Where do all the STEM graduates go? Higher education, the labour market and career trajectories in the United Kingdom.

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Emma Smith
Centre for Education Studies
University of Warwick
Email: e.smith.22@warwick.ac.uk

Patrick White
School of Media, Communications and Sociology
University of Leicester

Abstract

Problems with the supply of highly skilled STEM workers have been reported by employers and governments for many decades, in the UK, the USA, and elsewhere. This paper presents some key findings from a project funded by the Nuffield Foundation that examined patterns of education and employment among STEM graduates in the UK. Five large-scale secondary data sets – comprising administrative, survey, cross-sectional and longitudinal data – were analysed in order to provide the most comprehensive account possible. The findings suggest that there is no overall shortage of STEM graduates but there is considerable variation in the career outcomes and trajectories of different groups. Recruitment to STEM degrees has stalled over the past 20 years but most STEM graduates never work in highly skilled STEM jobs – in any case, the majority of professional STEM workers do not have (or presumably need) degrees. Some groups of STEM graduates are currently under-represented in the highly-skilled STEM workforce and increased recruitment from these groups could grow the numbers entering STEM occupations. However, employers may have to modify their views on exactly what constitutes a valuable or desirable employee and to what extent it is their responsibility to train their workers.

Introduction

This paper provides a summary of the findings from a series of recent research projects looking at the educational and employment trajectories of science, technology, engineering and mathematics (STEM) graduates in the United Kingdom. These findings represent the most complete account yet of participation along the UK STEM pipeline.

The analyses used existing data on hundreds of thousands of individuals, from several different sources. By using both longitudinal and cross-sectional datasets we were able to examine patterns of participation in STEM education and careers across the life course: from university, to early employment and through to later life careers.

The wider context for our research is a longstanding concern about the supply of STEM graduates and a so-called 'STEM skills deficit'. In trying to understand whether there is a shortfall of STEM skills we have asked the following questions:

i. What are the patterns of participation in STEM degrees between 1988 and 2012?

ii. What proportion of STEM graduates enter highly skilled STEM jobs[1] shortly after graduating?

iii. What proportion of STEM graduates aged 25 to 64 worked in STEM shortage areas between 2004 and 2010?

iv. How do the career trajectories of STEM graduates change between the age of 26 and 42? How does this vary according to subject specialism?

v. How do the career trajectories for STEM graduates compare with those with degrees in non-STEM subjects?

vi. Are there different patterns of labour market participation for STEM graduates with degrees from different types of institution?

vii. What proportion of HS STEM workers are non-graduates? Has this changed over time?

These questions serve as foci for the organisation of this paper. Because of space limitations we are not able to address gender issues or consider the role of immigration in the STEM shortage debate. However see Smith (2012) and Smith and White (2018) for further detail on our research, especially as it relates to gendered participation in STEM shortage subjects. Before summarising our findings, we briefly outline some of the concerns about the supply of STEM graduates that persist in the UK context and provide a short overview of the data used in our research.

Background to the study

'Why there is an engineering shortage in the UK' The Telegraph, 6th June 2017.

'Skills Shortages Holding Back UK's Economic Recovery', BBC online, 1st December 2014

Media accounts frequently report problems with the supply of highly skilled (HS) STEM workers. These reports echo the concerns expressed by both industry and governmental bodies that the supply of STEM graduates is crucial to the current and future economic prosperity of the nation but that employers are currently unable to recruit a sufficient number of workers with the right skills (e.g. CBI, 2014, Select Committee on Science and Technology, 2012). A shortage of adequately skilled STEM workers, it is argued, is holding back economic growth and placing UK industry at a disadvantage in relation to international competitor countries (e.g.

Cm8980, 2014, Wakeham Review 2016). Numerous corporate and government bodies have examined the supply of the STEM workforce and have found it wanting in terms of both quantity and quality. As a consequence, policymakers have responded to calls from industry, government and universities to enact policies and initiatives – often requiring the investment of considerable amounts of public funds – aimed at remedying the situation.

Improving the recruitment, retention and training of the next generation of STEM professionals has been an area of perennial concern for policy makers and employer organisations in the UK and elsewhere (e.g. Cm 8980 2014, EU Skills Panorama 2012, National Academy of Sciences, 2010). According to the Confederation of British Industry and other sector skills organisations, employers report widespread difficulties in recruiting people with STEM skills at every level: from new apprentices to more experienced workers (CBI 2014, IET 2015, Engineering UK 2016). In a society with increasing demands for scientific- and technological-based goods and services, a shortage of appropriately skilled workers is, according to some, a threat to our 'productivity, competitive position and level of innovation' (Greenfield et al. 2002:27).

These accounts have not gone unchallenged, however. Other commentators have argued that the supply of STEM workers is more than enough to meet demand and that the picture is much healthier than is often suggested. Rather than there being a shortage of STEM professionals, they claim that many highly qualified STEM graduates struggle to find appropriate employment and instead find work in non-STEM fields, are 'underemployed' in STEM occupations that do not require their full range of skills and knowledge, or are unemployed (e.g. Teitelbaum 2014, Smith and White 2017, The Grattan Institute 2016).

Whether a sufficient number of highly qualified STEM workers are being educated and trained in the UK, and elsewhere, is an important question. The answer has implications not only for educators, employers and policy makers but also individuals who are currently engaged in, or are considering entering, education or training in this area. At the moment, however, there is insufficient evidence to resolve this debate.

This lack of good quality evidence is perhaps surprising given that STEM skills shortage debates are not new. Concerns about the supply of highly skilled STEM workers have been central to public policy on education, science and engineering in the USA and the UK since at least the time of the Second World War (e.g. Bush 1945, Steelman 1948, Cmd. 6824, 1946). Academic studies as far back as the 1950s have criticized the proponents of the shortage debate for a 'misunderstanding of economic theory as well as … exaggeration of the empirical evidence' (Arrow and Capron, 1958:292). They have also drawn attention to the conceptual, methodological and ideological obstacles to producing good quality evidence about whether or not there is a shortage or surplus of highly skilled scientists and engineers (e.g. Wilkinson and Mace 1973, Committee on Science, Engineering and Public Policy, 1995, Smith 2017). Such concerns extend to the present: with a recent review into higher education and STEM subjects by the UK House of Lords concluding that:

> '…lack of data makes it very difficult to assess whether there is in fact a shortage of STEM graduates and postgraduates and in which sectors. This is critical because, if it is not known whether there is a shortage, remedial actions cannot be put in place' (Select Committee on Science and Technology 2012:6).

The aim of this paper is to contribute to a much needed body of evidence on STEM skills supply by summarising our findings from a series of large scale studies that have looked at the trajectories of STEM graduates as they move from higher education into their early career destinations and beyond.

Data used in the analysis

The findings presented in this paper are taken from a series of studies that have involved the analysis of five national datasets:

- Universities and Colleges Admissions Service data (UCAS)
- Destinations of Leavers from Higher Education data (DLHE)
- The Annual Population Survey (APS)
- The 1958 National Child Development Study (NCDS58)
- The 1970 British Birth Cohort Study (BCS70)

There is not space to provide a detailed account of each dataset here, especially one that will satisfy an international audience, but brief details about the data used in the study are provided in the Appendix.

