Was Britain delayed in development of the engineering profession?

David Mitch
Department of Economics
University of Maryland Baltimore County
Baltimore, Maryland 21250
U.S.A.
Email: mitch@umbc.edu

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. 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.

While engineering did develop as a profession in Britain, it has long been charged that it was laggard in doing so (Lundgreen 1990; Barnett 1986). This is often attributed to a British skepticism of abstract reasoning and formal scientific training and preference for practical experience as a means of developing expertise. Thus, through much of the nineteenth century, pupilage to a senior practicing engineer was the preferred method of entering the engineering profession rather than through university course work. While virtually all accounts acknowledge that the engineering profession was slower to develop in Britain than in both its continental and transatlantic rivals, some voices have been more sanguine than others about its course. Sanderson (1972a) and Divall (1990) generally paint a view of substantial industrial support and of academic response to establishment of university based engineering while Robertson (1981) acknowledges the general support of employers for the value of engineering. By some accounts such as Landes (1972) and Barnett (1986), British sluggishness in developing a university basis for engineering figured prominently in its loss of industrial international leadership in the late nineteenth and early twentieth centuries (See Sanderson 1999 for a fuller overview of these issues).

Examining claims of delayed development of engineering and its consequences for economic decline have been rendered problematic by lack of a clear standard for appropriate development. Generally the standard of comparison has been the level achieved in other countries such as Germany or the United States. But it is not clear these are appropriate measures of what would have been optimal for the Victorian and Edwardian economies. And even if it is granted that these are relevant reference points, it remains to establish the magnitude of the impact on national output of any associated underinvestment in the British stock of engineers.

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.

I. A Sketch of Factors Influencing the Rise of the Engineering Profession in Britain.

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 (1972a) 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. One 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.

Furthermore, the interaction between employers and university and expert trainers would not appear to have been solely mediated by a market clearing entrance salary or even

salary matches. First, it has been suggested for 20th century engineering markets that expectations of future salaries can often cause supply and demand to be out of kilter as in classic corn-hog cobweb cycle patterns and there is some evidence that training and matriculation in various engineering specialties was subject to such fluctuations (Freeman 1971). There were further issues of long run expectations and accommodations on both employer and university sides as to acceptability and ongoing interactions on dimensions other than starting salary. One the hand, there had to be growing acceptance on the employer side that university training was worthwhile for the aspiring engineer. On the other hand, universities had to be prepared to accommodate employer demands for cultivating practical skills and employer support was often critical in funding the expensive laboratories and other dimensions associated with the introduction of engineering education at the university level. A further dimension that arose was that due to the practical expertise involved, professional associations arose involved in certifying professional qualifications over and above having obtained a university degree qualification. Senior engineers frequently could draw a substantial income from pupilage fees and had incentives on these grounds to restrict certification standards for those who had no more than a university degree.

The factors sketched above provide a basic agenda of issues to consider in looking at the chronology of development of engineering in Britain in international context.

II. Interpreting Basic Price and Quantity Evidence.

Many previous assessments of English provision of engineers for industry have been based on quantity evidence. It has been common to produce estimates of the stock of engineers of various categories at particular points in time and point out the England was well behind rivals such as Germany and the United States in the absolute levels of these stocks. Implicitly these comparisons claim similar population levels or perhaps even more generally, similar scales for the economies in question. Other comparisons of engineers per capita have also suggested a British deficiency. (See Robertson 1981 for examples of such comparisons though he himself is skeptical of their value).

Sanderson and Divall have pointed out that one should allow for industrial structure in making such quantity comparisons. Even within the manufacturing sector, some industries were likely to have had a far greater propensity to call for technically trained expertise than others and the share of such industries in overall manufacturing activity probably varied considerably across leading industrial nations. While some of this variation could well reflect the national supply of engineering talent, it could also reflect other differences in international comparative advantage. Sanderson and Divall in more focussed comparisons of particular industries find less differences in utilization of engineers than suggested by the gross comparisons above.

If one focuses on expansion of the engineering profession, one can point to evidence of quite marked expansion in Britain as well as other allegedly scientifically advanced countries such as the U.S. and Germany. Some estimates suggest more rapid expansion in these other countries but one can produce other estimates suggesting expansion by at least as many multiples in England as in these other countries.

