CENTRE ON SKILLS, KNOWLEDGE AND ORGANISATIONAL PERFORMANCE

The Scale of 'Leakage' of Engineering Graduates from Starting Work in Engineering and its Implications for Public Policy and UK Manufacturing Sectors

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ABBREVIATIONS

ABI	Annual Business Inquiry
ABS	Annual Business Survey
AGCAS	Association of Graduate Careers Advisory Services
AISS	Alliance for Information Systems Skills
CRAC	Careers Research Advisory Centre (The Career Development Organisation)
DBIS (BIS)	Department for Business, Innovation and Skills
DfEE	(former) Department for Education and Employment
DHLE	Destinations of Leavers from Higher Education
DTI	(former) Department of Trade and Industry
HESA	Higher Education Statistics Agency
HESCU	Higher Education Career Services Unit
IEEE	(US) Institute of Electrical and Electronics Engineers
IET	Institution of Engineering and Technology
IMechE	Institution of Mechanical Engineers
ITNTO	Information Technology National Training Organisation
JACS3	Joint Academic Coding System Version 3.0
LFS	Labour Force Survey
MAC	Migration Advisory Committee
NIESR	National Institute for Economic and Social Research
NSF	(US) National Science Foundation
RAEng	Royal Academy of Engineering
SIC	Standard Industrial Classification
SOC	Standard Occupational Classification
STEM	science, technology, engineering, and mathematics
UKCES	UK Commission for Employment and Skills
UKESF	UK Electronics Skills Foundation

Abstract

The fact that not all graduates from vocational higher education courses go and work in the 'natural' profession or 'natural industry sector' corresponding to the course content is recognised. However, the *scale* of the 'leakage' of those completing engineering courses away from working in relevant engineering companies comes as a considerable surprise. The fraction of those graduating from particular engineering disciplines who go into the corresponding industry sector (in particular within manufacturing) is not only not 100 per cent, but generally less than 50 per cent and, in some cases, less than 10 per cent.

This paper presents evidence from the Higher Education Statistics Agency's (HESA) surveys, Destinations of Leavers from Higher Education (DHLE), over 10 years that shows just how invalid is the idealised 'linear pipeline' assumption that has prevailed (often by default) in much higher education skills supply thinking over recent years, and examines the implications. Any shortages, in a particular engineering manufacturing sector, of bright young people who might understand the engineering principles and technical details involved in that work, arise not from a lack of supply of such graduates as a whole but from the fact that most of them go and work elsewhere.

A default response focused on trying to get more (young) people to sign up for the corresponding higher education courses in order to tackle any shortages in individual manufacturing sectors would therefore generally be particularly wasteful from a policy point of view. An ultimately more effective response would rather be to work to significantly raise the attractiveness of the sector to students on the courses.

This paper also considers the natural response from a classical economics perspective – of urging engineering employers, if they perceive a supply shortage, to raise their starting salary offers to graduates. While plausible, this suggestion ignores the realities of the business model within the sector in the highly competitive market context in which these companies must trade. Their operating profit levels mean that engineering manufacturing companies cannot afford, as easily as employers in various other sectors can, to offer higher salaries: the market in which engineering employers recruiting graduates operate is not a 'level playing field'.

As well as examining aspects of the *reported skill shortage* context of the issue, the paper also throws light on answers to the questions that naturally follow a recognition of the comparatively large scale of leakage: Where *do* engineering graduates from particular disciplines go and work? What *other* disciplines are recruited by engineering firms? In addition, evidence from DLHE data on initial unemployment of graduates from different disciplines confirms that the shortages often asserted are not generally enough to put the corresponding labour markets into a particularly 'tight' state.

Evidence on role requirements from the Migration Advisory Committee suggests that such recent engineering skill shortages as are substantiated could not generally be directly resolved with 'fresh' graduates. The rather complex realities of engineering graduate recruitment outcomes uncovered by this analysis will help policy analysts realise the need for more robust evidence of market failure when considering possible policy responses attempting to link reported skill shortages in specific sectors to higher education flows into the workforce.

Scope of paper

This paper assesses initial destination sectors of (first degree) graduates from different engineering disciplines over recent years. It addresses three main areas:

- Clarification of the flows of engineering graduates from different disciplines into their first jobs in different industry sectors: new evidence is provided on both the sectors where most graduates from each discipline go and the engineering disciplines most recruited by each significant sector
- The implications of this evidence for employers and public policy analysts to concerns about shortages of supply of the technical skills from each discipline
- Provision of additional contextual information on the public policy considerations that arise from the implications, including (a) examination of skill shortages as perceived by employers in a sector; (b) evidence on the profitability of different recruiting sectors likely to affect the ability of employers in different sectors to increase starting salaries in the graduate recruitment market; and (c) evidence on the unemployment rate over recent years of engineering graduates from different disciplines

The paper does not:

- Examine information on the sectoral destinations of engineering graduates beyond the six months after graduation data provided by the HESA census on DLHE. This is mainly because the subsequent survey – three-and-a-half years after graduation – is not, because of insufficient sample size, able to provide evidence down to sufficient detail on sectors and subsectors
- Consider sector presence from engineering graduates in the *overall stock* of the UK workforce. While the Labour Force Survey (LFS) now gathers more detailed degree subject information than in the past, the sample size generally limits the granularity of LFS cross-tabulations down to the level examined with HESA DLHE data, particularly if trends over time are to be considered
- Examine information on flows of engineering graduates into engineering *occupations*,¹ rather than sectors, since the paper explores the *employer* perspective on the graduate recruitment labour market, which will vary significantly by sector

The contribution of the paper is therefore felt to be:

- Providing evidence for those interested in the graduate recruitment labour market of the development over the last 10 years of the sectoral destination of flows from engineering disciplines evidence which shows a number of counterintuitive patterns
- Showing how the realities of these flows substantially reduce the cost-effectiveness of the default policy response to perceived skill shortages in manufacturing sectors
- Overall, strengthening awareness of the importance of the time dimension in skills policy-making

¹ The possibility that initial occupations may not be technical is, however, considered.

1. INTRODUCTION

When students graduate from university, one of the most important life choices they make is where they start their working career. In the UK, as in other countries, that choice is influenced by many different factors. The first job taken by a graduate might not even be the start of a career – it might be a temporary job in a pub or fast-food restaurant or on a building site, to earn money to travel or spend on something special, perhaps a wedding.

A whole range of factors influences these decisions, and views of policy or industry strategists about where a graduate 'should' go and work, while perhaps understandable, are generally of little consequence. That was true even before the substantial real cost of the human capital investment in higher education began to be covered less by the state and increasingly by the student him/herself, or indeed before more graduates than ever before failed to gain employment after completing their degrees.

