Moving along the STEM pipeline? The long-term employment patterns of Science, Technology, Engineering and Maths graduates in the United Kingdom.

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Abstract

Concerns over the supply of highly-skilled (HS) science, technology, engineering and maths (STEM) workers are well established and have been a feature of policy discourse in the UK for more than 50 years. Since the 2016 referendum on leaving the European Union, these concerns have been exacerbated by uncertainty about the movement of labour between UK and Europe. More recently, the COVID-19 pandemic has highlighted the importance of STEM skills in a wide range of areas. However, despite continued government investment in initiatives to address these concerns, the evidence base for shortages is neither well-established nor compatible with economic theories of labour supply.

In order to fill a gap in the current evidence, we report on a unique analysis following the career destinations of STEM graduates from the 1970 British Cohort Study. While only a minority of STEM graduates ever work in highly-skilled STEM jobs, we identified three particular characteristics of the STEM labour market that may present challenges for employers: STEM employment appears to be predicated on early entry to the sector; a large proportion of STEM graduates are likely to never work in the sector; and there may be more movement out of HS STEM positions by older workers than in other sectors.

Keyworks: BCS70, graduate employment, higher education, labour markets, skill shortages, STEM.

Introduction

Problems with the supply of highly-skilled (HS) workers in the areas of science, technology, engineering and mathematics (STEM) are regularly reported in the mainstream media (e.g. Wall 2014, Grant 2015, Little 2020). It is commonly argued that shortage of adequately skilled STEM workers, particularly graduates, is holding back economic growth and placing UK industry at a disadvantage in relation to international competitor countries. 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 2015, Wakeham Review 2016). These concerns have heightened since the results of the 2016 referendum on the UK's membership of the European Union because of uncertainty about the future movement of labour between European countries (see: HM Govt. 2017a, 2017b) and, more recently, the COVID-19 pandemic has led the media to highlight the importance of STEM skills among UK workers (Pozniak 2020). Policymakers have responded to calls from industry, universities and other interested parties by introducing policies and initiatives aimed at remedying this 'shortage', often requiring the investment of considerable amounts of public funds.

However, establishing whether there a sufficient number of highly qualified STEM workers are being educated and trained in the UK, and elsewhere, is difficult. This is partly because of competing definitions of ‘shortages’ being used by stakeholders, which are both socially constructed and ideological (Smith 2017).

Alternative accounts of the state of the STEM labour market have as long a history as the ‘crisis’ accounts, although these have tended to receive less attention among policymakers. As the discussion later in this paper shows, questions have been raised about both the data and the analyses used by individuals and groups claiming that shortages exist and, as the evidence from our project shows, there are good reasons to doubt the popular notion of widespread problems with the supply and quality of STEM workers (Smith 2017, Smith & White 2018a). However, the relationship between the supply of, and demand for, STEM workers is not simple, and the STEM labour market differs in important ways from other sectors.

What has been noticeably absent from most research on the STEM labour market is detailed analyses on the trajectories of STEM graduates and STEM workers over the course of their careers. As we discuss in detail below, previous analyses have not examined subject-level differences or offered much differentiation in terms of job type. It is also the case that more research has been conducted in the US compared to the UK.

The aim of this paper is to contribute to the STEM skills deficit debate by using the best currently available data to provide detailed empirical evidence on the employment patterns of a cohort of the UK population over a 16-year period, from age 26 to 42. We provide a unique and original examination of these individual-level data, with a focus on STEM occupations, and paying particular attention to the careers of graduates.

This paper addresses the following research questions:

- What types of occupation do STEM and non-STEM graduates hold over the two decades after leaving university?
- What proportion of STEM graduates work in STEM-related careers?
- To what extent do graduate careers vary between different STEM subject areas?
- What do these findings tell us about the STEM labour market and the supply of STEM graduates?

Before describing the data sets used in the analysis and the subsequent findings, we first consider the wider context of the STEM skills deficit debate.

The supply and demand of STEM workers

> STEM skills are crucial for the UK's productivity, and a shortage of STEM skills in the economy is one of our key economic problems. The future workforce relies on many more children and young people being encouraged to take STEM subjects and enter STEM careers.
>
> *Delivering STEM Skills for the Economy* (House of Commons 2018: 3)

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, Europe and the US (e.g. HM Treasury/BIS 2014, EU Skills Panorama 2012, National Academy of Sciences 2010, CBI 2017). According to the Confederation of British Industry (CBI), employers report widespread difficulties in recruiting workers with STEM skills at every level: from new apprentices to more experienced workers. Over half of businesses (52%) claimed to be experiencing, or expecting to experience, difficulties in recruiting appropriately skilled STEM staff (CBI 2015). Surveys by sector skills organisations paint a similar picture (e.g. ABPI 2015, IET 2015, Engineering UK 2015, 2016, 2018,). A shortage of appropriately skilled STEM workers is, according to some, a threat to our 'productivity, competitive position and level of innovation' (Greenfield et al. 2002: 27). As a recent Government Green Paper shows, the focus of political concern is often on the supply of graduates:

> We have particular skills shortages in sectors that depend on STEM subjects, where we need more of these graduates to compete successfully in a global economy.
>
> *Building our Industrial Strategy* (HM Government 2017a: 16)

These concerns are reflected in the range and scope of initiatives and policies that have aimed to raise young people's participation in STEM subjects at university. The rationales behind such initiatives have been predominantly economic and echo industry's concern for a suitably skilled workforce (e.g. CBI 2015), particularly in the face of competition from other established and emerging economies such as India and China (Leitch Review of Skills 2006, HM Treasury/BIS 2014):

The previous Coalition Government's plans for the Comprehensive Spending Review ensured that Science and Research investment would be ring-fenced and that the cost of supporting students studying STEM subjects in Higher Education (HE) would be maintained (BIS 2010, Willetts 2010). STEM subjects have an enhanced status as 'strategically important and vulnerable' (HEFCE 2008) subjects and in the context of planned funding cuts to the HE sector in England, they are the key area which has been identified by the previous Labour government as well as the last Coalition Government for 'enhanced support'. This means that whereas other subject areas will see a reduction in the number of funded places for students, money will be diverted to STEM courses 'which meet strategic skill needs' (DIU, 2009, p. 45).

