

The Demand for Qualified Engineers in Great Britain, 1921 to 1971

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“The scientific and engineering manpower problem is one of the principal preoccupations of the British Government” (Payne 1960, p.10).

From the mid-Victorian period onwards, the British have had an inferiority complex with regard to the supply of technically trained personnel in their labor force. Yet over the course of the twentieth century, the perception that advances in technology have presented distinct challenges in developing suitably skilled expertise is hardly peculiar to the British. In the 1950s and 1960s, many in the United States and in other OECD countries expressed concerns about impending shortages of scientifically and technologically trained personnel.

Using as a simple benchmark, the percentage of the total labor force who were scientists and engineers, the British level was not particularly low for scientists and engineers combined but was noticeably low if the focus is on engineers.

In contrast with the ancient learned professions of law, medicine, and theology, the profession of engineering has emerged primarily in the last two to three centuries. The rise of the engineering profession can be seen as fundamental in facilitating the increasingly scientific basis of technological advance during this period. Despite the inherently practical character of engineering, the training of engineers over this period came increasingly to be university based in developed countries such as France, Germany, the U.S. and Britain. Constructing a history of the rise of the engineering profession provides both the challenge and opportunity of allowing for the historical trends at work in the emergence of this distinctive new occupation as well as the fact that it was subject to the basic market forces of supply and demand.

Lundgreen (1990) among others has distinguished various national traditions in the rise of school based engineering. He distinguishes the early rise of state and to a large degree military sponsored engineering training for both civilian public works such as bridges and for more military related projects in France and to a lesser extent the German states in the eighteenth and early nineteenth centuries from the more industrial related support for the rise of engineering as a profession in Britain and the United States.

Despite concerns of delayed development in Britain throughout the later nineteenth and early twentieth centuries, the various branches of engineering did establish themselves in various professional societies and with university programs.

This paper will turn to the twentieth century. It is instructive to consider how the engineering profession developed in Britain after its initial foundations had been established. Whatever its relative performance level, the engineering profession was able to accomplish remarkable expansion over the course of the twentieth century.

Table 1 Scientific and Technical Personnel in Relation to Civilian Employment 1959 for Selected Countries

Country	University Trained Scientists and Engineers as % of Civilian Labor force	All Scientists and Engineers as % of Civilian Labor force
Austria	0.6	1.4
Belgium	0.5	1.0
Canada	1.3	1.3
Denmark	0.8	1.2
France	0.8	0.8
Germany	0.6	1.3
Greece	0.4	0.4
Ireland	0.5	0.5
Italy	0.9	1.7
Netherlands	0.4	1.0
Norway	0.9	1.9
Sweden	0.7	1.4
Switzerland	...	0.8
Turkey	0.1	0.1
United Kingdom	...	1.0
United States	...	1.7

Source: OECD 1963, Table 61, p.112

Table 2. University Graduate Scientists and Engineers per 1,000 labor force

Country (year of estimate)	Scientists	Engineers
Great Britain (1955)	2.5	1.4
Italy (1951)	1.5	2.8
France (1954)		7.3
Netherlands (1947)	1.0	1.7
Sweden (1954)		3.1
Denmark (1956)		3.3
Norway (1955)	0.9	5.4
United States (1956)	2.7	6.6

Source: Payne (1960). p.31

Some International Perspectives on the Relationship between Scientists, Engineers and Economic Development

A 1963 OECD survey provides some more general perspective on the relationship between the utilization of professionally qualified engineers and economic development. Of some 16 countries surveyed on their scientific and technical personnel, some basic correlations yield the following relationships. First, not surprisingly, both engineers relative to the labor force and scientists relative to the labor force are positively correlated with GNP per capita (+0.49, +0.33) and negatively correlated with percent of the labor force in agriculture (-0.49, -0.37). Thus, increasing the percentage of engineers and of scientists in the labor force can be seen as proceeding with economic development.

One might expect that an important contribution of technical personnel such as scientists and engineers would lie in fostering technological advance through innovation and research. In terms of association with patents and R& D activity, it is of interest to note that percentage of the labor force who are engineers is negatively correlated with numbers of patents (-0.45) and percentage of GNP allocated to R& D activity (-0.29) while the percentage of the labor force who were scientists is positively correlated with patents (+0.81) and R&D percentage of GNP (+0.9). However, countering the notion that engineers have an adverse impact on patenting and are not supported by R&D activity, the absolute numbers of both engineers and of scientists was positively correlated with patents and R& D percentage (for engineers +0.69, +.77, for scientists +0.81, +0.81).