A key issue in quantity estimates is how an engineer is defined and how one allows for changing certification and educational standards over time. This makes it problematic to

dwell on exact comparisons of numbers of engineers in various countries or changes in these numbers over time. Table 1 focuses on estimates based on membership in professional engineering societies in various developed countries. This surely understates the total numbers with some training and expertise in engineering skills. The difference is suggested by the difference between total U.S. membership in leading engineering societies and Blank and Stigler's estimates of numbers of engineers based on census occupational data.

Table 1: Estimates of stock of engineers in Britain and other developed Countries, 1870-1940

		1870	1880	1890	1900	1910	1920	1930	1940
Britain									
	Civil	1600	3000	4750	6300	8850			
	Mine			1250	2500	3250			
	Mech.	1000	1500	2800	3150	5600			
	Electr.	350	1000	2100	4000	6200			
	Total*	4128	8047	15043	23189	36272			
U.S.A.									
	Civil	250	600	1300	2200	5300			
	Mine		1000	2000	3000	4000			
	Mech			1050	1950	3850			
	Elect.			500	1200	6700			
	Total			2850	8350	19850			
	TotalA Blank/ Stigler	7094	7061	28239	43239	88755	136121	227590	277872
Germ.									
	Civil	3350	6500	6650	7650	9800			
	Mine		300	900	2350	4450			
	Mech	1800	3950	6900	15250	23950			
	Elect				3000	4700			
	Total				28250	42900			
France	Civil	1000	1800	2300	3400	7000			

Sources: Lundgreen 1990, p.70. The figures for individual engineering specialties are the figures for membership in engineering professional societies compiled by Lundgreen. For Britain, the Total* figure comes from Buchanan 1985, p.44 and includes membership in professional societies other than those included in Lundgreen's compilation. For the U.S.A., the TotalA figure comes from Blank and Stigler (1957, p.5) and are based on census occupational figures for the category of engineer rather than membership in professional societies.

Table 2. University Students in technology courses in Great Britain

	1929-30	1938-39	1950-51	1967-68
Percentage of all Students	12.5%	13.6%	15.8%	23.8%
Total Number	7434	8625	16118	51796

Source: Edgerton 1996, p.22.

Between 1870 and 1940, engineers in Britain increasingly tended to have some university training although even at the latter date, a significant number of those employed in British engineering occupations appear to have qualified largely by pupillage (Divall 1990, p.96).

Salary, or in other words price, evidence has also been used by some historians to make inferences about the adequacy of British provision of engineers and related scientific and technical personnel (Pollard 1989, p.121). However, the conflicting interpretations offered underscore the point that price evidence alone leaves the basic identification problem regarding the role of supply and demand factors. Thus, some commentators have suggested that low relative salaries for engineers in Victorian and Edwardian Britain imply a lack of demand whereas others have argued that relatively high salaries imply a deficiency in supply and possibly disequilibrium in meeting employer demands. Relatively high salaries could also reflect the presence of barriers to entry such as restrictions by experienced engineers offering pupilage opportunities as a way of sustaining high pupilage premiums. And the further important complication arises of making allowance for variation in quality and extent of training and in inherent ability and selectivity for those being trained.

One can undertake to examine price and quantity trends as indicators of relative trends in demand versus supply. Rising salaries in the face of rising quantity would suggest demand shifts outstripping supply shifts. Falling salaries with quantity increases would indicate supply shifts outstripping demand. Level salaries whether at a relatively high or low level would suggest supply keeping pace with demand.

Routh's (1980, p.63) estimates of engineering salaries in Britain 1913-14 to 1960 suggest that they at least kept pace with that in most other professions on average and indeed rose faster than some. The estimates for starting salaries reported by Sanderson (1972 a p.303) for Imperial College suggest a widening dispersion between 1920 and 1940. Divall's (2000, p.308) estimates of chemical engineering salaries between 1900 and 1990 show a definite rise relative to a UK price index though until the 1970s, they "were broadly similar to those of a skilled fitter" based on estimates of Newman and Foster.

How well did the British market for engineers perform?

Blank and Stigler (1957, pp.22-24) use the concept of shortage to develop a criteria for whether there were deficiencies in the supply of scientists and engineers in the U.S. between 1929 and the mid-1950s. The definition of shortage they offer as most "natural" for a "free labor market" is that "a shortage exists when the number of workers available (the supply) increases less rapidly than the number demanded *at the salaries paid in recent*

past." [italics in original, p.24]. The "well defined" result they then predict is that "then salaries will rise, and activities which once were performed by (say) engineers must now be performed by a class of workers who are less well trained and less expensive" (p.24). They go on to note the general downward trend in relative engineering wages throughout the interwar and early post war period, a trend they find incompatible with a general shortfall in the supply of engineers and one that they observe can be viewed as influenced by the more general compression of skill premia during this period.

