

The Industrial Revolution in Theory and in History: World Economic Growth Since 10,000 BC

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Lecture 3 – The Great Divergence

Figures and Tables

1. Divergence Paradox

1800-2000 mobility of goods, capital, technology improved
1800-2000 inequality of income per person across countries increased

2. TFP overwhelming source of divergence

The source of divergence in income per person was almost entirely increasing differences in the efficiency (TFP) of economies.

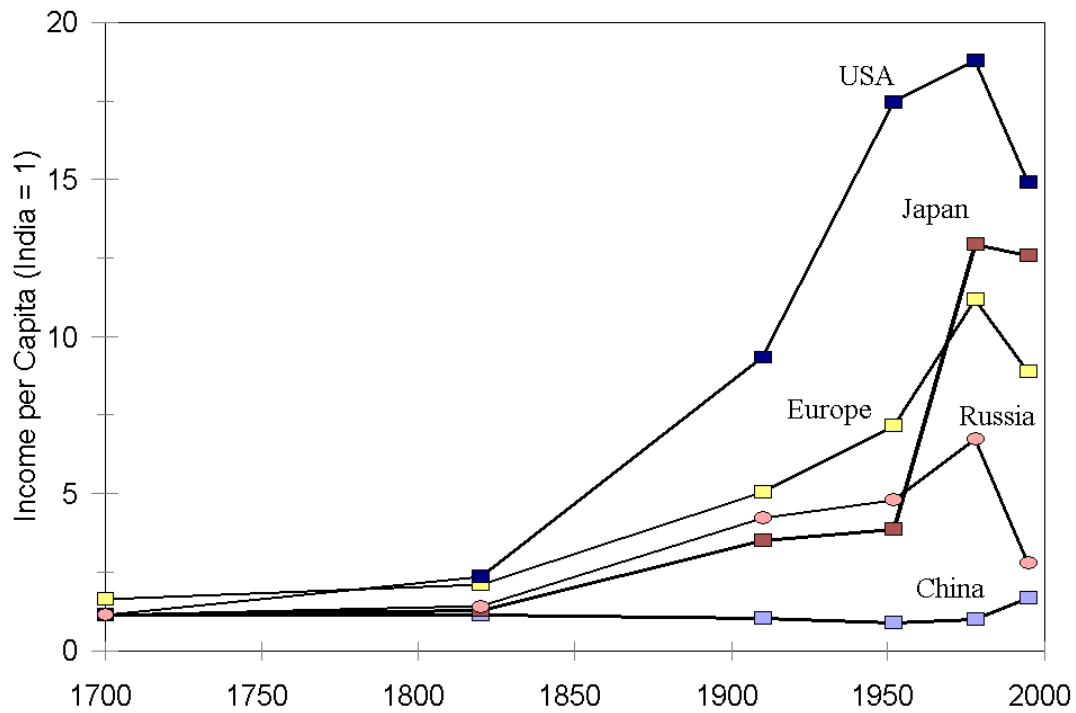
3. TFP differences have little to do with diffusion of production techniques. Differences stem from differences in the use of the same technology.

4. Differences in the efficiency of use

⇒ **low income levels**

⇒ **slow adoption of Western technology in poor countries**

Figure 1: Incomes per Capita Relative to India



Sources: 1700, 1820, Maddison (1989), 1910, Prados de la Escosura (2000) and Maddison (1989), 1952, 1978 and 1992, Penn World Tables.

Table 1: Income per Capita, 1910 and 1990

Country	(1) GDP per capita relative to India, 1910	(2) GDP per capita relative to India, 1990	(3) Calculated Efficiency (TFP), 1910 $\alpha=0.33,$ $\gamma=0.1$	(4) Calculated Efficiency (TFP), 1990 $\alpha=0.33,$ $\gamma=0$	(5) Calculated Efficiency (TFP), 1990 $\alpha=0.50,$ $\gamma=0$
USA	9.4	14.3	3.9	4.4	2.7
Australia	9.2	11.4	2.9	3.5	2.1
Canada	9.1	13.6	3.6	3.8	2.3
Great Britain	8.0	10.5	4.4	3.8	2.5
New Zealand	7.9	8.9	3.1	-	-
Argentina	7.6	3.7	4.0	2.3	1.7
France	7.2	11.0	3.9	3.6	2.2
Germany	7.0	11.6	4.2	3.4	2.1
Sweden	6.0	11.7	3.6	3.3	2.0
Italy	4.9	9.9	3.1	3.8	2.4
Spain	4.8	7.6	2.8	3.4	2.2
Ireland	4.8	7.5	2.9	-	-
Finland	4.6	11.1	2.8	3.0	1.7
Russia	4.2	-	2.2	-	-
Portugal	3.7	5.9	2.5	2.8	2.1
Japan	3.5	11.3	2.8	2.7	1.6
Ottoman Empire	3.3	3.0	2.0	-	-
Philippines	2.4	1.3	1.8	-	-
Thailand	1.6	2.8	1.3	1.5	1.3
Korea	1.5	5.3	1.5	2.4	1.6
Indonesia	1.3	1.6	1.2	-	-
China	-	1.0	-	-	-
Zimbabwe	-	0.9	-	0.6	0.5
Zambia	-	0.5	-	0.7	0.8

