How Does Technological Progress Impact Work?

Some Lessons from History

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Workers in the Industrial Revolution

- Common perception that workers were victimized by technological progress
- Real wages stagnated even as productivity advanced driven by famous inventions
- Dark satanic mills and plight of the handloom weavers
- Cause celebre for Marxists and frightening precedent for 21^{st} century workers

Real Wages of Labourers

1760	100	1810	99.8
1770	96.7	1820	112.6
1780	95.3	1830	128.4
1790	96.2	1840	140.7
1800	95.3	1850	151.8

Source: Clark (2005)

British Economic Growth during the Industrial Revolution (Crafts, 1985)

- No ‘ take-off’: **modest growth**
- Transition to modern economic growth and escape from ‘Malthusian Trap’
- Precocious industrialization
- TFP growth increases significantly but not spectacularly

Growth during the Industrial Revolution

(% per year)

	Real GDP	Population	GDP/ Person	TFP	Y/L	Real Wages
1760-1800	**1.2**	**0.8**	**0.4**	**0.4**	**0.4**	**-0.1**
1800-1830	**1.7**	**1.4**	**0.3**	**0.4**	**0.3**	**1.0**
1830-1860	**2.3**	**1.4**	**0.9**	**0.7**	**0.9**	**0.6**

Sources: Broadberry et al. (2015); Clark (2005); Crafts (2018)

‘Slow’ TFP Growth

- **Uneven** technological progress
- **Slow incremental improvements** and diffusion of well-known inventions, e.g. steam power
- Disincentives to innovative activity
- Confirmed by slow growth of wages

17^{th}-and 18^{th}-Century Model

(Crafts and Mills, 2009)

$$LogW = a - bLogPop + ct$$

- Trend growth of W is 0 pre-1800; b = 0.7
- Real wages fall if population growth > c/b = 0.4%
- Pre-1800 prediction would be a fall in real wages of about 20% from 1800-1830 population increase

Real Wages Revisited

- The key feature of the Industrial Revolution is **‘the dog that didn’t bark’**

- Faster productivity growth (higher c) meant that real wages stagnated rather than collapsed in the face of serious demographic pressure

- Workers would have benefited from faster technological progress and capital deepening

Sources of Power, 1760-1907

(Thousand Horsepower)

	1760	1800	1830	1870	1907
Steam	5	35	165	2060	9659
Water	70	120	165	230	178
Wind	10	15	20	10	5
Total	85	170	350	2300	9842