Is there a shortage in the supply of STEM workers?

The existence of a STEM skills deficit has not gone unchallenged. Some 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 either: struggle to find appropriate employment and can only 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 (see: Smith & Gorard 2011, UKCES 2011, Harris 2014, Teitelbaum 2014).

The STEM shortage debate is characterised by competing ideologies over what constitutes a shortage. Claims about shortages have often rested on hypothetical demands tied to normative judgements about economic growth, been based on a narrow range of questionable assumptions (Hansen 1961), predicted according to unpublished demographic projections that were never subject to independent review (Weinstein 2002, Hicks 2009, Smith 2017), or grounded in employer perceptions of the situation outside of their own organisation rather than the number of vacancies needing to be filled (Meager 1986).

As far back as the 1950s and 1960s, widespread political concerns about a 'swing from science' and a 'brain drain' of highly qualified professionals were being questioned by economists who saw the issue as a 'mass of contradictions compounded by a lack of understanding about what labour market demand actually meant' (Gannicott and Blaug 1969:57. See also: Wilkinson and Mace 1973). More recent work into the supply and demand of high level STEM skills, undertaken on behalf of the UK Commission of Employment and Skills, found that the available data do not suggest a higher vacancy rate for jobs that require workers with STEM skills, neither do they reveal an overall shortage of STEM graduates (UKCES 2011, 2013). Such contradictions are not limited to the UK. 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). Writing from a US perspective, Teitelbaum (2003:47) argues that STEM shortage claims are 'inconsistent with all available quantitative evidence ... [and] many of the solutions proposed to deal with the putative "crisis" are profoundly misdirected'. The economist Paul Krugman has described the purported skills gap as 'a prime example of a zombie idea - an idea that should have been killed by evidence, but refuses to die' (Krugman 2014:A21).

While shortage claims have frequently been challenged by research findings, the rhetoric contained in these 'crisis accounts' is strong and the 'shortage' discourse has succeeded in becoming the dominant political and public view. As a consequence, alternative accounts are largely absent from wider discussion which, in turn, has served to 'confuse serious thinking and to distort public policy' (Teitelbaum 2014: 26).

Many of the proposed solutions to the apparent STEM recruitment crisis focus on the supply side, urging action to increase the numbers of students pursuing degrees in science and engineering. However, an extensive report into the supply and demand for high-level STEM skills in the UK by Bosworth and colleagues indicates that supply and demand calculations for 2020 'do not suggest an *overall* shortage of STEM graduates (in terms of numbers) in most regions or nations of the UK' (UKCES 2013:xiii, emphasis added). Some evidence does point to contexts in which science and engineering shortages *may* be apparent, but this evidence also shows that such shortages can be limited to particular periods of booming expansion, to certain disciplinary specializations that have moved in and out of favour (such as the varying fortunes of nuclear power and the ascent of fracking in the energy industry) and to specific geographic locations (see also: UKCES 2013). These 'pockets' of shortages may be transitory and are certainly difficult to predict (UKCES 2015).

The regular reports published by policymakers and industry often contain potential remedies and, often, requests for additional funding. However, as Wright and Sissions (2012) have noted, effective policy cannot be made without sufficient data on both the supply of, and demand for, labour in the sector. The preceding discussion suggests that sector-level analyses can be misleading and that analysis needs to be conducted at a more granular level. The currently available data on the supply and demand for STEM workers is both inconsistent and partial, and there is a lack of detailed and reliable evidence in this area. This concern is reflected in the conclusions of both the House of Commons Committee of Public Accounts, and a House of Lords Select Committee:

> BEIS and DfE do not currently have sufficient understanding of what specific skills businesses really need or how Brexit will affect the already difficult task of ensuring the supply of STEM skills in the workforce.
>
> House of Commons Committee of Public Accounts, 2018, p. 5.

> The lack of reliable data on the supply and demand for STEM graduates and postgraduates makes it very difficult to assess whether there is a shortage of STEM graduates and postgraduates, and in which sectors.
>
> Select Committee on Science and Technology, 2012, para 72.

Cross-sectional analyses of labour market participation play an important role in creating a stronger evidence base in this area. As part of our research we analysed Annual

Population Survey (APS) and Labour Force Survey (LFS) data to examine historical trends, the findings of which can be found elsewhere (see: Smith & Gorard 2011, Smith & White 2018a, 2018b). But as valuable as these analyses are, they can only provide information about participation during a particular *period*. As the samples of these studies are not consistent over time, analyses of these data sets is less effective at examining how participation in the labour market changes as people progress through their careers. When people enter the STEM labour market, how long they stay in it, and when they leave it, are all important questions in terms of providing a clear picture of the issues facing both employers and employees in this sector.

Very little longitudinal research has been conducted in this area, almost certainly because of the challenges presented by the nature of the available longitudinal data, more generic issues with longitudinal data, and the level of disaggregation needed to conduct analyses with variables, such as degree subject, that contain so many individual categories.

Schoon et al. (2007) examined determinants of entry to STEM careers in the UK but did not use degree subject as an explanatory variable (as it was not available in the cohort studies at that time) or look at fine grained variations in the types of destinations. In the United States, Xu (2013) compared graduates' aspirations with their eventual occupational destinations 10 years later, and Sullivan et al. (2018) have compared the earnings of UK graduates with degrees in different subjects later in their careers. However, because of limitations in sample size, both of these studies had to collapse subjects into broad groups and, because of this, were unable to examine differences between individual degree subjects.

