DEMONSTRATING THE VALUE OF

Science, Technology, Engineering, and Mathematics

MAIN REPORT

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Emsi

Acknowledgements

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Key Findings

The results of this study show that Science, Technology, Engineering, and Mathematics (STEM) learners receive a positive return for their investment of a STEM education and have a significant impact on the UK's economy. Using a two-pronged approach that involves an investment analysis and a regional economic impact analysis, we calculate the benefits to learners and the UK's economy. Key findings of the study are as follows:

Investment Analysis

Benefits to Learners

- STEM learners as a whole paid an estimated total of **£4.1 billion** to cover the cost of tuition fees and books and supplies at institutions across the UK in FY 2016-17. All learners also forwent an estimated **£16.1 billion** in earnings that they would have generated had they been working instead of learning.
- In return for the monies that STEM learners invest in their education (in the form of tuition fees and forgone earnings), they will receive a present value of **£77.9 billion** in increased earnings over their working lives.
- Every £1 that STEM learners pay for their education yields **£3.80** in higher future wages. This translates to a **13.4%** annual rate of return on their investment.

Regional Economic Impact Analysis

Impact of Added Workforce Skills

- HE and FE institutions in the UK serve over two million learners annually; nearly all of these STEM learners stay in the UK upon the completion of their studies. Their enhanced skills and abilities bolster the output of employers, leading to higher income in the UK and a more robust economy.
- The accumulation of former STEM learners who are currently employed in the UK's workforce amounts to **£75.1 billion** in added income in the UK's economy each year. The £75.1 billion accounts for former learners' higher income as well as £31.1 billion in income for businesses in the UK. This is equivalent to around 5.9% of the UK economy and supports around 1.3 million jobs.
- STEM occupations are placed industry-wide, but while job growth is strong and concentrated in London and the South East, programmers and software development professionals see the most job openings in the majority of regions. Manufacturing and IT roles dominate STEM occupations, but with significant growth and openings in digital and life science professions. Job postings reveal programming languages are the most sought-after skill for STEM occupations.

Chapter 1 : Profile of STEM Across the UK

Science, Technology, Engineering, and Mathematics (STEM) education and its importance to the UK's economy has been a key topic of discussion in the education sector, private sector, and government at both a local and national level for a number of years. There have been numerous pieces of literature that address STEM's importance and strategies for improving the uptake of a STEM education for learners. This report investigates the economic benefits on the UK as a direct result of STEM credentials. Key findings are as follows:

- Former FE and HE STEM learners contribute £75.1 billion to the UK's economy through their increased earning and productivity.
- In 2016, there were approximately 2.5 million people employed in STEM occupations in the UK, with just one out of every five STEM jobs filled by women.
- All non-STEM occupations are expected to grow at 3.9% between 2016 and 2024 while STEM occupations are expected to grow at 4.2%. STEM occupations have a median hourly wage of £19.60 compared to just £13.09 for non-STEM occupations.
- An analysis of Emsi data found businesses that have a high concentration of STEM workers spend 17% more on employment placement agencies than other businesses.
- Numerous business surveys and publications show there is a shortage of STEM candidates. We find that STEM graduates contribute significantly to the UK's gross national product (GNP) and that the UK's GNP is ultimately stymied by the shortage of skilled STEM learners.

Some notable organisations have investigated the economic value of STEM, such as the Engineering UK 2017 report which noted the Gross Value Added (GVA) of engineering to the UK economy was £486 billion in 2015 and that there were 650,000 engineering enterprises in the UK. Technology is also changing how we live and work at a rapid pace. A report done by Tech City UK titled Tech Nation 2017 found that digital tech businesses in the UK had a turnover of over £170 billion in 2015 and the number of digital tech businesses grew twice as fast as non-digital businesses. These reports in addition to our findings clearly show, albeit from slightly different angles, that the value of STEM focused industries and STEM credentials are a significant portion of the UK's economy.

While these reports show the importance today, other studies have focused on areas of opportunity for STEM education and STEM focused industries. As referenced in this report and Understanding the Careers Cold Spots, prepared by The Careers and Enterprise Company, girls are underrepresented in STEM subjects especially when looking at the narrow definition of STEM as addressed later in this report. The Tech Nation 2017 report found that in digital tech businesses, men outnumber women by three to one. Beyond this, many employers struggle to find enough STEM graduates. The Understanding the Careers Cold Spots report mentions that "firms report difficulty in recruiting staff with particular technical skills, which are underpinned by STEM A levels." Similarly, the Engineering UK 2017 report conservatively found that there will be an annual shortfall of 20,000 engineering graduates in the UK through 2024. Survey results from the Tech Nation 2017 report found that 25% of digital tech businesses described sourcing talent as a major challenge and 50% had a shortage of highly skilled employees. According to the report, 13% of digital tech workers are originally from outside the UK while across the rest of the economy only 10% are international workers.

STEM is and will continue to be a bright spot in the UK's economy with 265,000 skilled entrants needed annually to meet the demand of engineering enterprises through 2024, as referenced in the Engineering UK 2017 report. Between 2016 and 2024, Emsi's data show that STEM occupations will grow by 4.2% with a median hourly wage of £19.60. STEM occupations have both higher wages and are expected to grow faster than non-STEM jobs. Engineering firms meet the demand for skilled workers through FE and HE institutions in the UK. However, as also noted in the Engineering UK 2017 report, it is estimated that for engineering roles requiring Level 4+ skills, there will be 40,000 EU and other international graduates that enter the UK's workforce annually to help meet the demand of engineering firms.

Despite the areas of opportunity for more home-grown talent and for more female STEM learners, the number of STEM jobs have grown and will continue to grow. These jobs, as addressed in this report, have higher wages as compared to the average wages across all occupations in the UK, representing an opportunity for learners considering a STEM credential. From a national perspective, increasing the number of STEM graduates to meet the demand of engineering industry is estimated to be worth £27 billion in economic growth for the UK according to a report by EngineeringUK and CEBR.

Even though there aren't other studies that address how much economic growth would occur by meeting the talent demand of other STEM sectors, there are multiple studies that show businesses could use more STEM graduates. For example, The Association of the British Pharmaceutical Industry published a report titled Bridging the Skills Gap in the Biopharmaceutical Industry which detailed what skills employers are concerned about finding. These skills range from Health Informatics to Clinical Pharmacology with employers reporting both concern for the quantity and quality of candidates with these skills. This report builds on the existing body of literature on the value of STEM and FE and HE education in general to show the value that current and former STEM learners contribute to the UK's economy. These findings support the notion that STEM skills shortages are an impediment to economic growth in the UK.

With this background in place, the input data for this analysis falls under three categories: regional economic conditions, research (e.g., reports, journal articles and data releases conducted by ONS, HESA, etc.), and college and university data. This chapter discusses these data, providing context for the subsequent analysis and assumptions utilised in evaluating STEM education.

Science, Technology, Engineering, and Mathematics Learners in the Labour Market

Former STEM learners support a variety of industries across the UK. The STEM occupations with the highest employment in the UK in 2016 were production managers and directors in manufacturing, programmers and software development professionals, and IT specialist managers. Former STEM learners can also be found in a range of industries, with the top STEM industries in 2016 being Computer consultancy activities, Engineering activities and related technical consultancy, and Computer programming activities. Although these have the highest levels of employment, it should be noted that there are a wide range of industries supported by STEM learners. Other examples of industries where many former STEM learners are employed include the Manufacture of motor vehicles, Manufacture of air and spacecraft and related machinery, Extraction of crude petroleum, and Research and experimental development on biotechnology. We plot a heat-map to show this spread of industries employing across STEM occupations. Figures A4.13 to A4.15 can be found in Annex 4; the lighter the grid square, the higher the concentration of STEM occupations employed in the industry. Note that occupations are spread across three separate heat-maps, but only to account for the full range of STEM occupations working across the various industry categories.

According to our projections, STEM occupations are set for strong growth in Britain (see Annex 4, Figure A4.1). Across 2016 to 2024, we expect growth of around 7.5% in both programmers and software developer jobs and IT and telecommunications professionals; around 5.5% job growth of IT specialist managers and 6.3% growth of IT business analysts, architects and systems designers.

At a more granular level, for STEM occupations, we plot annual job openings and job growth from 2016 to 2024 for each Government Office Region (see Annex 4, Figures A4.2 to A4.12), restricting the analysis to include those with a Location Quotient (LQ) of more than 1. The Location Quotient is a measure to quantify how concentrated a particular occupation is in a region, compared to the nation, thereby revealing how unique an occupation is in comparison to the national average. This latter restriction ensures that the analysis is not dominated by jobs seeing 'catch-up growth' and is plotted as a 2016 metric in the yellow boxes in the Annex Figures.

The LQ suggest that London and the South East tend to have regional advantages in several STEM occupations. IT and telecommunications professionals has an LQ of 1.8, implying that this occupation is 1.8 times more concentrated in London than nationwide; while programmers and software developers and IT specialist managers are 1.5 times more concentrated in the capital. This tends to support previous findings such as the Royal Academy of Engineering's 2012 report on Further Education in STEM that found London and the South East together account for the largest share of STEM achievers.

However, the capital does not have a monopoly on STEM occupation concentration. In the South West, design and development engineers are 1.7 times more concentrated than nationwide, with a similar degree of concentration of environmental health professionals in

Wales and conservation professionals in the East of England. Scotland has a regional advantage in production managers and directors in mining and energy – these are three times more concentrated than the national average.

We find programmers and software development professionals are set to have the most job openings in the majority of regions. London should see the occupation growing by more than 10% over the period, the South by 6 to 7%, and solid growth in Scotland and Wales. London and the South East should account for much STEM occupation demand with almost 50,000 annual job openings as programmers and software developers, 30,000 as IT and telecommunications professionals, and another 31,000 as IT specialist managers.

These three occupations account for most annual job openings in the South West, with 14,000 (each with around 6.5% regional job growth over the forecast period) and a further 8,000 job openings as production managers and directors in manufacturing.

The East Midlands, Yorkshire and the Humber, and the East of England are each set for almost 8,000 annual job openings as production managers and directors in manufacturing, with the latter seeing annual demand from 7,600 job openings as programmers and software development professionals.

Other significant job openings are seen as IT business analysts, architects, and system designers, as well as IT operations technicians and IT and telecommunications directors – though most are concentrated in London, they each have between 7,500 to 9,500 annual job openings.

Aside from STEM job openings in manufacturing and IT, there are sizeable numbers in other industries. Biological scientists and biochemists see 4,000 annual job openings in the East of England, 3,400 in London, and 4,200 in the South East. Scotland sees another 3,200 annual job openings in this occupation – its fourth highest STEM occupation in terms of job openings, supported by more than 2,000 annual openings as laboratory technicians in this region. Web design and development sees almost 5,000 annual openings in London and about half that again in the South East.

Using our proprietary job postings data, we analyse the key skills posted in job adverts for STEM occupations. These reveal strong demand for a blend of hard and common skills. Table 4.13 in Annex 4 shows a snapshot of the most in-demand skills for STEM occupations across Britain. The most in-demand hard skills are mainly for programming languages (SQL, Java and C Sharp), associated with programmers and software developers. Agile software development is also much sought for this occupation. For web designers, in-demand skills tend to be for Cascading Style Sheets, HyperText Markup language and JavaScript. Of common skills across STEM, management and networking feature in the majority of job adverts.

STEM learners are in high demand across the UK. As referenced earlier in this chapter there is expected to conservatively be an annual shortfall of 20,000 engineering graduates in the UK through 2024. This has direct implications for both learners and employers in the UK. STEM occupations have an earnings premium compared to all other occupations in the UK, indicating that there is increased demand for STEM graduates. From an employer perspective, with demand for STEM graduates outstripping the supply of these graduates, STEM employers must compete for talent. In the report Apprenticeships Evaluation 2017: Employers prepared by IFF Research for the Department for Education, which surveys employers about their apprenticeships, they found that ICT and Engineering sectors are two of the top sectors for recruiting learners into jobs as opposed to having existing employees on an apprenticeship scheme. An analysis of Emsi data found that for the top 20 industries where STEM occupations are found, the average amount spent on employment placement agencies per employee annually was £338.30. However, for all other industries the average amount was £289.46. Therefore, STEM focused industries spend an additional 17% on employment placement agencies on a per employee basis. Typically, employment placement agencies are used to fill occupations where qualified candidates are difficult to find.

Defining Science, Technology, Engineering, and Mathematics Learning

The first step in this analysis was to define STEM. Across the UK, there are two well-known definitions of what constitutes STEM. The narrow definition of STEM focuses on just Science, Technology, Engineering, and Mathematics, while a broader definition includes subjects such as medicine. This analysis uses a narrow definition and therefore excludes credentials related to medicine.

For this analysis, we used learner data from Office of Qualifications and Examinations Regulation (OFQUAL) and Higher Education Statistics Agency (HESA) in order to ascertain the volume of STEM qualifications across the UK. Subject areas were used to exclude non-STEM completions. From an FE perspective, this means Science and Mathematics, Engineering and Manufacturing Technologies (excluding Transportation Operations and Maintenance), and Information and Communication Technology. For the HE data, the subject areas included are Biological Sciences, Physical Sciences, Mathematical Sciences, Computer Sciences, and Engineering and Technology.

Learner Demographics

Learner demographic data was derived from HESA for Higher Education (HE) learners and the Education and Skills Funding Agency for Further Education (FE) learners. Additionally, this analysis uses ILR data from a sample of colleges from across the UK that have worked with Emsi in the past.

The average age of learners was estimated to be 27 years old. The average age of learners was derived from a combination of data from the sample of FE colleges and data from HESA, average ages from these data sources were then weighted to reflect the number of FE and HE learners. The breakdown of these learners by gender was estimated to be 74% male and 26% female, and the breakdown by ethnicity was 66% white and 34% minority. It should be noted that by using a narrow definition of STEM that excludes medical subjects, the difference in gender is significantly skewed toward male learners. Data on ethnicity and gender becomes important in the calculation of marginal earnings change since earnings by gender and ethnicities differ, sometimes widely, depending on the region under analysis.

Learner Achievement

Learner achievement data are used to determine the value of the learning provided through UK colleges and universities in FY 2016-17. As previously noted, the analysis uses data from OFQUAL, the Scottish Funding Council, HESA, Higher Education Funding Council for England (HEFCE), and a sample of Individualised Learner Record (ILR) data from FE colleges across the UK. The OFQUAL data shows the number of FE qualifications awarded, while an assumption was made on the number of learners that worked towards but did not complete a qualification in FY 2016-17 for England, Wales, and Northern Ireland. For Scotland, both completions and partial completions were available through the Scottish Funding Council's Infact database. HE completions were sourced from HESA data, as well as data on the number of learners that were working towards but did not complete a qualification. For this study approximately 70% of the learners served were at level 3 or below while the remaining 30% were above level 3.