The issue of leakage from vocational degree courses is recognised in principle in relation to engineering (DBIS 2013) and to science, technology, engineering, and mathematics (STEM) more broadly (see, for example, DBIS 2011), and evidence of the scale of the problem is now beginning to be recognised (UK-CES 2013). EngineeringUK publishes a range of detailed analyses of first destinations of engineering graduates in its annual assessment of engineering in the UK and beyond (for example, EngineeringUK 2015), but does not show sector destinations down to individual manufacturing industries or consider the *fractions* of flows from each engineering discipline to each sector, which can help quickly identify the key patterns.

So, where *do* graduates go and work after gaining their degrees? The default assumption is often that, where the degree could be considered to be vocational (the usual examples relate to the better-known professions: medicine, law, accountancy, engineering, etc.), the norm would be for the graduate to start a career in the relevant profession/occupation and/or sector. Thus, for example, people tend to assume that law graduates go on into the law (whether in a law firm or as legal executives within some other organisation), and accountancy graduates go into finance/accounting (again, sometimes within accountancy companies or as bookkeepers, credit controllers, or accountants in other types of employer). Of course, those who have had the opportunity of a university education generally know cases where this has not happened – friends who have 'gone on to something completely different', but the default assumption nevertheless persists.

In reality, this linear pipeline assumption – where the body of knowledge acquired from the degree would be directly applied in the first job – is a long way from the truth, and the main purpose of this paper is to explore evidence that leakage of engineering graduates from relevant engineering sectors generally represents a majority, rather than a small minority, of the initial flows into work, and to examine the implications of this on conclusions that might be drawn for a policy or sectoral response to reported shortages.

The paper examines and maps in more detail than before the available evidence on the flows of students graduating from engineering degrees in the UK into work. From the HESA datasets on DLHE² it is possible to examine these flows in considerable detail for the UK – no such rich datasets are available in most other countries. While there are a considerable number of variables within the DLHE datasets, this analysis focuses particularly on the *sector*, or industry, in which new engineering graduates go and work, as classified in the UK's Standard Industrial Classification (SIC). The other indicator of the type of work new graduates enter that is available from DLHE datasets is the *occupation*. While in some ways even more important – in terms of what the graduates actually do – than the sector, occupational data does not enable us to cross-compare the experience and perspectives of *employers* on these flows, which is, of course, of paramount importance if the analysis is to tell us how this labour market is operating. As will be seen, the situation of employers in different sectors can vary considerably, so that employer perspectives must be considered *by industry*. Above all, it enables investigation of interactions between employers and jobseekers, allowing us to consider possible *market failures* about which economic policy might reasonably have concerns.

Clearly, in principle engineering graduates can go for their first job into an engineering sector (by being recruited by engineering employers) or into some other sector. Likewise, other graduates can get taken on by engineering employers, or by employers from other sectors. This basic structure of the graduate recruitment market is shown in Figure 1.

Figure 1: Flows of new graduates into different sectors



This general structure can also be applied in greater detail to specialisations within engineering, for example showing where graduates of aeronautical engineering go: some will go into aerospace manufacturing; others will go and work in sectors or industries that have nothing to do with aircraft³ (see Figure 2).

 $^{^2}$ This analysis uses data from the six-month DLHE survey (census) which covers the complete population: this includes students of UK *and* other EU domiciles. While the DLHE longitudinal survey (three-and-a-half years after leaving) has many attractions (in particular it provides a better indication of likely whole-career paths), it does not allow analysis at a fine enough grain of detail for this analysis, and the three additional years introduce a number of influences to career paths that can neither be known nor affected by policy.

³ It is true that, in addition to manufacturing there are sectors/industries where aeronautical engineering skills can be directly used, for example the airline industry, where significant teams of professional engineers and technicians help keep planes in the air and operational delays to a minimum. In addition, relevant engineering knowledge is required in various parts of the 'professional, scientific and technical sector' SIC category (for example, engineering consultancies). The key point is that the workings of the labour market for new graduates can only be understood by considering the perspectives of both the graduates and the recruiting employers.

Figure 2: Flows of new graduates into different subsectors: aerospace

ORIGIN OF FLOWS	DESTINATION OF FLOWS
Graduates from aeronautical engineering courses	Aerospace engineering manufacturing employers
Graduates from other courses	Other employers

Likewise with other engineering disciplines – marine engineering/naval architecture, electrical engineering, electronic engineering, automotive engineering, other⁴ mechanical engineering, chemical engineering, civil engineering, etc. In most cases the technical knowledge of the graduates in the specific 'narrow flows' into the manufacturing subsector(s) from the relevant engineering disciplines(s) is not the only technical understanding required in a particular sector. Thus, aerospace manufacturing requires, as well as knowledge and understanding of aeronautical engineering, expertise in electronic and hydraulic systems (of which there are many in an aircraft), as well as in the detailed workings of the highly complex mechanical engineering of the craft's engines – in other words, a broader flow of technical graduates is often needed.⁵ The contribution of each engineering discipline to manufacturing of products more directly associated with a different discipline is undoubtedly valuable, but, nevertheless, the policy debate in this area so far has generally focused on the 'narrow flows'.

Section 2 examines the scale of the 'natural flows' (the 'linear pipelines' – that is, recruitment by employers in a particular manufacturing subsector of engineering graduates from the corresponding 'natural' engineering discipline) by examination of the *fraction* of those from each discipline gaining employment anywhere that go into each relevant sector or subsector. These 'natural flows' are:

- Aerospace engineering graduates entering companies in SIC 30.3 (manufacture of air and spacecraft and related machinery)
- Automotive engineering graduates entering companies in SIC 29 (manufacture of motor vehicles, trailers and semi-trailers)
- Other mechanical engineering graduates entering companies in SIC 28 (manufacture of machinery and equipment)
- Chemical engineering graduates entering companies in SIC 20 (manufacture of chemicals and chemical products)
- Electrical engineering graduates entering companies in SIC 27 (manufacture of electrical equipment)

⁴ Automotive engineering is currently classified within mechanical engineering.

⁵ Often, of course, the value chain associated with manufacturing means that systems that go into a modern aircraft are often built by companies in other sectors (subcontractors – for example, electronic or electrical engineering manufacturing companies) and installed at a later stage.

