R&D, Structural Transformation, and the Distribution of Income

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Ten General Points about Automation and the Economy

1. Capital-Labor substitution is a fundamental, long-term process of modern growth;
2. Automation proceeds from physical and repetitive tasks to cognitive and contextual tasks;
3. The Digital Revolution continues and accelerates the process;
4. The Digital Revolution is science-based, raises the returns to R&D, and fosters a professional/technical class (managerial, R&D, design, higher education, healthcare);
5. National income shifts from basic labor to human capital, physical capital (natural capital, buildings, machines), and intellectual capital;
6. Work-time falls and is replaced by schooling/training, leisure, and retirement;
7. Older households tend to benefit, younger households tend to lose;
8. Higher-income, higher-educated, and higher-talent families engage in intergenerational transfers to ensure intergenerational benefits; lower-income, lower-educated, and lower-talent families may experience a rise or decline in wellbeing;
9. The IR revolution will also shift income from physical capital to intellectual capital (e-books, e-conference, e-commerce, e-banking);
10. We need five kinds of policies: new training, income redistribution, shared leisure, promotion of human-machine complementarities (humanities along side IR), IP governance

Automation has been driven by Five General Purpose Technologies: Steam, Electricity, ICE, Fordism-Taylorism, Digital

General Purpose Technologies cause deep structural changes:

- Raise national output
- Disrupt production processes
- Restructure labor markets and call for new skills
- Shift income and wealth distributions
- Change human geography and demography

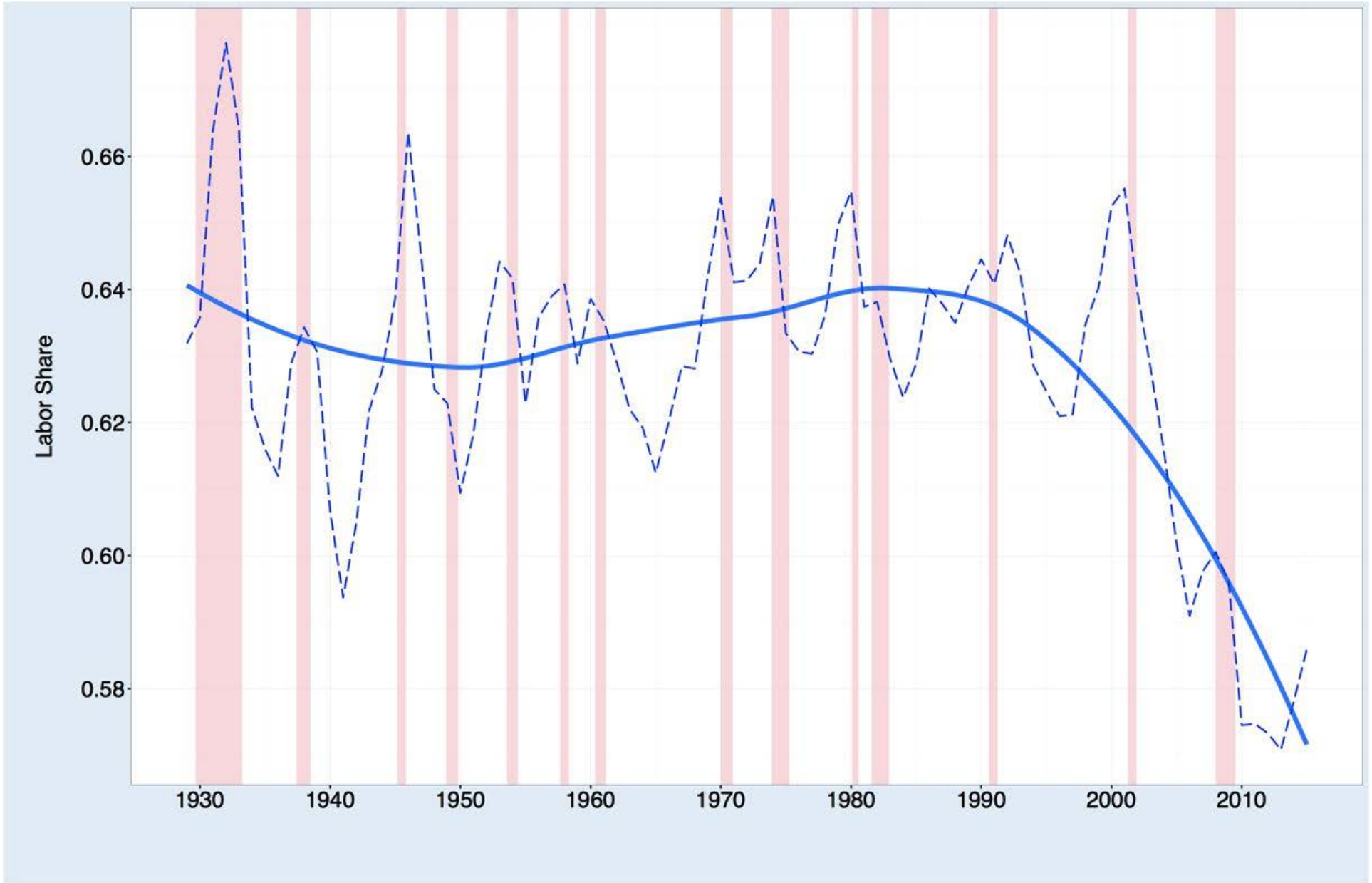
The Digital Revolution is 80 Years Old

Turing and von Neumann: computation
FDR and Bush: science-led U.S. development
Wiener and Simon: Science of the “artificial”
Shannon and Shockley: solid-state logic circuitry
Kilby, Noyce, Moore: integrated circuitry and microprocessors
Gates and Jobs: e-economy
Page and Brin: public information
Bezos and Ma: e-business
Zuckerberg and Mercer: big data
Watson and AlphaGo: artificial intelligence

Some key distinguished AI characteristics:

Science and engineering-based
Labor saving
High returns to knowledge (IP) and skills (HC)
Enables natural resource saving
Major distributional consequences
Uncertain ownership model of knowledge
    Will information be public, private, or regulated utility?

DECLINING LABOR SHARE: CONVENTIONALLY MEASURED



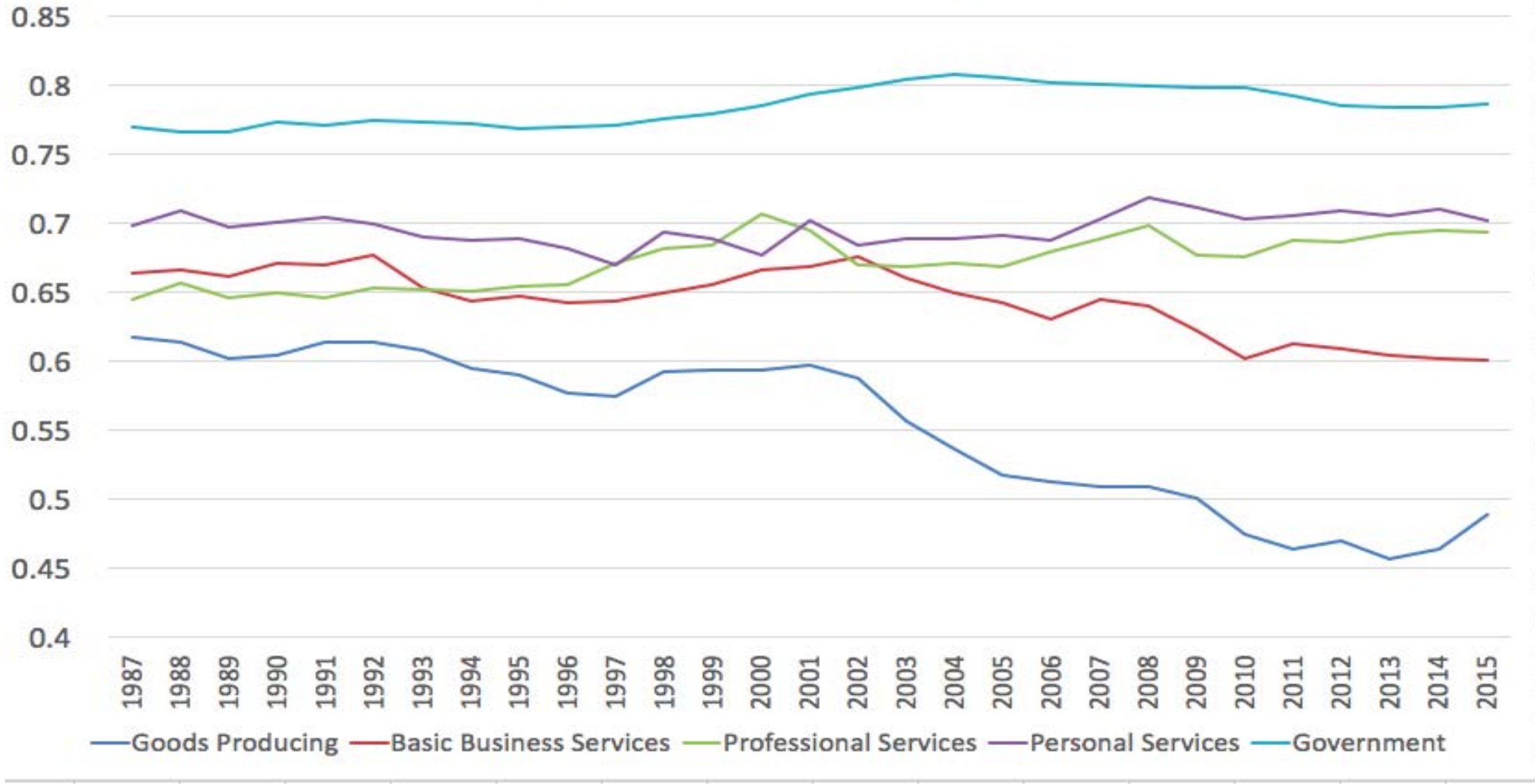
	Typical Expertise	Typical Workflow Predictability
Goods Producing	Low to Moderate	High
Basic Business Services	Moderate	Moderate to High
Personal Services	Low to Moderate	Low to Moderate
Professional Services	High	Low
Government	Moderate to High	Moderate to High