Guided Learning Hours (GLH) are used to measure a learner's level of learning activity. This data was derived from the sample of ILR data and was used for FE provisions in England, Wales, and Northern Ireland. To measure the level of learning activity in Scotland, Student Units of Measurement (SUMs) were pulled from the Infact database. For HE learners, we used the average full-time equivalency (FTE) specific to STEM learners and pulled from data available on the HEFCE website.

Regional Economic Conditions

The service region used throughout this report is the United Kingdom which includes England, Wales, Scotland, and Northern Ireland. This region serves as the backdrop against which the relative impacts of STEM learners are measured. The availability of quality education and training in the United Kingdom attracts new industry to the region, thereby generating new businesses and expanding the availability of public investment funds.

Table 1.1 summarises the breakdown of the United Kingdom's economy by major industrial sector, with details on employment and value added for each. Value added refers to the earnings, profits, and taxes that together represent the total value the industrial sector has added. The final column in Table 1.1 shows the percentage of total value added in the United Kingdom for which each sector is responsible.

Table 1.1: Employment and Value Added by Major Industrial Sector in the United Kingdom, 2016

	Jobs	Value Added (Millions)	% of Total Value Added
Agriculture, forestry and fishing	426,683	£12,373	<1%
Mining and quarrying	62,500	£10,237	<1%
Manufacturing	2,465,911	£115,913	9%
Electricity, gas, steam and air conditioning supply	112,235	£18,974	1%
Water supply; Sewerage, waste management and remediation activities	188,727	£13,226	1%
Construction	1,374,368	£78,200	6%
Wholesale and retail trade; Repair of motor vehicles and motorcycles	4,714,002	£155,982	12%
Transportation and storage	1,311,563	£56,865	4%
Accommodation and food service activities	2,095,286	£44,423	3%
Information and communication	1,184,586	£80,646	6%
Financial and insurance activities	1,057,132	£101,549	8%
Real estate activities	526,632	£51,624	4%
Professional, scientific and technical activities	2,404,600	£147,880	12%
Administrative and support service activities	2,506,619	£87,699	7%
Public administration and defence; Compulsory social security education	1,335,778	£55,298	4%
Education	2,644,899	£76,960	6%
Human health and social work activi-ties	3,926,066	£114,931	9%
Arts, entertainment and recreation	722,557	£29,483	2%
Other service activities	594,238	£25,912	2%
Totals	29,654,382	£1,278,175	100%

Source: Emsi.

Table 1.2: Highest Number of STEM Employees by Industry in Great Britain, 2016

	STEM Jobs	Total Jobs	% STEM Jobs
Computer consultancy activities	256,374	364,990	70%
Engineering activities and related technical consultancy	168,662	391,658	43%
Computer programming activities	115,821	166,001	70%
Public administration and defence; compulsory social security	94,479	1,241,358	8%
Other information technology and computer service activities	86,101	126,595	68%
Other research and experimental development on natural sciences and engineering	75,237	123,788	61%
Tertiary education	74,854	430,935	17%
Hospital activities	60,706	1,440,467	4%
Business and other management consultancy activities	55,812	465,180	12%
Financial service activities, except insurance and pension funding	49,929	494,915	10%
Other telecommunications activities	47,870	163,157	29%
Activities auxiliary to financial services and insurance activities	39,909	427,370	9%
Manufacture of air and spacecraft and related machinery	35,586	86,085	41%
Activities of head offices	35,016	275,571	13%
Electrical installation	32,819	204,296	16%
Construction of other civil engineering projects n.e.c.	31,307	111,395	28%
Other professional, scientific and technical activities n.e.c.	30,260	105,839	29%
General secondary education	29,219	612,418	5%
Machining	28,268	104,674	27%
Repair of computers and peripheral equipment	25,463	34,803	73%
Totals	1,373,691	7,371,495	19%

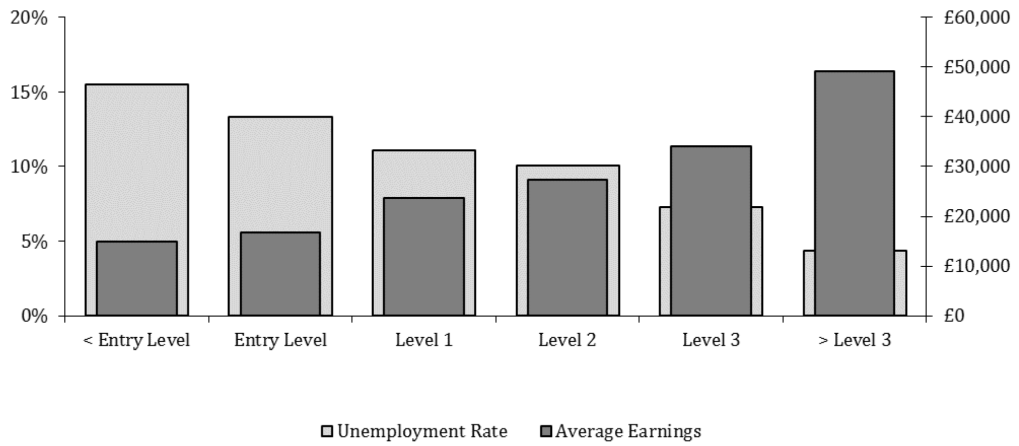
In Table 1.3 and Figure 1.1, the average earnings in the United Kingdom at the midpoint of an individual's working career are broken out by education level. In return for the costs of education, learners receive a stream of higher future earnings that continues to grow throughout their working lives. Mean income levels at the midpoint of the average-aged worker's career increase as individuals attain higher levels of education. The marginal differences between education levels form the basis for determining the earnings benefits that accrue to learners in return for their education investment. These have been weighted to reflect the higher earnings of STEM gradates as compared to non-STEM graduates.

Table 1.3: Average STEM Earnings and Unemployment Rates by Education Level in the United Kingdom, 2016

Education Level	Earnings*	Unemployment
< Entry Level	£14,974	16%
Entry Level	£16,659	13%
Level 1	£23,576	11%
Level 2	£27,397	10%
Level 3	£34,142	7%
> Level 4	£49,237	4%

* Earnings are specific to STEM occupations and weighted by gender and ethnicity demographics.
Source: ONS Labour Force Survey and Nomis Annual Survey of Hours and Earnings.

Figure 1.1: Average Income at Career Midpoint



Note as average earnings increase as they attain more education, employment prospects also increase. Table 1.3 shows the unemployment rate by highest qualification attained in the United Kingdom. The highest unemployment rates occur among workers with no qualifications or an entry level qualification.

Research

The data and methodology collected from research largely come from government studies and are usually treated as constants or parameter values in the analysis. For example, *The Green Book* issued by HM Treasury reports the following table in Annex 6.

Table 1.4: The Declining Long-term Discount Rate

Period of years	0-30	31-75	76-125	126-200	201-300	301+
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

Source: The 2012 Green Book Table 6.1

In accordance with this, we apply a 3.5% discount rate to the cash flows for the first 30 years and a 3% discount rate for the cash flows greater than 30 years.[1] Many of the research sources, along with the constants or parameter values drawn from them, will be referenced throughout this report, but a short list of the most prominent sources are provided here.

Table 1.5: Research Sources

Research Data	**Source**
Regional employment and earnings	Annual Survey of Hours and Earnings - ONS (NOMIS)
Earnings by education level and ethnicity	Labour Force Survey - ONS
Population	Population Estimates - ONS
Attrition	
Retirement	Gov.UK, Life Tables - NHS
Unemployment	Labour Force Survey - ONS

Conclusion

This chapter summarises key data and facts on STEM learners. The figures presented in the tables above represent the broader elements of the database used to determine the results. Additional detail on data sources, assumptions, and general methods underlying the analyses are conveyed in the remaining chapters. The core of the findings is presented in the next two chapters. The annexes detail a collection of miscellaneous theory and data issues.

[1] The time horizon does not extend beyond 75 years since it is limited to the learner's working life.

Chapter 2 : Investment Analysis

Investment analysis is the process of evaluating total costs and measuring these against total benefits to determine whether or not a proposed venture will be profitable. If benefits outweigh costs, then the investment is viable. If costs outweigh benefits, then the investment will lose money and is thus considered infeasible.

In this chapter, we analyse the benefits and costs of investing in a STEM education from the perspective of the learners. The backdrop for the analysis is the United Kingdom.

STEM Learner Perspective

Analysing the benefits and costs of education from the perspective of STEM learners is the most obvious—they give up time and money to attend an institution in return for a lifetime of higher income and improved employment opportunities. The benefit component of the analysis thus focuses on the extent to which learner incomes and employment probabilities increase as a result of education, while costs comprise all learners' direct outlays (tuition fees) as well as their opportunity costs (wages and income forgone while at the institution).

Education, Earnings and Employment

The correlation between education, earnings, and employment is well documented and forms the basis for determining the learners' benefits stream and future cash flows. Table 1.3 (Chapter 1) shows the mean income and unemployment rate by education level weighted by the gender and ethnicity of the learner population.[2]

The differences between income levels and unemployment rates begin to define the marginal value of moving from one education level to the next. Of course, several other factors such as ability, socioeconomic status and family background also correlate with higher earnings. Failure to account for these factors results in what is known as an 'ability bias'.[3] To account for the implicit bias in the data, Emsi commissioned a meta-analysis to ascertain the degree of bias and the amount by which the marginal gains should be reduced. Doctors Molitor and Leigh (2005) concluded that a 10% reduction in the earnings gain was necessary to account for such innate characteristics of the learners.[4]

Marginal Earnings Value per Guided Learning Hour

Not all STEM learners who attended an institution in FY 2016-17 obtained a qualification or certificate. Some may have returned the following year to complete their education goals,

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[2] Earning and unemployment rates are shown for the United Kingdom.

[3] Ability bias in data was recognised as early as Adam Smith, but was formally acknowledged as a biasing factor in human capital data by J.R. Walsh in 1935.

[4] The BIS adopted the approach of looking at earnings differences between cohorts with similar characteristics but where the educational levels differed. While this approach is useful and does not require explicit discounting, it cannot be used at a regional level since the earnings differ regionally from national averages.

while others may have taken a few units and entered the workforce without achieving a qualification. Since the education of such learners still carries value, though not the weight of a full qualification, we must look deeper than qualification completion to measure the value of intermediary education provision. The most consistent way of capturing the intermediary activity of the learners is through guided learning hours (GLH) or full-time equivalency.

It is important to remember that from an economics perspective, learners will eventually be paid according to their marginal value of product. Therefore, we link such output metrics to marginal gains in educational attainment. Attributing value to full qualifications alone assumes no increase in marginal value of product from intermediary education. According to prevailing human capital theory, such an assumption is flawed. It is more appropriate to utilise a quasi-continuous step function where learners increase their marginal value of product, and thus income, for every GLH received. The sheepskin effect, or more generically the signalling effect, resulting from the full qualification is the cause for the step function nature of the earnings curve. A qualification signals to employers the marginal value of product a learner can generate. Thus, a full qualification has additional value over a unit in terms of increased earnings and the employment premia. These two things combined represent the sheepskin effect.

We calculate the value of the STEM learners' GLH production through a process that divides the education ladder into a series of individual steps, each equal to one GLH's. We then spread the income differentials from Table 1.3 over the steps required to complete each education level, assigning a unique monetary value to every step in the ladder.[5] Next we map the learners' GLH production to the ladder, depending on their level of achievement and the average number of GLH's they achieve. Finally, we multiply the volume of GLH's at each step in the ladder by the marginal earnings gain attributable to the corresponding step to arrive at the learners' average annual increase in income. Under this framework the annual change in earnings, ΔE, is computed simply as: $\Delta E = \sum_{i=1}^{n} e_i h_i$ where $i \in 1, \ 2, \ldots n$ and n is the number of steps in the education ladder. Variables e_i and h_i represent the marginal earnings gain and number of GLH's completed by the learner body for each step *i*. Total earnings change divided by the total GLH's completed by the learners gives the average value per GLH for the FY 2016-17 learner body.

Table 2.1 displays the aggregate annual higher income for the STEM learner population. Also shown are the total GLH's generated by learners and the average value per GLH. Note that although each step in the education ladder has a unique value, for the sake of simplicity only the total and average values are displayed.

[5] Learners who obtain their first full qualification during the reporting year are granted the income boost derived from the signaling effect of the credential.

Table 2.1: Higher Annual Earnings, GLH Production, and Value Per GLH, FY 2016-17

Total Increase in Earnings	£3,973,792,601
Total Completed GLH's	482,556,197
Average Value Per GLH	£8.23

Source: Emsi.

Here a qualification must be made. Data show that earnings levels do not remain constant; rather, they start relatively low and gradually increase as the worker gains more experience. Research also indicates that the earnings increment between educated and non-educated workers grows through time. This means that the aggregate annual higher income presented in Table 2.1 will actually be lower at the start of the STEM learners' careers and higher near the end of them, gradually increasing at differing rates as the learners grow older and advance further in their careers.

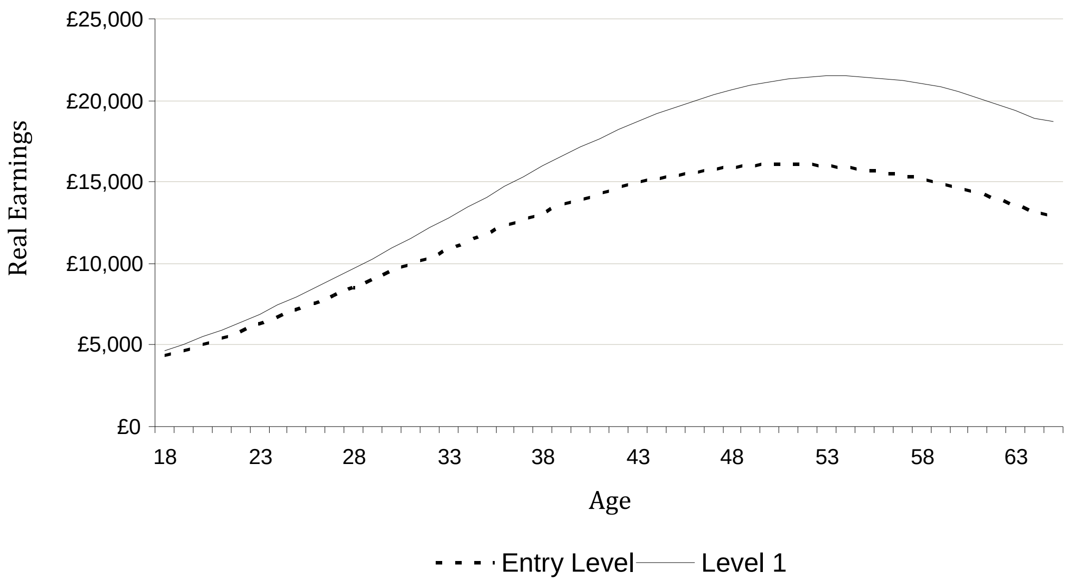
Generating the Stream of Cash Flows

The two names most often associated with human capital theory and its applications are Gary Becker and Jacob Mincer.[6] The standard human capital earnings function developed by Mincer appears as a three-dimensional surface with the key elements being earnings, years of education and experience. Figure 2.1 shows the relationship between earnings and age, with age serving as a proxy for experience. Note that, since we are using the graph strictly for illustrative purposes, the numbers on the axes are not specific to the United Kingdom.