- Electronic engineering graduates entering companies in SIC 26 (manufacture of computer, electronic, and optical products)
- Naval architecture graduates entering companies in SIC 30.1 (building of ships and boats)

It is necessary when considering these 'natural' flows to decide how to account for flows of graduates from *production and manufacturing* engineering courses. It could be argued that the natural destination of such graduates would be any kind of manufacturing. If the flows of these graduates into the specific subsectors were included in the flows from the other natural engineering source discipline (for example, electronic engineering for manufacturing of electronics products), the resulting leakage measure would inevitably be different from the fractions if such flows were not included.⁶

The surprise that is often felt when the scale of such leakage becomes clear is quickly followed by two questions:

- If graduates of the specific engineering discipline mostly do not go into the natural subsector, where *do* they go and work?
- What other graduates do engineering companies recruit?

The details of the flows from the different engineering disciplines into different engineering sectors are examined in Section 3, and the answers to these questions are explored in sections 4 and 5.

⁶ The percentage of engineering graduates in employment in, say, automotive manufacturing from the 'natural' sources would, if production and manufacturing engineering were included, be a *combination* of the percentage of automotive engineering graduates who are recruited into automotive manufacture and the percentage of production and manufacturing engineering graduates recruited into that subsector. Since those graduating from production and manufacturing engineering products (for example, 'supply' *all* the different subsectors of engineering manufacturing and manufacturing of non-engineering products (for example, food and beverages, or pharmaceuticals), it is likely that the fractions going into any one subsector would be comparatively low, so that, if the production and manufacturing fractions are included in the percentage figures, the combined fractions would be expected to be reduced, as compared with the fractions of those coming from the courses on the corresponding specific engineering discipline. The analysis in this paper therefore does not include those flows, but figures for the earlier years examined (2002–3 to 2006–7), with the production and manufacturing engineering flows included, confirm that the leakage is even greater.

2. SUMMARY FINDINGS: THE HESA/DLHE EVIDENCE FROM 2002–3 TO 2011–12

The overall nature of the flows in graduate recruitment is best understood by considering the fraction (percentage) of those graduating⁷ from each engineering degree course entering employment who go into the 'natural' sector.⁸ These are shown in Figure 3.



⁷ All HESA DLHE data in this paper is for first degrees. Leakage from the corresponding taught post-graduate courses – expected to be much less – will be examined in a subsequent analysis.

⁸ The fluctuations between years are greater for smaller flows, in particular automotive engineering (between 140 and 302 each year) and naval architecture (22–43 each year).

As can be seen, over the last 10 years, in all cases fewer than half of the employed graduates from each engineering discipline are recruited by the corresponding manufacturing sector. In general the fraction is less than a quarter, and for chemical engineering, electronic engineering, other mechanical engineering, and electrical engineering graduates, the fraction who find work within six months of graduation in the 'natural' manufacturing subsector is generally less than 10 per cent.

3. GRADUATE SUPPLY: FLOWS FROM ENGINEERING DISCIPLINES INTO ENGINEERING SECTORS

As will be seen, in reality graduates from different engineering disciplines go and work in a large number of different sectors (EngineeringUK 2015 provides a wealth of additional detail). This section examines in more detail, within the relevant official classifications, the specific engineering disciplines that relate directly to the various engineering industry sectors/subsectors, and sections 4 and 5 of this paper examine, respectively, the most significant proportions of employed graduates from each discipline who start work in different sectors, and the most significant proportions of graduates from the different disciplines who, six months after graduation, work in each of the engineering sectors. Figure 4 shows the two perspectives (origins and destinations) for the case of three discipline-manufacturing sector 'pairs'.

ENGINEERING DISCIPLINES			MANUFACTURING SECTORS
Civil engineering			Construction
Mechanical engineering	% of mechanical engineering graduates	% of engineering graduates recruited into	Machinery
Aerospace engineering	% of aerospace engineering graduates	% of engineering graduates recruited into	Air and spacecraft
Naval architecture	% of naval architecture engineering graduates	% of engineering graduates recruited into	Ships and boats
Automotive engineering	(See section 4)	(See section 5)	Motor vehicles
Electronic engineering			Electronic products
Electrical engineering			Electrical equipment
Production and manu- facturing			All manufacturing
Chemical engineering			Chemicals and chemical products

Figure 4: Flows from engineering courses into manufacturing subsectors

The categories shown are, for the engineering course disciplines, those of the (HESA/UCAS) Joint Academic Coding System Version 3.0 (JACS3⁹) and, for the sectors, the SIC – from 2002–3 to 2006–7: SIC 92 (~ SIC 03), and from 2007–8 to 2011-12: SIC 07.

The main focus of this paper is on the need for specialist engineering graduates with relevant technical expertise to that required in the corresponding subsectors of manufacturing. However, there are also needs for disciplinary engineering expertise within engineering companies beyond manufacturing. In particular, there are the companies classified within SIC 07 Section M: 'professional, scientific and technical activities'. This contains businesses providing a wide range of technical expertise and services, including: legal and accounting activities; architectural and engineering activities; technical testing and analysis; scientific research and development; advertising and market research; other professional, scientific and technical activities; and veterinary activities. In principle, the consultancy work of individual (freelance) professional engineers is covered within these categories, but so is the work of sizeable engineering consultancy companies (for example, Mott McDonald, Ove Arup and W.S. Atkins). Within SIC Section M, those businesses explicitly active in engineering, which might be thought of as 'engineering consultancies', include those engaged in:

71.12 Engineering activities and related technical consultancy

71.12/1 Engineering design activities for industrial process and production

71.12/2 Engineering related scientific and technical consulting activities

...

. . .

71.12/9 Other engineering activities (not including engineering design for industrial process and production or engineering related scientific and technical consulting activities)

71.20 Technical testing and analysis

72.19 Other research and experimental development on natural sciences and engineering

74.90 Other professional, scientific and technical activities n.e.c.
 74.90/1 Environmental consulting activities
 74.90/2 Quantity surveying activities

...

74.90/9 Other professional, scientific and technical activities (not including environmental consultancy or quantity surveying) n.e.c.

It is worth reflecting that the *outsourcing* process results in work that was previously done in-house – for example, by a manufacturing company – being bought in from a supplier. In principle, each outsourcing step would result in an *increase* in activity, and therefore staff, in the supply company (in this case often a subcontractor or consultancy), and a corresponding *decrease* in activity, and therefore staff, in the original

⁹ It is important to note that the main disciplinary groupings chosen for the JACS classification of engineering codes (category 'H') do not all correspond directly to the engineering disciplines of direct relevance to the corresponding manufacturing subsectors: in particular, 'automotive engineering' is a subcategory of the 'mechanical engineering' group of courses (H300), and 'electrical and electronic engineering' – largely involving different technologies and physical principles – are combined, together with other subdisciplines, in an integrated 'electronic and electrical engineering' group (H600). While some other mechanical engineers may be directly useful in the automotive manufacturing sector, some would not, and likewise for the usefulness of electronic engineers in electrical product manufacturing and electrical engineers for the manufacturing of electronic products.

firm. To the extent that outsourcing has increased over the period examined, this effect could be influencing some of the trends shown in sections 4 and 5.