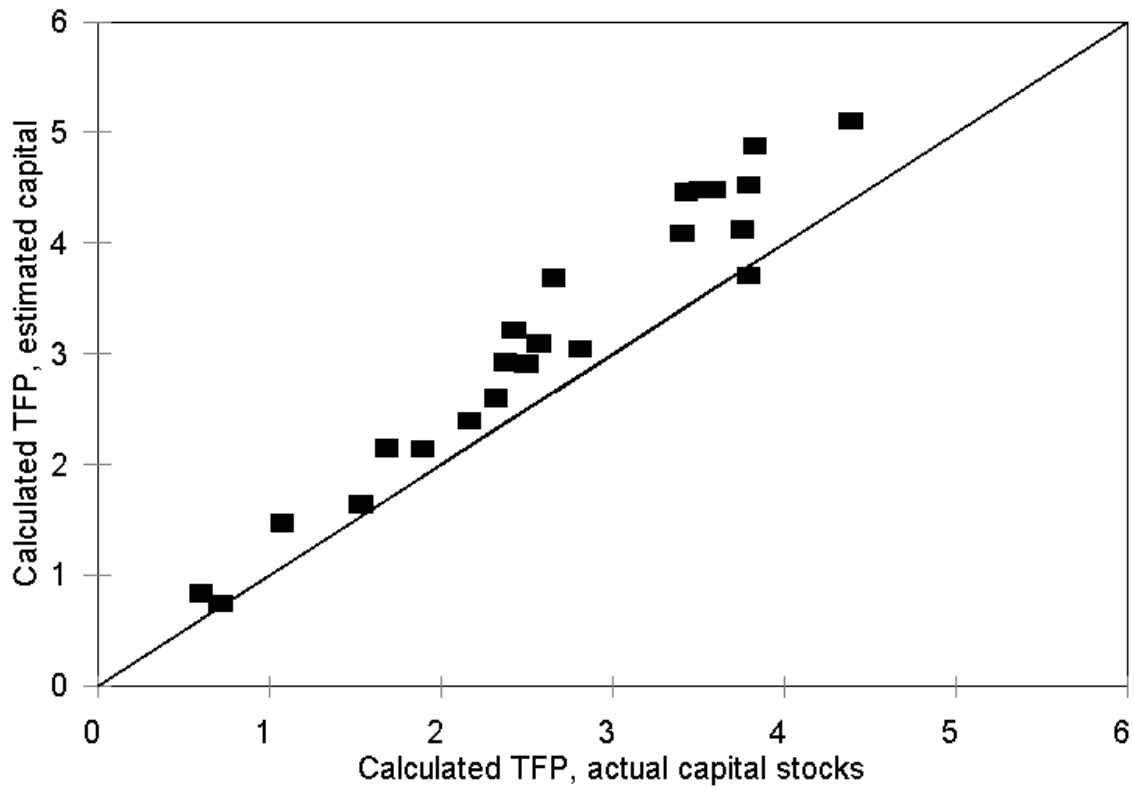
Sources: Prados de la Escosura (2000). Penn World Tables (PWT 5.6)

Notes: TFP in column (3) is computed assuming full capital mobility between countries.

Table 2: Population Densities circa 1800 in People per km² of arable.

Country	Arable Area, 1957 (m. km ²)	Population, 1800	People/km ²
China	2.88	330	114
India	1.94	190	98
Great Britain	.190	10.5	55
France	.346	27.2	79
Italy	.209	17.2	82
Spain	.219	10.7	49
Netherlands	.023	2.1	91
Belgium (1816)	.017	4.2	245

Figure 2: TFP Calculated with and without Capital Stock Information, 1990



Note: TFP calculated using $\alpha = 0.33$, $\gamma = 0$.