Figure 2.1 illustrates several important features of the Mincer function. First, earnings initially increase at an increasing rate, later increase at a decreasing rate, reach a maximum somewhere after the midpoint of the working career, and then decline in later years as individuals ease into retirement. Second, at higher levels of education, the maximum level of earnings is reached at an older age. And third, the benefits of education, as measured by the difference in earnings for two levels, increase with age.

[6] See Gary S. Becker, *Human Capital: a Theoretical Analysis with Specific Reference to Education* (New York: Columbia College Press for NBER, 1964); Jacob Mincer, 'Schooling, Experience and Earnings' (New York: National Bureau of Economic Research, 1974); and Mincer, 'Investment in Human Capital and Personal Income Distribution,' *Journal of Political Economy,* vol. 66 issue 4, August 1958: 281–302.

Figure 2.1: Lifetime Earnings Profile for Entry Level and Level 1 Qualification Recipients



In the model, we employ the Mincer function as a smooth predictor of earnings over time[7] for as long as learners remain active in the workforce. Using earnings at the career midpoint as our base (Table 1.3), we derive a set of scalars from the slope of the Mincer curve to model the learners' increase in earnings at each age within their working careers. The result is a stream of projected future benefits that follows the same basic shape as the Mincer curve, where earnings gradually increase from the time learners enter the workforce, come to a peak shortly after the career midpoint, and then dampen slightly as the STEM learners approach retirement at age 65.

The benefits stream generated by the Mincer curve is a key component in deriving the learners' rate of return. However, not all learners enter the workforce at the end of the reporting year, nor do all of them remain in the workforce until age 65. To account for this, we discount the learners' benefit stream in the first few years of the time horizon to allow time for those who are still studying at the institutions to complete their educational goals and find employment. This is referred to as delaying the onset of the benefits. Next, we discount the entire stream of benefits by the estimated number of learners who will die, retire or become unemployed over the course of their working careers.[8] The likelihood that learners will leave the workforce increases as they age—so the older the learner population

[7] The Mincer equation is computed based on estimated coefficients presented in Robert J. Willis, 'Wage Determinants: A Survey and Reinterpretation of Human Capital Earnings Function' in *Handbook of Labor Economics*, Vol. 1 (Amsterdam: Elsevier Science Publishers, 1986): 525–602. These are adjusted to current year dollars in the usual fashion by applying the GNP implicit price deflator. The function does not factor in temporary economic volatility, such as high growth periods or recessions. In the long run, however, the Mincer function is a reasonable predictor.

[8] These data are based on the ONS life tables and net regional migration data following a log linear trend line.

is, the greater the attrition rate will be. The resulting benefits stream can be found in Table 2.3.

STEM Learner Investment Costs

Having calculated the learners' benefits stream and adjusting it for attrition, we next turn to STEM learner costs. The learners' costs of investment are composed of direct outlays and opportunity costs. Direct outlays represent any out-of-pocket expenses to the learner, such as those for tuition fees, books, and supplies. Some learners incur more out-of-pocket expenses than others, for example adult learners aged 19 and over are more responsible for paying tuition costs whereas those aged 16-18 are fully funded. Higher education learners also have a higher tuition cost than learners at further education colleges.

For the purposes of this analysis, we just look at the total direct outlays incurred by the learner body as a whole, not separated out by funding levels. Direct outlays for tuition and fees were estimated based on previous studies completed in England, Wales, and Scotland for FE learners. For HE learners, tuition was estimated based on financial data from HESA. Since the direct outlays are based on previous studies for FE learners and aggregated financial data from HESA, they are intended to be a representation of costs to learners and may not reflect a specific individual's actual out-of-pocket tuition expense.

Opportunity costs apply to all learners and represent forgone income. We assume that every hour a learner is in the classroom or engaged in an educational activity is an hour they could have been receiving a wage. Since tuition fees simply capture the payments made by learners and their families directly to institutions, measuring costs and benefits through GLH's creates a more accurate representation.

Table 2.2: STEM Learner Investment Costs, FY 2016-17 (£ Thousands)

	Total
Learner Direct Costs	
Tuition and Fees	£3,693,024
Books and Supplies	£426,585
Working Learners	
Opportunity Costs	£5,854,225
Non-working Learners	
Opportunity Costs	£10,285,160
Total Learner Costs	***£20,258,994***

Source: Emsi model.

The majority of costs are not captured in the direct outlays of the learners but rather through their opportunity costs. These costs are a function of estimated STEM learner employment rates, the number of GLH's taken by the learners, prior education level, and the associated earnings by education level. Recall that Table 1.3 displays earnings at the midpoint of the individual's working career, not immediately upon exiting the institution. To arrive at the full earning potential of learners while enrolled, we must condition the earnings levels to the learners' age, which we accomplish simply by applying a scalar derived from the

Mincer curve described above. Another important factor to consider is the time that learners actually spend at the institutions since they would only be giving up earnings for the period in which the colleges and universities are in session, and then only for the hours they are in class. We use the volume of GLH's and full-time of learners as a proxy for working hours forgone.

Since learners in both apprentice programmes and those otherwise engaged in the labour force receive some portion of what their income would be otherwise, their opportunity costs are mitigated. They also forgo leisure, which Becker (1974) attributes value to. As the majority of the learners are not engaged in the labour force and because they forgo the entirety of their would-be income, it is not surprising that they represent the bulk of the learner body's opportunity costs. Opportunity and auxiliary costs total £16.1 billion. Learners employed while pursuing their STEM education do a great deal to mitigate their opportunity costs and thus will have higher than average benefit-cost ratios and correspondingly higher rates of return.

STEM Learner Investment Outcomes

Since the benefits to STEM learners do not all occur in the current year like the costs, we must discount the future benefits to their present value. As stated in *The Green Book,*

> *Discounting is a technique used to compare costs and benefits that occur in different time periods. It is a separate concept from inflation, and is based on the principle that, generally, people prefer to receive goods and services now rather than later. This is known as 'time preference'.*

In accordance with *The Green Book,* we apply a 3.5% discount rate for the first 30 years and a 3% discount rate for subsequent years. Standard investments tend to have a much shorter time horizon and use only one discount rate. However, education is a long-term investment and the different discount rates are used to account for any uncertainty resulting from the extended time horizon. Though the discount rate used is provided by *The Green Book,* it is not an observed value. Thus, in Chapter 4, a sensitivity analysis is provided to show how the results vary in accordance with the discount rate.

Discount Rate

The discount rate is a rate of interest that converts future costs and benefits to present values. For example, £1,000 in higher earnings realised 30 years in the future is worth much less than £1,000 in the present. All future values must therefore be expressed in present value terms in order to compare them with investments (i.e., costs) made today. The selection of an appropriate discount rate, however, can become an arbitrary and controversial undertaking. As suggested in economic theory, the discount rate should reflect the investor's opportunity cost of capital, i.e., the rate of return one could reasonably expect to obtain from alternative investment schemes.

Column 1 of Table 2.3 shows the number of years beyond the analysis year (i.e., year zero is the analysis year where costs are incurred and net benefits are negative). Columns 2 through 4 show the gross cash flows received each year, the percent of learners active in the workforce (including the employment premia) and the net higher earnings that are projected to be realised. Column 5 shows one year's worth of costs to the learners.[9] Lastly, Column 6 shows the net cash flows.

The estimated average STEM learner age while enrolled is 27. Adding one year to this (the analysis year) and subtracting from the retirement age of 65[10] yields a time horizon of 38 years. The last four rows in the table show the learner investment results: net present value (NPV), benefit/cost ratio (B/C), internal rate of return (IRR),[11] and payback period. Equations and definitions of these terms may be found in the glossary provided in Annex 2.

The FY 2016-17 STEM learner body is expected to see the present value of their lifetime incomes rise by £77.9 billion, while the costs of obtaining these gains is only £20.3 billion. This means STEM learners receive a net gain of £57.6 billion and, on average, their benefits are 3.8 times larger than their investment. Put another way, for every £1 STEM learners invest in direct outlays and opportunity costs, they receive £3.80 in return. This translates into a 13.4% average annual rate of return, with all of the learners' costs recovered in 10 years.

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[9] The £20.3 billion in costs is already in present value since it occurs in the current year and does not need to be discounted.

[10] We recognise that not all learners will retire at age 65 - some may exit the workforce early or remain in until they are older. The retirement age of 65 is an average based on the State Pension age and is useful in calculating an average time horizon for the average learner.

[11] The IRR is used for investments where the principle invested is not recaptured at the sale or maturity date of the investment, such as is the case with stocks or bonds.

Table 2.3: STEM Learner Perspective (£ Millions), FY 2016-17

Year	Gross Higher Earnings	% Active in Workforce	Net Higher Earnings	Cost	Net Cash Flow
0	2,109	12%	244	20,259	-20,015
1	2,264	33%	745	0.0	745
2	2,423	51%	1,234	0.0	1,234
3	2,587	65%	1,688	0.0	1,688
4	2,754	75%	2,069	0.0	2,069
5	2,924	82%	2,392	0.0	2,392
6	3,097	86%	2,673	0.0	2,673
7	3,271	89%	2,924	0.0	2,924
8	3,447	91%	3,131	0.0	3,131
9	3,623	91%	3,319	0.0	3,319
10	3,799	92%	3,489	0.0	3,489
11	3,974	92%	3,648	0.0	3,648
12	4,147	92%	3,804	0.0	3,804
13	4,317	92%	3,957	0.0	3,957
14	4,484	91%	4,107	0.0	4,107
15	4,646	91%	4,253	0.0	4,253
16	4,803	91%	4,393	0.0	4,393
17	4,955	91%	4,527	0.0	4,527
18	5,100	91%	4,654	0.0	4,654
19	5,237	91%	4,774	0.0	4,774
20	5,366	91%	4,886	0.0	4,886
21	5,486	91%	4,989	0.0	4,989
22	5,597	91%	5,082	0.0	5,082
23	5,698	91%	5,166	0.0	5,166
24	5,788	90%	5,239	0.0	5,239
25	5,866	90%	5,301	0.0	5,301
26	5,934	90%	5,351	0.0	5,351
27	5,989	90%	5,390	0.0	5,390
28	6,032	90%	5,416	0.0	5,416
29	6,063	89%	5,431	0.0	5,431
30	6,081	89%	5,433	0.0	5,433
31	6,087	89%	5,422	0.0	5,422
32	6,080	89%	5,399	0.0	5,399
33	6,061	88%	5,363	0.0	5,363
34	6,029	88%	5,315	0.0	5,315
35	5,985	88%	5,255	0.0	5,255
36	5,930	87%	5,183	0.0	5,183
37	5,863	87%	5,099	0.0	5,099
NPV			***£77,886***	***£20,259***	***£57,627***
B/C ratio					***3.8***
IRR					***13.4%***
Payback (yrs)					***10***

Chapter 3 : Regional Economic Impact Analysis

In this section, we examine the economic impacts of STEM learners on the UK's business community through the increased consumer spending and enhanced business productivity generated by STEM learners. The impacts reflect the economic relationships among the UK's industries and are calculated using Emsi's proprietary input-output (IO) model. The model uses national data from the Office for National Statistics' (ONS) Supply and Use Tables (SUTs), as well as national industry jobs totals and national sales-to-jobs ratios, to calculate how much each industry purchases from every other industry. The factor of change that occurs from this economic activity are known as the knock-on (multiplier) effects. For more information on the Emsi Regional I-O model, please refer to Annex 3.

When exploring the economic impact of STEM learners, we consider the following hypothetical question:

How would economic activity change in the UK if former STEM learners did not exist in FY 2016-17*?*

The economic impact should be interpreted according to this hypothetical question. Another way to think about the question is to realise that we measure net impact, not gross impact. Gross impacts represent an upper-bound estimate in terms of capturing all activity stemming from the learners; however, net impacts reflect a truer measure since they demonstrate what would not have existed in the UK's economy if not for the STEM learners.

Economic impact analyses use different types of impacts to estimate the results. The impact focused on in this study assesses the change in income. This measure is similar to the commonly used gross national product (GNP). Income may be further broken out into the **labour income impact**, also known as earnings, which assesses the change in employee compensation; and the **non-labour income impact**, which assesses the change in business profits. Together, labour income and non-labour income sum to total income.

Another way to state the impact is in terms of **jobs**, a measure of the number of full- and part-time jobs that would be required to support the change in income. Finally, a frequently used measure is the **sales impact**, which comprises the change in business sales revenue in the economy as a result of increased economic activity. It is important to bear in mind, however, that much of this sales revenue leaves the economy through intermediary transactions and costs. All of these measures – added labour and non-labour income, total income, jobs, and sales – are used to estimate the economic impact results presented in this section. The analysis breaks out the impact measures into different components, each based on the economic effect that caused the impact. The following is a list of each type of effect presented in this analysis:

- The **initial effect** is the exogenous shock to the economy caused by the initial income of former current and former STEM learners.

- The initial round of spending creates more spending in the economy, resulting in what is commonly known as the **multiplier effect**. The multiplier effect comprises the additional activity that occurs across all industries in the economy and may be further decomposed into the following three types of effects:
  - The **direct effect** refers to the additional economic activity that occurs as the industries affected by the initial effect spend money to purchase goods and services from their supply chain industries.
  - The **indirect effect** occurs as the supply chain of the initial industries creates even more activity in the economy through their own inter-industry spending.
  - The **induced effect** is excluded from this analysis because in national models induced effects are generally regarded to overstate impacts.

Sales vs. Earnings example

Two visitors spend £50,000 each in the economic region. One visits a local auto dealer and purchases a new luxury automobile. The other undergoes a medical procedure at the local hospital. In terms of direct economic impact, both have spent £50,000. However, the expenditures will likely have very different meanings to the local economy. Of the £50,000 spent for the luxury automobile, perhaps £10,000 remains in the region as salesperson commissions and auto dealer income (part of the economic region's overall earnings), while the other £40,000 leaves the area as wholesale payment for the new automobile, ending up in Japan or Germany perhaps. Contrast this to the hospital expenditure. Here perhaps £40,000 appears as physician, nurse, and assorted hospital employee wages (part of the region's overall earnings), while only £10,000 leaves the area to pay for hospital supplies, or to help amortise building and equipment loans. In terms of sales, both have the same impact, while in terms of earnings, the former has one-fourth the impact of the latter.