OCCUPATIONAL COMPOSITION OF THE US LABOR FORCE: Decline in Arduous Physical Work

	1900	2015
Agriculture Workers	.36	.01
Production Workers	.24	.14
Trade, Transport, Administrative	.16	.28
Other Service	.19	.18
Professional (including Government)	.04	.39

MANUAL LABOR HAS DECLINED FROM AROUND 70% TO AROUND 20% OF THE LABOR FORCE

Figure 2. Labor Share by Sector



Motor Vehicle Assembly

LABOR SHARE OF VALUE IN MOTOR VEHICLE PRODUCTION (SMOOTHED OVER PEAK YEARS)

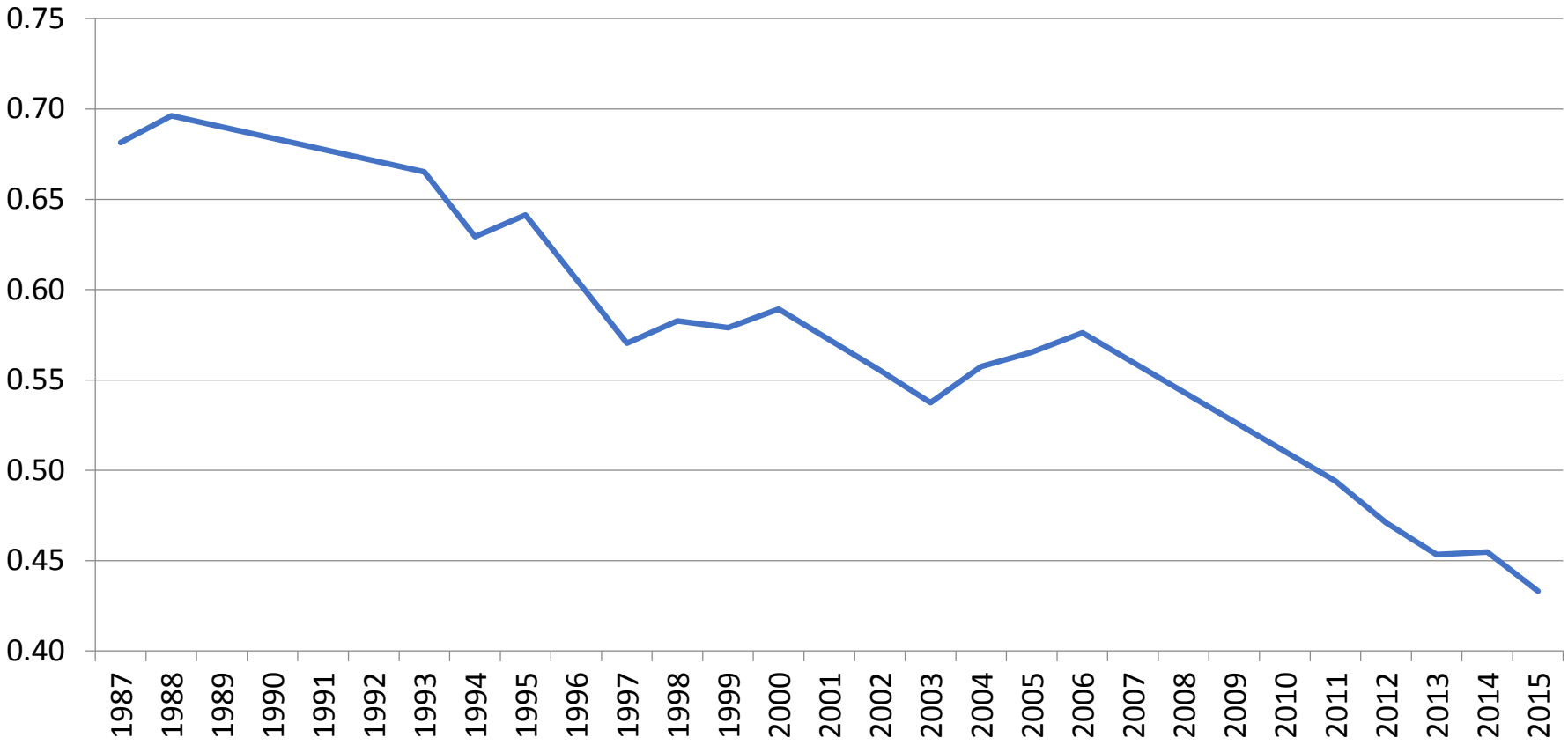
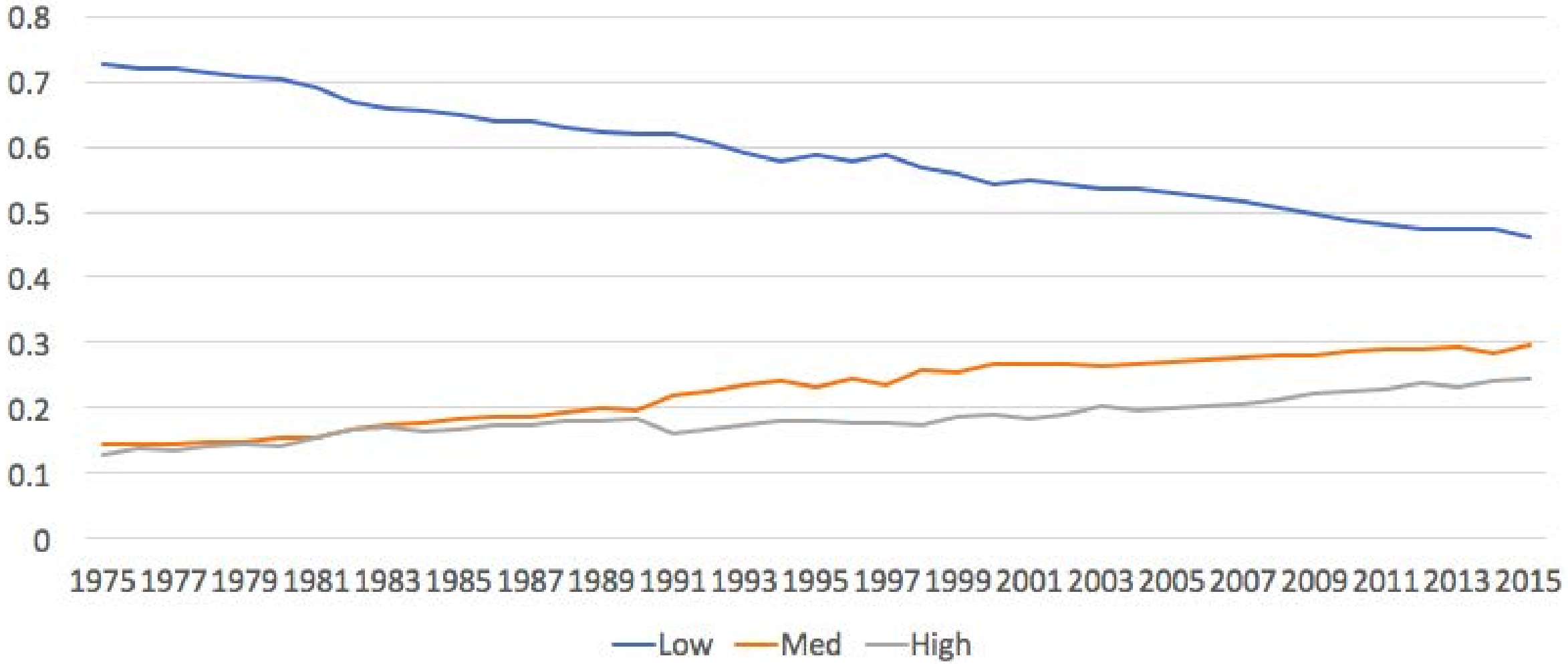