TFP differences have little to do with diffusion of production techniques

TABLE 3: TIME LAGS IN THE DIFFUSION OF INNOVATIONS

<i>Country</i>	<i>Newcomen Engine</i>	<i>Spinning Jenny</i>	<i>Water Frame</i>	<i>Mule</i>	<i>Power Loom</i>	<i>Watt Engine</i>	<i>Steam Railway</i>
Great Britain	1712	1768	1769	1779	1800	1775	1825
France	1726	1772	1779	1800	-	1778	1832
Belgium	1721	-	1801	1821	-	1791	1835
Netherlands	-	-	1785	1839	-	-	-
Germany	1722	1782	1783	1799	1842	1791	1835
Switzerland	-	-	-	-	-	1824	1847
Spain	-	-	-	-	-	1789	1848
Portugal	-	-	-	-	-	1803	-
Italy	-	-	-	-	-	1787	1839
Austria	1724	-	-	-	-	1817	1838
Hungary	1733	-	-	-	-	1803	-
Sweden	1728	-	-	-	-	-	-
Russia	-	-	-	-	-	1790	1838
U.S.A.	1755	1775	1789	1789	1811	1803	1830
Canada	-	-	-	-	-	1811	1836
Brazil	-	-	-	-	-	1810	1854
Argentina	-	-	-	-	-	-	1857
Mexico	-	-	-	-	-	1818	-
India	-	-	-	1817	-	1800	1853

Notes: The Table gives the date of the first use I found recorded of the machine. Its use earlier than this date is possible.

Sources: Henderson (1965), Jeremy (1981), Pollard (1981), Rolt and Allen (1977), Tann and Breckin (1978), Woodruff (1976).

Table 4: Platt Ring Frame Orders by Country, 1890-1934

Country	Sales, 1890-1914 (9 years)	Sales, 1914-1936 (9 years)
Austria	4	0
Belgium	17	15
Brazil	95	43
Canada	15	17
China	5	64
Czechoslovakia	14	10
Egypt	0	5
England	110	74
Finland	1	0
France	41	31
Germany	47	6
Guatemala	1	1
Hungary	0	4
India	66	132
Italy	69	29
Japan	66	117
Mexico	75	7
Netherlands	7	2
Nicaragua	2	0
Peru	7	0
Poland	41	8
Portugal	8	0
Russia	131	23
Spain	95	35
Sweden	3	0
Switzerland	3	0
Turkey	0	6
USA	2	0
West Africa	0	2

Source: Platt Ring Frame Order Books, Lancashire Record Office.

Differences in the efficiency of use

TABLE 5: COTTON TEXTILE COSTS, CIRCA 1910

<i>Country or Region</i>	<i>Weekly Wage (55 hours)</i>	<i>Plant and Machinery Cost (\$/spindle)</i>	<i>Coal Cost (\$/ton)</i>	<i>Total Manufacturing Cost (England = 100)</i>	<i>Implied Profit Rate (%)</i>
U.S. South	6.5	17.4	3.8	130	-0.7
England	5.0	12.7	2.5	100	8.0
Spain	2.7	19.3	6.5	91	10.5
Mexico	2.6	19.3	10.0	94	9.6
Russia	2.4	20.7	7.2	91	10.3
Italy	2.4	16.0	7.2	81	13.8
Japan	0.8	24.6	2.6	73	14.1
India	0.8	17.6	5.0	61	19.1
China	0.5	16.3	3.2	53	22.1

Source: Clark (1987).

TABLE 6: COTTON TEXTILE COSTS ADJUSTING FOR HOURS

<i>Country or region</i>	<i>Hours per year</i>	<i>Plant and Machinery Cost (\$/spindle)</i>	<i>Total Manufacturing Cost (England=100)</i>	<i>Implied Profit Rate (%)</i>
US South	3450	16.0	126	-0.8
England	2775	12.7	100	8.0
Spain	4455	14.6	84	14.1
Mexico	6750	11.5	82	14.4
Russia	4061	16.1	84	16.6
Italy	3150	16.1	79	13.5
Japan	6526	13.4	62	25.2
India	3744	15.3	58	23.4
China	5302	11.9	48	32.9

Source: Clark (1987).

**TABLE 7: MACHINES PER WORKER AND OUTPUT PER MACHINE,
CIRCA 1910**

<i>Country or Region (England=100)</i>	<i>Weekly Wage (55 hours)</i>	<i>Loom Equivalents Per Worker</i>	<i>Output per Spindle (oz/hour)</i>	<i>Real Wage Cost</i>
US North	8.8	3.0	0.60	106
US South	6.5	2.6	0.60	100
England	5.0	2.0	0.65	100
Spain	2.7	0.9	-	120
Mexico	2.6	1.1	-	95
Russia	2.4	1.1	-	87
Italy	2.4	0.9	0.67	107
Japan	0.8	0.5	0.63	64
India	0.8	0.5	0.56	64
China	0.5	0.5	0.52	40

Source: Clark (1987).