Impact of Added Workforce STEM Skills

HE and FE institutions in the UK serve over two million learners annually, nearly all of these STEM learners stay in the UK upon the completion of their studies and are more productive because of the quality education they attained at one of the many colleges or universities in the UK. Over time, the skills of former STEM learners accumulate, steadily increasing the training level and experience of the UK's workforce. As the skills embodied by former STEM learners stockpile, a chain reaction occurs: higher learner incomes generate additional rounds of consumer spending, while new skills and training translate to increased business output and higher property income, causing still more consumer purchases and regional multiplier effects. The sum of all these direct and indirect effects comprises the total impact of the learners' added skills in the UK's economy, which was equal to approximately £75.1 billion in FY 2016-17.

Calculating the Initial Effect

Assigning a monetary value to the added skills acquired by STEM learners still active in the UK's workforce requires data on the historical enrolments and corresponding achievement levels of STEM learners over the past 15-year period. Data for the 15-year period was gathered from the sources previously discussed in Chapter 1. GLH's and full-time equivalency are used to determine the achievement levels of STEM learners, and serve as a proxy for the level of skills learners contribute to the UK's workforce.

Of course, not all learners remain in the workforce until retirement age, nor do all learners enter the workforce immediately upon exiting the institutions. In the model, we adjust for these factors by applying yearly attrition rates derived from the probability that individuals will die, retire, or become unemployed over the course of their working careers. This allows us to estimate the net number of former and current STEM learners still active in the UK's workforce in FY 2016-17.

The next step is to multiply the net number of former learners still working in the UK by the average number of GLH's achieved per learner per year. According to data estimated, the average GLH's per enrolment was around 222 GLH's in FY 2016-17. We use this average as a starting point for estimating the average GLH's per learner over the previous 15-years. Using this methodology, the estimated number of GLH's in the regional workforce comes to 5.3 billion. These are the GLH's that accumulated in the workforce over the past 15-year period and were still active in the FY 2016-17 analysis year.

Next, we reduce the gross number of active GLH's to account for the learners' alternative education opportunities. For this analysis, we assume an alternative education variable of 10%, meaning that 10% of the learner population would have generated benefits. Since the majority of institutions in the UK receive public funding, we assume learners would have to leave the country to receive a private education or be limited to direct industry training through workforce experience to generate the impacts. A sensitivity analysis of this variable is provided in Chapter 4. The application of the alternative education adjustment reduces the gross total of GLH's in the regional workforce to about 4.8 billion.

Table 3.1 demonstrates the total initial added income to the regional economy due to the added skills by former STEM learners. First, we find the initial labour income. This calculation begins by taking the average value per GLH of £5.66 and multiplying it by the roughly 4.8 billion GLH's in the regional workforce. This yields a value of £26.9 billion in added labour income.

Added to the initial effect on labour income is another £18.6 billion in non-labour income, representing the higher property values and increased investment income stemming from the direct income of learners and enhanced productivity of the businesses that employ them. Non-labour income attributable to past learner skills is obtained by disaggregating higher learner income to the industrial sectors of the IO model and then multiplying these amounts by the associated value-added-to-earnings ratios. As shown in Table 3.1, the initial non-labour income attributable to current and former STEM learners in FY 2016-17 was equal to approximately £18.5 billion. This can be interpreted to mean that for every additional pound a former STEM learner earns in income another £0.69 is generated in terms on higher property values and increased business profits for STEM companies, for the initial effect. Summing labour and non-labour income together gives an initial effect of past learner skills equal to approximately £45.5 billion in FY 2016-17.

Table 3.1: Initial Added Labour Income (£ Millions), FY 2016-17

	Total
Initial labour income	£26,898
Initial non-labour income	£18,571
Total initial income	**£45,469**

* Numbers may not add due to rounding.
Source: Emsi model.

Calculating the Multiplier Effects

Economic growth stemming from a skilled workforce does not stop with the initial effect. Multiplier effects occur as STEM learners generate an increased demand for consumer goods and services through the expenditure of their higher wages. Further, as the industries where STEM learners are employed increase their output, there is a corresponding increase in the demand for input from the industries in the employers' supply chain. Together, the incomes generated by the expansions in business input purchases and household spending constitute the multiplier effect of the increased productivity of former learners from STEM learners.

The next few rows of Table 3.2 show the multiplier effects of learners' added skills. To estimate multiplier effects, we convert the industry-specific income figures generated through the initial effect to regional sales using sales-to-income ratios from the UK Regional I-O model. We then run the values through the UK Regional I-O model's multiplier matrix to determine the corresponding increases in industry output that occur in the region. Finally, we convert all increases in regional sales back to income using the income-to-sales ratios supplied by the UK Regional I-O model. The final results are £17.1 billion in earnings and £12.6 billion in other income, for an overall total of £29.6 billion in multiplier effects. The grand total impact from added STEM workforce skills thus comes to £75.1 billion, the sum of all initial and multiplier effects. The total figures appear in the last row of Table 3.2.

Table 3.2: Impact of Added Workforce STEM Skills (£ millions), FY 2016-17

	Labour Income (millions)	Non-labour income (millions)	Total income (millions)	Sales (millions)	Jobs
Initial effect	**£26,898**	**£18,571**	**£45,469**	**£89,845**	**818,340**
Multiplier effect					
Direct effect	£10,042	£7,228	£17,270	£36,642	304,887
Indirect effect	£7,032	£5,343	£12,374	£27,601	215,044
Total impact	**£43,971**	**£31,142**	**£75,113**	**£154,088**	**1,338,271**

Source: Emsi model.

Note that the £75.1 billion omits the effect of educated workers on innovation and technical progress. To the extent there are such technological gains, and theory suggests that there are, the stated results can be considered conservative.

Chapter 4 : Sensitivity Analysis

The purpose of a sensitivity analysis is to 1) see how sensitive the results are to a change in the primary assumptions, and 2) provide the reader with a plausible range wherein the true results will fall. Since we are not providing a statistical analysis of the assumptions, we will not provide a 90% confidence interval, but the concept is similar in that the range generated by the sensitivity analysis gives the most probable outcome.

These types of studies often use assumptions that do not stand up to rigorous peer scrutiny and generate results that overstate benefits. The approach here is to set this study apart from those undertaken strictly for advocacy purposes and provide a true economic audit of learner investment analysis results and economic impacts. For the investment perspective we test the discount rate. On the impact side we test the alternative education variables and value per GLH.

Sensitivity Analysis of Investment Assumptions

It is worth noting that while the alternative education variable is an assumption based on the educational potential of the learners in the absence of public funding, the discount rate comes to us from *The Green Book*. These rates are calculated by HMS Treasury, but they do vary by individual and are closely related to an entity's risk aversion. So, while these data are published and incorporate the public's willingness to accept risk, we still provide a sensitivity analysis since different regions and sub-cultures in the UK may have different risk tolerances.

STEM Learner Perspective

The alternative education variable does not affect the learners' stream of cash flows from Table 2.3 and thus is not included here. As can be seen, Table 4.1 below alters the assumed 'base case' values for the discount rate by first reducing it by 25% and 50% and then increasing it by the same.

Table 4.1: STEM Learner Perspective Discount Rate

	-50%	-25%	Base Case	25%	50%
Discount Rate	1.8%	2.6%	3.5%	4.4%	5.3%
NPV (£ millions)	£88,362	£71,336	£57,627	£46,511	£37,435
B/C	5.4	4.5	3.8	3.3	2.8

Source: Emsi.

The internal rate of return is not shown here because it is unaffected by the discount rate (see E.J. Mishan 1976). As the discount rate is varied, the NPV ranges from £37.4 billion to £88.3 billion and the benefit-cost ratio from 2.8 to 5.4. Even with a much higher discount rate, STEM learners still see a return above the threshold of 1.0, receiving £2.80 for every pound of their investment.

Sensitivity Analysis of Impact Assumptions

Impact of Added Workforce STEM Skills

Two assumptions feed into the primary impact measure of the impact of added workforce STEM skills. The alternative education variable accounts for the growth in impacts that would have been generated in the United Kingdom even if STEM education was not undertaken. The value per GLH, though calculated based on national earnings, may vary from year to year and is highly dependent on current economic conditions.

Table 4.2: Added Workforce STEM Skills Assumptions

	-50%	**-25%**	**Base Case**	**25%**	**50%**
Alternative Education Variable	5.0%	7.5%	10.0%	12.5%	15.0%
Impact (£ millions)	£79,286	£77,199	£75,113	£73,026	£70,940
Value Per GLH	£2.12	£4.25	£5.66	£7.08	£10.62
Impact (£ millions)	£28,167	£56,335	£75,113	£93,890	£104,836

Source: Emsi.

More interesting is the sensitivity of the results to the value per GLH. The magnitude of change this variable has on the final results is large, demonstrating this variable's calculation is crucial to the analysis. It also proves why it is so critical to use earnings figures that are also weighted by the learner body demographics.

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Annex 2: Glossary of Terms

Alternative education	A 'with' and 'without' measure of the percent of learners who would still be able to avail themselves of education if the publicly funded colleges and universities in the UK did not exist. An estimate of 10%, for example, means that 10% of learners do not depend directly on the existence of the colleges in order to obtain their education.
Asset value:	Capitalised value of a stream of future returns. Asset value measures what someone would have to pay today for an instrument that provides the same stream of future revenues.
Attrition rate:	Rate at which learners leave the workforce due to such factors as out-migration, retirement, or death.
Benefit/cost ratio:	Present value of benefits divided by present value of costs. If the benefit/cost ratio is greater than one, then benefits exceed costs and the investment is feasible.
Demand	Relationship between the market price of education and the volume of education demanded (expressed in terms of enrolment). The law of the downward-sloping demand curve is related to the fact that enrolment increases only if the price (learner tuition fees) is lowered, or conversely, enrolment decreases if price increases.
Direct effect	Additional economic activity that occurs as the industries affected by the initial effect spend money to purchase goods and services from their supply chain industries.
Discounting:	Expressing future revenues and costs in present value terms.
Economics:	Study of the allocation of scarce resources among alternative and competing ends. Economics is not normative (what ought to be done), but positive (describes what is, or how people are likely to behave in response to economic changes).
Externalities:	Impacts (positive and negative) for which there is no compensation. Positive externalities of education include improved social behaviours such as lower crime, reduced unemployment, and improved health. Colleges do not receive compensation for these benefits, even though education statistically correlates with improved social behaviours.

Gross National Product:	Measure of the final value of all goods and services produced. Alternatively, GNP equals the combined incomes of all factors of production, e.g., labour, land, and capital. These include wages, salaries, profits, rents, and other.
Indirect effect	Economic activity that occurs as the supply chain of the initial industries creates even more activity in the economy through their own inter-industry spending.
Induced effect	Economic activity created by the household sector as the businesses affected by the initial, direct, and indirect effects raise salaries or hire more people.
Initial effect	Income generated by the initial injection of monies into the economy through the expenditures of the institutions and their learners.
Input-output analysis:	Relationship between a given set of demands for final goods and services, and the implied amounts of manufactured inputs, raw materials, and labour this requires. In an educational setting, as colleges pay staff and spend money for supplies in the local economy, they also generate earnings in all sectors of the economy, thereby increasing the demand for goods, services, and jobs. Moreover, as learners enter or rejoin the workforce with added skills, they earn higher salaries and wages. In turn, this generates more consumption and spending in other sectors of the economy.
Internal rate of return:	Rate of interest which, when used to discount cash flows associated with investing in education, reduces the net present value to zero (i.e., where the present value of revenues accruing from the investment are just equal to the present value of costs incurred). This, in effect, is the breakeven rate of return since it shows the highest rate of interest at which the investment makes neither a profit nor a loss.
Labour income	Income which is received as a result of labour, e.g., wages.
Multiplier:	Measure of overall local earnings per pound of college earnings (i.e., on- and off-campus earnings divided by on-campus earnings). Multiplier effects are the result of in-area spending for goods and services and of everyday spending by college staff. The analysis also includes added local earnings attributable to past learners still active in the workforce. The local economy is larger because of learner skills, added spending associated with higher learner incomes, and enlarged output of industries where past learners are employed.

Net cash flow:	Benefits minus costs, *i.e.*, the sum of revenues accruing from an investment minus costs incurred.
Net present value:	Net cash flow discounted to the present. All future cash flows are, in this way, collapsed into one number, which, if positive, indicates feasibility. The result is expressed as a monetary measure.
Non-labour income	Income that is received from investments (such as rent, interest, and dividends) and transfer payments (payments from governments to individuals).
Opportunity cost:	Benefits forgone from alternative B once a decision is made to allocate resources to alternative A. For example, if an individual chooses not to attend college, he or she forgoes higher future earnings associated with further education. The benefit of education, therefore, is the 'price tag' of choosing not to attend college.
Payback period	Length of time required to recover an investment – the shorter the period, the more attractive the investment. The formula for computing the payback period is: Payback period = cost of investment/net return per period.

Annex 3: Emsi Input-Output Model

Introduction and Data Sources

Emsi's UK Regional Input-Output model represents the economic relationships among a region's industries, with particular reference to how much each industry purchases from each other industry. Using a complex, automated process, we can create regionalised models for any geographic area comprised of NUTS 3 areas.

Our primary data sources are the following:

1. Regional and national jobs-by-industry totals, and national sales-to-jobs ratios (derived from Emsi's industry employment and earnings data process).
2. The Office for National Statistics' (ONS) Supply and Use Tables (SUTs).

Creation of the Z Matrix

The SUTs show which industries make or use which commodity types. These two tables are combined to replace the industry-commodity-industry relationships with simple industry-industry relationships. This is called the national 'Z' matrix, which shows the total amount (£) each industry purchases from others. Industry purchases run down the columns, while industry sales run across the rows.

Table A3.1: Sample Z matrix (£ millions)

	Industry 1	*Industry 2*	. . .	*Industry 645*
Industry 1	3.3	1,532.5	. . .	232.1
Industry 2	9.2	23.0	. . .	1,982.7
. . .	. . .	. . .	. . .	. . .
Industry 645	819.3	2,395.6	. . .	0

In looking at the table above, the value 1,532.5 means that Industry 2 purchases £1,532,500,000 worth of commodities and/or services from Industry 1. In other words, the whole table is basically an economic double-entry accounting system, configured so that all money inflows have corresponding outflows elsewhere. All regular industries (such as 'oil and gas exploration,' 'machinery manufacturing,' 'supermarkets,' 'hospitals,' and so on) are captured in the Z matrix.