Figure 3. Share of Earnings by Educational Attainment



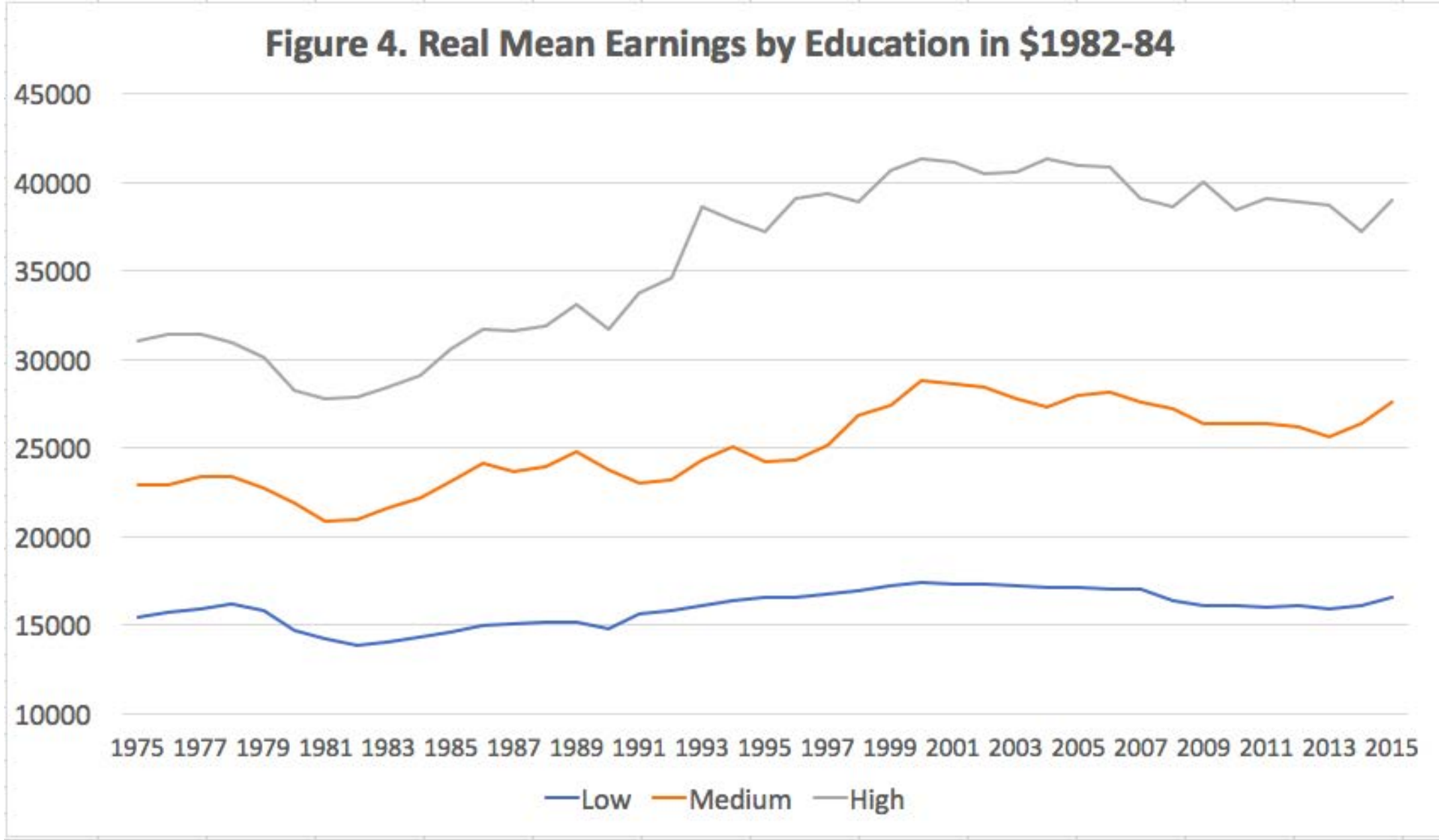


Figure 4. Real Mean Earnings by Education in $1982-84
45000
40000
35000
30000
25000
20000
15000
10000
1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
Low
Medium
High