In expanding the overall size of the technical and scientific workforce, the consideration arises of how much emphasis to put on basic research which can loosely be associated with those in the workforce identified as scientists compared with applied research and development which can loosely be associated with those in the workforce identified as engineers. As economic development and the cultivation of technical change proceeds, should relatively greater emphasis be put on science or engineering?

The percentage of scientists and engineers who were engineers is positively correlated with GNP per capita (+0.56) and negatively (weakly) correlated with percent of the labor force in agriculture (-0.055). This percentage (engineers to scientists and engineers) is negatively correlated with patents (-0.36) and positively correlated with R&D percentage (+.154). Focusing on those scientists and engineers who were university trained

and the percentage of those who were engineers, strengthens the positive correlation with GNP per capita (to +0.66) but reverses the correlation with percent of LF in agriculture to positive (+0.24); it also reverses the correlation with patents to positive (+0.56) and strengthens the relationship with R&D percentage relative to GNP (+0.43). This certainly suggests that the association between relative activity in engineering and the process of economic development and innovative activity depends on how the group engaged in engineering is defined and possibly its particular process of training.

Correlations

	1	2	3	4	5	6	7	8	9
1Eng. %	1								
2UN V ENG %	.743	1							
3AG ENG %	-.0985	-.281	1						
4LF AG %	-.0549	.239	.0042	1					
5GN PCA P	.5594	.662	-.0827	-.745	1				
6Pate nts	-.3616	.563	-.4979	-.4252	.6293	1			
7RD % GNP	.1543	.427	-.8167	-.872	.648	.699	1		
8AB S#EN G	.1194	-.346	.070	-.326	.711	.6935	.7675	1	
9AB S#SC I	-.054	-.443	-.440	-.285	.5475	.809	.813	.964	1
10% ENG LF	.6845	.223	.3872	-.493	.4923	-.446	-.288	.268	.167
11%S CILF	-.264	-.59	-.4635	-.3725	.3312	.810	.899	.6051	.751

Definitions of variables:

1)Eng% : Percentage of all scientists and engineers who were engineers circa 1950-60

2)UNIVENG%: Percentage of all university trained scientists and engineers who were engineers circa 1950-60.

- 3)AGENG%:Percentage of all scientists and engineers circa 1950-60 who were agricultural engineers.
- 4)LFAG%: Percentage of the labor force engaged in agriculture circa 1960
- 5)GNP/CAP: GNP per capita 1960
- 6)Patents: Number of patents circa 1960
- 7)RD%GNP: Expenditure on Research and Development as a percentage of GNP 1960
- 8)ABS#ENG: Absolute number of engineers in the labor force
- 9)ABS#SCI: Absolute number of scientists in the Labor force
- 10)%ENGLF: Percentage of the total labor force who were engineers circa 1960
- 11)%SCILF: Percentage of the total labor force who were scientists circa 1960.

Country	% Engineers of Sci + Eng.	% Engineers of University trained Sci. + Eng.	% Ag. Engineers of Sci. + Eng.	% of Labor force in Agriculture
Austria	78	62	22	22.7
Belgium	77	60	15	7.7
Canada	65	65	18	
Denmark	72	58	34	22.1
France	67	67	12	28.7
Greece	44	44	22	53.2
Ireland	57	57	15	
Italy	62	40		31.7
Netherlands	80	55	17	10.7
Norway	83	65	23	23.9
Sweden	82	60	15	14.7
Switzerland	67			16.5
Turkey	59	59	17	80.7
U.S.	54			4.5
U.K.	71			8.8
Yugoslavia	32	32	23	

Country	GNP/Capita 1960	Patents	% of GNP to R&D activity	Absolute # of Engineers (000)	Absolute # of Scientists (000)
Austria		6,850		36.5	3.5
Belgium	1196			30.5	4.5
Canada	1947	24,589	1.2	60.4	14
Denmark	1057	2833		20.9	1.2
France	943	33,850	1.3	140	28
Greece	340			5.8	4.4
Ireland	550	434			
Italy	516			190	103
Netherlands		13,900		36.1	5.2
Norway	1130	1985	0.7	32.0	1.6
Sweden	1380	6125	1.8		5.4
Switzerland	1428	10,350			4.9
Turkey	220			9.1	3.7
U.K.	1189	34,060	2.5	141.9	100
U.S.	2577	47,378	2.8	872	272
Yugoslavia	265		0.7	27.4	18.0

Sources: OECD 1963, Evan 1969

Growth of the Engineering Profession in Britain

Yet whatever its deficiencies relative to other countries circa 1960, Britain experienced a dramatic expansion in its professionally qualified engineers relative to the rest of its labor force over the twentieth century.