This paper draws exclusively on secondary data derived from 'official' sources. We are fortunate in the UK to have access to high quality data of this scope and scale. However, one of the challenges in using official data to explore trends over the long term is that they are susceptible to changes in the official definition of key variables, such as occupational group.[2] For this reason, our analysis covers the time period that allows the most stable analysis of comparable data for each of the six datasets. This means that our focus concludes in 2012 to coincide with key changes in 'official' definitions of occupational group, as well as in how early graduate career destinations are measured. Given the longevity of the patterns that we present here, there is no reason to believe that more recent data would reveal new trends; although this remains an important caveat to the summary presented here.

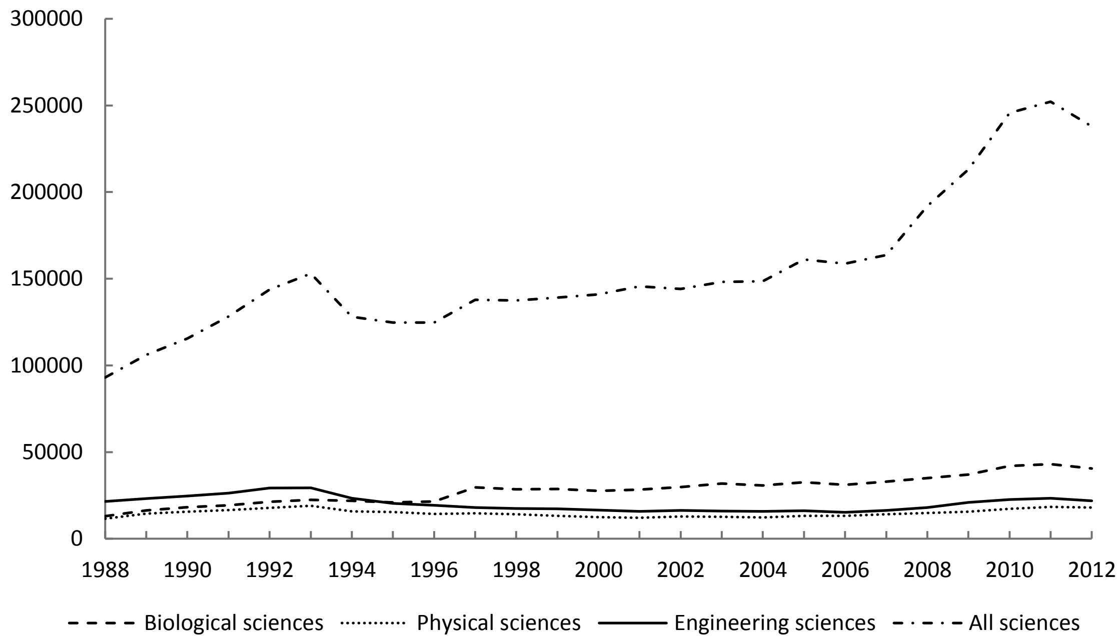
The next section summarises the key findings from this series of studies. They are structured according to the six expected observations that were outlined above. The analysis presented here is largely descriptive. This was determined by the quality and availability of data as well as by the research questions and our approach to seek out the most parsimonious patterns in the best quality data that was available to us.

Findings

What are the patterns of participation in STEM degrees between 1988 and 2012?

Since the late 1980s, the number of candidates who apply to undergraduate study[3] at university in the UK has more than doubled, reflecting decades-long policies by successive governments to turn higher education from an 'elite' to a 'mass' experience (Furlong and Cartmel, 2009). Trends in the application data for selected STEM subject areas are shown in Figure 1. The data show that applications for many 'shortage' subjects have remained flat over the last thirty years, despite growth in science-based subjects overall. Subject areas such as the allied medical sciences and, to some extent, the biological sciences have received an increasing number of applications – largely as a result of recruitment to subjects such sports science, psychology and nursing. However, recruitment to other STEM subjects in the physical and engineering sciences has not grown substantially either in proportional or absolute terms. For example, 5% of all applications from UK domiciled candidates in 1988 were to physical science subjects but by 2013 this had fallen to 3%. While there was a relatively small increase in the *number* of applications to these subjects, they have not retained their share of applications in a rapidly expanding university sector. Engineering has fared even worse. Despite decades of initiatives to encourage recruitment to engineering subjects, recruitment has actually declined in absolute terms: in 1994 there were 23,390 applications from UK candidates to study engineering subjects at UK universities but in 2012 there were only 21,832.

Figure 1: University applicants for selected STEM subject areas, UK domiciled undergraduate applicants, 1988-2012



Source: UCAS

These patterns in the application data are reflected in the numbers and proportions of applicants who are eventually accepted to study at university. While recruitment to subjects such as psychology and sports science has increased, acceptances to the natural sciences and engineering have stalled, reflecting the slowing demand for places shown above. For example, in 1986 just over 2,800 students were accepted to undergraduate programs in chemistry. By 2012 the figure had increased by just 1,000 students, despite undergraduate recruitment more than tripling over the same period. Reflecting the static pattern of demand for places noted above, the numbers recruited to undergraduate degrees in electronic and electrical engineering have hardly changed in thirty years: from 2,652 students in 1986 to 2,848 in 2012.

As can be seen from these data, there is no evidence that the many costly initiatives to increase the number of students studying 'shortage' STEM subjects have worked. In absolute terms, recruitment to these subjects has remained relatively flat and – given the increase in the number of undergraduates over the period – has actually fallen in proportional terms. It is not the case that this is simply down to a lack of places; applications have been remarkably stable over the period studied. There is certainly no sign of a rush to study these STEM subjects in order to take advantage of the labor market opportunities that would be expected when skill shortages exist.

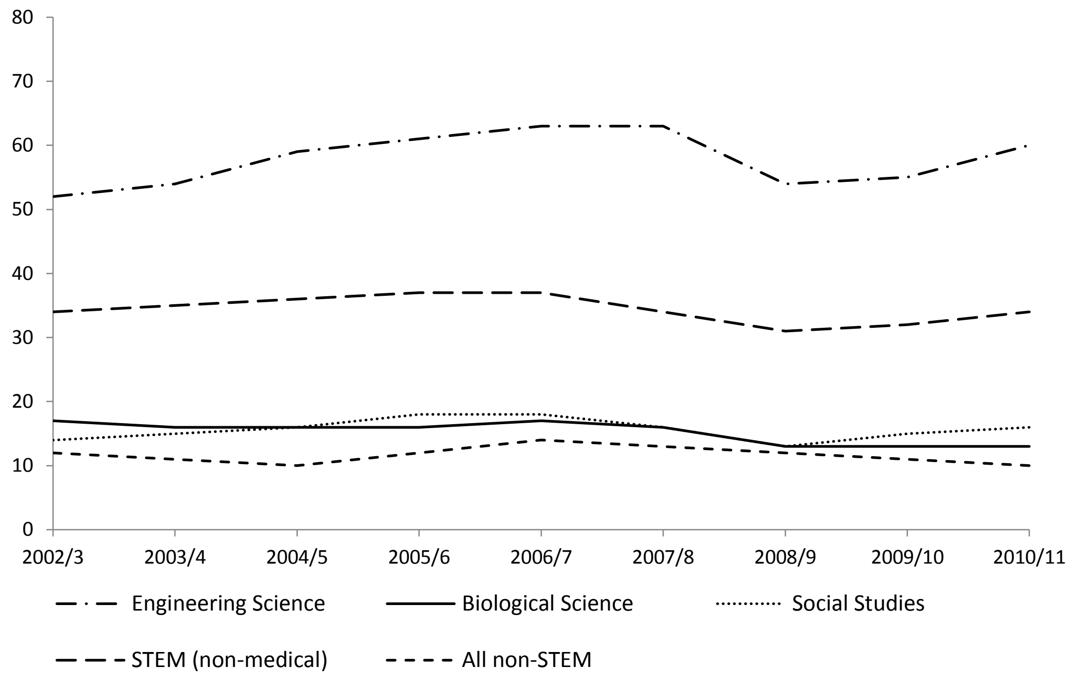
These findings are interesting in terms of the 'shortage' debate. On the one hand, the continued efforts to expand recruitment to particular STEM degrees have been unsuccessful, perhaps lending weight to the arguments of those who have claimed a continued shortage of 'crisis' proportions. But this can only be considered a problem if it also can be shown that an increase in STEM graduates from these subject areas is needed. As our findings presented in the following sections demonstrate, it is far from clear that this is the case.