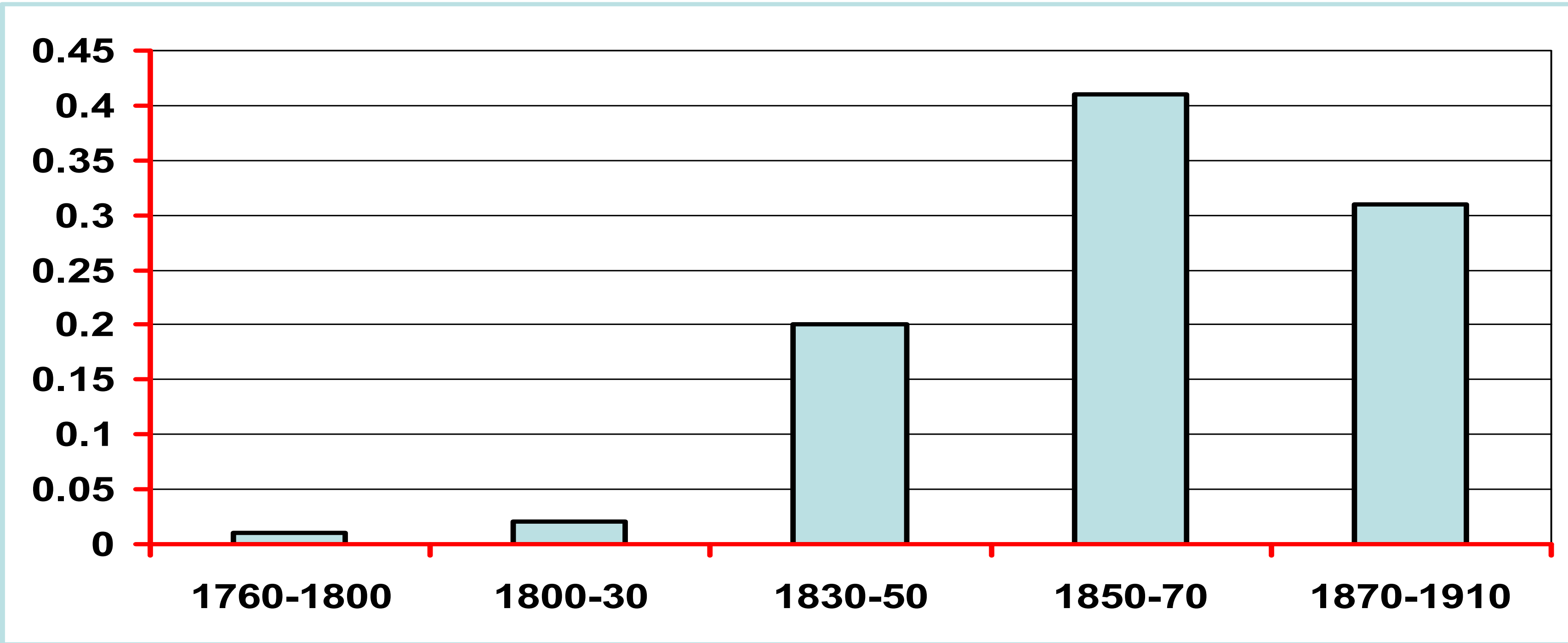
Steam Engine Technology

- Took a long time to become cost effective in most sectors

- Coal consumption per hp per hour fell from 30 lb pre-Watt to 12.5 lb for Watt engine to 2 lb by 1900 when psi reached 200 compared with 6 in 1770

- **The big breakthrough was not James Watt** but the move to the high pressure steam engine after 1850

Total Steam Contribution to Growth of Labour Productivity (% per year)



General Purpose Technologies

- Macro-productivity implications typically modest initially: arithmetic of growth accounting and time to realise full potential
- Solow Paradox based on unrealistic expectations but ICT had strong and relatively rapid impact
- Possible that GPT can have big cumulative effect but never raise the aggregate productivity growth rate very much

Contributions to Labour Productivity Growth (% per year)

	K/L	*TFP*	*Total*
Steam (UK)			
1760-1830	0.011	0.003	0.014
1830-1870	0.18	0.12	0.30
1870-1910	0.15	0.16	0.31
Electricity (USA)			
1899-1919	0.34	0.06	0.40
1919-1929	0.23	0.05	0.28
1919-1929 + spillovers	0.23	0.41	0.64
ICT (USA)			
1974-1995	0.41	0.36	0.77
1995-2004	0.78	0.72	1.50
2004-2012	0.36	0.28	0.64

Source: Crafts (2015)

Cotton Textiles

- Sector which had the fastest productivity growth based on famous inventions
- Mechanization, factory system, water then steam power
- Total **employment increased** both in short and long run but its composition changed
- Price-elastic demand and big market for exports

Best Practice Labour Productivity in Cotton Yarn Spinning (OHP)

(Broadberry and Gupta, 2009)

1780: Crompton's Mule	2000
1790: 100-Spindle Mule	1000
1795: Power-Assisted Mule	300
1825: Roberts' Automatic Mule	135

Employment in Cotton Textiles

1761	**34000**
1801	**242000**
1831	**427000**
1861	**446000**
1911	**544000**

Sources: Harley (1982); Farnie (1979)

Cotton Textiles Growth during the Industrial Revolution (% per year)

	Output	Employment	Y/L
1760-1800	**7.3**	**5.0**	**2.3**
1800-1830	**5.3**	**1.9**	**3.4**
1830-1860	**5.0**	**0.1**	**4.9**

Sources: Broadberry et al. (2015); Crafts (1985); Harley (1982); Farnie (1979)