Trends in Employment in the Higher Professions (thousands)

Profession	1911	1921	1931	1951	1971	1971/1911 x100
Engineering	25	35	51	138	425	1700
Science	5	13	20	49	77	1540
All Professions	185	195	241	434	824	448
Total British Labor force	18,347	19,333	21,029	22,514	25,021	136

Source: Routh (1980), p.13

As the table above shows, between 1911 and 1971, the number of engineers increased 17 times compared with 15 times for scientists, 4.5 times for all higher professions and 1.36 times for the labor force as a whole.

Growth of the Engineering Profession in the U.S.

Year	No. of Engineers
1870	7,094
1880	7,061
1890	28,239
1900	43,239
1910	88,755
1920	136,121
1930	227,590
1950	534,424

Source: Blank and Stigler (1957), p.5

The rate of expansion of the engineers reported by Blank and Stigler for a comparable period (1910 to 1950) was only slightly above that of the British figure –6 times for the U.S. compared with 5.5 times for Britain. The expansion of chemists in the U.S. for this same period was 4.65 times compared with 9.8 times for scientists for Britain (compare chemists only). Even allowing for issues of comparability, it would appear that Britain experienced a very considerable expansion of its engineering profession over the course of the 20th century and would certainly mitigate any strong claims of failure on either the demand or supply side of the profession to develop.

All the same despite Britain's marked expansion of engineers over the course of the twentieth century and their relatively greater increase than scientists, by the time of the OECD survey in the early 1960s, it still had a relatively low proportion of engineers to total scientific and technical personnel.

A Supply and Demand Framework for Examining the Expansion of the Engineering Profession.

In a basic supply and demand framework, one can view the rise of the engineering profession as due to the interaction between the demands of industrial employers as well as government demands for both civilian and military purposes for those with engineering training and the capacity of universities and experienced engineers offering pupilage opportunities to supply additional people with such training. In the British historiography of the engineering profession, both blades of the supply and demand scissors have been subject to scrutiny with both detractors and defenders. British industrialists have been criticized for their short sighted emphasis on practical experience rather than theoretical and scientific foundations for the aspiring engineer. Yet defenders have pointed out that survey evidence indicates that industrialists did appreciate the value of scientific and mathematical training and were willing to entertain various schemes to sandwich university course work with practical industrial experience. On the supply side, the ancient universities of Oxford and Cambridge have been criticized for their emphasis on maintaining a classical and abstract curriculum with inherent suspicion of course work and programs that would have practical applications.

However, Sanderson (1972) among others has mapped out in detail how the new civic or redbrick universities arose throughout the nineteenth century in large part through the support of industrialists and were quite receptive to establishing engineering and other applied programs oriented to industry. And furthermore, over the course of the century, Cambridge and to a lesser degree Oxford developed engineering and chemistry programs oriented towards industry.

As sketched thus far, simple quantity and salary trends in the labor market for British engineers should provide some perspective on the various claims. A substantial rise in quantity generally would seem to support optimist claims of responsiveness and forces shifting out both employer demands and university supply with movements in salaries indicating the extent to which demand or supply shifts predominated over each other. A sluggish change in quantity of engineers would be more consistent with the views of

pessimist critics of British technological upgrading and development of the engineering profession in particular.

However, one can locate sources of more specific influence that provide perspective on the forces at work. On the demand side these include industrial composition, international competition, and business cycle conditions. On the supply side there is the role of both centralized government support and funding for engineering as well as local governmental and civic support and funding. There was also the pool of suitable students and apprentices for entering engineering which would have been influenced by the overall capacity of various social and income classes for supporting themselves in costly higher education and pupilage endeavors.

Trends in the Demand for Engineers in Britain

The seventeen fold expansion in the number of engineers employed in Britain between 1911 and 1971 would strongly suggest a marked shift out in labor market demand; although with a high enough price elasticity and price declines, a shift out in supply could accomplish this, plausibility suggests that some substantial shift out in demand must have occurred.