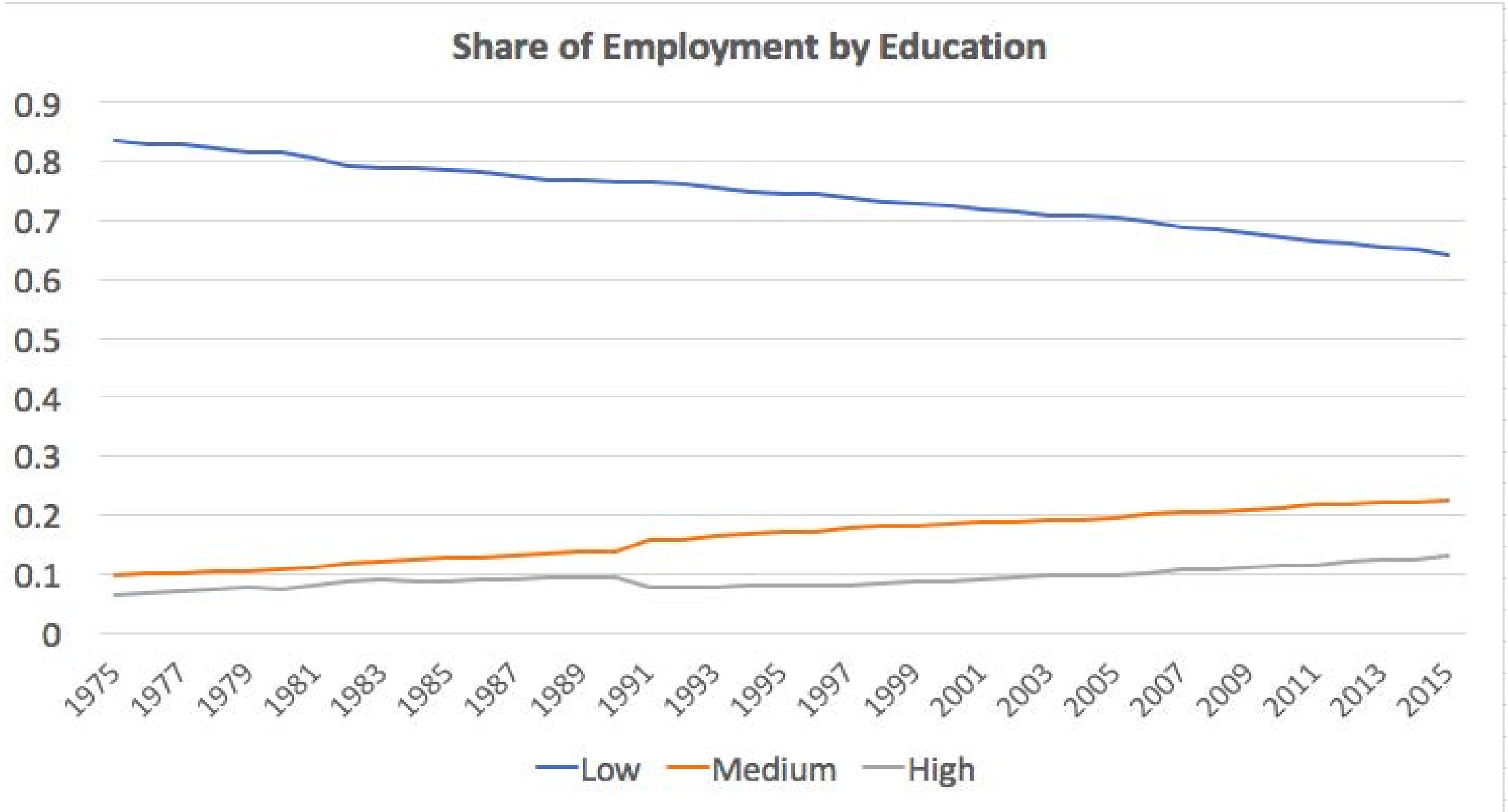
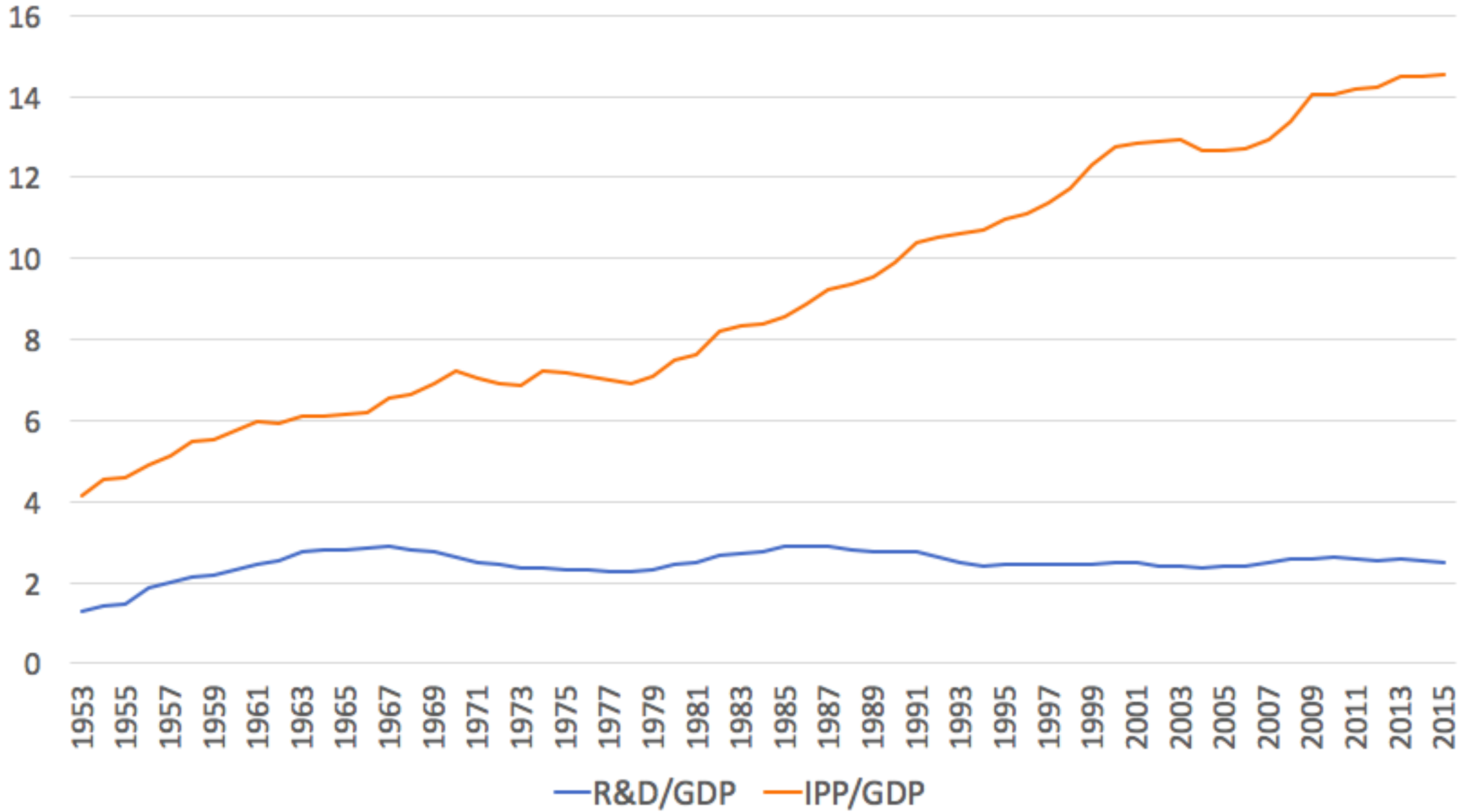
