investment in education, low efficiency in production.

What's Happening? (2)

- Relatively better institutions/social organizations "emerged" in places that were previously poor and sparsely settled.
  - E.g., compare the U.S. vs. the Caribbean or Peru.
- Institutions have persisted and affected the evolution of income, especially during the era of industrialization.
  - Those with political power, the Europeans, set up different economic institutions in different colonies.
  - Smallholder production in northeastern U.S., slavery in the Caribbean, forced labor in Central America.

Why Different Institutions?

- More profitable to set up “extractive” institutions in places with high population density and/or with resources to extract.
- Also makes sense to establish better institutions in places where they will live themselves as the majority (i.e., settle).
  - Europeans also structured the political institutions to support the different economic institutions.
  - More democratic in U.S., repressive in Caribbean, Central America.
  - Result: incentives to invest in physical and human capital and technology in the U.S., but not in Caribbean or Central America

Labor Market Institutions

- Previous discussion in terms of “big” institutions.
- Other features of institutional background also matter for technology.
  - Example: labor market institutions.
- Labor market institutions in continental Europe create more wage compression.
  - Greater inequality
  - Potentially more unemployment
  - Implications for technology?

Institutions and Technology

- Wage compression created by the minimum wage, unions and benefit system potentially encourage adoption of more “skill-balanced” technologies.
- U.S. experience: rapid SBTC.
- Continental Europe: SBTC less rapid.
- Consequence of labor market institutions?
  - Greater wage compression means that unskilled workers are paid higher wages, therefore, potentially more profitable to increase their productivity.
  - Potential explanation for less rapid SBTC in continental Europe.

Conclusions (1)

- Proximate causes of economic growth:
  - human capital, physical capital and technology.
  - all three important in practice, human capital not panacea.
  - but human capital a special role in enabling technological progress.
  - human capital also determines the nature of technological progress.
  - important implications for inequality and opportunities and pitfalls for less-developed countries.

Conclusions (2)

- Fundamental causes of economic growth:
  - factors outside in control: geography, culture, luck
  - Factors controlled by society: institutions (shaping incentives).
- Evidence institutional factors of primary importance.
  - Better institutions lead to greater human capital, physical capital and technology investments.
  - Potential effect of institutions on the rate and nature of technological progress.