As can be seen, in most cases the discipline of engineering involved is not indicated in the Section M SIC category, which limits the precision with which these subsectors can be examined in relation to particular engineering degrees, in terms of requirements for specific disciplinary knowledge. The main disciplines of engineering graduates entering professional, scientific and technical activities are shown in Section 5 (Figure 23).

4. WHERE DO GRADUATES FROM EACH ENGINEERING DISCIPLINE GO AND WORK?

The first reality that comes from the HESA DLHE evidence is that engineering graduates start work in a wide range of activities more or less right across the whole economy. Table 1 gives a good feel for this, showing, for the most recent year shown, the percentages of those employed from each of the seven JACS3 disciplinary engineering degree groups across the main 'destination' sectors: the seven manufacturing sectors that represent the 'natural destination' of graduates from the various JACS categories, plus an additional seven sectors which, overall, pick up the highest fractions of engineering graduates who do not go into manufacturing. It should be noted that the percentages of graduates from each JACS group across the main categories of the economy that are selected and shown in the first part of the table do not add up to 100 per cent. This is because there remain a number of other sectors (not shown) that take the small residual percentages (and likewise for the selected manufacturing subsectors in the bottom part of the table). Given this picture, the comparatively low percentages in individual manufacturing subsectors become less surprising. It should also be noted in passing (given concerns raised in recent years) that the fractions of engineering graduates who go into financial services are comparatively low.

This section and the next present a series of charts, showing the development of the *largest flows* of first-degree graduates from certain disciplines into certain sectors over the most recent 10 years for which data was available (2002–3 to 2011–12). This allows any significant trends in the data over this period to be seen at a glance (and enables quick checks for possible calculation errors in any particular year). Unfortunately, one of the two measurement frames – the official classification of industrial sectors (the SIC) – was updated in 2007, and the new version was therefore used for the HESA DLHE from 2007–8 onwards. While the SIC 2007 update maintained the same scope for the vast majority of sectors and subsectors, the scope of some of the sectors and subsectors considered in this analysis was restructured from the previous version. This makes it essential to recognise that, in some cases, the data before and after the change of SIC in 2007–8 are not directly comparable. Where a subsector being analysed is treated differently by the initial (SIC92/SIC2003) and subsequent (SIC07) classifications, no line is shown joining the two annual data points, to make it clear that there is a 'break' in what is being measured.

Not all the trajectories in the charts move relatively smoothly over the 10 years. As might be expected, the percentage movement between years is generally greater when the numbers of the graduates in question are comparatively low. The numbers of graduates in employment after six months varies considerably between engineering disciplines: comparatively few students graduating in naval architecture start employment (22–43 over the 10 years), electrical engineering (a range of 23–57),¹⁰ and, to a lesser extent, automotive engineering (140–302). The ranges of the total flows for each of the disciplines are shown in the titles of each chart in this section, and the size of the flows into sectors are shown in the chart titles in Section 5.

As mentioned, each chart shows the *highest* flows: in general, development of the top four or top five flows (including 'all manufacturing') over the 10 years are shown (with an additional flow shown if this is the 'expected'/natural flow) and the natural flow trajectory is highlighted with a thicker line.

¹⁰ These percentages are not 'statistically reliable' under HESA rounding methodology, nor are those for flows into 'the building of ships and boats' and 'manufacture of chemicals and chemical products'.

	Manufacturing (C)	Construction (F)	Professional, scientific and technical activities (M)	Wholesale and retail trade; repair of motor vehicles and motorcycles (G)	Transportation and storage (H)	Information and communication (J)	Financial and insurance activities (K)	Public administration and defence; compulsory social security (O)	Other sectors (SIC sections N, P, Q, R, S, T, U)	Total (selected sectors)	Grand total (all sectors)
Civil engineering (H200)	4.2%	25.3%	40.2%	2.3%	3.7%	2.1%	1.9%	5.2%	5.5%	90.4%	100%
Mechanical engineering (H300)	44.1%	2.1%	16.2%	6.3%	1.7%	2.5%	2.1%	2.9%	6.3%	84.2%	100%
Aerospace engineering (H400)	50.7%	1.1%	11.4%	6.1%	7.6%	3.5%	4.8%	4.1%	6.3%	95.7%	100%
Naval architecture (H500)	30.8%	3.8%	23.1%	3.8%	11.5%	0.0%	0.0%	0.0%	7.7%	80.8%	100%
Electronic and electrical engineering (H600)	24.7%	2.7%	11.5%	7.5%	2.5%	21.8%	3.0%	4.2%	10.7%	88.5%	100%
Production and manufacturing engineering (H700)	54.2%	3.1%	6.2%	11.8%	1.6%	4.4%	2.8%	0.9%	10.6%	95.6%	100%
Chemical engineering (H800)	28.8%	2.3%	23.3%	5.5%	0.5%	1.5%	3.3%	0.8%	5.8%	71.5%	100%

 Table 1: Distribution of engineering graduates from the main JACS3 groups into the main sectors of the economy (2011–12)

	Manufacturing (C)		Manufacture of chemicals and chemical products (20)	Manufacture of computer, electronic and optical products (26)	Manufacture of electrical equipment (27)	Manufacture of machinery and equipment n.e.c. (28)	Manufacture of motor vehicles, trailers and semi-trailers (29)	Building of ships and boats (30.1)	Manufacture of air and spacecraft and related machinery (30.3)	Total selected manufacturing subsectors	Grand total (all manufacturing)
Civil engineering (H200)	4.2%		0.0%	0.6%	0.2%	0.3%	0.1%	0.1%	0.2%	1.4%	4.2%
Mechanical engineering (H300)	44.1%	and	1.1%	1.9%	1.1%	6.9%	12.9%	0.5%	6.6%	30.9%	44.1%
Aerospace engineering (H400)	50.7%	within	0.0%	0.9%	0.9%	3.5%	6.3%	0.2%	25.6%	37.5%	50.7%
Naval architecture (H500)	30.8%	manufacturing:	0.0%	0.0%	0.0%	0.0%	0.0%	16.7%	0.0%	16.7%	30.8%
Electronic and electrical engineering (H600)	24.7%		0.3%	7.0%	2.0%	2.0%	3.3%	0.1%	2.4%	17.0%	24.7%
Production and manufacturing engineering (H700)	54.2%		1.5%	2.1%	4.5%	4.2%	14.6%	0.3%	8.9%	36.0%	54.2%
Chemical engineering (H800)	28.8%]	7.0%	1.9%	0.7%	1.5%	1.2%	0.0%	0.7%	13.1%	28.8%

The following charts, figures 5–13, show the development over the most recent 10 years for which data was available of the percentages of graduates in employment from each of the disciplinary categories that go into each of the sectors that take significant fractions of each.



