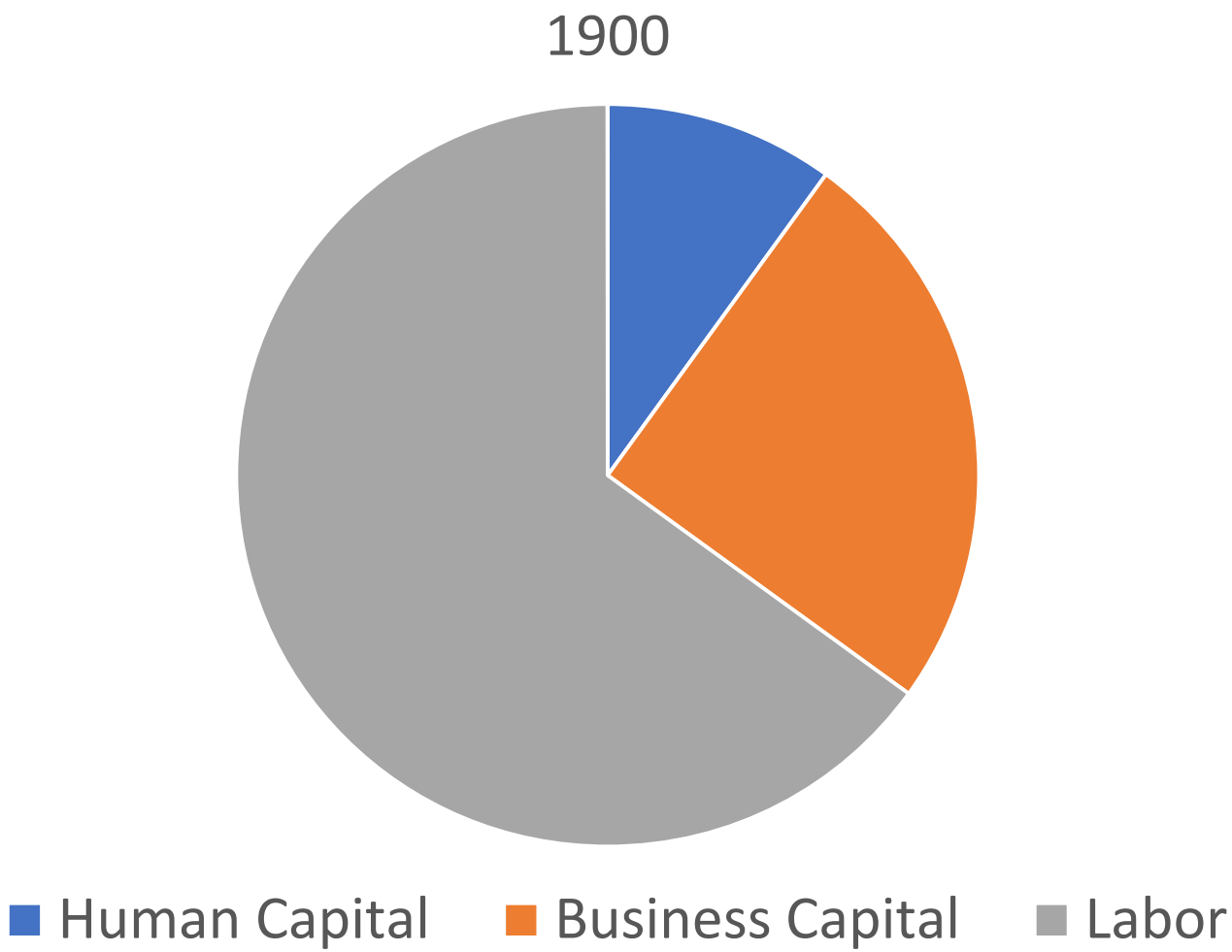
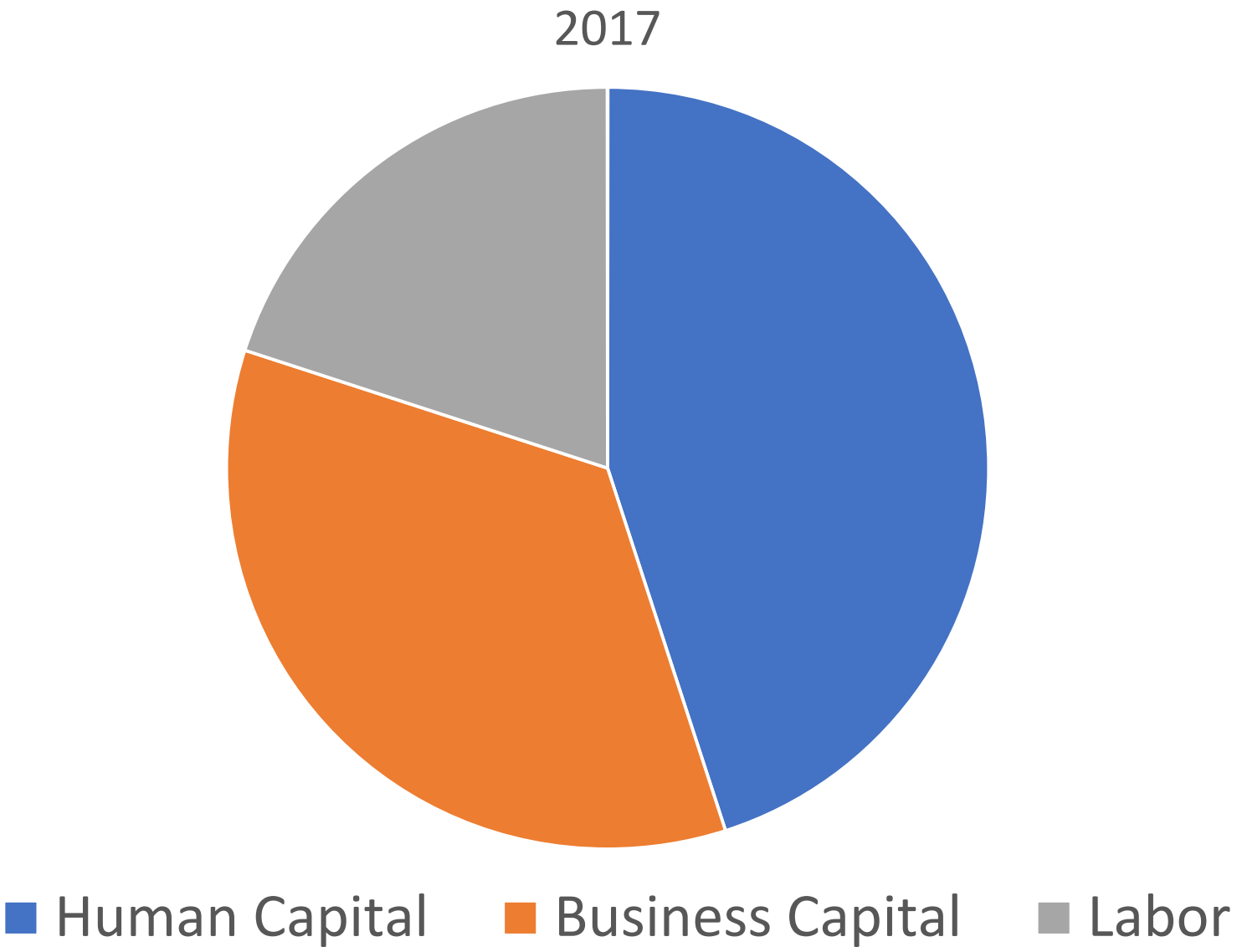