One approach to gaining more insight into the sources of this shift is to look at trends in the industrial composition of the engineering profession over this period. As has been noted for the United States, employment of engineers in Britain tended to be concentrated in certain reasonably narrowly defined industries.

Table 5. Distribution of Employment of Engineers in the U.S. by Major Industry, 1950

Ordnance	.5
Primary metals	2.8
Fabricated Metals	3.5
Machinery	7.7
Electrical Equipment	10.0
Motor Vehicles	2.9
Aircraft	4.0
Other Transportation Equipment	0.7
Professional and Scientific Equipment	2.2
Miscellaneous Manufacturing	0.9
Food	0.9
Textiles and Apparel	0.5
Lumber and Furniture	0.5
Paper	1.1
Chemicals	4.9
Petroleum refining	1.5
Rubber	0.8
Stone, clay, and glass	1.0
Petroleum Extraction	1.5
Other Mining	1.1
Construction	6.0
Railroads	1.3
Other Transportation	0.8
Telecommunications	1.5
Radio and TV	0.4
Public Utilities	2.5
Miscellaneous Business Service	4.0
Engineering and Architectural Services	10.0
Other Non-Manufacturing	2.8
Federal Government	9.6
State Government	4.7
Local Government	4.4
Universities and Colleges	2.8
Nonprofit Institutions	0.2

Source: Freeman (1971), p.56

Table 6. Distribution of British Scientists and Engineers among Manufacturing Industries
In the 1950s
percent

Electrical Engineering	25.0
Chemicals and allied trades	17.0
Other plant and Machinery (n.e.c.)	13.6
Aircraft	8.7
Motor Vehicles	4.3
Textiles and Clothing	4.2
Iron and Steel Manufacturing	4.1
Food, Drink, tobacco	3.4
Metal goods (n.e.c.)	3.4
Mineral oil refining	2.7
Misc. Manufact. (Rubber, Plastics)	2.5
Nonferrous Metals Manufact.	2.3
Construction Engineering	1.7
Wood, cork, paper, printing	1.7
Shipbuilding, marine engineering	1.6
Precision instruments, jewelry	1.6
Bricks, china, glass, cement etc.	1.6
Railway equipment	0.4
Agricultural machinery	0.2

Payne (1960), p.53

Table 7. Distribution of American Scientists and Engineers among Manufacturing Industries
circa 1953-4

Chemical and allied products	13.4
Electrical Equipment	13.1
Machinery	12.9
Other manufacturing (n.e.c.)	12.0
Aircraft and parts	10.4
Petroleum products and extraction	8.2
Construction	6.1
Primary metal industries	5.7
Metal products and ordnance	4.7
Professional & Scientific instruments	4.0
Food and kindred products	3.1
Stone, clay, glass products	2.1
Rubber products	1.7
Paper and allied products	1.4
Textile mill products and apparel	1.3

Source: Payne (1960), p.53

For England and Wales in 1951 a relatively small number of industries accounted for the bulk of engineering employment. Some 37 percent of mechanical engineers were employed in just 4 narrowly defined three digit industries: a) other non-electrical engineering, b) manufacture and repair of aircraft, c) national government service and d) consulting engineering. For other types of engineers, employment was even more concentrated. The electric goods, electricity, postal and telegraph sectors accounted for 76 percent of employment of electrical engineers. For civil engineers some 8 industries (ships and other engineering, civil engineering and contracting, water, gas, national government service, local government service, and other professional and business service) accounted for 88 percent of employment. And for chemical engineers, some 4 sectors (chemicals and dyes, mineral oil refining, other non-electrical engineering, and gas) accounted for 83.3 percent of employment.

One can compare this with the U.S. Case. Freeman's (1971) classifications indicate that 8 out of 33 industries (exact categories) accounted for 65 percent of engineering employment (machinery, electrical engineering, aircraft, chemicals, construction, miscellaneous business services, engineering and architectural services, and government).

A number of British government reports in the mid-1950s noted that the employment of scientists and engineers was concentrated in four industry groups (aircraft, chemicals, electrical engineering, and an amorphous 'other plant and machinery') which between them accounted for only thirty percent of the overall labor force but two thirds of employment of scientists and engineers (Payne 1960, p.50). Payne (1960, p.50) also observes that British employment in three of these industries, aircraft, chemicals, and electrical engineering accounted for only one-eighth of all manufacturing workers but one half of all employment of scientists and engineers. In contrast, the same three industries employed one-sixth of all workers in manufacturing industry but just over a third of scientists and engineers.