Disaggregation of the Z Matrix

The initial national Z matrix is then 'disaggregated' (or *extended*) from around 120 industries to approximately 645 industries. The disaggregation is performed by using probability matrices that allow us to estimate industry transactions for the more detailed sectors based on the known transactions of their parent sectors. The probability matrix is created from detailed Emsi industry earnings data, which are available for the approximately 645 industries and generated using a separate process.

Creation of the A Matrix

The national disaggregated 'Z' matrix is then 'normalised' to show purchases as percentages of each industry's output rather than total £ amounts. This is called the national 'A' matrix.

Table A3.2: Sample 'A' matrix

	Industry 1	*Industry 2*	. . .	*Industry 645*
Industry 1	.001	.112	. . .	.035
Industry 2	.097	0	. . .	.065
. . .	. . .	. . .	. . .	. . .
Industry 645	.002	.076	. . .	0

Each cell value represents the percentage of a column industry's total input purchases that goes toward purchasing inputs from each row industry. Thus, the cell containing .112 means that Industry 2 spends 11.2% of its total input purchases to obtain inputs from Industry 1.

Regionalisation of the A Matrix

To create a regional input-output model so that each region can be analysed on its own, we regionalise the national A matrix using that region's industry mix. The core regionalisation method is based on the work of University of West England economist A.T. Flegg[12] and uses cross-industry location quotients. In general, location quotients provide regional insight by determining the proportion of regional employment in a specific sector compared to the proportion of national employment in that same sector. In an effort to produce the best estimates, we calibrated the Flegg location quotients (FLQs) in our model with respect to 2007 data from the Scottish Government Input-Output Model. We calculate the FLQs using the following equation:

$$FLQ_{i,j} = \left(\frac{{J_i}^R}{{J_i}^N} \bigg/ \frac{{J_j}^R}{{J_j}^N} \right) \times \left(\log_2 \left(1 + \frac{\sum J^R}{\sum J^N} \right) \right)^{0.1}$$

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[12] Flegg, A.T. and C.D. Webber, 2000. 'Regional Size, Regional Specialisation and the FLQ Formula,' ***Regional Studies*** 34(6): 563-569; Flegg, A.T. and C.D. Webber, 1997. 'Regional Size, Industrial Location and Input-Output Expenditure Coefficients,' ***Regional Studies*** 32(5):435-444; Flegg, A.T. and C.D. Webber, 1997. 'On the Appropriate Use of Location Quotients in Generating Regional Input-Output Tables: Reply' ***Regional Studies*** 31(8): 795-805; Flegg, A.T. and C.D. Webber, 1994. 'On the Appropriate Use of Location Quotients in Generating Regional Input-Output Tables' ***Regional Studies*** 29(6): 547-561.

Where:

J = Jobs
i = row industry
j = column industry
R = Region
N = Nation
0.1 = Calibration

We create a separate matrix for the FLQs of all industries, as displayed below in Table A3.3. For example, the cell containing the FLQ of .12 was calculated by using Industry 1 as the row industry (or *i* in the equation above) and Industry 2 as the column industry (or *j* in the equation above).

Table A3.3: Sample FLQ matrix

	Industry 1	*Industry 2*	. . .	*Industry 645*
Industry 1	1	.12	. . .	.47
Industry 2	.98	1	. . .	.09
. . .	. . .	. . .	. . .	. . .
Industry 645	.20	.76	. . .	1

One other important aspect of the FLQ matrix is that we can use each FLQ as a regional purchase coefficient (RPC). RPCs are useful in estimating the percentage of industry demand that is met by purchases from other industries within the region. In this way, we can see how much money for industry purchases stays within the region and how much leaks out of the region.

Since the FLQ matrix has the same dimensions as the A matrix, it can be used to scale the national A matrix to the region using the Hadamard (i.e., element-by-element) product. The result is the regionalised A matrix, represented by the following equation:

$$A^R = A^N \otimes F^R$$

Where:

$\otimes$ = Hadamard multiplication
A^N = UK IO coefficients matrix
F^R = FLQ matrix
A^R = Regional IO coefficients matrix

The A-matrix regionalisation process is automated for any given region for which industry data are available. Although partially derived from national figures, the regional A matrix offers a best possible estimate of regional values without resorting to costly and time-consuming survey techniques, which in most cases are completely infeasible.

Creating Multiplier Effects and Using the A Matrix

Finally, we convert the regional A matrix to a regional B matrix using the standard Leontief inverse:

$$B^R = (I - A^R)^{-1}$$

The B matrix consists of inter-industry sales multiplier effects, which can be converted to jobs or earnings multiplier effects using per-industry jobs-to-sales or earnings-to-sales ratios. The resulting tables and vectors from this process are then used in the actual end-user software to calculate regional requirements, calculate regional economic base, estimate sales multiplier effects, and run impact scenarios.

Annex 4: STEM Labour Market Intelligence

Figure 4.1: STEM: Top 20 growth occupations in Great Britain 2016 to 2024

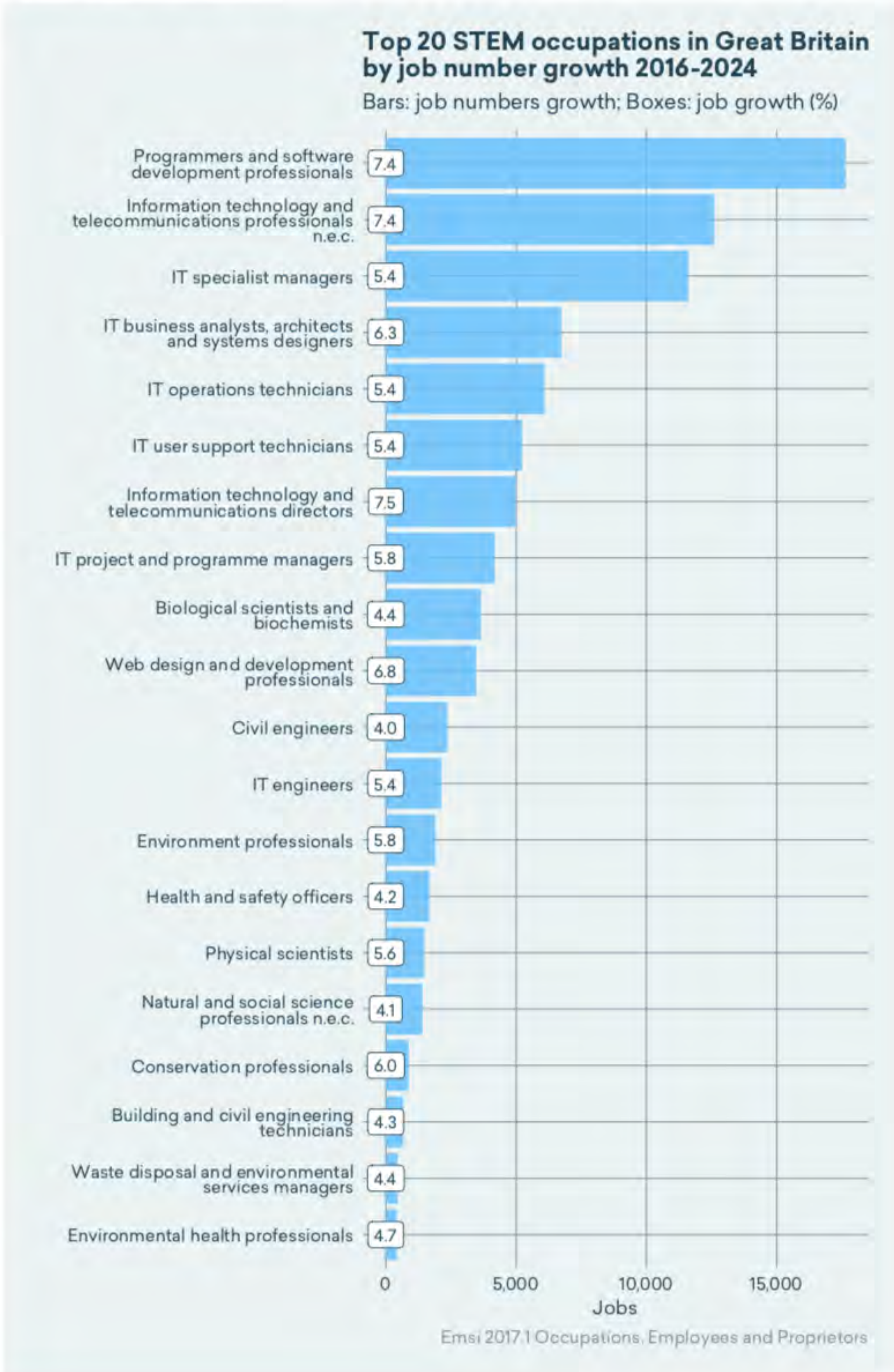

Figure 4.2: STEM: Job growth and annual openings in the North East 2016 to 2024 (where Location Quotient > 1)

Figure 4.3: STEM: Job growth and annual openings in the North West 2016 to 2024 (where Location Quotient > 1)

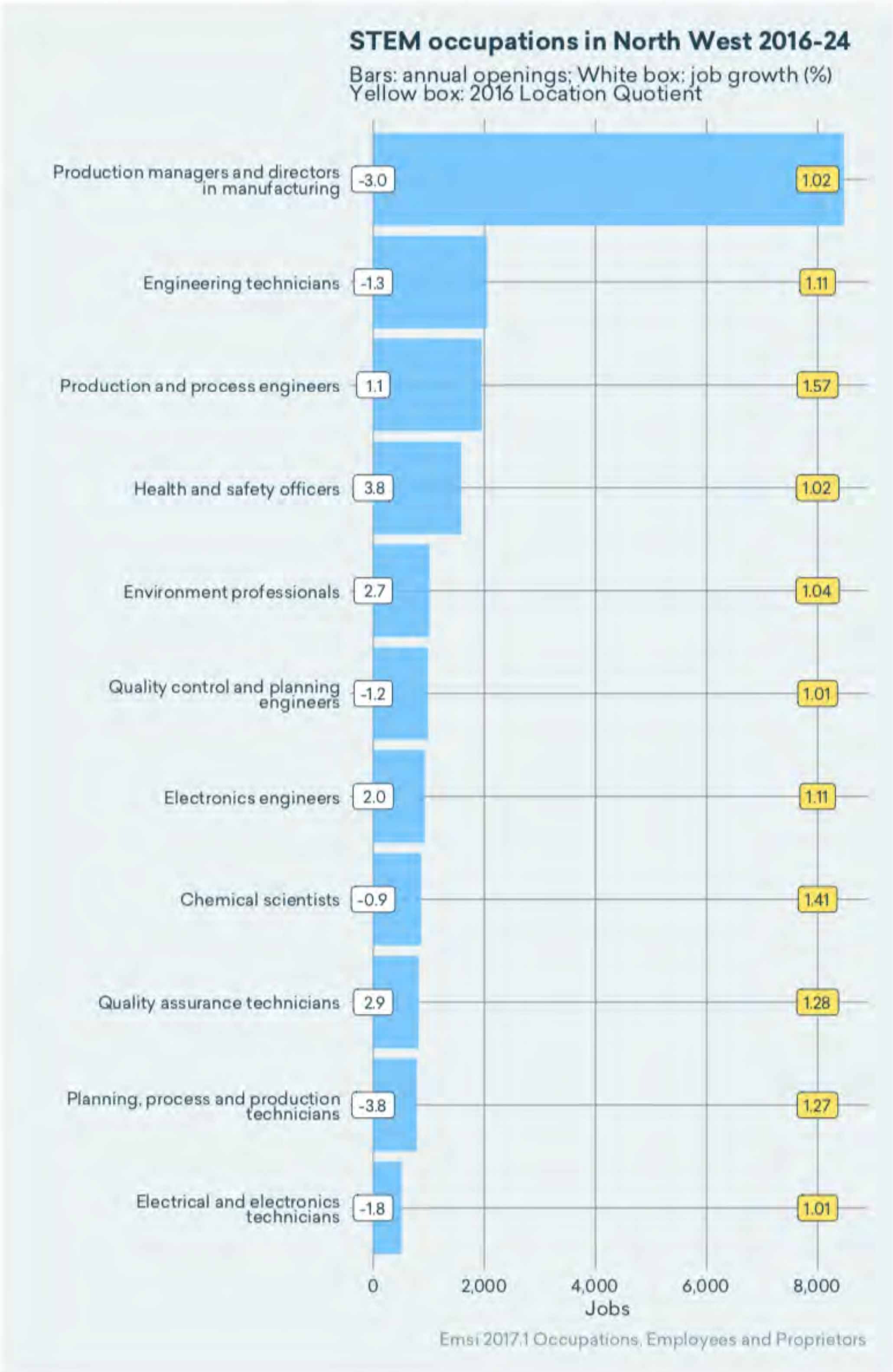

Figure 4.4: STEM: Job growth and openings in Yorkshire and the Humber 2016 to 2024 (where Location Quotient > 1)