Share of Employment by Education
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Low
Medium
High

Figure 6. R&D and Intellectual Property (%GDP)



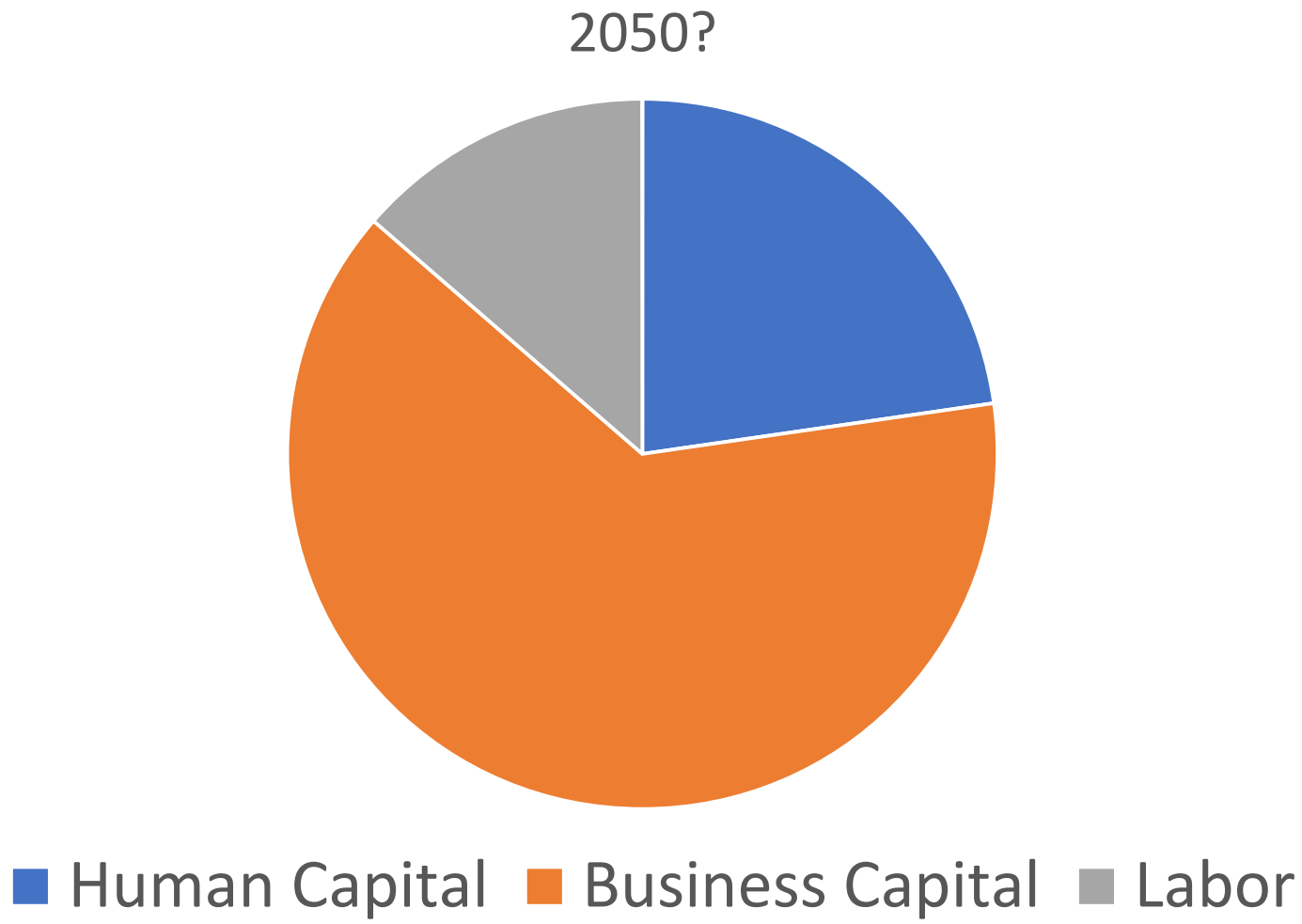
Stylized Depiction for 1900, 2017, 2050



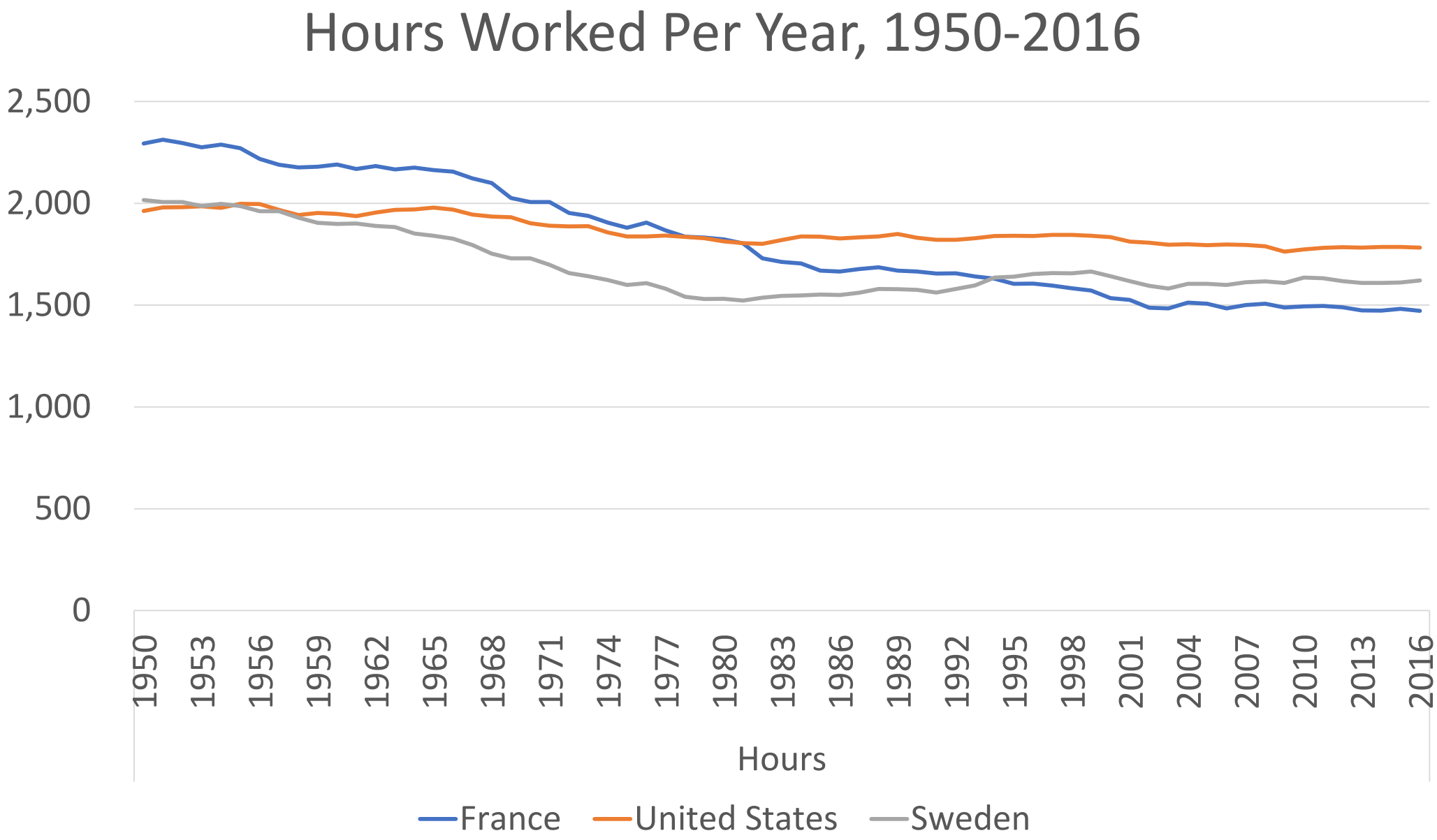

2017
Human Capital
Business Capital
Labor

BY 2050, A SHIFT AGAINST BOTH LABOR & HUMAN CAPITAL?

WHO WILL OWN THE IP?



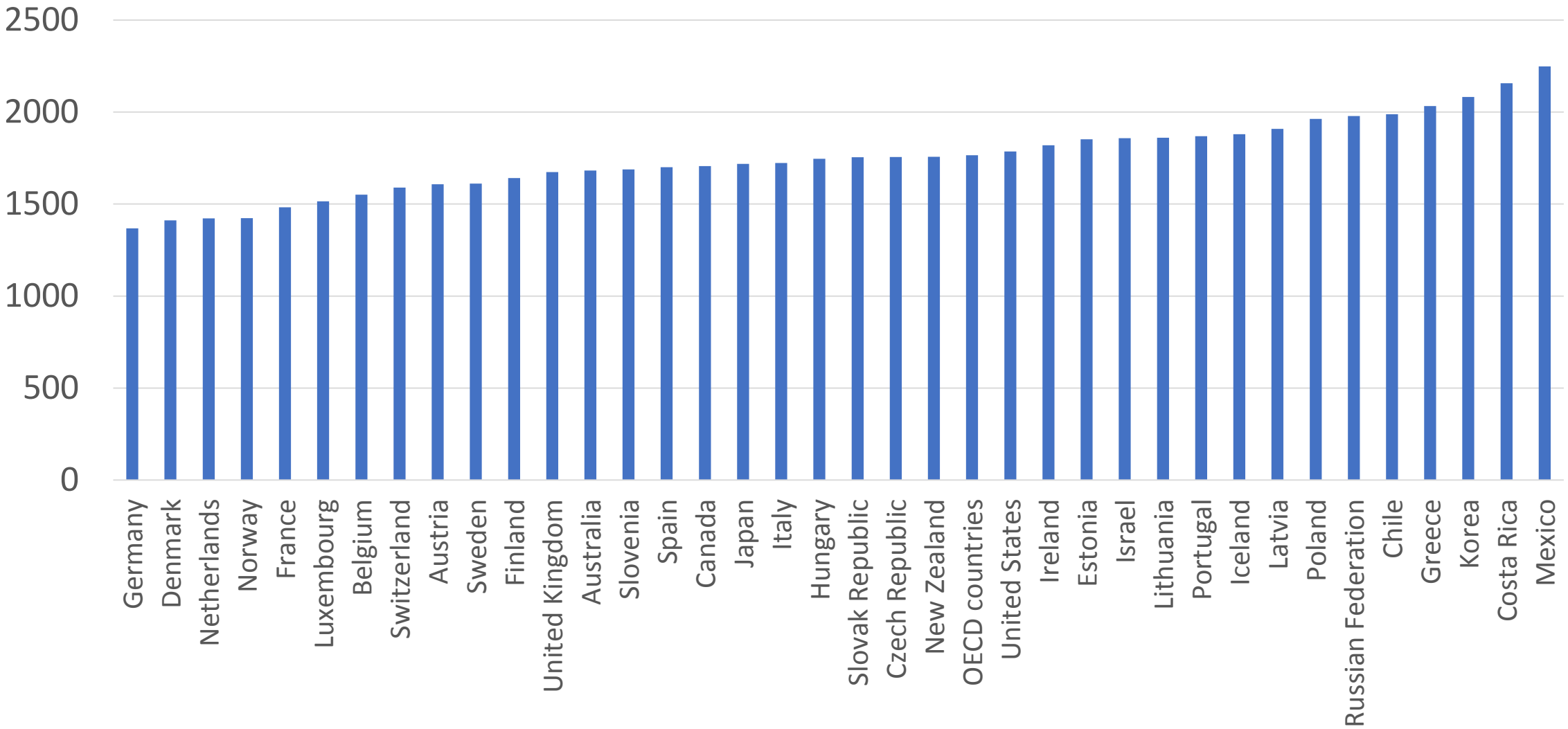
	1900	2015
Percent of Adults Working Monday-Friday	90%	54%
Working Hours per Day Monday-Friday	10 hours	7.9 Hours
Percent of Adults Working Saturday-Sunday	90%	23%
Working Hours per Day Saturday-Sunday	6 hours	5.6 hours
Working Weeks Per Year Excluding Vacation + Holiday	51	48.5
Total Working Hours Per Adult Per Day (rough)	7.8 hours per day	3.18 hours per day



DIFFERENCE BETWEEN US AND FRANCE IN 2016 IS 311 HOURS, OR 7.8 WEEKS AT 40 HOURS PER WEEK.