TABLE 8: OUTPUT PER WORKER IN COTTON SPINNING (lbs/hr, 20s yarn)

<i>Year</i>	<i>USA</i>	<i>UK</i>	<i>India</i>	<i>Japan</i>
1880	2.6	2.9	0.7	-
1890	-	3.7	0.8	0.8
1900	-	-	0.9	1.3
1913	4.7	3.9	0.8	1.7
1924	5.3	3.4	1.1	2.0
1929	6.8	-	1.1	3.0
1937	8.0	4.0	-	4.0
1949	12.9	5.0	1.1	3.7
1956	-	4.7	1.5	6.8
1967 ^a	39.5	12.2	4.3	13.2
1978 ^b	-	29.4	4.0	-

Notes: ^aLowest cost mills.

^b40s count yarn.

**TABLE 9: LABOR COST PER POUND IN
COTTON SPINNING (INDIA = 100)**

<i>Year</i>	<i>USA</i>	<i>UK</i>	<i>India</i>	<i>Japan</i>
1880	192	182	100	-
1890	-		-	
1900	64			
1913	137	154	100	54
1924	185	127	100	192
1937	182	156	100	-
1949	103	76	100	49
1956	-	149	100	52
1967 ^a	146	198	100	78

Notes: ^aLowest cost mills.

TABLE 10: OUTPUT PER SPINDLE-HOUR IN COTTON SPINNING (20s yarn)

<i>Year</i>	<i>USA</i>	<i>UK</i>	<i>India</i>	<i>Japan</i>
1880	(2.26)	(3.13)	2.10	-
1890	(2.53)	(3.55)	3.07	2.59
1900	3.07	-	3.07	3.67
1913	3.25	(3.30)	3.00	4.36
1924	3.13	2.94	3.24	4.17
1929	3.26	-	3.36	4.39
1937	3.33	3.83	-	4.49
1949	3.83	3.64	2.90	4.44
1955	-	3.27	3.32	4.89
1964	-	3.59	3.10	-
1967 ^a	5.35	4.42	4.17	6.73

Notes: ^aLowest cost mills.
 Brackets indicate the most tentative observations. Output given in lbs per 100 spindle hours.

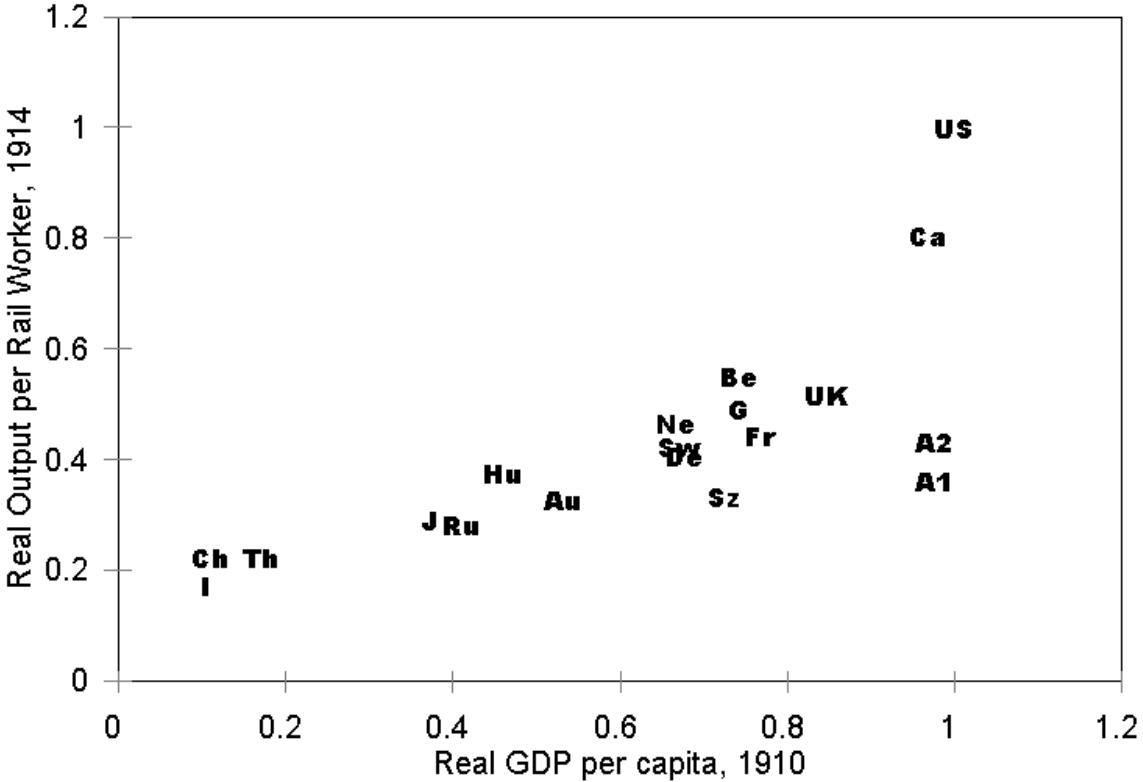
Table 11: Railroad Operating Efficiency circa 1914