The examples above illustrate the problems facing researchers who wish to contribute to the STEM supply and demand debate by using longitudinal data to examine career trajectories. While the categories used in the studies cited above may have been suitable for the questions the authors were asking, for a more direct analysis of how career change over time affects the STEM labour market a much more fine-grained approach is required. Although, as we discussed above, there are many areas of contention in this debate, particularly about the size and nature of any shortages but also how shortages are defined and measured (see Smith 2017 for a detailed discussion). However, there is widespread agreement that differentiating between graduates with degrees in different subjects, and looking closely at the type of STEM jobs that they work do – or don't – work in, is crucial. In this paper we try to reconcile this tension to make the best use of the available cohort data in order to contribute to the ongoing debate.

The analyses reported in this paper originate in a larger project that used many different data sets. It adds to our analyses of UCAS, HESA, APS and LFS data by using data from the 1970 British Cohort Study (BCS70) to examine the STEM labour market participation of a single cohort over an extended period of time. We also analysed data from the 1958 National Child Development Study (NCDS). As the findings were similar to the analysis of the BCS70, they are not included here but can be found in the publicly available main project report (see: Smith & White 2018a). In the follow sections we discuss and outline some important characteristics of the data, examine the strengths and weaknesses of the BCS70 – in general, and also in terms of the objectives of this research – and explain our analytic approach.

Data

This section describes the data sets that were used in the study and the categories used to classify STEM subjects and different occupational groups.

The 1970 British Cohort Study

The 1970 British Cohort Study (BCS70) follows the lives of around 17,000 individuals born in Great Britain in one week in April 1970. The study aimed to include all those born in that week, and so can be considered as population data for that week.[1] The number of active members has reduced over time, leaving researchers with a useable sample of around 10,000 individuals

Data from five of the eight existing sweeps of the study were used in this analysis, to provide a detailed account of the cohort members' employment patterns at ages 26, 30, 34, 38 and 42. These sweeps were chosen strategically to complement the other data sets we used in this project and to ensure that key variables were comparable.

The BCS70 is the best available source of data on the careers of a single cohort of the British population. As with all longitudinal studies there are some issues with data quality, most notably the risk of drop-out and non-response. However, response rates for all sweeps of the cohort studies are relatively high for longitudinal research as can be seen in Table 1. The 1996 sweep stands out as having a relatively low response rate but, as it is the first sweep following the graduation age of most students, we have included it in our analyses and take this into consideration when drawing our conclusions.

Table 1: Sample size and response rates for BCS70 members

Age of cohort	Year of sweep	Number of participants	Response rate (%)
26	1996	9003	56
30	2000	11261	70
34	2004	9665	75
38	2008	8874	76
42	2012	9841	75

Characteristics of the cohort

Table 2 provides background information on the characteristics of the BCS70 sample across the five sweeps used in this study. Slightly over half were female and about 14% held a first degree by the age of 26, although the proportion of first degree holders was notably higher in 1996 than in subsequent years (owing to variation in participation in later years). Cohort members with STEM degrees comprised around 6% of the sample (slightly less than half of all degree holders). The representativeness of the sample is discussed below, in the section on analysis.

Table 2: Selected characteristics of the BCS70 cohort members

Age of cohort	Year of sweep	Female		First degree		STEM degree	
		N	%	N	%	N	%
26	1996	4901	54	1711	19	720	8
30	2000	5790	51	1455	13	684	6
34	2004	5038	52	1340	14	611	6
38	2008	4665	53	1310	15	595	7

42	2012	5110	52	1349	14	612	6

STEM subject groups

Our primary interests in this paper are the occupational destinations of STEM graduates although, where appropriate, we compare these to the destinations of non-STEM graduates. Detailed information on non-graduates is available in the final project report (see: Smith & White 2018a).

Defining STEM subjects is not straightforward, as there are several commonly-used classifications (see Select Committee on Science and Technology 2012). In the absence of a consensus, and to achieve consistency with other data sets used in our research, we adopted the widely-used UK universities and colleges admissions authority (UCAS) definition. This classifies the following as STEM subject areas:

- Medicine and Dentistry
- Subjects allied to Medicine
- **Biological Sciences**
- Veterinary Sciences, Agriculture and related
- **Physical Sciences**
- Mathematical Sciences
- Computational Sciences
- **Engineering and Technologies Sciences**

- Architecture, Building and Planning

In this paper we concentrate mainly on the three numerically largest STEM subject groups indicated in bold in the list above, and in the results tables in the rest of the paper. However, we also discuss the Computer Sciences as, alongside the Engineering Sciences, it is one of subject areas are the most commonly discussed in terms of skills shortages. The Mathematical Sciences are sometimes grouped with the Computer Sciences and are also one of the Strategically Important and Vulnerable Subjects (SIVS) outlined by the Select Committee on Science and Technology (2012).

SIVS subjects include: Engineering; Maths; Psychics and Chemistry (both of which are in the Physical Sciences subject area) but the Computer Sciences and Biological Sciences have also received some support through this policy. All these subjects are included at various points in our analyses, where relevant.

Neither Architecture, Building and Planning nor Agriculture are often part of the discourse of STEM shortages and so are not a focus of this paper. Medicine, Dentistry and Veterinary Sciences have very different relationships with the labour market compared to the rest of the STEM subjects and, for analytic clarity, have been separated from them in most of our analyses.

Occupational groups

Where possible, all occupational data are categorised according the nine SOC2000 occupational classifications (see: ONS 2000). This categorisation, rather than the NS-SEC for example, was used to ensure consistency with the other data sets used in the project. It also allowed us to explore differences in the types of jobs that graduates held, over and above the division into 'graduate' and 'non-graduate' positions (see below).