That the fragmentary evidence available on engineering salaries for Britain during this period suggests an upward trend despite some evidence for skill compression during the interwar period provides an initial indication that the British market for engineers may not have functioned as well as that in the U.S. (Routh 1980, p.126).

Accounts of the engineering profession between 1870 and 1950 in Britain mention a number of instances of acute shortages in engineering related fields, especially during the interward period. Sanderson (1972a, p.290) mentions in particular "unusually high salaries" for oil engineers and geologists during the 1930s despite an economy in the midst of depression. He also points to assertions of acute shortages of chemical engineers, metallurgists, marine engineers, and mining engineers during this period (pp.289-92). He mentions instances of apparent deficiencies in university response to imbalances across engineering specialties. He notes concerns in the late 1930s that although there was an acute shortage of metallurgists and that although the metal industries employed five times the workers of the chemical industries, yet in 1935-36, the universities produced 369 graduates in chemistry they only produced 14 in metallurgy (p.289-90). He also notes the marked drop in the number of honours degrees awarded in mechanical engineering from 226 in 1928-9 to 36 in 1929-30 despite ongoing concerns of shortages in that specialty (pp.291-2).

Divall (1990) cites examples of responses corresponding to the second part of the Blank/Stigler prediction above of substituting to less well trained and expensive workers in response to shortage conditions. In the 1870s, concerns about a shortage of properly trained civil engineers led to the British government to support establishing the Royal Indian Engineering College in London (p.70). And he cites one assessment that in the late 1930s when there was a perceived shortage of mechanical engineers that a graduate with training in electrical engineering could obtain work in mechanical engineering (p.73).

It should be noted that prior to World War I, engineering graduates from the University of London were reported to have been a glut on the market and in retrospect some historians have faulted employers for providing insufficient employment opportunities (Sanderson 1972 c, p.259). Thus, rather than just supply deficiencies resulting in periodic shortages, the British market for engineers can be seen as subject to the same cobweb cycle fluctuations due to expectation lags as Freeman (1971) has argued has characterized the U.S. market for engineers in the mid-20th century.

Employer Utilization of Engineers

Since the university or college trained or professionally certified engineer was a relative new entity, the issue arises of how employers came to incorporate their services in industrial enterprises. As Robertson (1981, pp.53-54) has noted a number of features of British industry may have limited the extent of utilization of engineers. First of all, engineers were more commonly with associated with research and development activities rather than

routine production (Sanderson 1972b; Roberson 1981). Firms in established industries with limited research and development activities would on these grounds have limited their call for engineers. Insofar as Britain was slow in its development of more research oriented industries such as chemicals and electrical products this would have limited its demand for engineers though one should also allow for reverse causation from the supply of engineers to comparative advantage in such industries.

Robertson also suggests that the smaller scale of British firms with their more restricted middle management structure may have limited the career paths developed for engineers with production expertise into managerial positions. However, Divall (1990) suggests that many engineers would have found employment with relatively small firms in Britain. And Sanderson estimates from University of Liverpool registers that Liverpool graduates found employment with a wide range of firms. However, he also notes that they may have been disproportionately concentrated in just a few firms.

Robertson further notes that British firms tended to outsource product design work to consulting engineers which limited the development of in-house opportunities for engineering employment.

Sanderson notes the potential resentments that could be created among older employers in creating career advancement paths for university graduates in industrial firms. More generally, there is the issue of the extent to which firms had to modify their career and salary structures in order to attract and retain professionally qualified engineers.

A sociological study of mechanical engineers in Britain for the early 1960s (Gerstl and Hutton 1966,pp.72, 74) report a similar distribution across functional activities for their employers as that in a U.S. survey of engineers for 1946 reported by Blank and Stigler (1957, p.52). The category of "technical administration" appears as the most frequently reported activity in both surveys.

Factors influencing Trends in the Demand for Engineers

Blank and Stigler (1957, p.56) for the period 1890 to 1950 estimate that about 40 percent of the expansion in employment of engineers over this period can be attributed to the relative expansion of industries intensive in the utilization of engineers, that is to inter-industry shifts. This decomposition leaves the majority of expansion attributable to increased utilization within industries. They note that there is variation within industries at a point in time across firms in the utilization of engineers. Freeman (1971, p.57) reports similar results for the period 1950 to 1966 although he notes considerable variation between time periods in the relative importance of inter versus intra industry change in the utilization of engineers.