Country	Year	Output per worker, \$	Output per track mile, \$	Efficiency (USA=1)	Miles per locomotive per year
Australia	1914	691	4,421	0.41	24,243
Austria	1912	567	9,677	0.61	16,934
Belgium	1912	959	10,332	0.78	18,282
Canada	1914	1,400	5,487	0.62	25,175
China	1916	389	5,495	0.37	30,408
Denmark	1914	709	6,669	0.53	15,006
France	1911	772	7,451	0.59	22,926
Germany	1913	857	11,826	0.81	25,746
Hungary	1912	653	5,443	0.45	-
India	1914	297	4,208	0.28	-
Japan	1914	507	6,488	0.46	27,196
Netherlands	1912	812	6,982	0.57	32,330
Romania	1913	489	6,738	0.46	23,340
Siam	1914	389	2,128	0.21	17,592
Sweden	1912	739	3,288	0.35	22,442
Switzerland	1913	577	6,831	0.49	-
UK	1912	898	9,457	0.72	25,854
USA	1914	1,743	10,565	1.00	26,092

Sources: Boag (1912), Bureau of Railway Economics (1915), various national railway statistics.

Note: Our method means that output per worker is measured in the same prices everywhere. Freight output was estimated as (tons×\$0.285 + ton-miles×\$0.0066). The quality of passenger service varied greatly. For India, for example, revenue was 2.4¢ per mile for first class and 0.4¢ for fourth class. We adjusted passenger-miles by assuming first class was equivalent everywhere and weighting passenger miles in other classes according to the relative revenue generated per passenger-mile.

Figure 3: Output per worker on railways versus GDP per capita, 1910



Note: A1 is New South Wales, A2 is South Australia. Otherwise country codes as before.

Inefficiency of use

⇒ slow adoption of Western technology in poor countries

Table 12: The Bombay Textile Industry, 1907-1938

Year	Gross profit rate on fixed capital	Size of the Bombay Industry (m. spindle- equivalents)	Output per worker in Bombay (Index)	Output per worker in Japan (Index)
1905-9	0.06	3.09	100	100
1910-4	0.05	3.43	103	115
1915-9	0.07	3.68	99	135
1920-4	0.08	4.05	94	132
1925-9	-0.00	4.49	91	180
1930-4	0.00	4.40	104	249
1935-9	0.02	3.91	106	281

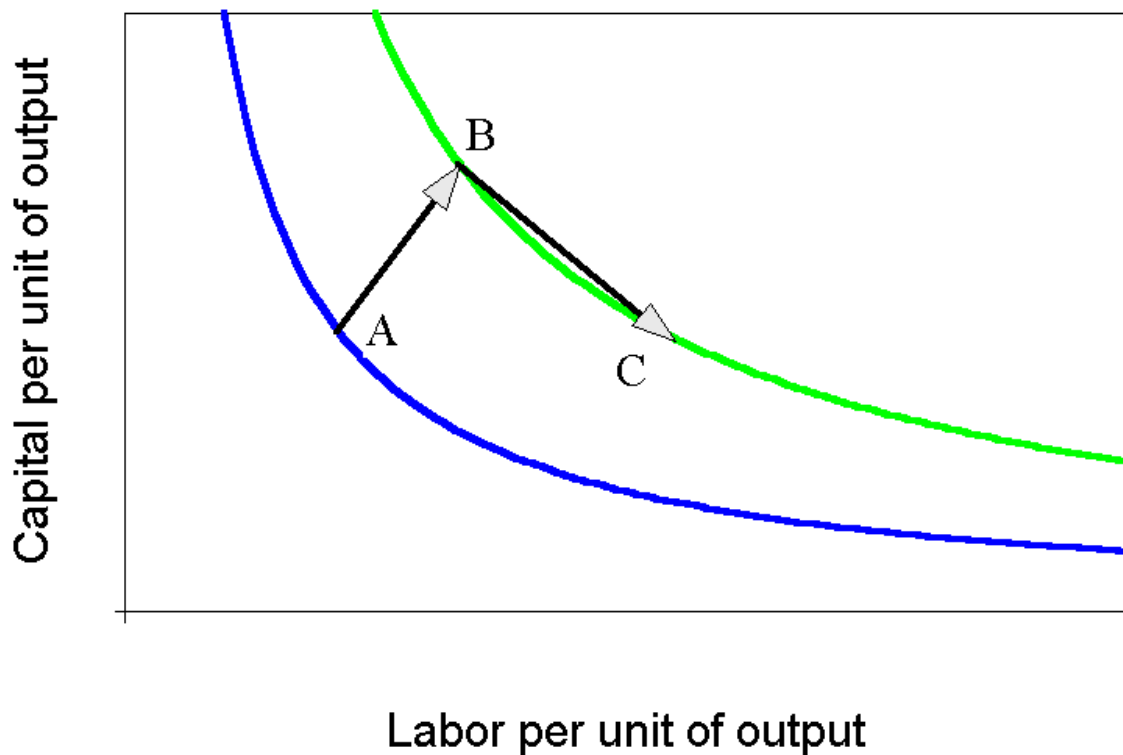
Notes: Profits and output per worker were calculable only for the mills listed in the Investor's India Yearbook.