- SOC Group 1 Managers and Senior Officials
- SOC Group 2 Professional Occupations
- SOC Group 3 Associate Professional and Technical Occupations
- SOC Group 4 Administrative and Secretarial Occupations
- SOC Group 5 Skilled Trades Occupations
- SOC Group 6 Caring Personal Service Occupations
- SOC Group 7 Sales and Customer Service Occupations
- SOC Group 8 Process, Plant and Machine Operatives
- SOC Group 9 Elementary Occupations

Graduate[2] employment

As participation in higher education has increased, so has the range of what might be considered to be 'graduate jobs'. To help address this issue Elias and Purcell (2004) propose a five-category classification of graduate destinations. The first of Elias and Purcell's four categories – 'traditional', 'modern', 'new' and 'niche – are taken to constitute graduate employment and the fifth, non-graduate employment. Under this classification, graduate employment is defined as most occupations that fall into SOC categories 1-3 (Managerial, Associate/Professional and Technical); while non-graduate employment mainly fits into SOC categories 4-9 (Administrative and Secretarial, Personal Service, Sales and Customer Service, Machine Operatives and Elementary Occupations). However, this overlap is not perfect and, in our view, Elias and Purcell's classification is a more sophisticated measure.

Elias and Purcell's (2004) classification was chosen because it allowed us to move beyond SOC2000 measures but was also compatible with the data available in the numerous data sets used in our project, and so ensured comparability between analyses. Although, perhaps more sophisticated, classifications have been developed, these require different types of data not available in these data. Green and Henseke (2016) provide a detailed critique of the available classifications and their data requirements.

Highly-skilled STEM employment

Deciding whether or not a graduate is employed in a highly-skilled (HS) STEM job is not straightforward (Mellors-Bourne *et al.* 2011). We have adopted the classification of STEM sector employment used by United Kingdom Commission for Education and Skills (2011) that takes into consideration 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	*Highly skilled 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

We chose this classification over other possible candidates as it is the one used most frequently by the policymakers and industry representatives who are most vocal about the purported STEM skill shortages. This allowed us to assess these claims on their own terms, rather than add an additional layer of complexity of ‘translating’ other classifications when assessing these claims. The fact that the classification uses the SOC2000 groups also allowed us to classify occupations in the different data sets used on the wider project.

Detailed discussion of the merits of different classifications can be found in Mellors-Bourne et al. (2011).

Analysis

As we discussed in relation to the existing longitudinal research in this area, there are several factors that mitigate against a true longitudinal analysis of career trajectories in the STEM labour market. The combination of a small sample and a large variation in both the type of graduates and employment outcomes prevented the type of analysis that would have been ideal. The size of the resulting subgroups in any longitudinal analysis would have been far too small for meaningful analysis.

Various strategies could have been used to increase the useable sample size, but weighting has been shown to have little effect on any statistical outputs and multiple imputation has only been shown to consistently improve standard errors (Mostafa & Wiggins 2014), which are not appropriate measures to use with a non-random sample. In any case, the likely gains in useable sample size would not make a substantial difference to our choice of analysis.

In light of the above limitations, we chose to conduct a different type of analysis. The aim of our project was to provide evidence to inform the continuing debate on 'shortages' of STEM workers, particularly in relation to destinations STEM graduates, rather than to make a wider contribution to an understanding of life course trajectories. Our analyses have been in the 'political arithmetic' tradition (see Heath 2000) and are primarily concerned with describing patterns and trends in education and the labour market (see Gerring 2012 on the value of descriptive analysis). Because of the limitations in the data set that would compromise a genuine longitudinal analysis, we decided that a comparison of cohort data over time would better serve our purposes. For this analysis we analysed each sweep of data separately before examining how patterns of labour market participation changed as the cohort aged.

There are advantages and disadvantages to this approach, and our choice affects both the type of questions that our analysis addresses and the claims that can be made. Any comparison of the same cohort over time meant that we were not restricted to analysing only those cohort members who participated in all five sweeps and, as a result, had a larger effective sample size in each sweep. These larger sample sizes allowed bivariate analyses to be conducted at the level of individual degree subjects and job categories without resulting in extremely small cell populations and the volatility associated with these (although, as can be seen in the results, it did not completely eliminate this problem).

This approach, however, does mean that not exactly the same cohort members are being compared between sweeps, and this raises issues for the conclusions that can be drawn. We address the issues relating to non-response and how this might affect the comparison made between cohort in our conclusions, taking into consideration what is known about the characteristics of those who are more likely to be under-represented in the data.[4] However, we believe that, in relation to the aims of our research, this approach was more useful and had fewer disadvantages than longitudinal analysis that would have necessitated collapsing categories and obscuring key differences between both the cohort members and their occupational destinations. It is for this reason that we concentrate on the findings from comparisons of cohort data in this paper.

Our comparisons of the labour market participation of the cohort at different ages is limited to bivariate analyses. Statistical modelling is often used in the analysis of longitudinal data, in order to control for the effects of confounding variables. In the context of comparing cohorts over time, the role of such modelling is less clear, as data from each cohort is not being combined into a single data set. While we could have constructed models for each of the sweeps and compared coefficients between them, the issues with these comparisons we described above would been exacerbated, making comparisons between the coefficients problematic. As missing data is cumulative in statistical modelling, meaning that only cases with data for all the variables in a model can be included, the usable sample size for each cohort would have decreased and variation between the cohorts, in this respect, would have increased.

Although we chose a simpler approach to analysis for this data set, the results of the statistical modelling we conducted with the APS and LFS data are available elsewhere (Smith and White 2018a). These analyses are much more robust due to the larger sample sizes and, although answering slightly different questions, provide evidence that complements the findings presented here.

Findings

In order to answer the research questions outlined at the start of this paper we present the findings as follows. First we consider the destinations of STEM and non-STEM graduates regardless of degree subject. We use the nine main SOC categories to examine occupational patterns among graduates in general, before narrowing our focus to the three most popular STEM subject areas. We then compare the findings for STEM subjects with those for the largest non-STEM subject areas. In the final section, we examine the occupational trajectories of STEM and non-STEM graduates entering HS STEM jobs.