What proportion of STEM graduates enter highly skilled STEM jobs shortly after graduating?

A central focus of the STEM shortage debate has been the lack of highly qualified graduates entering highly skilled[1] (HS) STEM sector jobs. Only about one-third of non-medical STEM graduates who entered employment were working in HS STEM jobs six months after graduation. However, there is considerable variation in the proportions of graduates with different STEM degrees gaining HS STEM positions. For example, between 55% and 60% of engineering science graduates who gained employment were working in HS STEM jobs six months after graduating, but for biological science graduates the proportion was just 16%. This is only slightly higher than the average proportion of graduates from non-STEM subjects, which was 12% on average, and in some years was actually lower than this. It is important to note that not only do only a minority of STEM graduates who find work soon after graduating are employed HS STEM positions but that some subject groups do no better than non-STEM graduates. This raises the issue of the desirability – or need – for STEM degrees to work in HS STEM positions, which is a topic we return to later.

If only a minority of STEM graduates who find employment shortly after graduation go into HS STEM positions, there would not seem to be a shortage of STEM graduates *per se*. There may be a shortage of STEM graduates who want to work in HS STEM positions, or STEM graduates who employers are prepared to employ in such positions, however. Even in the engineering sciences – the STEM subject group with the highest level of HS STEM employment – only slightly more than half of employed graduates move into highly skilled science work shortly after graduation. It is also important to consider that these figures only include those graduates that found work and that considerable proportions of STEM graduates are unemployed at this point of their careers. In the next section we shift focus from immediate destinations after graduation and look at STEM graduates of all ages.

Figure 2: Proportion of graduates gaining employment and entering HS STEM occupations, by subject group.



Source: DLHE

What proportion of STEM graduates aged 25 to 64 work in STEM shortage areas between 2004 and 2010?

While the DLHE survey, discussed in the last section, provides data on immediate post-graduation destinations, APS data can tell us about the occupations of the working-age population as a whole. Table 1 shows the proportion of STEM graduates working in graduate-level[4] and HS STEM jobs for combined APS data from 2004, 2006, 2008 and 2010 (three key shortage occupations – science, engineering and IT professions are shown highlighted). The 12 occupational groups included in the table were the largest 'recruiters' of STEM graduates and, combined, make up over 60% of the employment destinations of APS respondents with STEM degrees.

The vast majority (over 80%) of STEM graduates who were in work were employed in graduate level jobs. But a significantly lower proportion worked in highly skilled STEM jobs – this varied from over 60% of engineering graduates to around one third of biological science graduates. Just 17% of employed STEM graduates held positions in the three occupational groups that are the focus of most STEM shortage concerns: 4% were science professionals, 6% worked as engineering professionals and 7% were employed as IT professionals. More STEM graduates worked in teaching or functional management than in any of the three shortage areas. If there are genuine shortages in these areas, it must be the case that the remaining 83% of STEM graduates either: do not wish to work in science, engineering or IT; choose to work in other STEM occupational areas; prefer the pay and conditions offered in other occupational sectors; or are considered unsuitable by STEM employers in shortage areas.

Table 1: Occupational sectors for employed STEM graduates aged 25 to 64.

	All STEM		Eng. Sci.		Math/Comp Sci		Bio. Sci.		Phys. Sci.	
	N	%	N	%	N	%	N	%	N	%
Graduate job	39448	87	7229	86	6288	85	5531	82	5610	85
HS STEM job	21068	46	5148	61	3418	46	2168	32	2673	41
Production managers	2250	5	1182	14	124	2	95	1	272	4
Functional managers	3865	8	877	10	1138	15	560	8	773	12
Science professionals	1695	4	43	0.5	24	0.3	702	10	642	10
Engineering professionals	2957	6	2330	28	101	1	42	0.6	281	4
IT professionals	3133	7	588	7	1944	26	116	2	359	5
Health professionals	4796	10	20	0.2	11	0.1	450	7	91	1
Teaching professionals	4145	9	332	4	1054	14	1076	16	1012	15
Business/Statistical profs	1054	2	162	2	447	6	120	2	209	3
Architects and planners	1592	3	158	2	14	0.2	9	0.1	52	1
Eng. & Sci. technicians	702	1	167	2	54	1	161	2	177	3
IT service delivery	655	1	99	1	359	5	51	1	94	1
Associated health profs	3090	7	17	0.2	18	0.2	174	3	48	1

Source: APS 2004, 2006, 2008 and 2010 combined

Table 1 also shows that employment in the three key ‘shortage’ areas is dominated by STEM graduates from particular subject areas. For example, IT professional occupations were the most popular occupational destinations for employed mathematics and computer science graduates, with 26% finding work in this area. But only 2% of biological sciences and 7% of engineering sciences graduates in employment worked in professional IT positions. A similar picture can be seen for engineering professional occupations. Again, more than a quarter (28%) of engineering science graduates were employed in this area, compared to only 6% of STEM graduates overall, 4% of those with physical science degrees and 1% of maths and computer science graduates. Professional science occupations account for the destinations of only 10% of employed biological science graduates and 10% of physical science graduates, but much smaller proportions of graduates from other STEM areas work as professional scientists.

Table 2 shows the subject specialisms of graduates working in selected HS STEM occupations. It shows that, for example, 73% of graduates working in engineering professional roles have an undergraduate degree in engineering. So while the data shown earlier indicate that the career destinations of engineering graduates are very favourable in comparison with graduates from other non-medical STEM subject areas, we can also see that professional engineering jobs remain largely closed to those without a degree in the subject, with little movement into these jobs either by graduates from other disciplines or from engineers seeking work in other sectors.

A similar issue arises for science professional roles, which were largely taken by biological and physical science graduates. Employees with degrees in these two areas made up 76% of the graduate workforce in this sector. In contrast, half of the graduates working in IT professional positions had a degree in a subject other than mathematics or computing, with 15% of these professional IT jobs being undertaken by engineering graduates. Although those with degrees in engineering, maths and computing make up nearly two-thirds of the graduate workforce in IT, this sector does seem to recruit graduates from a wider range of subject backgrounds than does, for example, engineering. However, if the 'shortage' accounts are to be believed, this more catholic approach to recruitment has not yet provided the labour force that is needed in this sector.

Table 2: Subject specialisms of graduates working in HS STEM and selected higher recruiting occupations (%).