Spatial Adjustment

- Factories in industrial towns and large cities
- Workers traded off higher wages against health risks and lower life expectancy
- Technological constraints precluded high-rise dwellings and living at distance
- Market and government failure delayed public health investments

Population (thousands)

	17th century	1801	1841	1871
Birmingham	**2.7**	**71**	**183**	**344**
Glasgow	**18.0**	**77**	**275**	**522**
Leeds	**3.5**	**53**	**152**	**259**
Liverpool	**1.2**	**82**	**286**	**493**
London	**500**	**1117**	**2239**	**3890**
Manchester	**2.4**	**75**	**235**	**351**

Sources: Langton (2000); Mitchell (1988)

Life Expectancy at Birth (years)

	London	Large Towns	Small Towns	Rural	England & Wales
1751/60	20.1		27.5	42.2	39.0
1811/20	36.0	32.5	35.3	43.3	41.1
1861/70	37.7	33.0	38.0	46.5	41.2

Source: Woods (2000)

Lessons (1)

- The caricature view of the Industrial Revolution is seriously misleading
- Real wages kept pace with productivity in the long run but growth was modest initially
- Quality not quantity of employment was the real issue
- Technological progress was regrettably slow in much of the economy
- Steam as a GPT had a big cumulative effect eventually but contributed little before 1830

A New Productivity Paradox

- Since the start of the 21st century, **TFP growth has slowed down** markedly but technology seems to be advancing rapidly
- Great excitement (or fear) about robots, AI etc.
- We can see the digital revolution everywhere but in the productivity statistics
- A worthy successor to the Solow paradox of 30 years ago

Current Opinions

- Very wide range of (implied) projections for medium-term TFP growth among technology pundits
- Gordon (2016): 0.4 % per year
- Brynjolfsson and McAfee (2014): 2.0% per year
- Kruse-Andersen (2017): recent history says US growth is semi-endogenous so Gordon too optimistic

Econometrics vs. Techno-Optimism

- Recent econometric estimates of trend U.S. TFP growth show a big fall (Antolin-Diaz et al., 2017; Ollivaud et al., 2016)

- Using similar methods, one would have been quite pessimistic ex ante in 1992 about medium-term TFP growth but seriously wrong ex-post

- **'Techno-optimists'** may be wrong but **should not be too dismayed by econometricians**