In some cases these results are 'predictable' (for example, with the largest fraction of aerospace engineering graduates going into manufacture of air and spacecraft and related machinery over the whole period (Figure 8), and more or less the same (Figure 7) for automotive engineering graduates going into manufacture of motor vehicles, trainers, and semi-trainers), but in others less so.

Fewer than 10% of mechanical engineering graduates (not including automotive engineering) go and work (Figure 6) in manufacture of machinery and equipment n.e.c. (the fifth-highest flow of these graduates).

The flows of electrical engineering graduates into manufacture of electrical equipment (Figure 10) are so low over the 10 years that they do not even make the top five.

Flows of electronic engineering graduates into manufacture of computer, electronics, and optical products are the lowest of the top five flows of these graduates (Figure 11).

The flows of chemical engineers into manufacture of chemicals and chemical products (Figure 13) are below those going into professional scientific, and technical activities, or mining and quarrying, and those into the manufacturing of pharmaceutical or coke and refined petroleum products do not make the top five.

5. WHICH ENGINEERING DISCIPLINES DO THE DIFFERENT SECTORS RECRUIT FROM?

This section (figures 14–23) shows the flows from 2002–3 to 2011–12 from the perspectives of the receiving employers: the percentages of the engineering graduates recruited by each sector that come from the main disciplines relevant for the technical activity in that sector.





















In some cases these results are as might be expected (for example, with significant recruitment of civil engineering graduates into the construction sector (Figure 14), and of chemical engineering graduates into chemical manufacturing (Figure 16), but in others less so.

More mechanical engineering than naval architecture graduates are recruited into shipbuilding (Figure 21); as many mechanical engineering graduates are taken on in the manufacture of air- and spacecraft as aerospace engineering graduates (Figure 22). Fewer graduates of production and manufacturing engineering courses are taken on in manufacturing as a whole than graduates from mechanical engineering (Figure 15).

The disciplines most in demand in the professional, scientific, and technical services subsectors are evidently civil and mechanical engineering (Figure 23).

6. INTERPRETATIONS AND IMPLICATIONS

The above evidence confirms that (a) engineering graduates are evidently valued in many sectors of the economy; and (b) the 'linear pipeline' assumption widely made thus far for flows from engineering higher education courses into 'the manufacturing subsector that would be expected' is fundamentally flawed. There *is* certain awareness of leakage within skills policy: DBIS (2011) concluded, in relation to STEM graduates in 'non-STEM' work, that 'The research has called into question the widespread assumption that STEM students expect themselves to become STEM workers/employees. This "default" career direction is clearly not what many STEM students or graduates have in mind or are adhering to. The situation is more complex and career paths less simple and less predictable than generally thought.' However, the *scale* of the

leakage for engineering disciplines is still surprising: the fraction of graduates from such courses entering employment who follow this expected linear path is below 50 per cent, generally well below, and for some disciplines below 10 per cent. And, in terms of the total number of graduates completing the degree courses, these fractions are in fact *higher* than what is actually happening, since not all graduates gain employment within six months of graduation. The corresponding fractions of all who graduate from the course in question are, therefore, even lower. Worse still, all the figures relate to sectors rather than occupations. This means that not all those in the sector involved will be in technical occupations: some will be working in, for example, sales or marketing roles within the engineering manufacturing sector being considered. Thus, while useful contributions will no doubt still be made, the fractions of those with particular engineering degrees who will draw, more than superficially, on the knowledge and understanding from their degree courses will be lower still than the percentages shown. The higher the level of leakage, the more wasteful any investment in more 'course starters' in support of the corresponding sector would be by the time the cohort arrives on the labour market. With the maximum expected returns to that sector being as low as this, public investment in support of a particular sector would be difficult to justify through efforts to recruit more people onto the relevant courses. While the engineering graduates who gain employment elsewhere are contributing to the economy, so are those from other courses (including those beyond engineering and STEM), and special pleading for these courses could evidently not be justified in terms of effectively responding to any particular skill shortages in a corresponding sector, or indeed of a possible market failure.

Electronics provides a particularly intriguing example, with the fraction of electronic engineering graduates entering electronics manufacture in the last few years being around 7–8 per cent. This reality is of particular interest given that concern about perceived skill shortages in electronics manufacturing and falling numbers of relevant graduates for what is often viewed as a strategic sector led to the recent establishment of the UK Electronics Skills Foundation. The UKESF was set up (with government support):

- To address the threat of diminishing skills capability in the UK electronics sector UKESF is addressing the risk posed by the significant decline in the numbers of UK students accepting places on Electronic Engineering degree courses.
- To secure a sustainable supply of quality and industry-prepared graduates UKESF is helping to attract, prepare and retain talent for the UK electronics industry to maintain and grow its global leadership position [see www.ukesf.org].

While concerted action by any industry to tackle its perceived skill shortages is to be applauded, and the second objective is laudable, it is both interesting, and no surprise given the default assumption, that the response to the first objective is focused on tackling the 'risk posed by the significant decline in the numbers of UK students accepting places on Electronic engineering degree courses' (see www.ukesf.org), as well as trying to find a way of attracting some of the more than 90 per cent of employed electronic engineering graduates flowing into the labour market who decide not to go and work in the sector. With such a high level of leakage of these graduates, presumably the logical reaction would be for policy *not* to respond to the problems of a sector in this situation, especially with support from public funds.

The issue of *relevance of work in the sector to the degree discipline* is clearly central to these considerations. Each engineering discipline covers a considerable body of knowledge, and the technical specifics of work in engineering cover a significant number of highly specialised work areas. The appendix gives an illustration of the wide range of 'broad work areas' directly relevant to some of the main engineering disciplines, and shows examples of some specific activities (these relate to safety-critical work) within some of these broad work areas. Professional engineers in a traditional technical career would spend much of their working life in one such broad work area (or at most several). In reality, expertise is needed in a very large, and growing, number of highly technical areas – very many times more than the number of engineering disciplines. While the broader engineering principles learned on a good degree course remain valuable, the technical relevance of a specialist vocational degree therefore needs to be examined at a rather specific level.