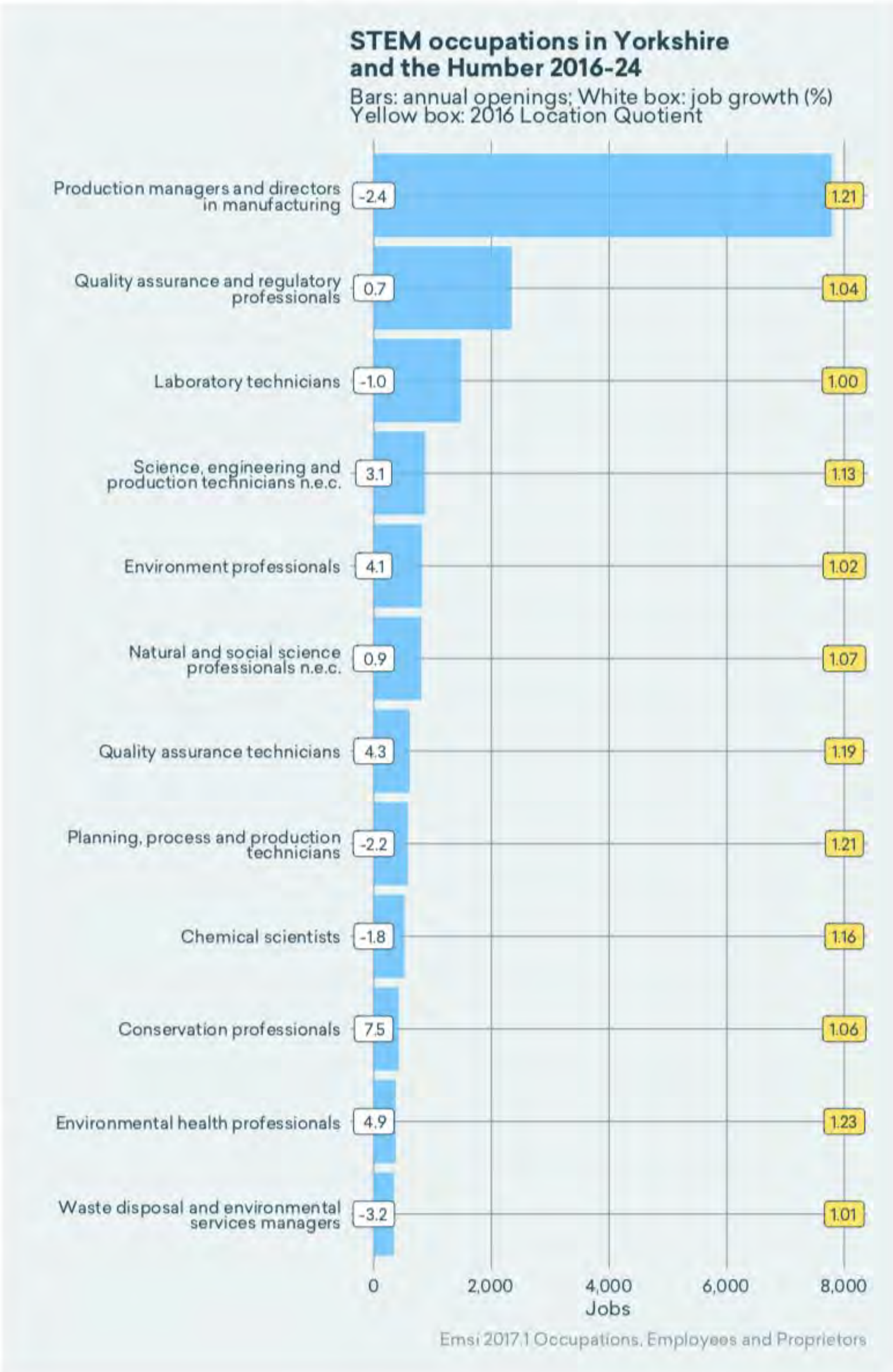

Figure 4.5: STEM: Job growth and openings in the East Midlands 2016 to 2024 (where Location Quotient > 1)

Figure 4.6: STEM: Job growth and openings in the West Midlands 2016 to 2024 (where Location Quotient > 1)

Figure 4.7: STEM: Job growth and openings in the East of England 2016 to 2024 (where Location Quotient > 1)

Figure 4.8: STEM: Job growth and openings in London 2016 to 2024 (where Location Quotient > 1)

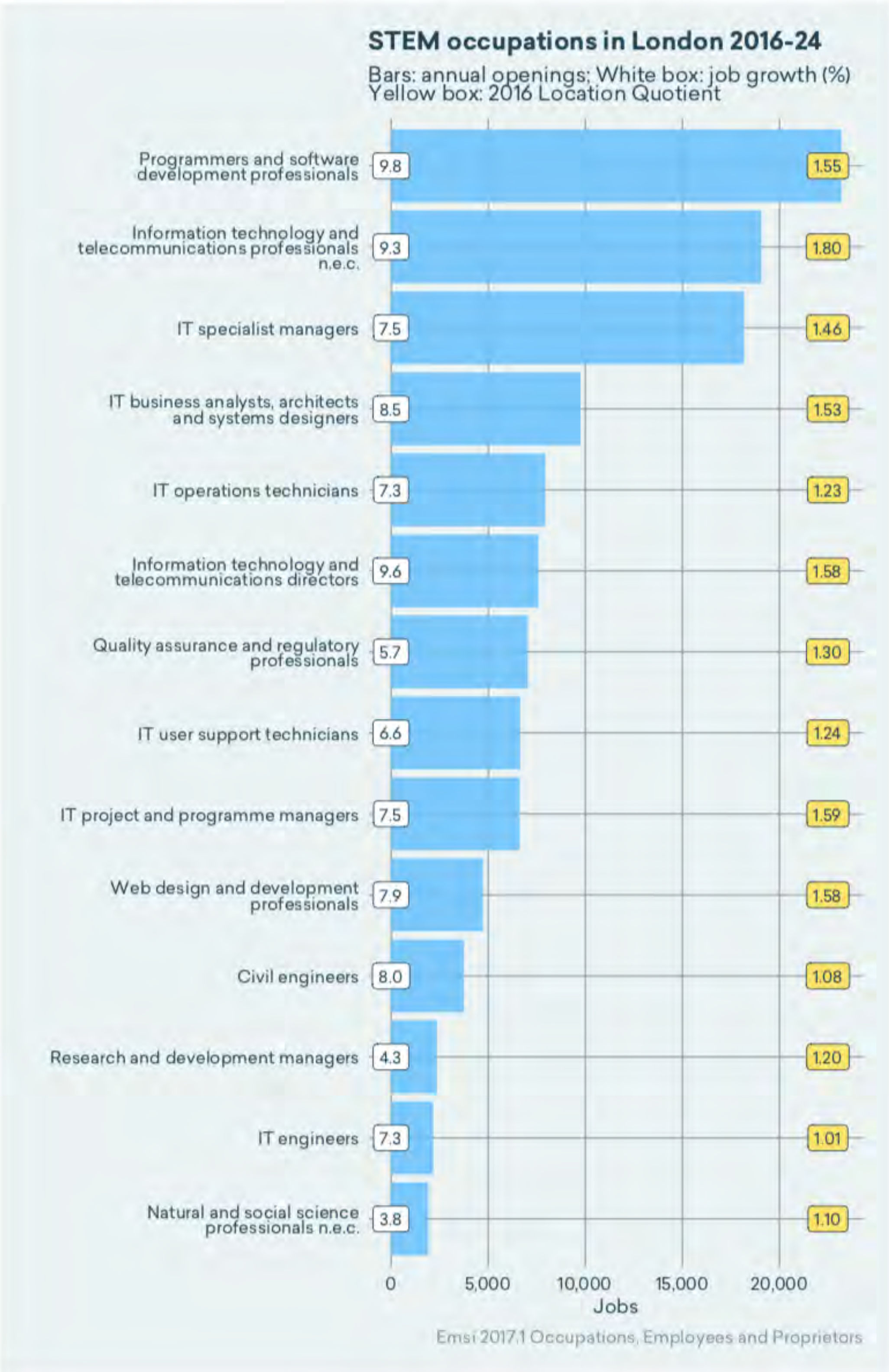

Figure 4.9: STEM: Job growth and openings in the South East 2016 to 2024 (where Location Quotient > 1)

Figure 4.10: STEM: Job growth and openings in the South West 2016 to 2024 (where Location Quotient > 1)

Figure 4.11: STEM: Job growth and openings in Wales 2016 to 2024 (where Location Quotient > 1)

Figure 4.12: STEM: Job growth and openings in Scotland 2016 to 2024 (where Location Quotient > 1)