	N	Bio Sci.	Phys Sci.	Math/Comp Sci.	Eng. Sci.	Social Studies	Bus Admin	Other subject
Production Managers	3284	3	9	4	37	4	16	27
Functional Managers	10386	6	8	11	9	9	31	26
Science Professionals	1854	40	36	1	2	1	1	19
Engineering Professionals	3367	1	9	3	73	1	4	9
IT Professionals	4083	3	9	50	15	3	8	12
Health Professionals	5301	9	2	0.2	0.4	1	0.5	87
Teaching Professionals	19426	6	5	6	2	6	4	71
Research Professionals	1013	19	14	9	4	14	5	35
Legal Professionals	2538	1	1	1	1	9	2	85
Business Professionals	3927	3	6	12	4	13	48	14
Architects	1938	1	3	1	8	4	7	76
Science/Eng. Technicians	929	19	20	6	19	3	4	29
IT Technicians	980	5	10	39	10	5	10	21
All HS STEM jobs	30367	8	9	12	18	5	13	35
All jobs	119467	6	6	7	7	9	13	52

Source: APS 2004, 2006, 2008 and 2010 combined

It is unsurprising that the three 'shortage' occupational areas recruit largely from graduates in allied subject disciplines. However, given that 'shortage' accounts have persisted for many decades, and employers continue to complain about their inability to fill posts in these occupational areas, it is surprising how few graduates from other STEM areas are employed in STEM shortage occupations. Whether the explanation for this can be found in the preferences or perceptions of STEM graduates or the recruitment practices of employers is an important question, but one that goes beyond the scope of these data.

How do the career trajectories of STEM graduates change between the age of 26 and 42? How does this vary according to subject specialism?

We used longitudinal data from the BCS70 to look at career trajectories of respondents from age 26 to 42. The vast majority (83%) of STEM graduates were working in a graduate job by the age of 26, a figure that rises at age 30 and again at age 34 (Table 3). This suggests that there is some later movement into graduate jobs, even for those who have not entered graduate level positions some years after finishing their degree.

In contrast, the proportion of STEM graduates working in highly skilled (HS) STEM jobs fell slightly over this period, as did the share working as science or engineering professionals. At no point between the ages of 26 and 42 were more than 11% of STEM graduates working in these two key ‘shortage’ areas of the labour market, and by age 42 only 7% were employed in these occupational groups. A larger proportion (10%) of STEM graduates entered professional IT roles but this peaked at 12% at age 30 before falling at each subsequent sweep to only 7% by age 42.

Table 3: Long term employment trajectories of STEM graduates, ages 26 to 42.

	Age 26		Age 30		Age 34		Age 38		Age 42	
	N	%	N	%	N	%	N	%	N	%
Graduate job	590	83	636	87	551	91	543	90	565	88
Highly skilled STEM job	590	50	636	49	551	48	543	44	565	40
Highest recruiting occupational groups										
Functional managers	34	6	49	8	73	13	75	14	74	13
Science professionals	25	4	27	4	25	5	16	3	16	3
Engineering profs	43	7	36	6	32	6	23	4	22	4
IT professionals	62	10	77	12	60	11	41	8	40	7
Health professionals	59	10	50	8	47	8	50	9	60	11
Teaching professionals	62	10	58	9	52	9	56	10	66	12

Source: BCS70

While the proportion of engineering science graduates working in graduate-level jobs remained high across each sweep of the cohort study, the percentage employed in HS STEM jobs fell as the cohort members became older (Table 4). Only a minority of engineering science graduates were employed in engineering professional occupations each of the age points surveyed. Less than one-third (31%) worked in this kind of occupation at age 24 and the numbers fell at each subsequent sweep. The data suggest that some movement out of these jobs (and engineering professional roles in particular) may have been into managerial roles, which might account for some of the decline in HS STEM employment among this group.

Table 4: Long term employment trajectories of engineering graduates, ages 26 to 42.

	Age 26		Age 30		Age 34		Age 38		Age 42	
	N	%	N	%	N	%	N	%	N	%
Graduate job	112	85	121	82	108	87	101	85	101	87
Highly skilled STEM job	112	69	121	63	108	62	101	60	101	56
Highest recruiting occupational groups										
Production managers	14	12	13	11	10	9	21	21	15	15
Functional managers	7	6	9	7	17	16	10	10	8	8
Engineering professionals	35	31	28	23	24	22	19	19	17	17
IT professionals	13	12	24	20	16	15	10	10	14	14

Source: BCS70

The trajectories of physical science graduates show similar patterns of attrition from both highly skilled STEM jobs and employment in key ‘shortage’ areas over the course of their careers (Table 5). While 12% worked as science professionals at age 30, this declined to just 7% by age 38. Eight per cent were employed as IT professionals at age 30, but this had fallen to only 3% by age 42. The most common occupational destination for physical science graduates was teaching. At every BCS70 sweep from age 26 to 38, a larger proportion of physical science graduates worked in this occupational group than any other. At age 42 this was matched by the proportion working as functional managers. By this point functional management and teaching accounted for the employment of 30% of the physical science graduates who were in work.

Table 5: Long term employment trajectories of physical science graduates, ages 26 to 42.

	Age 26		Age 30		Age 34		Age 38		Age 42	
Physical science graduates	N	%	N	%	N	%	N	%	N	%
Graduate job	127	77	151	85	124	91	126	86	137	84
Highly skilled STEM job	127	42	151	50	124	47	126	40	137	40
Highest recruiting occupational groups										
Functional managers	12	9	11	7	11	9	17	13	20	15
Science professionals	14	11	18	12	13	10	9	7	10	7
IT professionals	6	5	12	8	11	9	7	6	4	3
Teaching professionals	18	14	22	15	22	18	19	15	20	15

Source: BCS70

While biological science graduate were as likely as other STEM graduates to secure graduate level jobs, they were less likely to work in HS STEM occupations (Table 6). The largest proportion working in these roles was 33%, at age 26 and 30. However, by age 42 only a quarter of biological science graduates were working in the HS STEM sector as a whole; a lower proportion than those working as teaching professionals (27%). The relatively high proportion of biological science graduates who work as teachers is in stark contrast to the proportion working as professional scientists, which fell from 10% at age 26 to only 5% at age 42. By age 42 more than five times as many biological scientists were working as teachers than as science professionals.

Table 6: Long term employment trajectories of biological science graduates, ages 26 to 42.

	Age 26		Age 30		Age 34		Age 38		Age 42	

Biological Sci. graduates	N	%	N	%	N	%	N	%	N	%
Graduate job	82	83	89	85	76	87	81	95	84	89
Highly skilled STEM job	82	33	89	33	76	32	81	23	84	25
Highest recruiting occupational groups										
Functional managers	3	4	5	6	9	12	13	16	11	13
Science professionals	8	10	6	8	6	8	5	6	4	5
Teaching professionals	18	22	16	18	15	20	18	22	23	27

Source: BCS70

The small numbers of cohort members in these subgroups mean that we must be cautious about drawing firm conclusions at the level of degree subject. However, our analysis of NCDS data revealed very similar findings, even at degree subject level. While the exact proportions in particular cells may not be replicated at the national level, the consistency of the patterns found in all the data sets used in the projects suggests that the patterns we found are likely to be representative of the broader context.

In summary, our analysis of the longitudinal cohort data revealed the following patterns. First, graduate level employment among STEM graduates remains high over the course of cohort members' early careers. At no point between the ages of 26 and 42 did this fall below 83%. In contrast employment in HS STEM positions is highest at age 26 (50%) but falls at each subsequent survey sweep to 40% by age 42. Professional-level employment in the 'shortage areas' of science, IT and engineering also fell slightly as the cohort ages. There are differences between graduates in different subjects, with engineering graduates having both the highest rates of HS STEM employment and in their own field. Biological science graduates are notable for both the small proportion working in HS STEM jobs (33% at best) and small proportion who held professional science roles (peaking at 10%). Regardless of subject specialism, however, the trend from graduation to early middle-age is one of attrition from skilled jobs in the STEM sector.