Occupational destinations for STEM and non-STEM graduates

Table 3 shows the proportion of employed STEM and non-STEM graduates who enter each of the nine SOC 2000 occupational groups. The proportion of graduate cohort members in the five non-graduate occupational groups - SOC 5 to 9 - is relatively small, and so these groups have been combined in the table.

The majority of STEM and non-STEM graduates were employed in SOC2 or higher occupations in every sweep of the survey. SOC2 (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 SOC1 (Managerial) and SOC3 (Associate Professional and Technical) jobs.

Table 3: SOC occupational outcomes for employed BCS70 STEM and non-STEM graduates, percentages, ages 26 to 42.

	Age 26		Age 30		Age 34		Age 38		Age 42	
	STEM	nSTEM	STEM	nSTEM	STEM	nSTEM	STEM	nSTEM	STEM	nSTEM
SOC1	14	23	16	20	25	25	28	25	27	25

SOC2	53	39	51	35	51	41	45	39	45	43
SOC3	17	16	22	27	18	23	19	24	18	21
SOC4	8	16	5	10	2	8	3	9	4	6
SOC5-9	8	7	6	8	4	4	5	4	6	4
Total N	590	608	636	661	551	561	543	541	565	582

Although there are differences in the proportions of STEM and non-STEM graduates in SOC1 and SOC2 jobs earlier in their careers, by age 42 these figures were very similar. Non-STEM graduates appear more likely to enter SOC1 jobs shortly after graduation but a similar proportion of STEM graduates go on to work in managerial (SOC1) positions later in their careers. As we discuss later, this pattern may be a result of STEM graduates being promoted from technical to managerial positions over the course of their careers.

These differences may be partly explained by the different sectors of the labour market in which these groups are competing. It should also be considered that although SOC1 positions may be qualitatively different from SOC2 positions, they are not always more highly paid, and are not necessarily more desirable. However, the key point is that the vast majority of graduates enter, and remain in, graduate (SOC1-SOC3) positions throughout their careers. In terms of high-status employment, over the course of a career, there is little evidence of any additional 'value' to holding a STEM degree.

At the lower end of the table, in terms of SOC5 to SOC9 occupations, there seems to be little difference between STEM and non-STEM graduates. The proportions in this type of employment fluctuated slightly over the cohort members' careers and decreased slightly between age 26 and 34, but only a small proportion of graduates (between 4% and 8%)

were employed in these types of jobs in any one sweep. Although these aggregate summaries could disguise movement between SOC5-9 jobs and occupations in the other four categories, it appears likely that only a small minority of graduates remain in SOC5 to SOC9 occupations throughout their careers.

Tables 4 to 7 show the main jobs types held by all employed STEM graduates as well as those from the main STEM subject groups that are the focus of this study: namely engineering, and the biological and physical sciences.

Table 4: Employed BCS70 cohort members with STEM degrees in graduate jobs and the highest recruiting SOC 2000 occupational groups, ages 26 to 42.

Age Year	Age 26 (1996)		Age 30 (2000)		Age 34 (2004)		Age 38 (2008)		Age 42 (2012)	
	N	%	N	%	N	%	N	%	N	%
Graduate jobs	590	83	636	87	551	91	543	90	565	88
Highest recruiting SOC 2000 Occupational Groups										
Functional managers (113)	34	6	49	8	73	13	75	14	74	13
Science professionals (211)	25	4	27	4	25	5	16	3	16	3
Engineering profs (212)	43	7	36	6	32	6	23	4	22	4
ICT professionals (213)	62	10	77	12	60	11	41	8	40	7
Health professionals (221)	59	10	50	8	47	8	50	9	60	11
Teaching profs (231)	62	10	58	9	52	9	56	10	66	12
Business/stat profs (242)	23	4	17	3	25	5	21	4	17	3

In terms of the seven SOC2000 occupational groups that were the largest ‘recruiters’ of STEM graduates, the most important finding shown in Table 4 is the relatively small proportion of employed cohort members with STEM degrees working in the key shortage areas of engineering (SOC212), ICT (SOC213) and science (SOC211) professions at any time in their careers. Only 4% of the employed STEM graduates in the BCS70 worked as science professionals at age 30, a figure that changed very little in later sweeps. A slightly larger proportion found work as engineering professionals. At age 30, 6% of employed STEM graduates held this type of occupation, with this figure falling slightly to 4% by ages 38 and 42. Similarly, while 12% of STEM graduates were working as ICT professionals at age 30, it had declined to 7% by age 42.

As can be seen the table, the numbers in some of the cells are very small and, given the issues with comparisons between cohorts, we should be cautious about drawing conclusions about the changes over time. However, the key point here is that at no point between the ages of 26 and 42 were more than 22% of STEM graduates working in these three key ‘shortage’ areas of the labour market, and by age 42 only 14% were employed in these types of occupation.

So while at any sweep in the survey between 83% and 91% of STEM graduates worked in graduate-level occupations, far fewer of them worked in science, engineering or ICT. A greater proportion (9% to 12%) went into teaching than either science (3% to 5%) or engineering (4% to 7%), and nearly as many worked as health professionals (8% to 11%) as were employed in ICT (7% to 12%). Employment in business and statistical work (3% to 5%) was almost as common as working as a science professional.

Management was the only one of the seven most popular occupational destinations where there was any appreciable change over time. While only 6% of STEM graduates worked as functional managers (SOC 113)[3] at age 26, this rose to 8% by age 30 and 13% by age

34. This may be due to promotion to managerial positions over the course of cohort members' careers and could also be a contributing factor to the decline, during the same period, in the proportions working in some of the other occupational groups. Because of the aggregate nature of these summaries, and the small numbers in some cells, any conclusions drawn can only be tentative. We have highlighted this pattern, however, due its congruence with the results of other analyses presented later in this paper, examining much larger groups.