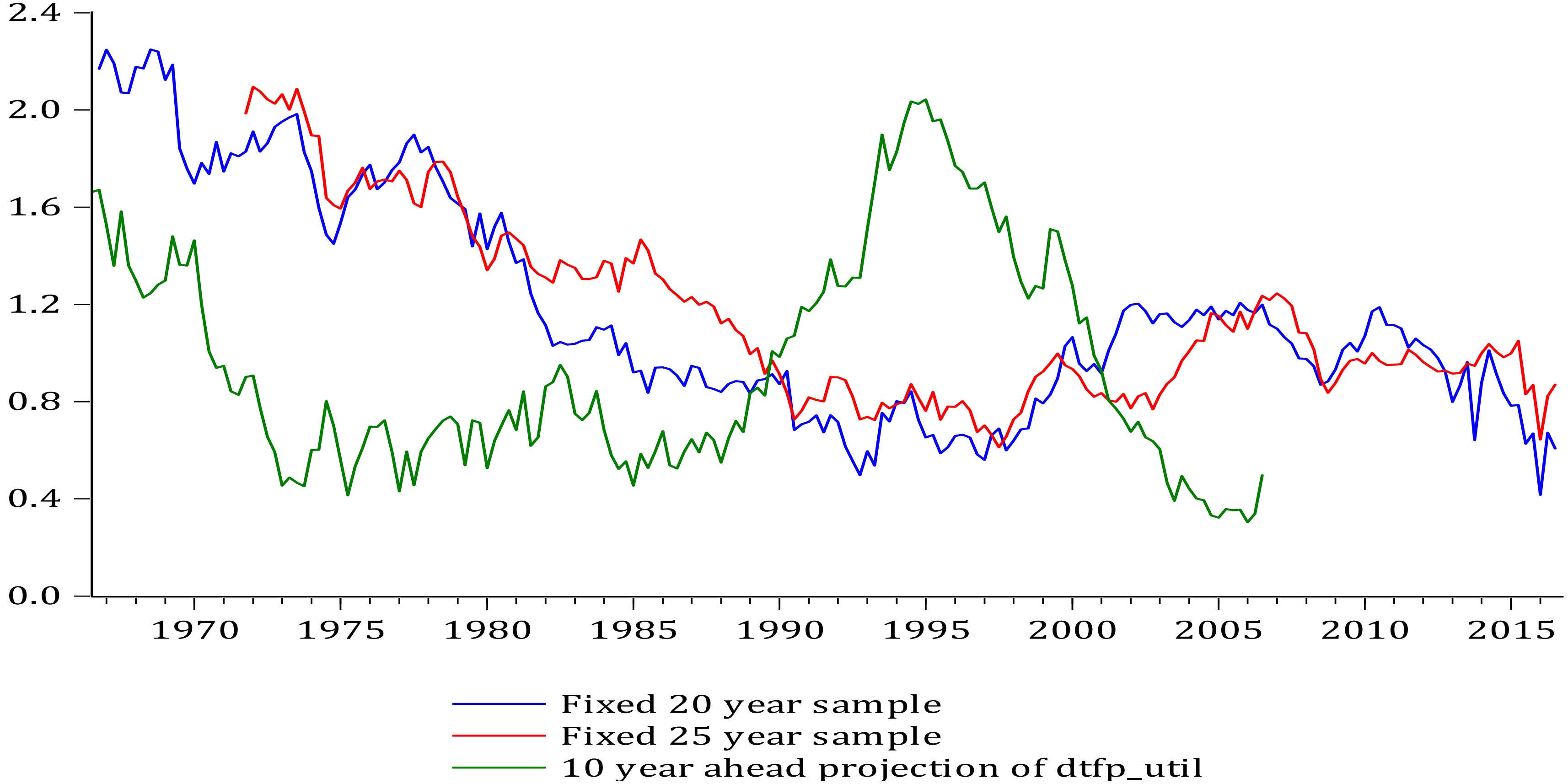
Past U. S. TFP Growth

(Crafts and Mills, 2017)

- Trend TFP growth has declined slowly from 1.5% to 1% per year in the last 50 years based on smoothed full-sample estimates of an unobserved-components model in which trend growth follows a random walk

- However, average TFP growth outcomes over a 10-year period vary a lot

- Making a 10-year ahead projection using trends inferred from estimating the model on past information does not work well


2.4
2.0
1.6
1.2
0.8
0.4
0.0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Fixed 20 year sample
Fixed 25 year sample
10 year ahead projection of dtfp_util

Are Ideas Getting Much Harder to Find?

- **Bloom et al. (2017): Yes!** – since 1930s rising research intensity but falling TFP growth such that the number of researchers has to double every 13 years just to maintain TFP growth

- It's a semi-endogenous growth story where past TFP growth largely reflects the transitory impact of increases in R & D/GDP

- If this is the right model, given that U.S. employment growth will decline markedly; steady state TFP growth could be as slow as 0.25% per year (Kruse-Andersen, 2017) so not much scope for real wage growth

Perhaps Not?

- **TFP ≠ technological progress**; rapid 1930s' TFP growth across sectors not highly correlated with R & D and partly reflects cleansing effect of Depression so not a good measure of productivity of R & D (Bakker et al., 2017)

- **Other indicators are less pessimistic** for growth prospects; half-life for patents = 114 years and for tech books no diminishing returns

- A techno-optimistic view would be that productivity of R & D might increase significantly in digital world through much better data analysis and recombinant innovation (Mokyr, 2013)

R & D and the Production of Ideas in the United States, 1955-2010 (1965 = 100)

	R & D	*(R & D)/GDP (%)*	*New Tech Books*	*Patents*
1955	**68.2**	**1.45**	**51.8**	
1965	**100.0**	**2.72**	**100.0**	**100.0**
1980	**162.8**	**2.21**	**198.1**	**78.4**
1995	**258.1**	**2.40**	**301.2**	**124.2**
2010	**375.1**	**2.73**		**214.5**