Figure 4.13: STEM staffing pattern part 1, 2016

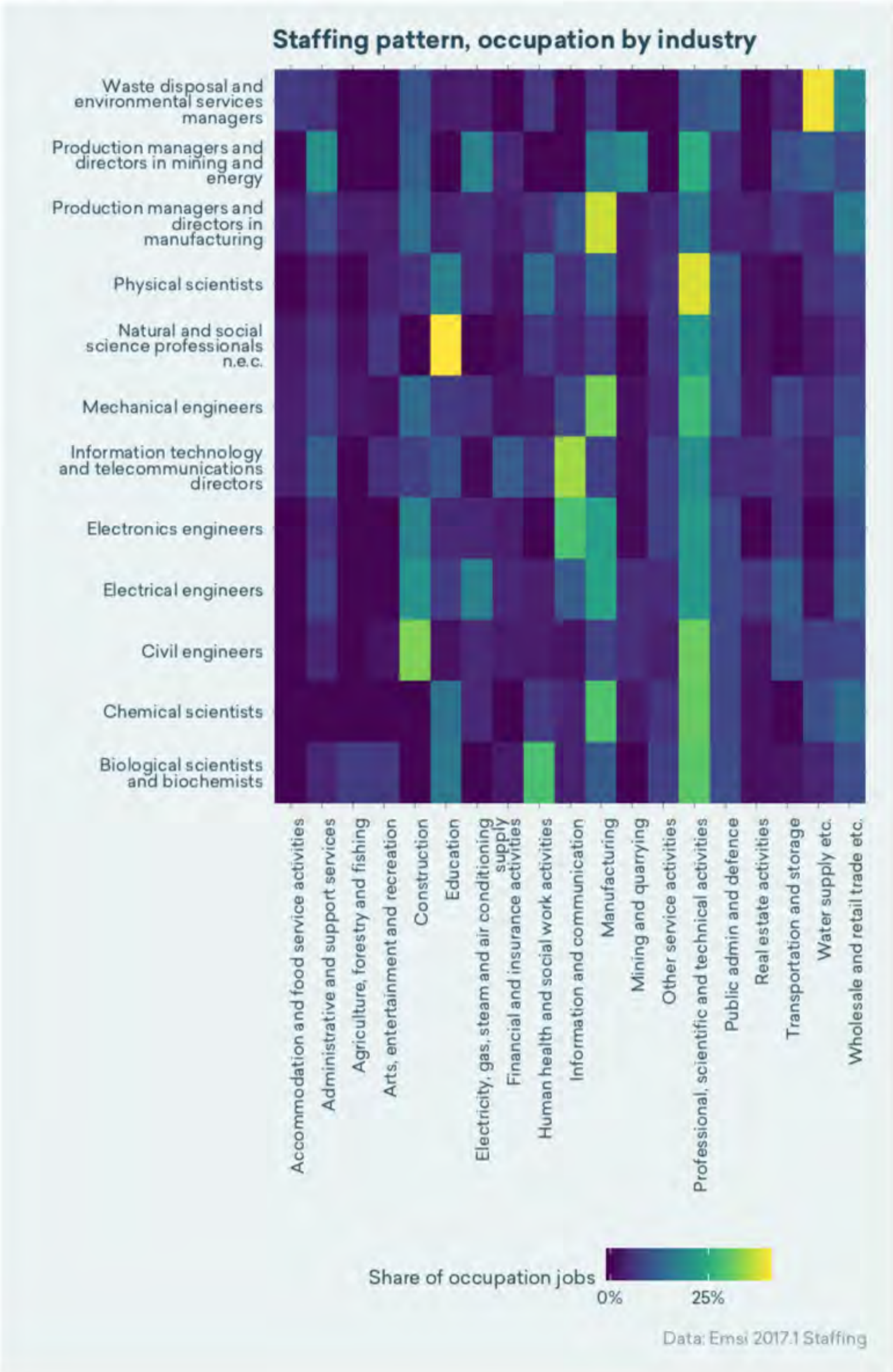

Figure 4.14: STEM staffing pattern part 2, 2016

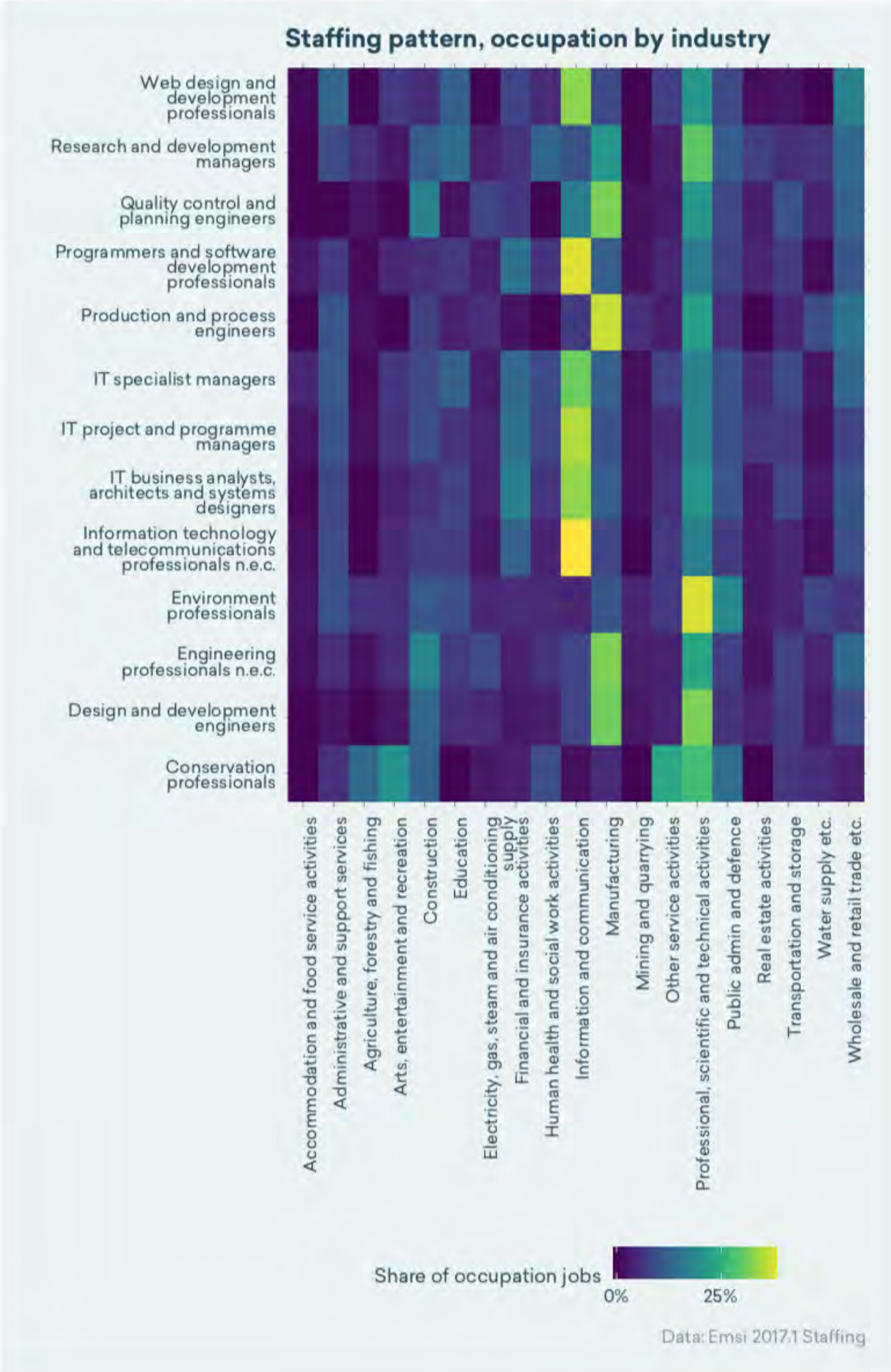

Figure 4.15: STEM staffing pattern part 3, 2016

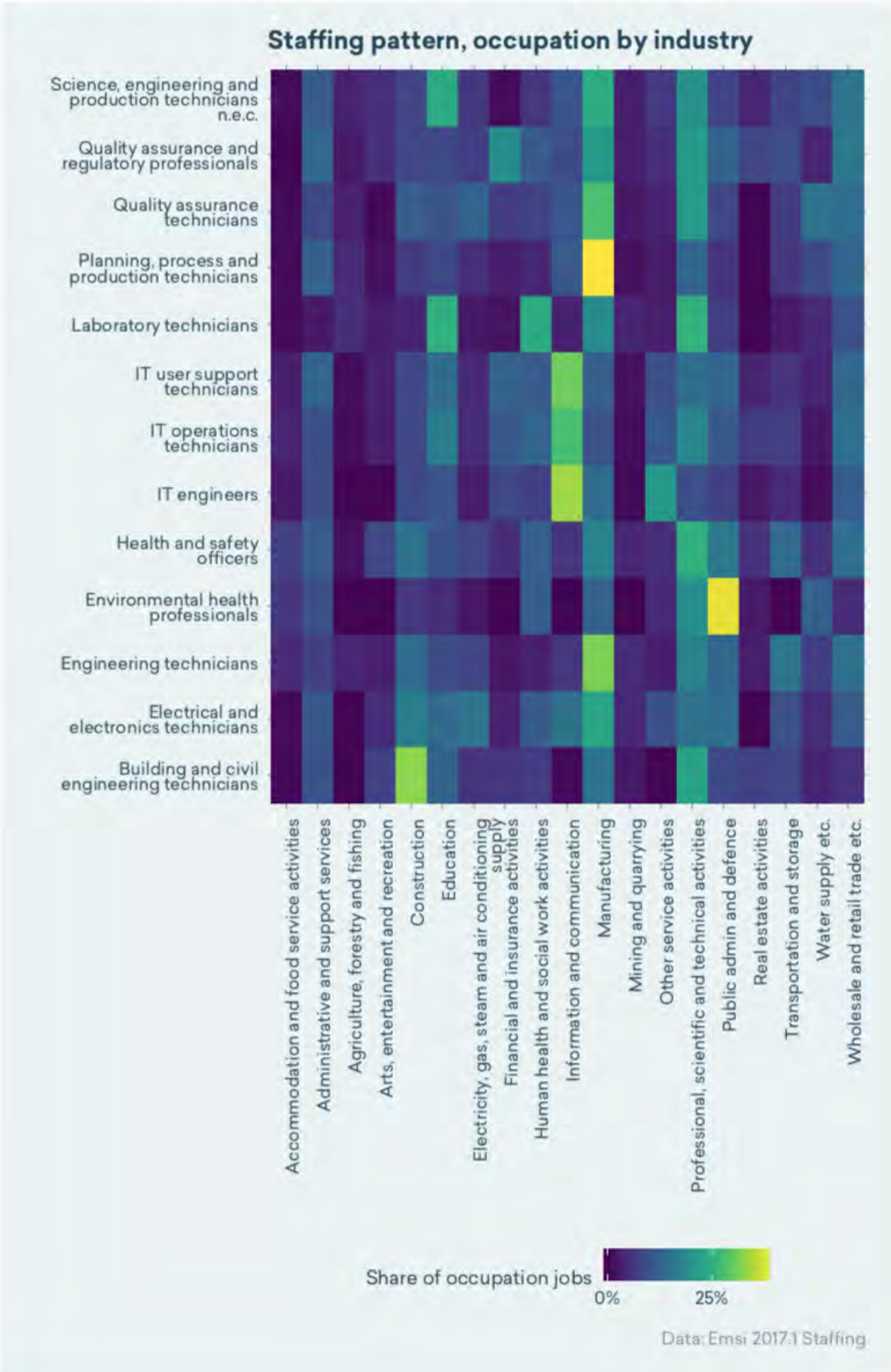

Table 4.1: STEM Occupations in North East

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Production managers and directors in manufacturing	9,556	9,638	82	1.04	1.05	3,068	43,555
IT specialist managers	5,914	6,267	354	0.76	0.76	1,824	43,035
IT operations technicians	3,701	3,928	227	0.90	0.90	1,136	26,146
IT user support technicians	3,675	3,937	262	1.04	1.05	1,172	26,853
Information technology and telecommunications professionals n.e.c.	4,435	4,793	358	0.71	0.71	1,478	36,878
Design and development engineers	3,492	3,778	285	1.46	1.55	1,183	41,163
IT business analysts, architects and systems designers	2,939	3,203	264	0.76	0.78	1,013	36,962
Programmers and software development professionals	6,005	6,712	707	0.69	0.72	2,261	38,771

[a] *with more than 1000 openings

Table 4.2: STEM Occupations in North West

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Production managers and directors in manufacturing	28,221	27,379	-842	1.02	1.01	8,473	42,619
Engineering professionals n.e.c.	8,061	7,872	-189	0.97	0.95	1,954	42,536
Engineering technicians	8,310	8,204	-107	1.11	1.10	2,050	37,960
Mechanical engineers	5,669	5,649	-20	0.83	0.82	1,429	39,790
Biological scientists and biochemists	7,979	7,972	-7	0.90	0.87	1,987	37,461
Design and development engineers	6,364	6,368	4	0.89	0.89	1,639	40,768
Laboratory technicians	7,939	7,953	14	0.99	0.98	1,975	20,904
Civil engineers	4,722	4,751	29	0.74	0.73	1,201	31,574
Production and process engineers	7,369	7,454	85	1.57	1.60	1,954	43,534
Quality assurance and regulatory professionals	7,643	7,839	195	0.92	0.93	2,892	41,038
Environment professionals	3,675	3,773	98	1.04	1.02	1,014	36,483
IT operations technicians	10,380	10,678	298	0.84	0.83	2,864	29,099
Health and safety officers	4,455	4,625	170	1.02	1.03	1,584	36,920
IT specialist managers	18,197	18,945	748	0.78	0.78	5,322	43,784
IT project and programme managers	7,231	7,532	302	0.93	0.93	2,118	50,482
IT user support technicians	8,258	8,615	357	0.78	0.78	2,414	31,803
IT business analysts, architects and systems designers	10,718	11,277	559	0.93	0.93	3,272	41,808
Information technology and telecommunications directors	5,544	5,871	327	0.77	0.77	2,080	62,525
Programmers and software development professionals	20,652	21,957	1,305	0.80	0.80	6,573	40,019
Information technology and telecommunications professionals n.e.c.	15,491	16,553	1,062	0.83	0.84	5,018	36,026
IT engineers	3,480	3,729	249	0.81	0.84	1,116	21,798
Web design and development professionals	4,575	4,906	331	0.83	0.84	1,513	31,054

[a] *with more than 1000 openings

Table 4.3: STEM Occupations in Yorkshire and the Humber

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Production managers and directors in manufacturing	25,565	24,954	-611	1.21	1.20	7,793	40,622
Mechanical engineers	4,479	4,401	-77	0.85	0.83	1,094	42,494
Laboratory technicians	6,165	6,100	-64	1.00	0.98	1,486	19,864
Engineering professionals n.e.c.	6,152	6,094	-58	0.97	0.96	1,534	35,318
Design and development engineers	4,639	4,610	-29	0.85	0.84	1,176	39,728
Quality assurance and regulatory professionals	6,578	6,625	47	1.04	1.02	2,346	38,147
Biological scientists and biochemists	5,753	5,875	123	0.84	0.84	1,566	35,651
Civil engineers	4,189	4,333	144	0.86	0.87	1,207	39,104
Health and safety officers	3,083	3,193	111	0.92	0.93	1,088	34,882
IT operations technicians	7,388	7,700	311	0.78	0.78	2,153	28,226
IT business analysts, architects and systems designers	6,643	6,924	281	0.75	0.75	1,961	40,810
IT specialist managers	13,759	14,457	698	0.77	0.78	4,196	43,846
IT user support technicians	6,807	7,171	364	0.84	0.85	2,068	27,914
Programmers and software development professionals	13,707	14,460	753	0.69	0.69	4,261	36,462
IT project and programme managers	4,097	4,342	246	0.69	0.70	1,294	63,128
Information technology and telecommunications directors	4,447	4,753	306	0.81	0.81	1,751	66,040
Information technology and telecommunications professionals n.e.c.	8,802	9,416	614	0.62	0.62	2,892	41,725
Web design and development professionals	3,257	3,490	233	0.77	0.78	1,076	24,066

[a] *with more than 1000 openings

Table 4.4: STEM Occupations in East Midlands

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Design and development engineers	5,709	5,637	-72	1.26	1.24	1,432	39,603
Engineering technicians	5,285	5,264	-21	1.12	1.11	1,307	36,358
Production managers and directors in manufacturing	24,823	24,871	48	1.42	1.44	7,746	40,893
Mechanical engineers	5,407	5,475	68	1.24	1.25	1,428	37,482
Engineering professionals n.e.c.	6,678	6,805	128	1.27	1.29	1,795	38,771
Information technology and telecommunications professionals n.e.c.	6,721	6,874	153	0.57	0.55	1,833	31,678
IT business analysts, architects and systems designers	4,190	4,307	117	0.57	0.56	1,167	42,661
Quality assurance and regulatory professionals	6,081	6,268	187	1.16	1.17	2,344	37,170
IT operations technicians	6,343	6,550	206	0.81	0.81	1,792	30,867
IT user support technicians	6,821	7,050	229	1.02	1.01	1,934	29,370
Programmers and software development professionals	11,901	12,319	418	0.72	0.71	3,418	39,874
IT specialist managers	11,364	11,784	420	0.77	0.77	3,279	38,938
Civil engineers	3,958	4,121	163	0.98	0.99	1,173	36,379
Information technology and telecommunications directors	4,532	4,731	199	0.99	0.98	1,627	53,685
Biological scientists and biochemists	4,721	4,942	221	0.84	0.85	1,432	39,374
Laboratory technicians	5,873	6,175	302	1.16	1.19	1,796	20,405

[a] *with more than 1000 openings

Table 4.5: STEM Occupations in West Midlands

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Quality control and planning engineers	3,371	3,234	-137	1.52	1.48	1,144	35,526
Production and process engineers	4,397	4,219	-178	1.19	1.16	1,052	37,939
Production managers and directors in manufacturing	29,040	28,435	-605	1.34	1.33	8,885	40,810
Design and development engineers	6,609	6,489	-120	1.17	1.15	1,638	40,622
Engineering technicians	5,584	5,549	-35	0.95	0.94	1,362	31,325
Engineering professionals n.e.c.	7,537	7,507	-31	1.15	1.15	1,892	42,536
Mechanical engineers	6,720	6,729	9	1.24	1.24	1,751	42,474
IT specialist managers	15,000	15,360	361	0.81	0.80	4,079	43,347
Health and safety officers	3,647	3,737	91	1.06	1.06	1,235	30,347
IT operations technicians	8,914	9,181	267	0.92	0.91	2,462	25,251
Biological scientists and biochemists	4,749	4,913	164	0.68	0.68	1,361	41,995
Laboratory technicians	5,652	5,859	206	0.89	0.91	1,608	19,718
Quality assurance and regulatory professionals	6,536	6,790	254	1.00	1.02	2,592	42,682
IT user support technicians	7,091	7,388	296	0.85	0.85	2,055	29,598
IT project and programme managers	4,354	4,538	184	0.71	0.71	1,278	64,293
IT business analysts, architects and systems designers	6,616	6,945	329	0.73	0.73	2,003	38,917
Information technology and telecommunications professionals n.e.c.	11,097	11,760	663	0.76	0.76	3,490	33,509
Programmers and software development professionals	15,180	16,107	927	0.74	0.74	4,795	37,502
Information technology and telecommunications directors	4,433	4,738	304	0.78	0.79	1,733	64,626

[a] *with more than 1000 openings

Table 4.6: STEM Occupations in East of England

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Production managers and directors in manufacturing	25,025	25,050	25	1.08	1.07	7,842	43,326
Design and development engineers	6,444	6,463	19	1.07	1.05	1,639	41,787
Mechanical engineers	6,064	6,168	103	1.05	1.04	1,643	46,779
Quality assurance and regulatory professionals	6,274	6,415	141	0.90	0.88	2,357	38,646
Engineering technicians	6,099	6,271	172	0.97	0.97	1,706	34,965
Engineering professionals n.e.c.	7,336	7,543	207	1.05	1.05	2,052	38,979
IT specialist managers	20,482	21,764	1,281	1.04	1.04	6,526	47,528
Research and development managers	4,329	4,607	278	1.24	1.25	1,386	50,898
Laboratory technicians	7,629	8,135	506	1.13	1.15	2,466	20,925
Science, engineering and production technicians n.e.c.	4,133	4,426	293	1.35	1.38	1,360	24,898
Civil engineers	6,658	7,131	473	1.25	1.26	2,192	42,245
IT project and programme managers	6,352	6,807	455	0.97	0.97	2,093	52,978
Natural and social science professionals n.e.c.	3,567	3,823	256	1.14	1.15	1,172	42,390
IT business analysts, architects and systems designers	9,392	10,077	686	0.97	0.97	3,114	46,405
Health and safety officers	4,430	4,762	333	1.21	1.23	1,776	39,062
IT user support technicians	8,686	9,342	657	0.98	0.98	2,900	29,141
IT operations technicians	11,358	12,235	877	1.10	1.11	3,815	29,078
Web design and development professionals	4,690	5,077	387	1.01	1.01	1,604	31,013
IT engineers	5,214	5,661	447	1.45	1.48	1,777	31,512
Physical scientists	3,116	3,384	269	1.29	1.31	1,079	42,370
Programmers and software development professionals	21,722	23,624	1,902	1.00	1.00	7,586	43,618
Information technology and telecommunications professionals n.e.c.	14,870	16,178	1,308	0.95	0.95	5,192	45,510
Information technology and telecommunications directors	5,853	6,417	564	0.97	0.97	2,480	76,981
Biological scientists and biochemists	11,185	12,296	1,111	1.50	1.54	4,037	39,686