This evidence of surprisingly low entry into the 'expected/relevant sector' inevitably raises the question *why*? (especially if such flows are, from an overall economic policy point of view, viewed as being strategically important for that sector). As pointed out at the outset, these flows arise from what goes on in a market. A new graduate has certain capabilities to offer to a recruiting employer, and each graduate will, in considering his/her options on graduation, have a perception of the relative attractions of working for that employer, as compared with others. Some employers in the relevant industry will be looking for graduates from such courses, and some will not (for example, most graduate recruitment is from larger employers). So, not all employers in that sector will be seeking these graduates, and not all such graduates will be looking for such graduates meet them, and when such graduates meet the recruiting employers – the result of the encounter may not be a job offer that is accepted. In short, as with any labour market (or indeed any social encounter), 'it takes two to tango', and in many cases the mutual attractiveness of the two parties may simply not be sufficient to lead to a will on both sides to get together.

Thus, the 'natural' sector for those graduating from a particular vocational course may not turn out to be particularly attractive to the graduates, whether because of impressions formed during the course, initial encounters with potential employers, or for some other reason. Likewise, for those employers who do decide to (try to) recruit from those who have completed the 'relevant' course, the candidates they see may turn out, for whatever reason, not to be sufficiently attractive, or to command, in the recruiting employer's mind, enough confidence that they would fit into the team and make a valuable contribution.

There are a number of reasons why employers might be disappointed with graduate candidates, and employer surveys of skill needs regularly show up complaints about perceived shortcomings in new graduates' capabilities. There are often mentions of lack of understanding of basic scientific or engineering principles, or lack of practical skills, and in the past concerns have been raised that some graduates lack adequate awareness of, or respect for, business realities and the profit motive. From the point of view of the job-seeking graduate, some engineering employer working environments are perceived to be less attractive, with concerns sometimes expressed about out-of-date equipment and dirty or old workplaces, and/or perhaps employer attitudes that are perceived to be uninspiring or unsympathetic.

In addition, of course, some employers complain that new graduates lack experience, although this is not entirely surprising, since by that age many young people have simply not had an opportunity to gain significant experience.

These are the kinds of realities that can play a role in explaining the scale of leakage.

If the cause of any potential lack of supply for the 'natural' sector is insufficient attractiveness of work in that industry, then, in principle, the most meaningful response, particularly from the public policy point of view, would be effort from the recruiting companies, and, in principle, from the leading sector employers as a whole, to get across to final-year (and probably also penultimate-year) undergraduate students a more attractive image of the sector as a place to work. The need for such a sector promotion response by employers is recognised by policymakers and recommended in both MAC (2013) and DBIS (2013). Clearly, if the sector involved is one selected for support in the context of an (active) industrial strategy, then public funds could more reasonably be deployed in support of any promotional campaigns agreed within the sector, although public support for promoting more people to sign up for a relevant degree course would nevertheless remain a comparatively ineffective, if not wasteful, option.

DBIS (2011) explored in some detail the factors that result in STEM graduates being in non-STEM work, and pointed out, among other things, that some who start engineering degrees do not view the course as a pathway to engineering work, but simply as a field of interest, and proceed with, and generally enjoy, the course with no intention of pursuing an engineering career. Courses may be vocational, but those who take them may not always do so in pursuit of the vocation! However, the evident limits to the mutual attractiveness of employer and candidate are large enough that, if the scale of leakage is felt to be sufficiently 'wasteful', then light could be thrown on the situation and the nature of lack of attractiveness through serious survey work on the two sides. Thus, a thorough survey of perceptions of engineering students – in particular in their last year, but probably also in previous years – about work in the 'natural' sector for that course, together with a more comprehensive survey of employer experience in graduate recruitment than has recently been carried out in this area,¹¹ would help establish what is going on – the key cause(s) for each discipline of the leakage. Without such evidence, policy conclusions about the underlying causes of the problem of leakage and how they should be tackled (if this were cost-justified) would be ill-advised.

7. THE PLAUSIBLE RESPONSE FROM ECONOMIC THEORY

The most obvious way to increase the attractiveness of work to potential graduate applicants is generally assumed to be through increasing its financial remuneration. This continues to be the first response of economists, and some others outside the industry, to reports of recruitment problems by engineering companies: 'If engineering companies want more of the best engineering graduates, they should offer higher salaries...!'

¹¹ A thorough survey of this type in respect of information technology graduate recruitment was carried out, in 1999, by the Alliance for Information Systems Skills and the Information Technology National Training Organisation (AISS/ITNTO 1999).

At first sight this is plausible. Employers, particularly large ones operating in global markets, increasingly accept that the 'battle for talent' is both a global competition, and ever more important – as important sometimes for a business as the battle for market share. So why don't engineering employers raise their graduate starting salaries? Mason (1999) has suggested that one reason might be that human resource management traditions in engineering companies have involved 'internal labour market' considerations with a much greater weight given than in other sectors to salary comparabilities with existing staff. However, on closer consideration it emerges that there is not a 'level playing field' for graduate recruiters. There are, of course, always issues with employers trying to increase salaries to be able to recruit better talent: two major factors are comparability with existing employee salaries, and constraints on cost levels imposed by the business model, market positioning, and the need to keep a business's product/service price competitive.

As already mentioned, engineering graduates are often perceived to be useful 'catches' in many sectors of the economy, even where little engineering activity is directly involved. Thus, in principle, a good engineering graduate might be presented with opportunities for a career start in many different sectors.



Figure 24: Competition for engineering graduates: the recruitment market 'playing field'

There are, however, important differences in the business and cost realities of employers in different sectors, and these can lead to factors that might influence a graduate when considering work, and perhaps job offers, in those sectors. While there are generally certain broad 'going rates' for graduate starting salaries (see HESCU/AGCAS 2014), these could vary considerably for an engineering graduate between sectors. Although starting salary is only one dimension of the attractiveness of an offer, it is always a significant one and is increasingly important for a young labour market entrant in a world of high, and rising, property prices.

Differences in (average) starting salaries between sectors (for a particular type of graduate) can occur for different reasons, but inevitably both going rates for a graduate entrant and a company's ability to increase an offer beyond the prevailing going rate will depend on the financial flexibility of that company, and this, in turn, will depend on the level of the employer's profitability. Where there are significant variations in average profitability between sectors, these differences will therefore result in the competitive playing field for graduate recruitment not being level. Where sector profitability is comparatively high, go-

ing rates for fresh graduates in a sector will be able to be higher than where profit margins are under strong – generally international – competitive pressure.