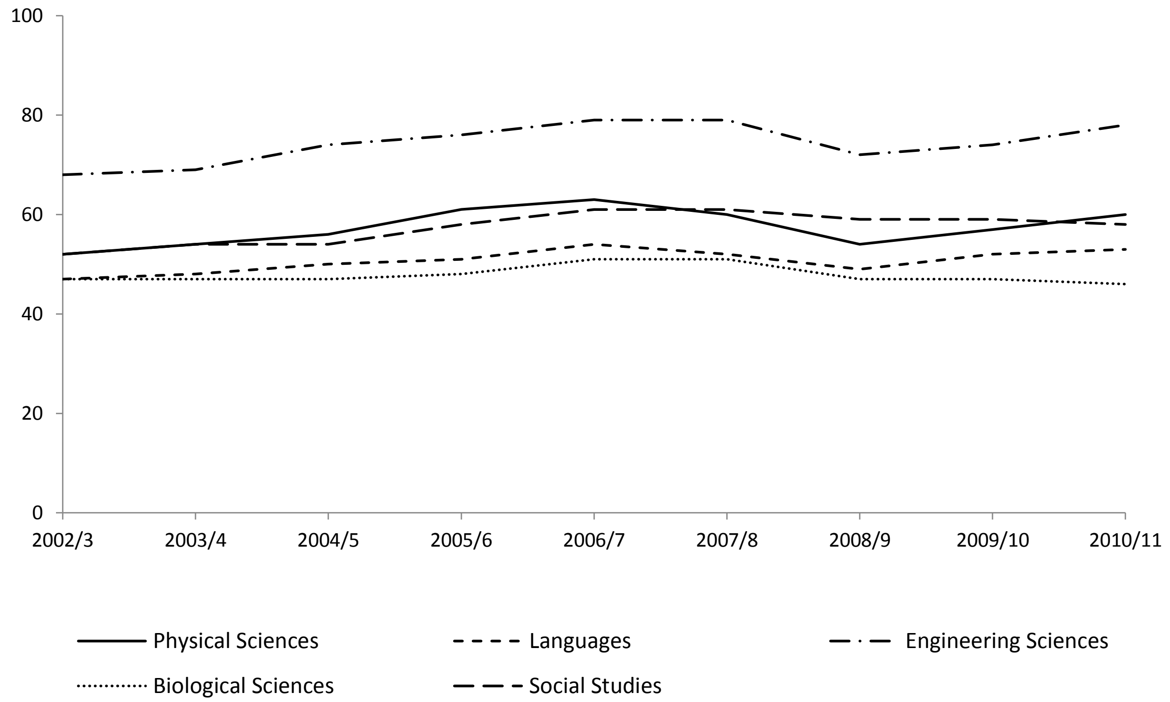
How do the career trajectories for STEM graduates compare with those with degrees in non-STEM subjects?

So far our reporting has focused only on STEM graduates. However, in a situation of labour shortage, where STEM skills are at a premium, we might expect STEM graduates to have more favourable employment outcomes than their peers with degrees in other subjects. In this section we compare the career trajectories of STEM and non-STEM graduates, starting with occupational destinations six months after graduation.

a) Early career destinations of STEM and non-STEM graduates

Between 2002/3 and 2010/11, there were few differences in the overall proportion of STEM and non-STEM graduates entering graduate-level jobs shortly after they left university (Figure 3). These data show that, as a group, STEM graduates do not have substantially higher chances of obtaining graduate-level employment. While graduates from some subject areas – such as the engineering sciences – have better than average prospects in this respect, graduates in the biological sciences actually fare slightly worse than their peers with languages and social studies degrees. The variation between STEM subjects is, in this respect, greater than the difference between STEM and non-STEM subjects at the aggregate level. Although not shown in Figure 3, unemployment data for recent graduates also show similar patterns among STEM and non-STEM graduates, with few substantial differences between the two subject areas. For example, over the period studied, around 8% of language graduates were unemployed six months after graduation, compared with approximately 10% of engineers. In relation to both graduate-level employment and unemployment levels, STEM degrees offer little in terms of a ‘premium’ in their value in the labour market.

Figure 3: Percentage of students entering employment who gain graduate-level type jobs, selected subject areas,



Source: DLHE

b) Employment patterns among STEM and non-STEM graduates in the wider workforce

Table 7 provides further evidence that differences between individual STEM subjects tend to be larger than those between STEM and non-STEM subjects as a whole. Similar proportions of STEM and non-STEM degree holders, who were aged 25 to 64 and were in employment, were working in graduate-level jobs. Unsurprisingly, a much lower proportion of non-STEM graduates (13%) held HS STEM jobs compared to STEM graduates (46%). However, employment in HS STEM positions is certainly not uncommon for non-STEM graduates. Over one-quarter of employed business and administration graduates worked in HS STEM jobs, as did 16% of those with degrees in social studies.

Table 7: Graduate-level and HS STEM employment, employed graduates aged 25 to 64, selected subject areas

	Graduate level job		HS STEM job	
	N	%	N	%
All STEM subjects	39448	87	21068	46
All non-STEM subjects	47090	82	7756	13
Total	86538	84	28824	28
Biological Science	5531	82	2168	32
Physical Science	5610	85	2673	41
Mathematics	1950	87	839	37
Computer science	3504	85	2163	52
Engineering	7229	86	5148	61
Technology	928	77	401	33
Social Studies	7702	81	1500	16
Business and administration	12284	81	3985	26
Languages/linguistics	4442	78	460	8
Historical/Philosophical studies	3688	78	558	12

Source: APS 2004, 2006, 2008 and 2010 combined

c) Occupational trajectories of STEM and non-STEM graduates

The cohort data allowed us to compare the occupational trajectories of STEM and non-STEM graduates. As can be seen in Table 8, the majority of STEM and non-STEM graduates were employed in managerial or professional occupations in every sweep of the study. Professional occupations were the most common destination at every age point, with substantial proportions of both STEM and non-STEM graduates also finding employment in Managerial and Associate Professional and Technical (APT) jobs.

Table 8: Major occupational groups for employed BCS70 STEM and non-STEM graduates, ages 26 to 42 (%).

	Age 26		Age 30		Age 34		Age 38		Age 42	
%	STEM	Non-S	STEM	Non-S	STEM	Non-S	STEM	Non-S	STEM	Non-S
Managerial	14	23	16	20	25	25	28	25	27	25
Professional	53	39	51	35	51	41	45	39	45	43
APT	17	16	22	27	18	23	19	24	18	21
Administrative	8	16	5	10	2	8	3	9	4	6
Non-graduate	8	7	6	8	4	4	5	4	6	4
Total N	590	608	636	661	551	561	543	541	565	582

Source: BCS70

Two key patterns emerged from our analyses. First, STEM graduates were more likely to be employed in professional positions compared to those with degrees in non-STEM subjects.

This was the case at every survey sweep but, by age 42, the proportions were very similar, at 45% for STEM graduates and 43% for non-STEM graduates. However, graduates in non-STEM subjects were more likely than STEM graduates to take up managerial positions early in their careers. At age 26 and 30, substantially greater proportions of non-STEM graduates worked as managers, but by age 34 STEM graduates had ‘caught up’ and at ages 38 and 42 were more likely to be managers than their non-STEM graduate peers.