Notes: tech books based on titles in the catalogue of the Library of Congress; patents are those of domestic origin; all data are 5-year averages.
Sources: Alexopoulos and Cohen (2011); National Science Foundation (2017); United States Patent and Trademark Office (2016)

Lessons (2)

- Delayed impact of new GPT seems a quite plausible resolution of productivity paradox
- Estimates of trend TFP growth are not a reliable guide to the future
- TFP growth does not equate to technological progress
- The productivity slowdown is real but not necessarily permanent

Technological Progress and Living Standards

- Real wages and real GDP/person growth underestimate growth in workers' living standards during 20th century (cf. Gordon, 2016)

- Impacts on life expectancy and leisure are key reasons

- Conventional quantification suggests the former is much more important

- Yet **Keynes (1930)** stressed the latter and predicted that market **work** would fall to **15 hours per week by 2030**

Imputing Gains from Changes in Leisure and Life Expectancy to Augmented GDP

- Usher (1980): estimate the **consumption equivalent of change within a period** and add to end-period GDP before calculating growth rate
- Value changes in market-work hours at the wage rate
- Use VSL to estimate value of death averted with which to multiply changes in population-weighted average of mortality rates (Nordhaus, 2002)

Market Work: Yearly Hours

1870	**2755**
1913	**2655**
1950	**2112**
1973	**1919**
2001	**1655**

Sources: Huberman (2004); Maddison (2003)

Life Expectancy at Birth (years)

1870	**41.3**
1913	**53.4**
1950	**69.2**
1973	**72.0**
2001	**78.1**

Source: Government Actuary's Department

Growth of Augmented Real GDP/Person

(% per year)

	Mortality Imputation	Leisure Imputation	Augmented Y/P
1873-1913	**1.8**	**0.1**	**2.9**
1913-1951	**1.7**	**0.3**	**3.0**
1951-1973	**0.9**	**0.3**	**3.6**
1973-2001	**1.4**	**0.2**	**3.5**

Source: Crafts (2007) revised

Growth of Augmented Real GDP/Person

(% per year)

	GDP/P	Mortality Imputation	Leisure Imputation	Augmented GDP/P	Real Wages
1870-1913	**1.0**	**1.8**	**0.1**	**2.9**	**1.0**
1913-1950	**1.0**	**1.7**	**0.3**	**3.0**	**1.5**
1950-1973	**2.4**	**0.9**	**0.3**	**3.6**	**3.2**
1973-2001	**1.9**	**1.4**	**0.2**	**3.5**	**1.2**

Source: Crafts (2007)

Keynes' Prediction Revisited

- Between 1929 and 2000, average work-week for a full time UK worker fell from 47 to 42 (Huberman & Minns, 2007)
- Taking holidays into account, annual hours fell from 2257 to 1655, equivalent to a reduction from 43 to 32 for each week of the year; this still does not seems as big as Keynes expected
- What difference does a 'life-cycle approach' make?

Expected Years of Retirement

- Increased considerably during 20th century largely as a result of lower mortality
- In 1881, a 20 year-old could expect 1.76 years but in 2001 could expect 15.62 years
- On a life-time basis the **expected amount of leisure/non-market work rose by 46% between 1931 and 2001** compared with Keynes' prediction of 50% per week (65 to 97 hours)
- Keynes had the right idea but got the details wrong

Expected Length of Retirement at Age 20

(years)

	Actual	With 1881 Mortality
1881	1.76	1.76
1901	2.84	2.46
1931	4.66	3.05
1961	6.83	3.79
1981	10.29	5.17
2001	15.62	6.51

Source: Crafts (2005)

Lessons (3)

- Longer life expectancy is highly valued by workers so growth of living standards faster than growth of real wages during 20th century

- A significant part of the welfare gain from lower mortality risks is longer retirement which means much more leisure on a lifetime basis

- With regard to changes in leisure time, extensive as well as intensive margin matters; Keynes (1930) not quite as wrong as usually supposed