One important area for further investigation is the extent to which the Blank/Stigler/Freeman finding of substantial changes in both inter and intra industry variation holds up for Britain as well as for other leading industrial countries such as France and Germany. It would seem quite plausible given the relative novelty of engineering as a profession that the importance of intra industry and indeed intra firm increases in utilization of engineering will hold up in the British case as well. And one can attempt to gauge any British lag in the rise of the engineering profession by examining the pace of both inter industry change and intra industry change in the incorporation of engineers relative to the United States.

Factors Influencing Trends in the Supply of Engineers.

One can point to two central issues on the supply side that require further investigation. The first concerns the extent to which Britain's generally much more selective and limited access higher education system impeded expansion of the supply of engineers. The second concerns the continued presence of non-graduate engineers in both the U.S. and Britain through the mid-twentieth century and the extent to which a greater and more persistent willingness to use non-graduate engineers in Britain mitigated any restrictions due to its more elitist system of higher education. Further examination of the salary structure, of differences between countries in functional tasks assigned to engineers compared with those who can be classed as of lower occupational status and of trends in the social origins of engineers, as well as of the evolving role of non-graduate engineers in both the U.S. and Britain would provide further perspective on these supply trends.

Conclusion

One can interpret its marked extent of expansion as favoring an optimistic interpretation of the rise of the engineering profession in Britain. However, evidence of the presence of shortages at a number of points in the interwar period in contrast to the situation in the United States would seem to support a more pessimistic point of view. Important areas for further investigation include the role of both the composition of British industry and the organization of British firms in influencing the extent of utilization of engineering expertise as well as whether restricted access of the British population to higher education generally substantially restricted the supply of engineers. And given the potential centrality of engineering to ongoing technological advance whether any delays in the development of this profession impeded economic growth or contributed to loss of industrial leadership and shift away from more human capital intensive comparative advantage patterns deserves further investigation.

References:

Corelli Barnett (1986) *The Audit of War*

David Blank and George Stigler (1957) *The Demand and Supply of Scientific Personnel*. NBER.

Stephen Broadberry (2003) "Human Capital and Productivity Performance: Britain, the United States and Germany, 1870-1990" in Paul David and Mark Thomas eds. *The Economic Future in Historical Perspective.*

D.C. Coleman (1973) "Gentlemen and Players" *Economic History Review* 26: 92-116.

Colin Divall 1990 "A Measure of Agreement: Employers and Engineering Studies in the Universities of England and Wales, 1897-1939" *Social Studies of Science* Vol.20: 65-112.

Colin Divall and Sean F. Johnston, 2000 *Scaling Up. The Institution of Chemical Engineers and the Rise of a New Profession.* London: Kluwer Academic.

David Edgerton. 1996. *Science, technology and the British industrial 'decline' 1870-1970.* Cambridge: Cambridge University Press.

Richard Freeman (1971) *The Market for College-Trained Manpower. A Study in the Economics of Career Choice.* Harvard University Press.

J.E. Gerstl and S.P. Hutton (1966) *Engineers: the Anatomy of a Profession* London: Tavistock.

David Landes. 1969. *The Unbound Prometheus.*

Peter Lundgreen (1990) "Engineering Education in Europe and the U.S.A., 1750-1930: The Rise to Dominance of School Culture and the Engineering Professions" *Annals of Science* 47: 33-75.

Sidney Pollard (1989) *Britain's Prime and Britain's Decline. The British Economy 1870-1914.* London: Edward Arnold.

Paul L. Robertson. (1981) "Employers and Engineering Education in Britain and the United States, 1890-1914" *Business History* Vol. 23 (1): 42-58.

Guy Routh (1980) *Occupation and Pay in Great Britain 1906-79* second edition. London: Macmillan.

Michael Sanderson (1972a) *The Universities and British Industry 1850-1970.* London: Routledge Kegan Paul.

Michael Sanderson 1972b "Research and the Firm in British Industry 1919-1939" *Science Studies* April.

Michael Sanderson 1972c "The University of London and Industrial Progress 1880-1914" *Journal of Contemporary History* Vol.7 (No.3/4): 243-262.
Michael Sanderson 1999 *Education and Economic Decline in Britain, 1870 to the 1990s.* Cambridge: Cambridge University Press.