Although there are differences between the proportions of STEM and non-STEM graduates in managerial and professional occupations at different points in their careers, there is certainly no evidence of an overall career advantage for cohort members with STEM degrees. While these data are from the BCS, the analysis of the NCDS produced similar findings, suggesting that these patterns are not unique to a particular cohort.

The above analyses have shown that differences in employment outcomes *between* STEM subject areas are actually greater than those between STEM and non-STEM areas. There is also relatively little variation between the immediate and longer-term occupational destinations of STEM and non-STEM graduates in terms of graduate level employment. There is some evidence of a lag in the time it takes non-STEM graduates to attain graduate level jobs (especially professional jobs) and this may be due in part to the non-specialist nature of many non-STEM degrees. This suggests that encouraging students to study STEM degrees on the basis of better labour market outcomes is ethically questionable. STEM graduates have little advantage over non-STEM graduates in terms of securing graduate level employment and, perhaps most importantly, most STEM graduates never work in HS STEM jobs.

Are there different patterns of labour market participation for STEM graduates with degrees from different types of institution?

One of the most important findings from our analyses of the HESA First Destination data was the disparity between the proportions of graduates from different types of higher education institutions who enter HS STEM jobs shortly after graduating. We compared Russell Group

Table 9: Employed graduates working in HS STEM jobs six months after leaving university, HESA First Destination Surveys, 2002/03 to 2010/11

Highly-skilled STEM jobs	Russell group						UA/M+					
%	02/03		06/07		10/11		02/03		06/07		10/11	
	N	%	N	%	N	%	N	%	N	%	N	%
All STEM subjects	9239	53	11370	61	12347	60	4702	29	5163	31	5227	26
All subjects	11813	35	15010	42	16327	42	6635	17	7690	19	7634	15
Biological sciences	795	25	883	26	773	23	442	13	493	12	436	8
Physical sciences	859	33	1190	48	1292	47	350	28	386	33	432	30
Mathematical sciences	539	41	717	55	906	59	59	20	80	38	83	32
Computer science	811	60	773	75	639	80	1488	43	1498	52	1207	49
Engineering & technology	1505	62	1877	75	1946	74	979	44	1075	51	1028	53

* Small N, less than 50

institutions with those members of the University Alliance (UA) and Million+ (M+) groups. Russell Group members are generally older, research intensive, more prestigious institutions, whereas UA/M+ tend to be newer and more focused on teaching. More than twice the proportion of graduates from Russell Group universities entered HS STEM jobs compared to those who studied at the newer institutions that were members of the University Alliance (UA) or Million+ (M+) groups. The difference between STEM graduates was of a similar size with, in 2010/11 for example, 60% of those from Russell Group institutions finding HS STEM positions but only 26% of those from UA/M+ universities doing so. As Table 9 shows, disparities in individual STEM subjects were sometimes even larger. In the same year, only 7% of biological science graduates from UA/M+ institutions found work in HS STEM subjects compared to 23% of their peers with degrees from Russell Group universities. What type of institution students attend clearly affects their likelihood of gaining HS STEM employment shortly after graduation.

What proportion of HS STEM workers are non-graduates? Has this changed over time?

Our analysis of APS data from 2004 to 2010 suggests that over that period just over half of all HS STEM positions were held by non-graduates (Table 10). Disaggregating the data by age group shows that this proportion is lower among younger workers, at 37% for those aged 25-29 years, but higher among older workers, at 64% for those aged 55-59 years. In terms of STEM 'shortage' occupations, just under half (43%) of IT professionals did not have degrees and 60% of professional engineers were non-graduates (higher than the figure for HS STEM jobs in general). As with STEM professions as a whole, younger workers were more likely to have degrees than their older colleagues but in every age group there were substantial proportions of non-graduates in these two professions.

Relatively small proportions of non-graduates work in science professional occupations, for example, the figure for 25 to 29 year-olds was only 7% and among 55 to 59 year-olds, at 32%, it was much lower than in IT or engineering. It would appear that either jobs in professional science are more likely require a degree or the ratio of positions to applicants is more favourable than in other STEM occupational areas.

Table 10: Percentage of non-graduates working in key occupational sectors, by selected age group

SOC group	All respondents		Age 25-29		Age 35-39		Age 45-49		Age 55-59	
	N	%	N	%	N	%	N	%	N	%
Production manager	9228	72	283	58	1291	66	1634	73	1292	79
Functional manager	13394	54	741	42	2267	49	2288	57	1348	65
Science profession	533	22	29	7	69	18	104	33	61	32
Eng professional	5311	60	378	43	712	54	856	67	721	70
IT professional	3335	43	417	35	680	42	450	49	210	50
Health professional	681	11	69	10	117	11	101	11	60	11
Teaching profession	5680	21	207	8	439	14	765	20	1425	34
Legal professional	280	10	15	4	39	8	39	10	48	16
Business profession	2425	36	195	23	390	34	356	38	321	48
Sci/Eng technician	3621	79	293	62	496	76	604	85	508	84
IT technician	2110	67	367	61	357	66	299	72	149	77
HS STEM job	36475	53	2937	37	5463	49	5798	59	4436	64
Graduate job	117361	54	8752	40	17442	52	19273	58	14224	61
All jobs	393907	77	36249	68	56165	75	60888	79	49396	82

Source: APS 2004, 2006, 2008 and 2010 combined

Discussion

Understanding the relationship between supply and demand in the STEM sector is not straightforward and the complexity of the phenomenon has been a central feature of discussions in the area for many decades. Our research has sought to understand, using the best data available, the broad patterns of participation in STEM sector occupations over the long term. It has focused on graduates but also considered the careers of non-graduates working in STEM fields. It has examined occupational destinations shortly after graduation, longer-term career trajectories and also historical trends in the STEM labour market as a whole. Although the demand for STEM workers has not been measured directly – through an examination of unfilled posts for example – patterns in the STEM labour market and the trajectories of STEM graduates and workers can be used as indicators of demand. As with any investigation of this type, we are limited by the quality and scope of the data available to us. Accounting for patterns and trends in the data is also difficult and we have, wherever possible, offered the most parsimonious explanation for our findings. Nevertheless, despite these limitations in the type of data that is available for analysis, this study represents the most comprehensive analysis of the career trajectories of STEM graduates in the UK, and the consistency of findings both within and between the different datasets means this study makes an important contribution to the work on supply and demand in the STEM sector.

So what do our analyses tell us about the extent of any STEM shortages? In this section we highlight some of our most important findings and explore the issues they raise for the 'STEM shortage' debate.

The supply of STEM graduates, particularly to some subjects, appears to be remarkably stable – in absolute terms – even in the context of an expanding undergraduate population. The data on applications and admissions suggest that the provision for undergraduate degrees in 'shortage' STEM subjects has remained stable simply because demand had not risen. Given that UK universities compete for students, and are financially rewarded for recruiting additional entrants, the simplest explanation for this lack of expansion is a limit in the number of students wishing to study these subjects. This is notable not simply in terms of the failure of initiatives intended to target these areas but also because of the longstanding and widely publicized labor shortages in business and industry. Either students have not received this message or it has not motivated them to change their career plans. The extent to which this is a problem, however, depends on whether the nature and size of any shortages. As the following discussion explains, our analyses suggest that, even in the areas where shortages have been reported as being most severe, simply increasing the number of graduates in unlikely to be an efficient way of growing recruitment to HS STEM positions.