France = - 20 WKS
US = -4.5 WKS
Sweden = -9.9 WKS

HOURS WORKED PER YEAR, 2015



GERMANY = 1368 (34 WEEKS @ 40 HOURS PER WEEK)
MEXICO = 2248 (>52 WEEKS @ 40 HOURS PER WEEK

$$Q = P^{a} N^{b} B^{(1-a-b)}$$

$$P = L_P + t_P * M_P$$

$$N = L_N + t_N * M_N$$

$$L_U = L_{PU}$$

$$L_I = L_{NI} + L_{PI}$$

$$K = B + M_P$$

$$W_U = a*(L_U + t_P*M_P)^{(a-1)} L_I^{b} S^{(1-a-b)}$$

$$W_I = b*(L_U + t_P*M_P)^{a} L_I^{(b-1)} S^{(1-a-b)}$$

Figure 7. Labor by Educational Attainment

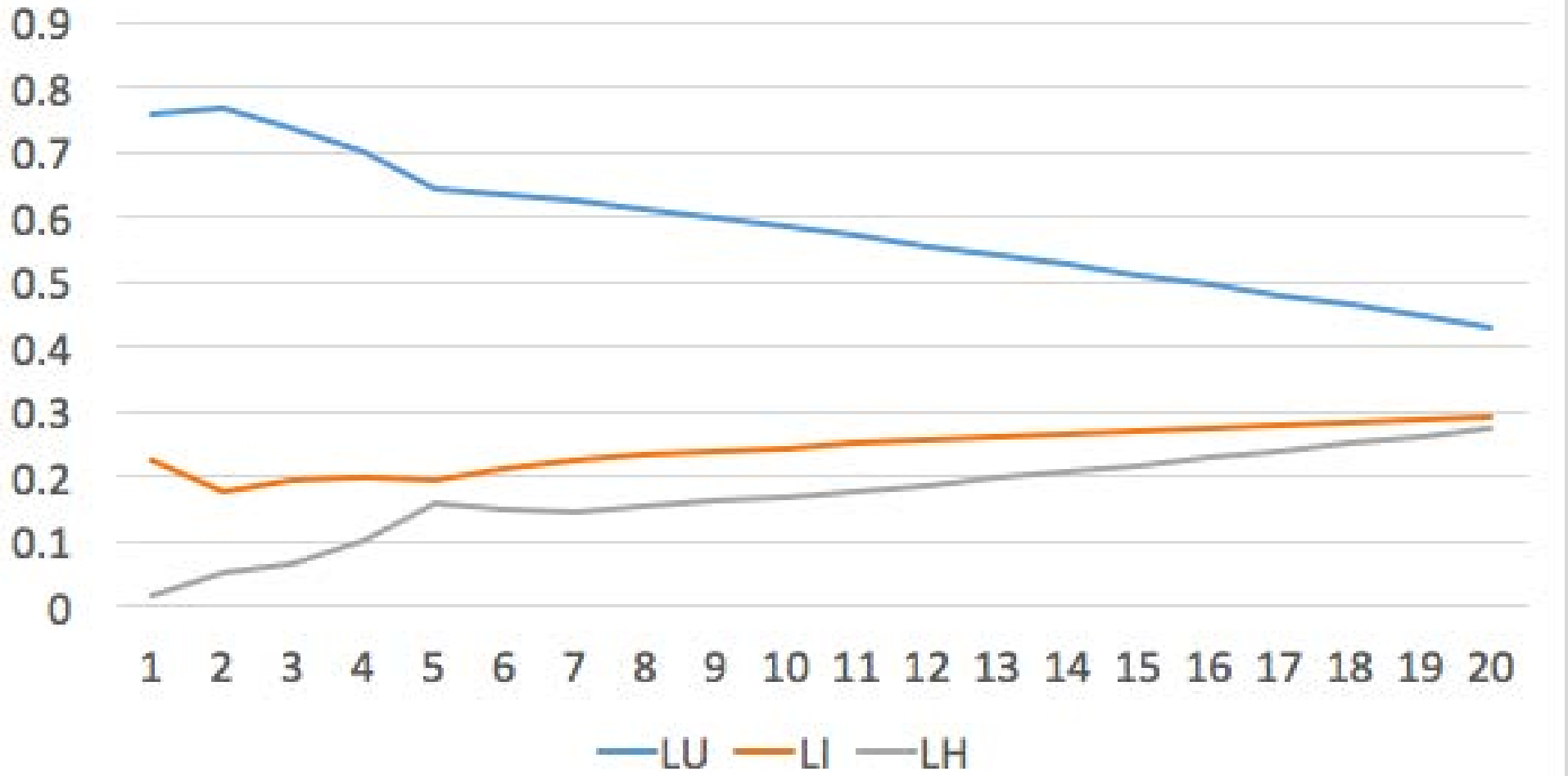


Figure 8. Labor By Educational Attainment
Automation for Low-Skilled and Intermediate-Skill Tasks