Table 5: Main occupational groups for employed BCS70 engineering science graduates, age 26 to 42

Age Year	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
Highest recruiting SOC 2000 Occupational Groups										
SOC 1 jobs	26	23	31	26	31	29	39	39	33	33
Production manag. (112)	14	12	13	11	10	9	21	21	15	15
Functional manag. (113)	7	6	9	7	17	16	10	10	8	8
SOC 2 jobs	61	54	59	49	50	46	41	41	39	39
Engineering profs (212)	35	31	28	23	24	22	19	19	17	17
ICT professionals (213)	13	12	24	20	16	15	10	10	14	14
SOC 3 jobs	9	8	13	10	18	17	9	9	17	17

As was the case for STEM graduates as a whole, the vast majority of engineering science graduates were in graduate-level employment throughout their careers (Table 5). However, only a minority of employed engineering science graduates were working in engineering professional occupations (SOC 212) at any of the age points surveyed. The next most popular occupational destination for engineering graduates was work in the ICT sector, which varied between 10% and 20% at different sweeps. The levels of participation in these jobs are consistent with patterns found in the larger-scale Annual Population Survey data (see: Smith & White 2018a). The overall picture suggests that, even for those with degrees in more vocationally-oriented subjects such as engineering, a substantial proportion of graduates work outside of the STEM sector in the two decades after they graduate and only small numbers work in key 'shortage' areas.

Table 6: Main occupational groups for employed BCS70 biological science graduates, age 26 to 42

Age Year	Age 26 (1996)		Age 30 (2000)		Age 34 (2004)		Age 38 (2008)		Age 42 (2012)	
	N	%	N	%	N	%	N	%	N	%
Graduate job	82	83	89	85	76	87	81	95	84	89
Highest recruiting SOC 2000 Occupational Groups										
SOC 1	7	8	9	10	19	25	20	25	20	24
Functional managers (113)	3	4	5	6	9	12	13	16	11	13
SOC 2	42	51	42	47	36	47	34	42	42	50
Science professionals (211)	8	10	6	8	6	8	5	6	4	5
Teaching profs (231)	18	22	16	18	15	20	18	22	23	27
SOC 3	20	24	26	29	14	18	23	28	15	18

As is the case with graduates generally, the vast majority of employed BCS70 biological science graduates worked in graduate positions throughout their careers (Table 6). The teaching profession was by far the most common career destination, with between 18% and 27% of employed cohort members with a biological science degree working as teachers. However, only a very small proportion (between 5% and 10%) of biological science graduates worked as science professionals at any age and very few biological science graduates worked in any kind of STEM positions at any point in their career.

As with the engineering sciences above, there was little evidence that cohort members were moving into scientific roles later in life. Any movement was away from STEM occupations into other areas of work. Again, the numbers are very small, but the consistency in this finding between groups and sub-groups, and the congruence with patterns found in the other data sets we analysed, suggest that there is a real possibility of attrition from STEM jobs as cohort members progress through their careers.

Teaching was also the most population occupational destination for physical science graduates (Table 7). As with the biological scientists above, relatively few physical scientists (between 7% and 12%) ever worked in scientific professional roles. Apart from teaching (15% to 18%) the most common destination was functional management (7% to 15%).

Table 7: Main occupational groups for BCS70 physical science graduates, age 26 to 42

Age Year	Age 26 1996		Age 30 2000		Age 34 2004		Age 38 2008		Age 42 2012	
	N	%	N	%	N	%	N	%	N	%
Graduate job	127	77	151	85	124	91	126	86	137	84
Highest recruiting SOC 2000 Occupational Groups										
SOC 1	20	16	20	13	31	25	30	24	38	28
Functional managers (113)	12	9	11	7	11	9	17	13	20	15
SOC 2	57	45	79	52	62	50	53	42	52	38
Science profs (211)	14	11	18	12	13	10	9	7	10	7
ICT professionals (213)	6	5	12	8	11	9	7	6	4	3
Teaching profs (231)	18	14	22	15	22	18	19	15	20	15
SOC 3	24	19	34	22	23	18	28	22	30	21

To place STEM graduate career trajectories in context, Table 8 presents the same data as above for non-STEM graduates in the three largest subject groups: the social sciences; business and administration subjects; and languages.

There are few differences in the general graduate employment trajectories of STEM (Table 4) and non-STEM degree holders (Table 8). Although non-STEM graduates were less likely to enter graduate jobs in the five or so years after graduation, they appear to have caught up with STEM graduates by their mid- to late-30s.

Table 8: Main occupational groups for employed BCS70 non-STEM graduates, ages 26 to 42

	Age 26		Age 30		Age 34		Age 38		Age 42	
	N	%	N	%	N	%	N	%	N	%
All graduates in grad. job	1378	80	1334	84	1177	90	1155	89	1069	88
All STEM grad. jobs	590	83	636	87	551	91	543	90	565	88
All non-STEM grad. job	608	78	661	81	561	87	541	88	582	88
Social Sciences	N	%	N	%	N	%	N	%	N	%
Graduate job	98	68	110	77	93	96	98	92	95	88
Functional managers (113)	11	11	12	11	10	11	15	15	15	16
Teaching profs (231)	8	8	9	8	14	15	16	16	18	19
Business/stat profs (242)	8	8	6	5	15	16	6	6	6	6
Admin. finance (412)	10	10	5	4	0	0	1	1	2	2
Business administration	N	%	N	%	N	%	N	%	N	%
Graduate job	138	75	151	80	127	87	127	85	129	87
Functional managers (113)	32	23	31	20	39	31	36	28	41	32
Business/stat profs (242)	18	13	13	9	21	16	17	13	10	8
Admin. finance (412)	19	14	12	8	3	2	7	5	7	5
Languages	N	%	N	%	N	%	N	%	N	%
Graduate job	128	78	126	82	102	82	95	82	110	86
Functional managers (113)	15	12	9	7	13	13	7	7	11	10
Teaching profs (231)	41	32	39	31	28	28	28	29	35	32

In terms of graduate-level employment and high status SOC1 and SOC2 occupations, STEM graduates and non-STEM graduates are reasonably similar. The vast majority of those in employment held graduate-level positions for the first two decades of their careers and both groups will have similar levels of employment in SOC1 and SOC2 positions. In terms of securing and remaining in high status employment, there is no clear advantage to holding a STEM degree over one in another subject, particularly when longer term career patterns are considered.