The majority of STEM graduates never work in HS STEM jobs, even in subject areas such as engineering that are most successful in this respect. Some STEM subjects, biology in particular, have very poor records of supplying HS STEM workers. STEM graduates are no more likely to enter graduate positions than those with degrees in other subjects, and are just as likely to be unemployed – there is no evidence for a labour market advantage as one might expect in a shortage situation. Any mismatch between the supply and demand for STEM workers cannot, therefore, be attributed to the number of students graduating with STEM degrees. Problems with the 'supply' of STEM workers are more likely to be explained by the willingness of graduates to pursue careers in STEM fields and, or, the recruitment practices of employers.

One important finding from our work is the narrow field from which many key shortage occupations still recruit. Perhaps it is unsurprising that the three key 'shortage' occupational areas (science, IT and engineering professionals) recruit largely from graduates in allied subject disciplines. Engineering graduates might be expected to be more attracted, and often better suited, to professional engineering roles. Similarly, it is understandable that those with maths and computer science degrees are over-represented in the IT professional workforce. However, given that 'shortage' accounts have persisted for many decades (e.g. Smith 2017), and employers have complained about their inability to fill posts in these occupational areas (CBI 2014), it is surprising how few graduates from other STEM areas are employed as engineering or IT professionals.

There is also attrition from STEM occupations over the course of individuals' careers that is not seen in other fields. A larger proportion of STEM workers move out of highly skilled positions later in their careers. Unlike in other professions, such as education or health, this is not balanced by an intake of more mature recruits; graduates are unlikely to enter STEM positions if they do not do so shortly after graduation. There is also little evidence that STEM graduates enter HS STEM occupations later in their careers.

One reason for this might be that rapid technological changes in the field mean that STEM degrees have a short 'shelf life' and the knowledge and skills that are developed become quickly out of date. Another reason for STEM graduates not entering the field later in life might be the need to invest in postgraduate qualifications and the additional financial cost that this incurs, or the terms and conditions of employment, such as more precarious fixed term work contracts.

Engineering is often the subject area that is selected by employers and policy makers to exemplify the purported STEM skills deficit (e.g. Engineering UK 2016). Engineering stands out among the non-medical STEM subjects as being particularly successful in terms of graduate career destinations: about one third of engineering graduates find work as professional engineers. Yet in the context of assumed shortfalls in the throughput of graduate engineers from schools and universities, and with engineering graduates holding the vast majority of the professional engineering occupations, it is surprising that the engineering sector remains so reliant on engineering graduates rather than recruiting more graduates from related educational backgrounds. Although our data indicate that the career destinations of engineering graduates are favourable, they also show that professional engineering jobs remain largely closed to graduates with degrees in other subjects. This suggests either that these shortage occupational destinations are unattractive to many STEM graduates or that these careers are effectively closed off to them by the recruitment practices of employers.

It could also be the case that there is a ‘natural’ ceiling to recruitment to the pool of engineering graduates and that only a minority of those with engineering degrees want to work in the sector, regardless of the employment offer on offer. Therefore, one way to increase the pool of ‘suitable’ candidates would be to increase the number of those studying for engineering degrees, in the knowledge that only a minority would enter the sector. This seems to be the preference of employers and the main thrust of recent policies (e.g. Cm 8980, 2014). However, as our research shows, the differential levels of recruitment suggests either that only certain types of graduate want to enter the engineering labour market or that employers select the majority of their workers from particular social and educational groups. The fact that much lower proportions of engineering graduates from UA/M+ institutions enter the profession compared to those graduating from Russell Group universities might suggest that the latter explanation is more likely.

The most obvious alternative source of potential engineering professions is STEM graduates with non-engineering degrees. Given that the majority of professional engineers either have no degree or a degree in a non-STEM subject, STEM graduates look to be a relatively desirable pool of labour. Given its size, a relatively small increase in the proportion of engineering professionals recruited from this group would result in a substantial increase in the absolute number of STEM workers. It is difficult to believe that maths or physics graduates, for example, do not have knowledge and skills that are transferable to engineering, and they will also have other transferable skills associated with a university education. At present, very few physical and biological science graduates embark on careers in the engineering sector. This may be because they have no desire to enter this area, or because employers would prefer engineering graduates or non-graduates with engineering experience, but if a shortage really exists it would seem strange to ignore the potential for recruitment from this group.

The number of potential workers in any group is an important but often overlooked consideration in discussions of STEM 'shortages'. And the largest group of potential employees are non-graduates. The proportion of graduates in professional engineering positions, for example, is much lower than in other non-STEM areas – in the health and legal sectors, for example – where a degree level qualification has long been mandatory. As the majority of engineering professionals do not have degrees, it is important to question the extent to which an engineering degree – or a degree in any subject – is *necessary* to work as an engineering professional, or whether it is merely something that is *desirable* to employers. It is possible that a degree level qualification is not needed to perform all professional engineering jobs and that many of these roles can be carried out effectively by non-graduates.

Our analyses clearly show that, in the UK, there is no overall shortage of STEM graduates. There may well be a shortage of STEM graduates willing to work in HS STEM roles in some occupational areas, or a shortage of those who employers consider 'suitable', but these are different issues. It is certainly the case that many of the indicators that are associated with labour shortages – such as very low levels of unemployment – are not present in these data. There are, however, important differences in the employment outcomes of different groups on STEM graduates. Those studying particular subjects or studying at certain types of institutions are much less likely to ever work in HS STEM positions. At present there are large sections of the STEM graduate population that are underrepresented in the STEM labour force. If employers are really having problems recruiting sufficient numbers of workers, they may have to rethink their ideas about who their potential workforce are, and to what extent it is their responsibility to train their workers.

Notes

[1] Deciding whether or not a graduate is employed in a HS STEM sector job is problematic and sometimes arbitrary. With this caveat in mind, we have adopted the classification used by the United Kingdom Commission for Education and Skills (UKCES) which uses the criteria of whether an occupation has a high proportion of graduates, a high proportion of STEM-degree holders and a high proportion of STEM-degree holders among graduate entrants. The list below shows the UKCES (2011) classification of HS STEM jobs and the corresponding UK Standard Occupation Classification (SOC) 2000 3-digit occupational codes.

SOC code	HS STEM occupations
112	Production Managers
121	Managers in Farming, Horticulture, Forestry and Fishing
211	Science Professionals
212	Engineering Professionals
213	Information and Communication Technology Professionals
221	Health Professionals
232	Research Professionals
242	Business and Statistical Professionals
243	Architects, Town Planners, Surveyors

311	Science and Engineering Technicians
312	Draughtspersons and Building Inspectors
313	IT Service Delivery Occupations
351	Transport Associate Professionals
353	Business and Finance Associate Professionals
355	Conservation Associate Professionals

[2]The 2000 Socio-economic classification scheme were used to code occupational groups in this study. This comprises 7 occupational categories of which managerial, professional and associate professional were most of interest in this study. For further detail see ONS (2000).

[3]Undergraduate (Bachelor) degrees in the UK are usually three years in length. Students choose their subject before entry to University and degrees are relatively narrow in their field of study and inflexible in terms of the range of subjects that can be taken, especially in comparison to similar programmes in the US. For example, a student enrolled on a BSc Chemistry degree will study content mainly in this area and the extent to which they will study modules in other subjects (especially beyond the sciences) is limited. Programmes where students study a range of subjects before declaring a 'Major' are rare in the UK where specialism happens relatively early in one's academic career. In addition, programmes such as Medicine and Nursing can be studied at undergraduate, as opposed to graduate, level.