Source: Wolcott and Clark (1999).

Inefficiencies look like they may attach to labor as a factor. Output per worker varies, output per unit of capital relatively constant.

But this could be generalized inefficiency or labor inefficiencies depending on elasticity of substitution.

Figure 4: A Generalized Inefficiency Interpretation of Efficiency Differences and Factor Proportions



A Technique with no substitution between capital and labor – doffing.

Table 13: SPINDLES DOFFED PER WORKER PER HOUR

Year	USA	Britain	India	Japan
1907	-	-	102	-
1921	728	-	118 ^a	-
1944	606	354	124 ^b	-
1946	770			
1949/50	933	570 ^c	-	505
1959	1,000	-	-	-
1969	-	600 ^d	-	-
1978	-	-	160 ^e	-
1990	-	-	230	-

Notes: ^aBombay City and Island. Calculated from Shirras (1923) on the assumptions that there is one side per ring spinner (170 spindles), that output per spindle-hour averages 0.038 lbs., and that the weight of the doff package is 0.084 lbs (the same as Britain in 1949).

^bIndia except the Bombay Presidency.

^cLowest cost mills.

^dAssumed performance in modernization study.

^eSouth Indian mills. Doff package assumed to be 0.12 lbs.

Sources: Shirras (1923), Cotton Spinning Productivity Team (1951), Ratnam and Rajamanickam (1980), Doraiswamy (1983), Textile Council (1969).