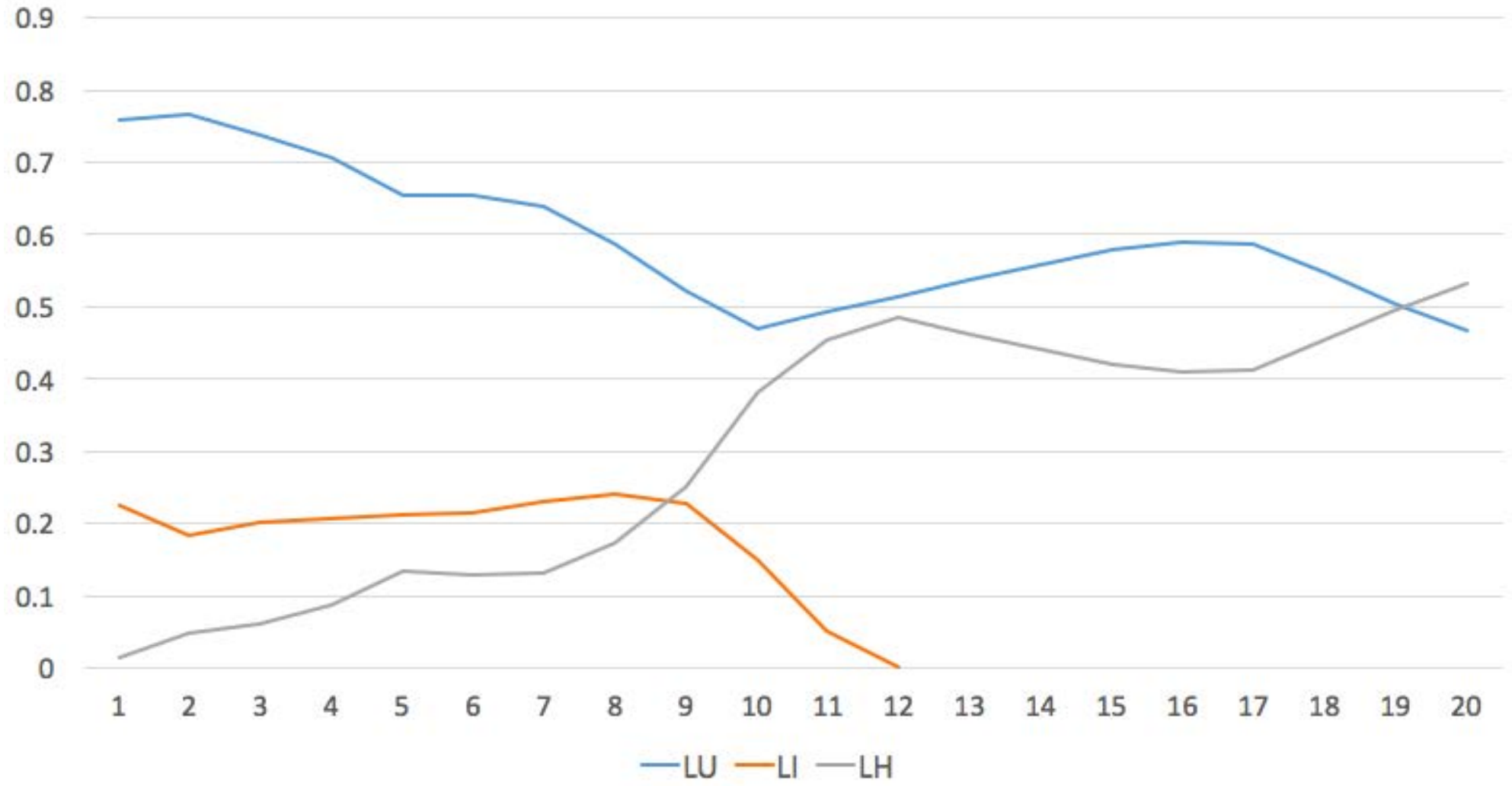
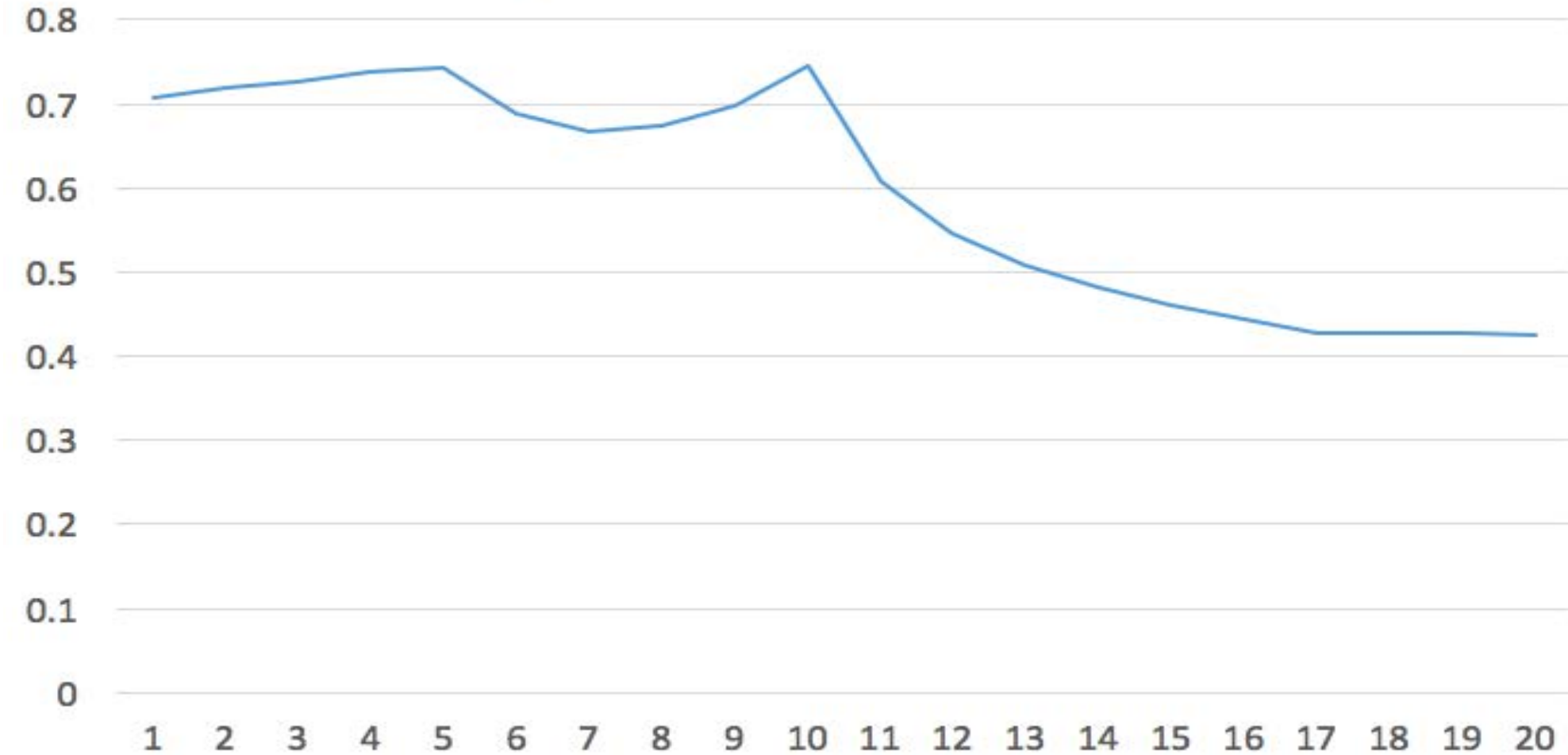
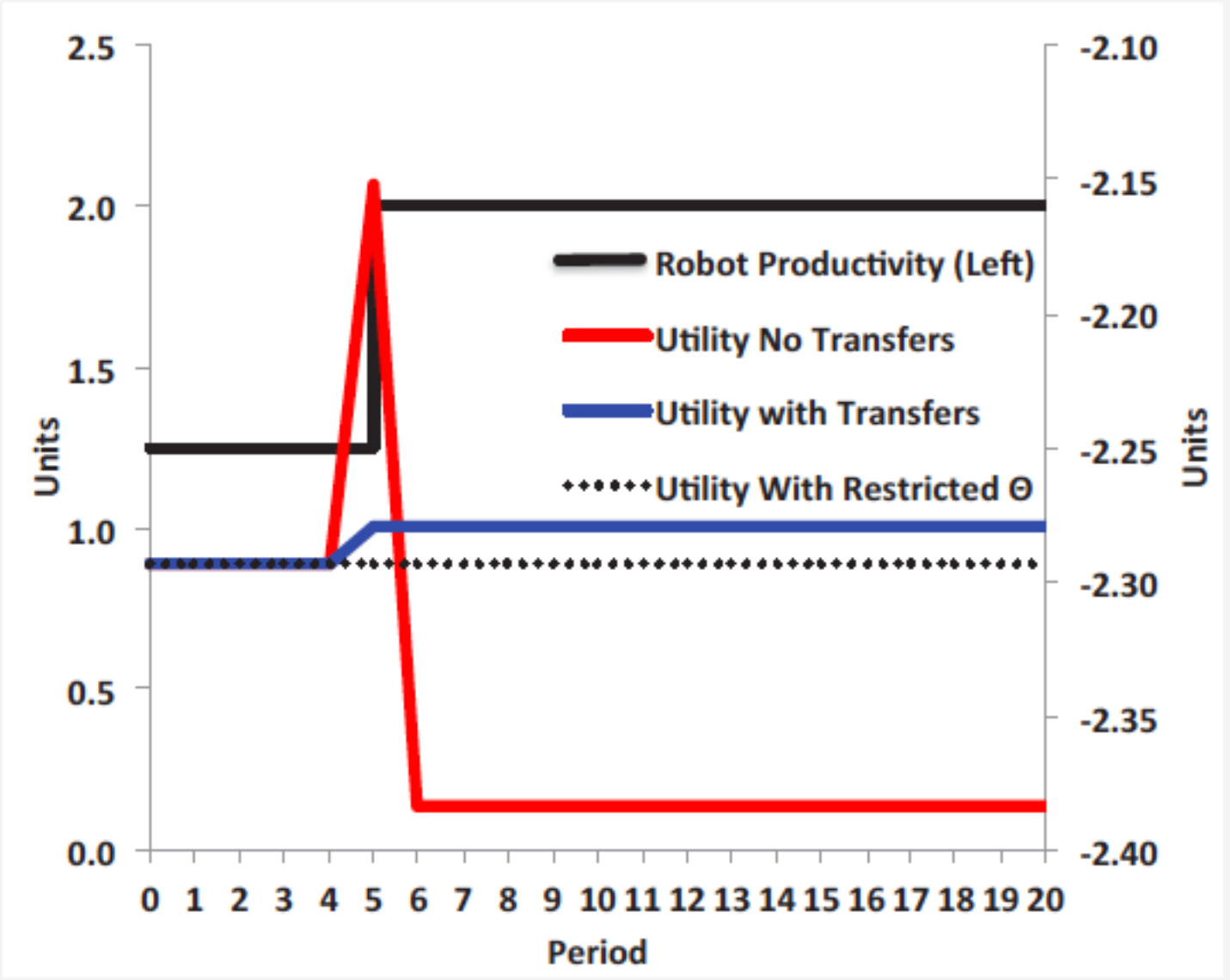


Figure 9. Labor Share of GDP



Robots: Curse or Blessing?



John Maynard Keynes, *The Economic Possibilities of Our Grandchildren*, 1930

The pace at which we can reach our destination of economic bliss will be governed by four things—our power to control population, our determination to avoid wars and civil dissensions, our willingness to entrust to science the direction of those matters which are properly the concern of science, and the rate of accumulation as fixed by the margin between our production and our consumption; of which the last will easily look after itself, given the first three.

Meanwhile there will be no harm in making mild preparations for our destiny, in encouraging, and experimenting in, the arts of life as well as the activities of purpose. But, chiefly, do not let us overestimate the importance of the economic problem, or sacrifice to its supposed necessities other matters of greater and more permanent significance. It should be a matter for specialists—like dentistry. If economists could manage to get themselves thought of as humble, competent people, on a level with dentists, that would be splendid!