[4]Definitions of graduate level employment are based on the work of Elias and Purcell (2004).

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Appendix 1

The five datasets that we draw upon in this paper are listed below. While we have done our best to summarise the key features of our data, we encourage the interested reader to seek out a more developed account in our other publications that are cited throughout the paper.

- Universities and Colleges Admissions Service data (UCAS)
- Destinations of Leavers from Higher Education data (DLHE)
- The Annual Population Survey (APS)
- The 1958 National Child Development Study (NCDS58)
- The 1970 British Birth Cohort Study (BCS70)

Any student who wishes to study an undergraduate (bachelors) programme at a UK university has to make their application through UCAS. UCAS releases annual data on applications and acceptances to university. These data provide information on a number of applicant characteristics including sex, institution and subject studied. Data from 1988 to 2012 were included in this analysis. Further information on these data, and their potential limitations, can be found in Smith (2010) and Gorard (2008).

DLHE is an annual graduate destination survey administered by the Higher Education Statistical Agency. The DLHE survey gathers information on the activities of graduates six months after they graduate. Response rates tend to be relatively high; for the physical sciences they are over 80%. This dataset only considers destinations at six months after the student has left university, and it is recognised that career trajectories may be very different in the subsequent period. However, it tells us a great deal about the sorts of jobs that are immediately available to STEM graduates. DLHE data from 1992 to 2012 were included in our analyses.

The APS provided us with a detailed cross-sectional snapshot of the occupational status of STEM graduates in the labour market. These data contain information on the occupational status of respondents between the ages of 25 to 64 years. APS data from 2004, 2006, 2008 and 2010 were included in our analyses. As there were no substantial differences between these four years, the findings presented here are for a combined data set of 803,634 cases.

The BCS70 follows the lives of around 17,000 individuals who were born in Great Britain in one week in April 1970, and who were aged in their mid-40s at the time of this research. Since the birth survey in 1970 there have been eight ‘sweeps’ that have gathered data on cohort members’ health and physical, social and educational development, as well as their economic, personal and occupational circumstances (CLS 2016). Data from five sweeps of the study were used in this analysis and provide a detailed account of the cohort members’ career trajectories at ages 26, 30, 34, 38 and 42. The BCS70 provides the best available source of data on the career trajectories of a representative sample of the British population. As with most longitudinal studies there are some issues with data quality, particularly with drop out and non-response. However, response rates for all sweeps of the BCS70 are around 75%.

The NCDS58 follows the lives of a cohort of individuals who were born in March 1958. To date there have been nine ‘sweeps’ of the NCDS, with the latest sweep taking place in 2012/13 when participants were 54 years old. Data were analysed at six points, starting in 1981 and captured the first employment destinations of the NCDS graduates as well as career patterns in the intervening decades. For reasons of space, and because most of the findings for the BCS70 were similar to those for the NCDS, this paper emphasises the results from the former study.

References

Arrow, K.J., Capron, W.M., (1959), Dynamic shortages and price rises: the engineer-scientist case, quarterly Journal of Economics, 73 (2), pp292-308.

Bush, V., (1945), Science the Endless Frontier, A Report to the President, Washington DC: US Government Printing Office.

CBI (2014), Gateway to growth, CBI/Pearson education and skills survey 2013, London: CBI;

CLS (2016), Centre for Longitudinal Studies, Institute of Education, www.cls.ioe.ac.uk

Cmd. 6824, (1946), Scientific man-power. Report of a committee appointed by the lord president of the council (The Barlow Report), London: HMSO.

Cm 8980, (2014), Our plan for growth: science and innovation, HM Treasury and Department for Business, Innovation and Skills, London: HM Treasury.

Committee on Science, Engineering and Public Policy (1995), Reshaping graduate education of scientists and engineers, Washington DC: National Academies Press.

Elias, P., Purcell, K., (2004), Researching Graduate Careers Seven Years On, SOC (HE): A classification of occupations for studying the graduate labour market, Research paper No. 6, Warwick Institute for Employment Research, accessed from www2.warwick.ac.uk/fac/soc/ier/research/completed/7yrs2/rp6.pdf

Engineering UK (2016), The state of engineering, accessed 14th June 2016 from http://www.engineeringuk.com/Research/Engineering_UK_Report_2016/

EU Skills Panorama (2012) STEM Skills Analytical Highlight, European Commission, accessed 9th June 2016 from http://www.in.gr/files/1/2013/05/23/STEMskills_en.pdf

Furlong, A., Cartmel, F., (2009), Higher Education and Social Justice, Buckingham: Open University Press.

IET (2015), Skills & Demand in Industry: 2015 Survey. The Institute of Engineering and Technology, accessed June 2016 from http://www.theiet.org/factfiles/education/skills2015-page.cfm

Gorard, S. (2008), Who is missing from higher education? Cambridge Journal of Education, 38 (3), 421–437.

Grattan Institute (2016), mapping Australian Higher Education, accessed 26th September 2017 from https://grattan.edu.au/wp-content/uploads/2016/08/875-Mapping-Australian-Higher-Education-2016.pdf

Greenfield, S., Peters, J., Lane, N., Rees, T. and Samuels, G. (2002) A Report on Women in Science, Engineering, and Technology for the Secretary of State for Trade and Industry, accessed March 2010 from http://extra.shu.ac.uk/nrc/section_2/publications/reports/R1182_SET_Fair_Report.pdf.

National Academy of Sciences (2010), Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5, Washington DC: The National Academies Press

ONS (2000), Standard Occupational Classification 2000, Volume1 Structure and descriptions of unit groups, London: The Stationery Office.

Select Committee on Science and Technology (2012), Higher Education in Science, Technology, Engineering and Mathematics (STEM) subjects Report, House of Lords Select Committee on Science and Technology, London: The Stationery Office Limited.

Smith, E., (2010), Do we need more scientists? A long term view of patterns of participation in UK Undergraduate Science Programmes, Cambridge Journal of Education, 40(3), pp281-298.

Smith, E., (2012), Women into Science and Engineering? Gendered patterns of participation in UK STEM subjects, British Educational Research Journal, 37(6), pp993-1014.

Smith, E., (2017), Shortage or surplus? A long-term perspective on the supply of scientists and engineers in the US and the UK, Review of Education, 5(2), pp171-199.

Smith, E., White, P., (2017), A 'great way to get on'? The early career destinations of science, technology, engineering and mathematics graduates, Research Papers in Education, 32(2), pp. 231-253

Smith, E., White, P., (2018), The employment trajectories of Science, Technology Engineering and Mathematics (STEM) graduates, Report for the Nuffield Foundation, Leicester: University of Leicester.

Steelman, J.R., (1948), Manpower for Research, Bulletin of the Atomic Scientists, 4(2) p57-58

Teitelbaum, M.S., (2014), Falling Behind? Boom, Bust and the Global Race for Scientific Talent, Princeton: Princeton University Press.

UKCES (2011), The supply of and demand for high- level STEM skills, UK Commission for Employment and Skills: Briefing paper, December 2011, accessed from https://www.gov.uk/government/publications/high-level-stem-skills-supply-and-demand

Wakeham Review (2016), Wakeham Review of STEM Degree Provision and Graduate Employability,https://www.gov.uk/government/publications/stem-degree-provision-and-graduate-employability-wakeham-review

Wilkinson, G.C.G., Mace. J.D., (1973), Shortage or surplus of engineers: A review of recent UK evidence, British Journal of Industrial Relations, 11(1), pp105-123.