[a] *with more than 1000 openings

Table 4.7: STEM Occupations in London

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Design and development engineers	6,143	6,241	97	0.55	0.54	1,686	52,541
Biological scientists and biochemists	12,051	12,289	237	0.86	0.83	3,341	46,342
Laboratory technicians	9,049	9,253	204	0.72	0.70	2,474	22,838
Electronics engineers	4,511	4,614	102	0.92	0.90	1,259	43,597
Production managers and directors in manufacturing	23,939	24,617	678	0.55	0.56	8,185	55,827
Physical scientists	3,679	3,808	129	0.81	0.79	1,078	35,776
Engineering technicians	6,671	6,917	246	0.57	0.57	1,943	41,350
Natural and social science professionals n.e.c.	6,503	6,748	245	1.10	1.09	1,917	44,866
Research and development managers	7,844	8,183	339	1.20	1.19	2,368	52,894
Environment professionals	4,905	5,131	226	0.88	0.86	1,505	50,648
Electrical engineers	4,074	4,264	190	0.78	0.78	1,255	50,294
Health and safety officers	5,830	6,105	275	0.85	0.84	2,126	38,938
Engineering professionals n.e.c.	7,765	8,147	382	0.59	0.60	2,420	48,422
Mechanical engineers	5,760	6,078	317	0.53	0.54	1,839	41,766
Quality assurance and regulatory professionals	16,980	17,945	965	1.30	1.31	7,031	50,274
Science, engineering and production technicians n.e.c.	3,938	4,191	254	0.69	0.70	1,267	31,013
IT user support technicians	20,624	21,981	1,357	1.24	1.23	6,660	33,946
Quality control and planning engineers	3,635	3,892	257	0.82	0.86	1,576	44,408
IT engineers	6,776	7,268	491	1.01	1.01	2,169	21,882
IT operations technicians	23,957	25,695	1,738	1.23	1.24	7,934	35,422
IT specialist managers	53,646	57,673	4,027	1.46	1.47	18,184	59,030
IT project and programme managers	19,530	21,001	1,470	1.59	1.59	6,619	55,453
Web design and development professionals	13,755	14,841	1,087	1.58	1.58	4,732	37,648
Civil engineers	10,764	11,626	861	1.08	1.10	3,752	35,880
IT business analysts, architects and systems designers	27,836	30,190	2,355	1.53	1.54	9,751	53,206
Information technology and telecommunications professionals n.e.c.	52,901	57,800	4,899	1.80	1.81	19,063	43,098
Information technology and telecommunications directors	17,965	19,698	1,733	1.58	1.59	7,590	84,947
Programmers and software development professionals	63,358	69,549	6,191	1.55	1.56	23,193	49,483

[a] *with more than 1000 openings

Table 4.8: STEM Occupations in South East

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Production and process engineers	5,589	5,484	-105	0.91	0.89	1,373	40,290
Electrical engineers	4,249	4,208	-41	0.97	0.94	1,050	49,005
Production managers and directors in manufacturing	33,502	33,347	-155	0.93	0.92	10,346	46,550
Design and development engineers	8,981	8,959	-22	0.96	0.94	2,280	42,224
Engineering professionals n.e.c.	11,947	11,926	-21	1.09	1.07	2,984	42,952
Civil engineers	6,782	6,772	-11	0.81	0.78	1,705	44,179
Engineering technicians	10,361	10,389	28	1.05	1.04	2,598	33,530
Mechanical engineers	8,855	8,931	76	0.98	0.97	2,320	41,288
Health and safety officers	5,024	5,123	99	0.88	0.86	1,688	35,443
Quality assurance and regulatory professionals	9,768	10,000	233	0.90	0.89	3,670	44,866
Science, engineering and production technicians n.e.c.	5,001	5,163	163	1.04	1.04	1,417	28,933
IT engineers	7,827	8,085	258	1.39	1.36	2,179	34,112
Electronics engineers	5,873	6,103	229	1.44	1.44	1,724	55,598
IT specialist managers	43,380	45,209	1,828	1.41	1.39	12,795	53,165
Laboratory technicians	11,720	12,227	507	1.11	1.11	3,461	20,384
IT user support technicians	18,150	18,956	806	1.31	1.29	5,393	30,638
Research and development managers	6,670	6,967	297	1.22	1.23	1,988	44,637
IT project and programme managers	14,185	14,879	694	1.39	1.37	4,293	46,758
Chemical scientists	3,896	4,091	195	1.23	1.25	1,185	28,787
IT business analysts, architects and systems designers	20,785	21,891	1,107	1.37	1.36	6,407	51,397
Programmers and software development professionals	51,475	54,436	2,960	1.51	1.48	16,159	45,698
IT operations technicians	20,637	21,833	1,196	1.28	1.27	6,469	30,139
Information technology and telecommunications professionals n.e.c.	34,085	36,109	2,024	1.39	1.37	10,802	40,040
Natural and social science professionals n.e.c.	5,660	6,009	349	1.15	1.17	1,795	42,390
Environment professionals	4,594	4,880	286	0.99	0.98	1,481	36,109
Information technology and telecommunications directors	12,926	13,741	816	1.37	1.35	4,977	65,998
Biological scientists and biochemists	13,081	13,947	867	1.12	1.13	4,231	40,206
Web design and development professionals	8,666	9,268	602	1.19	1.19	2,841	29,370
Physical scientists	5,293	5,732	439	1.41	1.43	1,816	37,045

[a] *with more than 1000 openings

Table 4.9: STEM Occupations in South West

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Laboratory technicians	5,219	5,235	16	0.84	0.81	1,334	19,282
Quality assurance and regulatory professionals	5,338	5,412	75	0.83	0.81	1,934	41,454
Biological scientists and biochemists	6,252	6,387	135	0.91	0.88	1,713	39,062
Production managers and directors in manufacturing	22,996	23,593	597	1.08	1.10	7,823	39,915
Engineering technicians	6,993	7,206	213	1.21	1.22	1,956	33,384
Production and process engineers	4,129	4,257	128	1.14	1.16	1,173	36,733
Engineering professionals n.e.c.	7,244	7,473	229	1.13	1.14	2,063	41,142
IT engineers	3,539	3,685	145	1.07	1.05	1,015	28,787
Civil engineers	4,342	4,524	182	0.88	0.88	1,282	37,960
Mechanical engineers	8,392	8,788	396	1.58	1.61	2,539	47,778
IT user support technicians	6,510	6,863	353	0.79	0.79	1,998	30,098
Design and development engineers	9,205	9,718	513	1.66	1.72	2,883	37,960
Health and safety officers	3,608	3,816	208	1.07	1.08	1,359	38,875
IT business analysts, architects and systems designers	7,084	7,494	409	0.79	0.79	2,230	45,677
IT operations technicians	8,761	9,283	522	0.92	0.92	2,745	26,270
IT project and programme managers	5,540	5,899	360	0.92	0.92	1,783	40,539
IT specialist managers	16,340	17,412	1,072	0.90	0.91	5,262	45,053
Programmers and software development professionals	16,944	18,080	1,136	0.84	0.84	5,494	41,662
Information technology and telecommunications professionals n.e.c.	10,666	11,387	721	0.74	0.73	3,477	35,630
Information technology and telecommunications directors	4,921	5,261	340	0.88	0.87	1,925	72,654

[a] *with more than 1000 openings

Table 4.10: STEM Occupations in Wales

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Production managers and directors in manufacturing	11,089	10,982	-107	1.00	1.00	3,408	39,790
Engineering technicians	4,244	4,308	64	1.41	1.42	1,105	33,114
Quality assurance and regulatory professionals	2,746	2,833	87	0.82	0.83	1,049	39,083
IT operations technicians	3,549	3,675	126	0.71	0.71	1,002	29,474
IT specialist managers	5,153	5,408	255	0.55	0.55	1,565	38,418
Programmers and software development professionals	4,211	4,492	281	0.40	0.40	1,368	33,114
Laboratory technicians	3,851	4,186	335	1.19	1.26	1,323	20,904

[a] *with more than 1000 openings

Table 4.11: STEM Occupations in Scotland

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Production managers and directors in manufacturing	20,042	20,310	267	0.93	0.95	6,525	45,802
Civil engineers	8,800	8,937	136	1.78	1.75	2,361	44,387
Engineering technicians	8,967	9,135	168	1.54	1.56	2,416	31,512
Engineering professionals n.e.c.	7,939	8,088	149	1.22	1.24	2,178	39,229
Design and development engineers	5,883	6,024	141	1.05	1.07	1,669	48,734
Mechanical engineers	6,491	6,651	160	1.21	1.22	1,812	41,829
Science, engineering and production technicians n.e.c.	3,700	3,792	92	1.30	1.30	1,018	26,312
Health and safety officers	4,386	4,502	115	1.29	1.28	1,509	35,339
Production and process engineers	4,753	4,893	140	1.30	1.34	1,353	39,541
Production managers and directors in mining and energy	3,026	3,124	98	2.97	2.97	1,048	55,640
Quality assurance and regulatory professionals	6,177	6,408	231	0.95	0.96	2,425	39,998
IT operations technicians	8,393	8,708	314	0.87	0.87	2,421	34,466
Laboratory technicians	7,495	7,828	334	1.20	1.21	2,225	26,458
IT specialist managers	11,936	12,499	564	0.65	0.65	3,613	49,691
IT user support technicians	7,939	8,327	388	0.96	0.96	2,396	28,226
IT project and programme managers	4,398	4,624	227	0.72	0.72	1,357	59,488
Environment professionals	3,555	3,750	195	1.28	1.29	1,113	32,864
Biological scientists and biochemists	10,033	10,611	578	1.44	1.47	3,157	37,939
Information technology and telecommunications directors	3,179	3,384	205	0.57	0.56	1,235	67,413
Physical scientists	3,594	3,829	235	1.61	1.63	1,169	38,646
Natural and social science professionals n.e.c.	4,218	4,496	278	1.44	1.49	1,370	38,189
IT business analysts, architects and systems designers	7,184	7,667	484	0.80	0.81	2,350	35,984
Information technology and telecommunications professionals n.e.c.	9,053	9,671	617	0.62	0.62	2,972	34,570
Programmers and software development professionals	13,780	14,845	1,065	0.68	0.69	4,675	40,664

[a] *with more than 1000 openings

Table 4.12: STEM Occupations in England

Occupation	Jobs 2016	Jobs 2024	Job Growth	LQ16	LQ24	Openings	Earnings (£)
Production managers and directors in manufacturing	222,667	221,885	-782	1.01	1.00	68,926	43,813
Production and process engineers	36,006	35,947	-59	0.96	0.95	9,133	39,323
Quality control and planning engineers	21,842	21,881	39	0.97	0.97	7,699	37,955
Engineering technicians	55,655	56,204	549	0.93	0.93	14,263	35,499
Engineering professionals n.e.c.	65,519	66,219	700	0.98	0.98	17,039	41,488
Design and development engineers	57,587	58,261	674	1.00	1.00	15,256	41,724
Mechanical engineers	53,643	54,609	966	0.97	0.97	14,514	42,597
Electrical engineers	26,149	26,760	611	0.98	0.98	7,195	47,722
Laboratory technicians	62,481	64,346	1,865	0.97	0.97	17,426	20,684
Electronics engineers	25,549	26,366	817	1.02	1.02	7,291	46,605
Quality assurance and regulatory professionals	67,455	69,627	2,171	1.01	1.01	26,029	43,356
Science, engineering and production technicians n.e.c.	28,250	29,215	965	0.97	0.97	8,027	26,025
Research and development managers	33,779	34,993	1,214	1.02	1.01	9,761	46,587
Natural and social science professionals n.e.c.	28,726	29,772	1,045	0.96	0.95	8,280	39,492
Biological scientists and biochemists	68,794	71,753	2,960	0.96	0.96	20,428	40,167
Civil engineers	47,203	49,258	2,055	0.93	0.93	14,096	37,758
Health and safety officers	33,994	35,509	1,514	0.97	0.97	12,329	35,992
IT engineers	35,465	37,350	1,885	1.03	1.03	10,647	27,391
IT user support technicians	86,622	91,303	4,681	1.02	1.02	26,592	30,786
IT specialist managers	198,082	208,871	10,789	1.06	1.06	61,462	50,130
IT operations technicians	101,439	107,081	5,642	1.03	1.03	31,367	30,159
Physical scientists	21,917	23,155	1,238	0.95	0.95	6,847	38,091
IT project and programme managers	66,217	70,103	3,886	1.06	1.06	20,869	51,819
Environment professionals	27,261	28,903	1,643	0.96	0.96	8,654	37,250
IT business analysts, architects and systems designers	96,203	102,309	6,106	1.04	1.04	30,916	47,533
Web design and development professionals	45,974	49,233	3,259	1.04	1.04	15,173	30,575
Programmers and software development professionals	220,944	237,243	16,300	1.06	1.06	73,732	44,101
Information technology and telecommunications professionals n.e.c.	159,068	170,870	11,803	1.07	1.07	53,218	40,078
Information technology and telecommunications directors	62,219	66,944	4,726	1.08	1.08	24,807	71,459

[a] *with more than 6000 openings

Table 4.13: Top skills posted for STEM occupations in Great Britain during 2017

Skill	Unique Companies	Unique Postings	Occupation
.NET Framework	6,480	36,610	Programmers and software development professionals
Agile Software Development	8,527	52,233	Programmers and software development professionals
Architecture	4,063	20,825	IT business analysts, architects and systems designers
C Sharp (Programming Language)	9,139	55,895	Programmers and software development professionals
Cascading Style Sheets (CSS)	7,355	37,072	Programmers and software development professionals
Cascading Style Sheets (CSS)	6,595	34,833	Web design and development professionals
Engineering	5,225	19,581	Production managers and directors in manufacturing
Engineering	4,024	19,047	Design and development engineers
Front End (Software Engineering)	4,180	18,950	Web design and development professionals
HyperText Markup Language (HTML)	5,795	27,502	Web design and development professionals
Information Security	5,746	31,580	Information technology and telecommunications professionals n.e.c.
Java (Programming Language)	7,597	51,410	Programmers and software development professionals
JavaScript (Programming Language)	9,367	58,289	Programmers and software development professionals
JavaScript (Programming Language)	6,085	35,705	Web design and development professionals
Management	11,090	36,621	Production managers and directors in manufacturing
Management	7,270	25,588	IT specialist managers
Management	5,049	21,665	IT business analysts, architects and systems designers
Management	5,552	23,371	Information technology and telecommunications professionals n.e.c.
Management	6,699	20,851	Quality assurance and regulatory professionals
Networking	4,718	18,837	Information technology and telecommunications professionals n.e.c.
Operations	5,924	18,146	Production managers and directors in manufacturing
PHP (Scripting Language)	3,565	18,095	Web design and development professionals
Server (Computer Science)	9,251	43,988	Programmers and software development professionals
Software Engineering	6,709	36,189	Programmers and software development professionals
SQL (Programming Language)	9,996	56,855	Programmers and software development professionals
Testing	7,892	39,175	Programmers and software development professionals
Web Development	3,774	20,291	Web design and development professionals

[a] *with more than 18,000 unique postings