FIGURE 7.4
Average Profit Rates and Manning Level Indices, 1935-1938

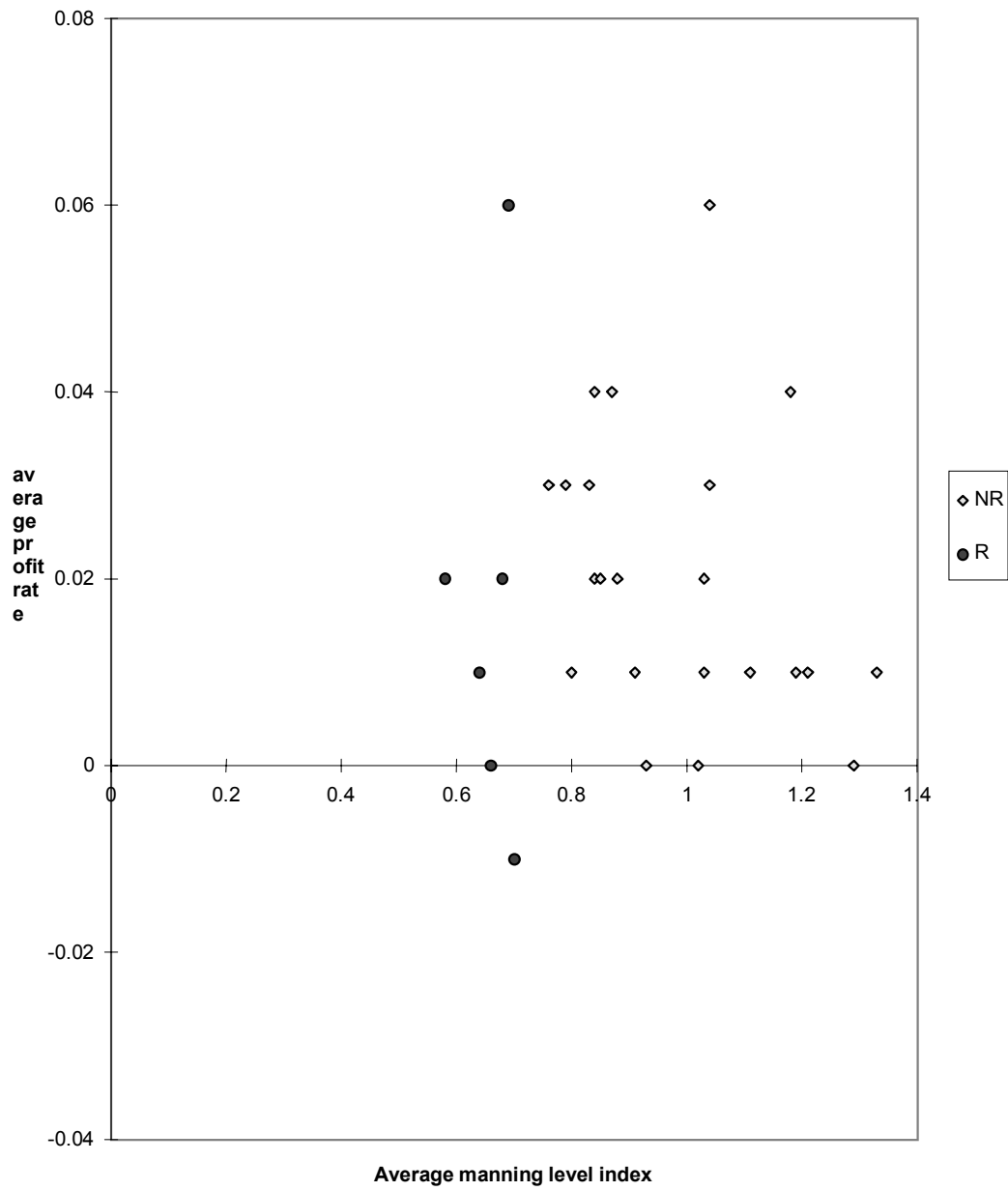
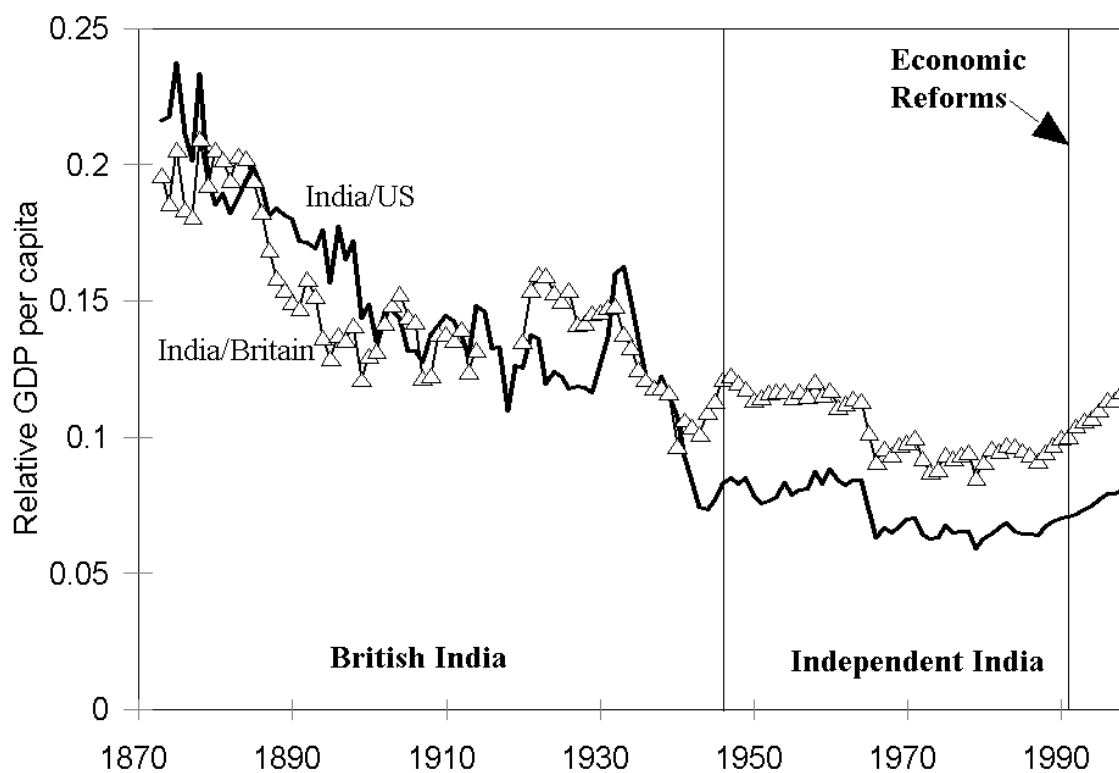
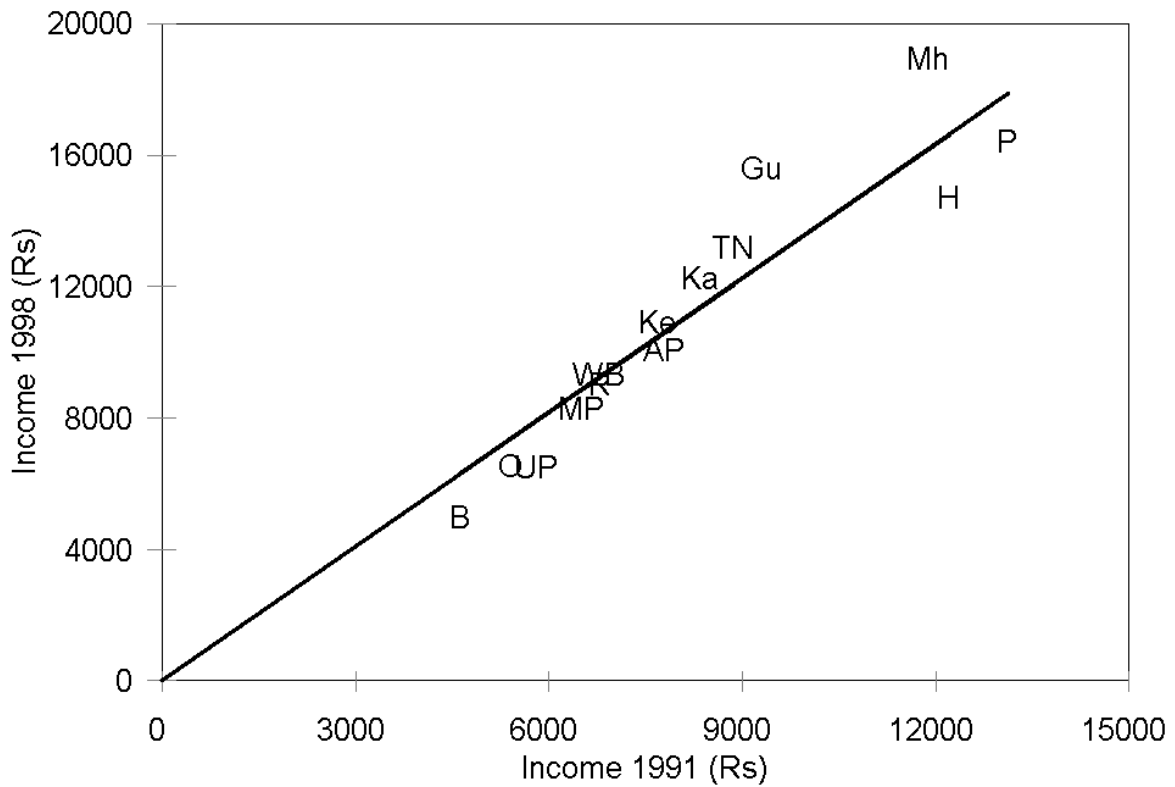