The widely perceived extreme case is the recruitment of talented graduates from science and engineering courses by financial services companies. Such graduates are generally comfortable, and capable, with quantitative analysis, which is important in a number of areas of financial services. While starting salaries in financial services can be very attractive, the leakage of STEM graduates into 'the City' is, in reality, much less than often assumed (less than 5 per cent of those who got jobs in 2011–12 for the engineering disciplines considered – see Table 1 in Section 4). However, the variation between sectors in terms of their ability to pay higher salaries to lure talent can be significant. One way of exploring this empirically is to consider the different levels of pay flexibility within different sectors that arise from variations in average profitability levels between them. While profitability cannot be taken fully out of the sectoral context (there are reasons for differences between sectors, and 'sectoral traditions' for how profits are deployed), in the final analysis it is an important measure of flexibility for employers to be able to respond to market conditions, including labour market competition for the best talent.

Average profitability for sectors can be estimated from Office for National Statistics data on sector financial information of, in particular, the former Annual Business Inquiry (ABI) and the Annual Business Survey (ABS) that followed it. ABI and ABS provide, for a wide range of industry sectors and subsectors (though not for financial services), data for the following variables:

- Total turnover
- Gross added value
- Employment costs
- Capital expenditure

Average sector profitability can be estimated as:

• Pre-tax operating surplus (gross added value less employment costs) as a fraction of total turnover

Pre-tax gross surplus would be:

• Operating surplus less capital expenditure¹² as a fraction of total turnover

The development of these two indicators is shown in figures 25–28 over more than a decade:

- For the non-financial business economy as a whole
- For UK manufacturing
- For real estate, renting, computers, and other business services¹³
- For legal, accounting, management consultancy, and other professional services

As can be seen, the overall average operating surplus, between 1996 and 2012, for the UK economy,

¹² Capital expenditure data is subject to timing errors.

¹³ The second two charts only show data up to 2007 – classification changes due to the introduction of SIC 2007 from 2008 onwards make direct comparisons with the 'real estate, renting, computers and other business services' sector and the 'legal work, accountancy, management consultancy and other professional services' subsector almost impossible.

not including financial services and public administration is $\sim 13-14$ per cent of turnover, while the average with capital expenditure deducted is about 9–10 per cent.

For UK manufacturing, the equivalent figures over this period are broadly similar to those, with a downward trend towards the end of the millennium, followed by a growth trend thereafter.

However, these estimates confirm that average profitability does indeed vary between sectors, with, for example, the corresponding average profits in 'real estate, renting, computers and other business services' more than five percentage points higher than for manufacturing, at around 20 per cent and 15 per cent of turnover. Profitability within 'legal work, accountancy, management consultancy and other professional services' has run another 10 points higher, at between 30 per cent and 35 per cent of turnover, with the gross surplus some 2–3 per cent lower.

Clearly the flexibility of employers in the 'real estate, renting, computers and other business services' and the 'legal work, accountancy, management consultancy and other professional services' sectors to be able to deploy substantial resources on salary increases in order to increase their attractiveness to new graduates without affecting the competitiveness of their services is *unequivocally greater* than that of employers in manufacturing.

Thus, the initial response of economic theory to perceived concerns about skill shortages – that is, for engineering employers to offer good graduates higher starting salaries – ignores certain crucial economic realities about sectoral differences.









The disadvantage of a manufacturing sector with real skill shortages, as compared with those in other sectors competing for such graduates, arising from the tighter profit margins necessary for them to compete effectively on the global market – in particular the disadvantage of manufacturing companies as compared with some services companies – is clearly an issue. The fact that the graduate recruitment market is, in this sense, not a level playing field could be argued in support of there being a (comparative) market failure. In this case, there would presumably be an argument for a public policy response – again, as in the case of a sector being deemed of strategic importance in the context of an industrial strategy – best involving support for efforts by the sector leadership to promote the attractiveness of working in the sector.

8. 'SHORTAGES OF ENGINEERING GRADUATES' IN A MARKET WHERE MANY CANNOT FIND WORK?

Not all graduates who seek work after completing their degrees manage to get jobs straight away. Not all engineering graduates who seek employment straight after graduation find work within six months. It is recognised that labour market conditions in the UK over recent years have posed real challenges to young people looking for work, even when they have a degree. Many factors have contributed to this, including both the general state of the labour market and employers continuing to seek – apparently paradoxically – young people with experience. At the level of the economy as a whole, there is a general acceptance that even where demand for skills is uniformly high, a certain residual level of unemployment will remain (although this is not acceptable in terms of policy rhetoric or desire for 'equality of opportunity'). This arises from a number of factors, and can be viewed in terms of the skill sets, and of the overall perceived potential value, of certain applicants for particular vacancies being below a minimum threshold. Employers may articulate

this in terms of certain applicants being simply 'not employable'. Thus, it is to be expected that, even where demand is generally high, some graduates, including a certain number of engineering graduates, will not manage to find work straight after graduation.

However, as with leakage from recruitment for work directly relevant to the content of the degree course, there remains a question about the *scale* of unemployment of engineering graduates that could prevail at the same time as shortages of relevant graduates are asserted. In reality, as explained, each recruitment transaction takes place within a specific context: a particular employer with specific skill needs and expectations, in a particular place with an existing team, offering a particular salary, and with a set of applicants. In addition, a wide range of human factors can play a role in the recruitment decision. However, in order for policy analysis to assess the realities of the engineering graduate recruitment labour market as a whole it is necessary to examine the unemployment rate of such people. Figure 29 shows the development over recent years of the percentage of economically active¹⁴ graduates with first degrees in each of the engineering disciplines considered above who are unemployed six months after graduation, and Figure 30 shows the numbers.



¹⁴ That is, not including 'those in further study' or those 'not available for employment'. While further study is generally a very satisfactory outcome from degree achievement, the numbers of those in that category are not relevant to the assessment of labour market conditions at the time.



The impact on the engineering graduate recruitment market of the 2008 credit crunch is clear, particularly for electronic and electrical engineering, mechanical engineering and, above all, civil engineering.

However, the two charts provide, between them, evidence that this labour market has not been particularly tight, especially over the last five years. It is true that some of the unemployed new graduates, while perhaps not 'unemployable', would inevitably be less attractive to recruiting employers in the ways noted in Section 6 (and, of course, like those who *did* get jobs, not all would want to deploy their specialist knowledge directly in their first job). However, with more than a hundred graduates unemployed each year over recent years, except for the courses with lowest numbers, and with the fractions of relevant economically active graduates still seeking work after six months far from negligible (in most cases more than 10 per cent), it is not easy to support serious arguments that there might be any substantial shortages of engineering graduates, in particular in aerospace, electronic, and electrical and chemical, process, and energy engineering. While the trend over the last few years is mostly downward, and will presumably continue to reduce as the economy picks up, many engineering graduates still fail to find jobs, and those who can't find work that directly uses what they have learned at University might well look elsewhere. HESCU/AGCAS (2014) concludes that 'many with Science and Technology degrees still find themselves in other jobs'.