One can decompose the growth in engineering employment into that due to growth of particular industries given their initial employment ratios of engineers and that due to the increase in employment ratios of engineers within sectors. See Freeman for a further discussion of the assumptions involved. In the case of engineering for long time intervals, one should allow for the emergence of new economic sectors.

Doing this decomposition for some 14 sectors that account for 60 percent of engineering employment in 1921 and 76 percent in 1971 yields the result that 37.7 percent of the expansion of engineering employment in these sectors can be accounted for by inter-industry changes in employment given 1921 employment ratios of engineers. (These 14 sectors were ones for which evidence on engineering employment was available for both 1921 and 1971). The inter-industry changes for these 14 sectors account for 29 percent of the overall change in English employment of engineers over this 50 year period. This implies that over 70 percent of the rise in engineering employment was due to rising employment of engineers within these industries not to mention the rise in importance in newer industries. This might suggest catch up adjustment in England due to delayed development in incorporation of engineers at the initial period. In fact the percentage accounted for by inter-industry changes is similar to those estimated by Blank and Stigler as well as Freeman for various periods in the United States. Thus, Blank and Stigler estimate that for the entire period, 1890-1950, a little over 40 percent in the entire change in employment of engineers and chemists can be explained by inter-industry changes. For each of the sub-periods, 1930-40 and 1940-50 that they are able to examine more exactly, they find that 38 percent of the overall change in employment of chemists and engineers can be accounted for by inter-industry changes. And Freeman, (1971, p.57) finds that for the period 1950-1960 that 40 percent of the overall change in engineering employment can be accounted for by inter-industry shifts although for the period 1960-1966, he finds that 82 percent of the much slower pace of change during this latter period can be explained by inter-industry shifts.

Table 8

Industry	Male labor force change 1921-71	% of Male L.F. engineers, 1921	Implied change in demand for engineers (cols.2x3)
Coal mining	-797,376	.0003	-239
Engineering	462,736	.004	1851
Electrical	398,514	.0023	917
Aeronautics	168,124	.019	3194
Building	860,188	.0017	1462
Gas	-7354	.0008	-6
Electricity	132,498	.003	397
Water	17,584	.0093	164
Railroad	-318,501	.0017	-541
Postal & Wireless	176,020	.0005	88
Insurance	71,211	.0115	819
Other Prof. Service	261,223	.2714	70896
Nat'l Gov't Service	313,582	.0051	1599
Local Gov't Service	169,419	.011	1864
		TOTAL	82,465

If the U.S. data suggests that the role of inter-industry shifts increased between 1890 and 1966, the English data suggest inter-industry shifts declined in importance relative to intra-industry changes over time. For the period, 1921 to 1931, inter-industry changes actually over-explain the rise of engineering employment which actually occurred in the 14 sectors in question, and explain three quarters of the overall change in engineering employment. For the period, 1931 to 1951, inter-industry changes account for 30 percent of the changes in the sectors in question and 15.4 percent of the overall change in engineering employment. For the period 1951 to 1971, inter-industry changes explain only 7.8 percent of the changes in the sectors in question and 6.5 percent of the overall changes.

Considering inter-industry changes for the period 1951 to 1971 as a whole one might expect that the ACE (Aircraft, Chemicals, Electrical) industries would dominate in importance given their final importance at the end of the period. Considering changes in labor force size and initial employment ratios, the aircraft and electrical industries do indeed seem to be important for the period as a whole both for the U.S. and Britain. Chemicals have less presence focusing just on engineering. However, other industry increases are also

important due to some combination of their initial size and their subsequent expansion. Thus construction was important in both Britain and the U.S. as was the telephone and telegraph sector. Motor vehicles played a more modest role. Other professional services, and government both local and national were especially important for Britain but are less in evidence of importance for the U.S. For the period, 1951 to 1971, general engineering became less important as a source of expansion for Britain as did motor vehicles while building continued in importance. Interestingly, the insurance sector was initially an important source of expanding employment but declined in importance in this latter period as did the role of national government while expansion of local employment continued to be of importance.