Figure 6: Indian GDP per Capita relative to Britain and the USA, 1873 to 1998



Sources: India. Pre-1947, Heston (1983). 1950-1980, Penn World Tables (PWT 5.6). 1981-1998, Statesforum. USA. 1873-1929, Balke and Gordon (1992). Economic Report of the President (2001). United Kingdom/Britain. 1873-1965, Feinstein (1972), 1965-1998, United Kingdom, National Statistical Office.

**Figure 7: Indian States - Income in 1998-9 as a function of 1991-2
(1993-4 Rupees)**



Note: Throughout in the figures we use the following symbols for states: AP, Andhra Pradesh, B, Bihar, G, Gujarat, H, Haryana, Ka, Karnataka, Ke, Kerala, MP, Madhya Pradesh, Mh, Maharashtra, O, Orissa, P, Punjab, R, Rajasthan, TN, Tamil Nadu, UP, Uttar Pradesh, WB, West Bengal. Rajasthan's income per capita is projected from 1997-8.

Source: Statesforum.

Table 14: Cloth Production in India by Sector, 1997-8 (meters²)

Year	Mill Production	Decentralized Powerloom Production	Decentralized Handloom Production
1900-3	483	0	793
1936-9	3,630	0	1,420
1951	3,740	-	-
1973	4,299	-	-
1980-1	4,533	4,802	3,109
1997-8	1,948	20,951	7,603

Sources: Office of the Textile Commissioner (1997, 1998). Mazumdar (1984), pp. 7, 36.