As we have seen, only a minority of engineering, physical science and biological science graduates ever work in areas identified as key STEM shortage areas: in some subject areas teaching and management are more common destinations. In the next section we examine highly skilled (HS) STEM employment in greater detail before reflecting on what this means in terms of ‘shortage accounts’.

Highly-skilled STEM jobs

Table 9 shows the proportion of graduates from the main subject groups who enter highly-skilled (HS) STEM jobs (see definition above). The three non-STEM subject groups in the table were selected because they were the largest, numerically. Over the period examined, between 13% and 16% of the participating cohort reported working in HS STEM jobs. This figure varied only slightly over all five sweeps of the study but represents only a small minority of those in employment. Among graduates, this figure was much higher, at between 28% and 34%.

The proportion of non-graduates working in HS STEM jobs was small but showed a considerable rise, from 8% at age 26 to 14% at age 38. As the numbers here are much larger than in the subject groups, it is worth taking this change over time seriously. It also means that by age 38 non-graduates were only half as likely as graduates to be in HS STEM jobs but outnumbered them numerically by nearly 6 to 1. Although non-graduates are not a focus of this paper, we explore their important contribution to the HS STEM workforce elsewhere (see: Smith and White 2018a). While graduates are often the focus of discussions about STEM skill shortages, it is important to remember that, numerically, many more HS STEM workers do not have degrees.

Table 9: Employed BCS70 graduates in HS STEM jobs by subject group, ages 26 to 42

	Age 26		Age 30		Age 34		Age 38		Age 42	
	N	%	N	%	N	%	N	%	N	%
All Cohort Members	6903	13	9096	15	7989	16	7492	16	8298	15
All graduates	1382	32	1337	33	1179	34	1156	31	1220	28
Non-graduates	5521	8	7759	12	6810	13	6336	14	7078	12
STEM graduates	597	51	984	49	900	48	871	44	944	40
Biological sciences	82	33	89	33	76	32	81	23	84	25
Physical sciences	127	42	151	50	124	47	126	40	137	40
Maths/computing	111	50	111	52	98	49	94	45	99	36
Engineering	112	69	121	63	108	62	101	60	101	56
Non-STEM graduates	604	12	1077	13	950	14	925	14	1037	13
Social Sciences	98	15	110	22	93	25	98	17	95	16
Business/admin.	138	25	151	26	127	31	127	25	129	21
Languages	128	8	126	14	102	9	95	18	110	11

As might be expected, a higher proportion of STEM graduates entered HS STEM jobs compared to graduates from non-STEM subjects. At the ages of 26 and 30, around half of STEM graduates were working in HS STEM jobs but this had declined to 40% by age 42.

The size of the groups here are relatively large but we still need to be careful in our interpretations of change of time. However, this trend is also reflected in all the main STEM subject groups examined here. So rather than seeing increases and decreases between subject groups combining to form an overall downward trend, there is a consistent fall in every main STEM subject group. Importantly, this decline in relation to HS STEM jobs is not reflected in the data for graduate employment and suggests that STEM graduates, although moving out of HS STEM roles, were remaining in graduate-level work. One explanation congruent with patterns in the data, is that they were entering management roles (as functional managers for example) that fall outside the definition of HS STEM jobs. It is for this reason that we included the discussion on management roles earlier: while the numbers were very small in some of the cells in Table 5, the findings appear consistent with the analyses of much larger groups. Disaggregating the data in different ways has led to some regularities that at the very least warrant further investigation.

Biological science graduates stand out among STEM graduates as having the lowest level of employment in HS STEM jobs. The proportion holding these positions (25% to 33%) was not much higher than that for graduate members as a whole and similar to those who held degrees in business and administrative subjects (21% to 31%). One reason for this may be because of the relatively high proportion of business and administration graduates working in business and statistical professions (Table 9), which are classed as HS STEM jobs. However, our findings show that not only do STEM graduates not necessarily have any general labour market advantage, but that those with STEM degrees in certain subjects are not even much more likely to work in HS STEM jobs.

Discussion

At the start of this paper we presented two contrasting views of the STEM skills 'crisis'. In the analysis that followed we examined labour market participation of a single cohort over time in order to examine the extent to which STEM graduates contribute to the STEM workforce at different points in their careers.

Three main findings emerged from our analyses. First, that in some respects the employment prospects and careers of STEM and non-STEM graduates are quite similar for this cohort. However, there are also important differences between the careers of graduates with STEM degrees in different subjects. Lastly, there is some evidence to suggest that there is a trend of attrition from STEM jobs and little movement into the sector.

There were few differences in the long-term career prospects of STEM and non-STEM graduates. By age 30 similar proportions had graduate jobs and, in general, the largest recruiting occupations for both groups were teaching and functional management. Our findings for this cohort reflect other studies that have found little difference in the labour market status of recently STEM and non-STEM graduates (e.g. UKCES 2013, Smith & White 2018a). In terms of the ability to secure and retain graduate-level employment, the advantage of having a degree in *any* STEM subject over just having a degree, is minimal.