To what extent was the expansion of the engineering profession in Britain fueled by the increased utilization of engineers in industries in which they were initially quite marginal or even absent in use. This is somewhat difficult to ascertain given the spotty coverage of engineering employment by industry for the 1921 and 1931 censuses (these censuses listed by industry the “most important occupations”). However, one can get an overall estimate of this by decomposing the overall expansion of the use of engineers in British industry between 1921 and 1971 into a) interindustry changes in employment in key engineering employing sectors b) increased utilization of engineers in these key sectors and c) the residual change attributed to all other industries subsuming increased utilization of engineers within these initially more marginal engineering using sectors:

Overall change in utilization of engineers between 1921 and 1971:

$$312,640 - 31,417 = 281,223$$

a) changes in use of engineers attributed to interindustry shifts in initially key engineering using sectors: 82,465

b) changes attributable to increased utilization of engineers within these key sectors between 1921 and 1971: overall change in these sectors minus change attributable to intersectoral changes = $238,010 - 19,075 - 82,465 = 136,470$

c) the residual including changes in initially more marginal engineering using sectors:
 $281,223 - 82,465 - 136,470 = 62,288$.

Thus of the overall change in employment of engineers between 1921 and 1971, $62,288/281,223 \times 100 = 22.1\%$ can be attributed to the spread of engineering to more initially marginal engineering using sectors. The dominant source of change would appear to

be increased utilization of engineers within initially engineering using sectors which accounts for $136,470/281,223 \times 100 = 48.5\%$ of the change. Interindustry shifts within these sectors account for the remaining 29.3 % of the change.

Summary of the decomposition of the expansion of engineering employment, 1921-1971:

- | | |
|---|--------|
| I. Changes attributable to initially high engineering employment sectors: | 77.8 % |
| a) Changes attributable to inter-industry shifts among
initially high engineering employment sectors | 29.3% |
| b) Changes attributable to intra-industry shifts
within initially high engineering employment
sectors | 48.5% |
| II. Changes attributable to increased employment of engineers among
Industries with little initial employment of engineers | 22.8% |

Table 9. Trends in proportion of engineers in total male labor force in selected industries 1921 to 1971

Industry	1921	1931	1951	1971
Coal mining	.0003	.002	.005	.0143
Chemicals		.0018	.0113	.0358
Engineering	.00405	.0045	.00919	.0044
Electrical	.0023	.0106	.028	.092
Motor Vehicles		.0009	.00285	.0259
Aerospace mfg	.019	.006	.0354	.092
Building	.0017	.00215	.00149	.0206
Electrical & Civil Eng. Contracting			.094	
Gas	.0008		.0226	.03
Electricity	.003		.0413	.0880
Water	.0093		.0468	.042
Railroad	.0017	.0017	.00196	.00995
Harbor, Dock, Port	.0025	.0003	.00196	
Postal, wireless	.0005		.054	.033
Insurance	.0115		.002/.0132	.0189
Other Professional services	.2714	.122	.057	.152
National gov't service	.0051	.00512	.00343	.010
Local gov't service	.011	.014	.0145	.024

The general analysis thus far points to the relative importance of intra-industry changes in increased utilization of engineers in sustaining demand increases overall. While this also appears to have characterized the U.S. over this period, Payne notes in general the substantially higher ratios of scientists to engineers in the U. S. compared with Britain both for specific industries and for manufacturing as a whole. It can also be noted that expansion of intra-industry utilization was far more pronounced and sustained in some industries than others even considering those initially intensive in use of engineers. Coal mining, electrical, motor vehicles, aerospace, and electricity all experienced several fold expansion in ratio of engineers to total employment over the period 1921 to 1971 while Insurance, other

professional consulting and both local and national government experienced more modest expansion and in some cases no change or even decline. There are issues of comparability across time periods that need to be considered further. It is especially striking that the general engineering sector, an important initial source of expansion does not experience an increasing ratio over time except for a suspect blip in 1951, but this requires further examination of comparability.

Blank and Stigler's estimates indicate even greater disparity across industries in the extent of increase in utilization of engineers for the United States between 1931 and 1951 than in Britain. Some sectors such as electricity and aerospace increase dramatically others such as government and construction remain relatively level.

Are these differences in increase associated with changes in productivity and technological advance across industries? One indication of this is that industries experiencing particularly large increases in their utilization of engineers to the rest of their labor force also tended to have a larger percentage of their engineers and scientists engaged in research and development activity relative to operations and administrative work. For example, electrical and aerospace fall into this category; however, motor vehicles is an example with a large increase in utilization but below average percentage engaged in research activity.

More generally, for some 11 industries for which estimates were reported of the percentage of scientists and engineers engaged in research and development for 1956 and for which it is possible to estimate the change in engineers as a percent of the labor force between 1921 and 1971, the simple correlation between the percentage of scientists and engineers engaged in research and development activity, which could be interpreted as an indicator of commitment to technological advance, and the change in ratio of engineers to the labor force between 1921 and 1971 is +0.596. The 11 industries are chemicals, ship-building, other plant and manufacture, construction engineering, electrical engineering, motor vehicles, aircraft, railroad locomotives and equipment, British transport (includes railroad operation), Gas, coal. O'Mahony's (1999) industry level labor productivity estimates can be drawn to provide more direct measures of productivity change for four of the 11 industries considered here (chemicals, electrical engineering, motor vehicles, other transport equipment, and other manufacturing). The correlation between change in the ratio

of engineers to labor force between 1921 and 1971 and O'Mahony's estimates of labor productivity change between 1950 and 1970 is +.8102.

Table 10

Industry	% of Engineers & Scientists engaged in R&D activity	Change 1931 to 1971 in % engineers in Male L.F.	Labor Productivity 1970/1950
Chemicals	.473	2.3	3.97
Ship-building	.089	.324	
Other plant & MFG	.303	.7	
Constructional Engineering	.115	.84	
Electrical engineering	.578	1.1	1.72
Motor Vehicles	.382	.3	2.04
Aircraft	.789	1.4	2.13
RR Equipment	.049	.208	
RR operation & British Transport	.111	.064	
Gas Council	.0845	1.12	
National Coal Board	.084	.536	

Sources: Ministry of Labor (1956), O'Mahony 1999

In addition one can consider whether industries employing relatively high shares of engineers in their workforces allocated a greater share of their time to R and D activity. For some 28 industries in 1956 the simple correlation between percentage of scientists and engineers engaged in R and D activity and the percentage of scientists and engineers in the workforce was +.4595. For some 10 of these industries which at least roughly correspond to those for which O'Mahony has constructed estimates of labor productivity since 1950 (chemicals, basic metals, electrical engineering, motor vehicles, other transport equipment, instrument engineering, textiles, food and tobacco, wood and paper, miscellaneous manufacturing). For these 10 industries the correlation between labor productivity change from 1950 to 1970 and the proportion of the labor force scientists and engineers in 1956 was +.3441. The (low) negative correlation between labor productivity trends and the percentage of scientists and engineers engaged in research is also suggestive. In this regard, Payne (1960, pp.56-57) reports paired industry comparisons based on survey evidence from the 1950s indicating the percentage of scientists and engineers engaged in Research and

Development (as opposed to operations and administrative work) was considerably higher in Britain for any given industry than in the United States.

Table 11

Industry	% of Engineers & Scientists engaged in R&D activity	% of Scientists & Eng. In L.F. 1956	Labor Productivity 1970/1950
Non-metallic Mineral processing	.327	.3	
Chemicals	.473	2.7	3.97
Mineral oil refining	.354	5.2	
Metal MFG. Iron & Steel	.240	.5	2.064
Non-ferrous metals	.297	1.1	
Ship-building	.089	.4	
Ag. Machinery	.08	.4	
Other Plant & Machinery	.303	1.0	
Constructional engineering	.115	1.5	
Electrical engineering	.578	2.0	1.72
Motor Vehicles	.382	.4	2.04
Aircraft	.789	1.9	2.13
RR Equipment	.049	.4	
Other metal goods	.179	.5	
Precision Instruments	.652	.9	2.68
Cotton textiles	.417	.1	2.79
Wool textiles	.262	.1	
Rayon etc.	.558	1.1	
Other textiles, leather	.225	.3	
Clothing	.22	.02	
Food, drink, tobacco	.256	.3	2.6
Wood, cork, printing	.406	.2	2.4
Other manufact.	.427	.6	1.97
Airways	.358	.5	
Atomic Energy	.692	10.9	
British transport	.111	.23	
Gas Council	.0845	1.2	
Nat'l Coal board	.084	.7	

Sources: Ministry of Labor (1956), O'Mahony 1999

Thus, there is at least suggestive evidence connecting industry level propensity to employ scientists and engineers with productivity advance. Moreover, there is some suggestion that industries with particularly large increases in utilization of engineers were those subject to relatively large changes in technological advance. One can contrast this with the explanation that large surges in utilization of engineers in particular industries were due to catch-up and delayed development.