This finding has implications for the messages sent to young people via policies and interventions aiming to increase participation in science. It is not clear that having a degree in the sciences, rather than in other subjects, provides any sort of advantage in terms of short- or long-term employability. This does not mean that we should not encourage young people to study science, rather that we should not promote science degrees as having greater labour market value than degrees in other subjects.

In some respects, however, all science degrees are not created equal: at least in terms of patterns of graduate employment. There is considerable variation *between* STEM graduates in the proportions working as scientific, research or engineering professionals. Engineering graduates, for example, fare much better in this respect than those with biological science degrees, who have lower levels of HS STEM employment than graduates from some social science subject areas.

However, at no point between the ages of 26 and 42 were more than 22% of STEM graduates in this cohort working in the three key 'shortage' areas of science, engineering and ICT, and by age 42 only 14% were employed in these areas. So while STEM graduates work in many different (often non-STEM) occupational groups in which many of them will be using their STEM skills (see also: UKCES 2013), only a minority secure and maintain employment in the key STEM 'shortage' areas.

A more tentative finding is that as cohort members careers progressed, there was attrition from STEM jobs. Cohort members were more likely to be employed in HS STEM jobs when they were younger and appear to either leave or be promoted out of the field – perhaps into management positions – as they get older. Although the numbers in the sub-groups were sometimes too small to stand as robust evidence on their own, this trend appeared in the results of several different analyses and appeared to be consistent regardless of the number of cases being examined.

There is also little evidence to suggest that STEM graduates who are working outside the sector enter HS STEM occupations later in their careers. One reason for this might be that rapid technological changes mean that STEM degrees have a short shelf life and the knowledge and skills that are developed become quickly out of date (see UKCES 2013). Other reasons for STEM graduates not entering the field later in life might be the need to invest in postgraduate qualifications or perhaps the terms and conditions of employment might be a deterrent; in particular the culture of relatively low wages, job insecurity and short-term contracts that appear to be normalised within the field (Body 2013). Our evidence suggests that the route into HS STEM jobs is predicated on early entry and there may to be limited opportunities for cohort members to enter STEM occupations later in life.

How can we reconcile these findings with the reports of the skills shortage in STEM occupations that were discussed at the start of this paper? If there was a shortage we might expect to see relatively large proportions of STEM graduates entering these key occupational groups and staying there. Similarly, we might also expect to see increased entry into these jobs in later life, as STEM graduates who might have taken different routes in early career now switch to well-paid and stable jobs in STEM shortage areas. There is little evidence of either. Indeed, over the course of 16 years of cohort members' careers, only a minority of STEM graduates ever work in STEM shortage areas.

The skills and knowledge of STEM graduates can undoubtedly be very useful – if not essential – for some roles in health, teaching and business. The high proportion of STEM graduates employed in jobs outside of HS STEM positions should not necessarily be interpreted as evidence of some kind of 'wastage' in the system or 'inefficiency' in the relationship between education and the labour market (Khan 2011). However, the fact that only a small minority of STEM graduates are employed as science, engineering or ICT professionals sits uneasily with the idea of an overall ‘shortage’ of science graduates.

What can the experiences of the BCS70 cohort tell us about the prospects of students who will graduate in the near future? It is certainly the case that a larger proportion of young people participate in higher education now than in the late 1980s, when many of the BCS70 cohort started their degrees. While the graduate labour market in general – and the STEM labour market in particular – have changed, it is also important to recognise continuities. Although the cohort studied in this paper entered the graduate labour market more than two decades ago, more recent evidence suggests that the demand for graduates has kept pace with the expansion of higher education and demographic change (Elias and Purcell 2009), and that the process of recruitment into the graduate labour market has changed much more slowly than the education system itself (Pitcher and Purcell 1998).

One of the remarkable outcomes of this research project has been the consistency of the findings, both over time and between different data sets. Our analysis of the 1958 NCDS data shows very similar patterns to those presented in this paper. The 1958 cohort entered university and the graduate labour market in a very different context than the BCS70 cohort, yet their patterns of participation were very similar (see: Smith & White 2018a). Our analyses of UCAS and HESA data on recent undergraduate participation and immediate post-graduation employment destinations suggest that the patterns for students in the early 2010s remain remarkably similar to their older peers. Our analysis of Annual

Population Survey data has shown that increases in participation in HE did little to increase the number of graduates working in STEM jobs (see: Smith & White 2018a).

The evidence base generated by our analyses points to several constants: flat levels of participation on undergraduate degrees in STEM ‘shortage’ areas; a minority of STEM graduates working in HS STEM positions; and attrition from HS STEM positions later in the careers of STEM graduates. There is little to suggest that these patterns will change in the near future.

However, it should be considered that these patterns persist within a context of what could be characterised as a ‘surplus’ of STEM graduates. Any ‘shortages’ that do exist are not caused by a lack of STEM graduates *per se*, but rather are the result of the combined effects of the recruitment practices of employers and the career choices of graduates. Employers can exacerbate or mitigate shortages by changing their expectations of the ‘quality’ of graduates they expect to employ. The career choices of STEM graduates will be affected by their experiences of science in education, their perceptions of the desirability of a STEM career, and the opportunities available elsewhere in the labour market. STEM labour shortages – as they have been characterised in recent times - are constructed by social processes. Their existence, or otherwise, cannot be established by a simple auditing exercise.

Notes

1. Later studies, such as the Millennium Cohortß Study, used random sampling. However, at the time of writing, the participants are not yet old enough to have graduated with undergraduate degrees.

2. A graduate is defined as a person who is aged between 21 and 64, not enrolled on any educational course and who has a level of higher education above A level standard.

3. The functional manager occupational sub-group includes managerial roles in finance, marketing, sales, personnel, ICT and research and development.

4. Non-response in BCS70 has been shown to be non-random, with 'men from lower social backgrounds and with less educated parents' being underrepresented. However, there is little to suggest variation between sweeps in this bias (Mostafa & Wiggins 2015, p. 144. See also: Plewis et al. 2004).

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