The focus here has been on the demand side of the labor market for qualified engineers. The suggestion has been that growth of demand was driven by technological advance in a relatively few specific industries. As already noted above, supply considerations must also enter into how England was able to accomplish as seventeen fold increase in the number of engineers over the first three quarters of the twentieth century. And supply side issues such as the processes of certification and qualification for entry into engineering, access to higher education, and provision for engineering training in higher education deserve further consideration but this will be left for elsewhere. However, that the marked expansion in the quantity of engineers occurred without a marked relative surge in any salary premium for engineers (see Routh 1980, pp.63-69) suggests that the supply side did indeed respond to demand shifts. In fact, studies of the U.S. engineering labor market have noted that compared with other professions, the supply of engineers is particularly responsive to changes in compensation (Ryoo and Rosen 2004).

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Table A. Employment various categories of engineers by industry, 1951

Industry	Male labor force	Mechanical Engineers	Electrical Engineers	Chemical Engineers	Civil Engineers	Total Eng/ Total LF
Coal Mining	666,558	146	114	25	18	.000454
Other Mining Quarrying	8551	13	2	9	2	.00304
Chemicals & Dye	151,631	672	147	1,027	210	.01356
Paint & Varnish	26,785	30	8	10	4	.00567
Mineral Oil refining	19,349	211	27	291	69	.03091
Iron & Steel	190,464	407	80	130	69	.003602
Iron Foundries	100,258	160	11	24	11	.00205
Sheets, tinplate	28,966	30	11	5	9	.00190
Iron & Steel Tubes	32,001	133	14	11	26	.00575
Non- ferrous metals	85,159	285	31	26	20	.00425
Shipbuilding and Ship repair	163,033	200	36	5	21	.00161
Marine Engineering	29,806	194	10	1	1	.00691
Agricultural Machinery	34,405	96	10		14	.00349
Boilers	17,202	277	14	41	28	.02093
Machine tools & Engineers	71,240	409	35	7	5	.0064

small tools						
Stationary Engines	26580	397	39	32	9	.017946
Textile Machines	58,209	490	8	3	2	.00864
Ordnance	40,534	331	64	5	18	.01031
Constructi onal engineerin g	66,026	203	14	69	651	.01419
Other non-electric engineerin g	388,596	3,556	318	515	221	.01186
Electrical machinery	108,009	738	3127	7	24	.03607
Electric wire & cables	39,269	96	466	7	16	.0149
Telegraph & telephone	29,340	108	676	2	1	.02682
Wireless apparatus	56,592	220	1951	4	3	.0385
Wireless valves	15,916	51	390	3	3	.02808
Battery & accelerator	10,694	16	43	4	1	.00598
Other electric goods	85,911	411	1,527	25	14	.02301
Motor vehicles	252,109	988	58	10	21	.00427
Motor repair	213,026	410	42	7	8	.00219
Aircraft	135,474	2,648	212	25	21	.02145
Vehicle parts	82,026	501	47	4	8	.006827
RR Locomotiv es	45,351	57	9	1	4	.00157
Other locomotiv e	14,488	103	39	1	5	.01022
Wagons	65,312	68	12	1	9	.00138
Carts &	6,727	14		1		.00223

perambul.						
Building	1,020,068	161	43	88	1412	.00167
Electric wiring	62,266	29	465		12	.00813
Civil engineering	120,987	189	93	39	5,053	.0442
Gas	121,817	80	36	1,565	1072	.02259
Electricity	148,817	167	5,741	37	206	.04133
Water	30,902	49	3	3	1,385	.0466
Railways	432,226	205	80	4	557	.00196
Tramway	212,151	95	21	1	45	.00076
Goods Transport Road	162,788	52		1	10	.00039
Sea Transport	76,787	207	16		6	.00298
Port, River, Canal	119,426	70	15	2	200	.01052
Harbor, Dock, Canal	27,289	70	15	2	200	.01052
Air Transport	18,109	246	22	1	7	.01524
Postal, Telegraph	212,799	29	1,108		4	.00536
Other Transport, Commun.	23,168	26	1		6	.00142
Storage	10,722	17	3		4	.00224
Nat. Gov't Service	866.179	1314	397	121	1140	.00343
Local Gov't Serv	460,101	208	121	16	6341	.01453
Other Prof. Service	85,527	1615	587	146	2,488	.05654
Other Service	107,479	155	34		65	.00236