In the light of this additional evidence, arguments attempting to get more people to take specific engineering courses based on a suggestion that 'there are not enough relevant graduates arriving on the labour market' would be difficult to justify, above all if use of any – increasingly scarce – public funds were to be considered in support of such an approach. Flows into engineering degree courses inevitably wax and wane. In some cases applications for a particular subject fall away as a result of perceptions (by those considering applying to university) of problems in the 'natural' sector corresponding to a particular course. It is hardly surprising that significant numbers of redundancies from relevant large engineering companies or, worse, plant closures that gain media attention, have some impact on school leavers' perceptions about future work opportunities and, therefore, selection decisions for higher education courses.

However, such thinking again draws on a linear pipeline assumption, and the DLHE evidence confirms that many employment opportunities exist even if the 'natural' sector were to suffer badly during the years of the course. From the employers' point of view, it is also understandable that leading figures in a sector might have concerns about falling application rates to the relevant courses (in essence, this is what has happened in relation to UKESF), but the evidence presented raises real questions about how significant falling inflows are for future supply to that sector.

Concern has often been raised about falls in applications to certain higher education courses: a significant fall in applications to computing courses in the early 2000s triggered common cause for concern between information technology companies and higher education computing departments. The focus was purely on the falling *numbers* of applications (the *change*), and the concern was that this would result in shortages for the sector that needed this expertise. The question of whether the previous numbers of graduates, or indeed the subsequent lower numbers, constituted a sufficient or insufficient supply for employer demand was *not* examined, the default assumption being that a fall in flows into, and therefore subsequently out of, higher education computing courses would result in a shortage. A moment's consideration of the interests of the two groups pressing for a response to the fall confirms that (a) it was in the direct interest of computing departments for flows into and through their courses to grow; and (b) the concerns of the sector depended, again, on the (now discredited) default assumption of the linear pipeline.

9. LESSONS FOR SKILLS POLICY AND RELEVANT SECTORS

9.1 Skills policy

What does this additional evidence tell policy analysts about possible responses to concerns in a sector about inadequate supply of relevant graduates (probably in the context of perceived shortage of skills)?

On the one hand a case could be made that there are no direct lessons for skills policy, or, rather, no need for a policy response. As is clear from the DLHE evidence – in particular shown in Section 4 – engineering graduates get recruited by employers in a wide range of sectors of the economy and, therefore, as much as any other new graduates, contribute to the production by that employer of goods or services for the marketplace, and/or to public sector work (in local or central government or to the UK defence forces), and so to the economy as a whole.

The various flows that take place represent the 'outcome' of the operation of the (engineering) graduate labour market. Section 7 points out one dimension of the differences between recruiting sectors: probable different abilities between sectors to raise starting salary offers in order to increase the attractive-

ness of work in a sector. Certainly, employers from different sectors are always in competition for the best graduates, whether engineering or not.

From a policy point of view, therefore, the key question would be: Is there anything wrong with these broad outcomes of this 'initial' labour market – ultimately, is there any market failure here that could justify some kind of policy response? How could this question be answered?

This is a market whose 'purpose' would, in principle, be to allocate the human resources of engineering graduates between different employers, according to their needs, and the assumption is that the price mechanism would help the market operate and make this happen. As indicated in Section 6, the outcomes arise from a large number of independent selection decisions between those seeking work (the engineering graduates) and those seeking these human resources (the recruiting employers). Are there, in this process, engineering graduates who would like to have worked somewhere different but were not able to, and/or are there employers who would have preferred to have recruited other, and/or more, such graduates? To the extent that skills policy generally takes as a starting point the human resources needs of employers (in order to reduce/eliminate constraints on growth of the businesses or public sector organisations, and, so, of employment), the usual consideration, and highest priority, would be whether employers are not finding enough ('good') engineering graduates. This brings us to the question of skill shortages – more precisely 'shortages of engineering graduates' as experienced (or perceived) by an employer, employers in a sector, or the economy as a whole.

How could the question of whether some employers would have liked to have recruited more engineering graduates from a particular discipline be clarified? While the DLHE numbers show what has happened, these flows tell us nothing about whether either some employers would like to have recruited more, or whether it would have been 'better' if some of the graduates who went to work in sector x had gone to work in sector y.

In addition, the analysis does not provide any information on whether, for example, some graduates from a particular engineering discipline might have wanted to get a job in the corresponding manufacturing subsector, but, because there were at the time simply not enough vacancies there, they had to take a job in a different sector (HESCU/AGCAS 2014).

The second point raises the question of (a) the relative shortages of engineering skills between different sectors; and (b) whether public policy might have preferences for certain sectors as compared with others, in respect of graduate recruitment. In principle it would be difficult to defend such preferences other than in the context of an (agreed national) industrial strategy (and indeed as between different priority sectors within an industrial policy).

In considering such questions, it is necessary to examine which qualities a recruiting employer is seeking in such graduates. Where an employer is not intending to use the specific knowledge of, for example, an electronic engineering graduate, but more his/her broader capability for quantitative analysis (or perhaps the understanding of rather broad engineering principles, or even the 'practical insights' of the engineering graduate), it could be argued that that employer would in principle be likely to be just as satisfied with, for example, a mechanical engineer or an electrical engineer. However, if an employer were recruiting

electronic engineering graduates to work in an electronic engineering occupation, then a mechanical engineer would presumably *not* be just as good. And, above all, if an employer in an electronic engineering sector (in particular SIC (07) '26 Manufacture of computer, electronic and optical products') is seeking someone with a certain understanding of electronic engineering principles and practice, then there is no doubt what specific engineering discipline would be required.

Thus, the different employers coming to the engineering graduate recruitment marketplace have key differences between sectors both in their relative 'ability to pay' and in the 'sets of skills' they are seeking. In that sense this market could be viewed as having non-trivial asymmetries that could amount to some kind of market failure. It is not, however, immediately obvious what policy response to try to improve the workings of the market and effectively tackle these problems could be.

The useful contribution engineering graduates evidently make well beyond engineering sectors does, in principle, raise a broader question for skills policy: Are there 'enough engineering graduates' appearing on the labour market for the economy as a whole? While all thresholds relating to skill shortages are ultimately arbitrary, in principle this question could be explored by examining relative unemployment rates for graduates from difference disciplines: clearly if the unemployment rates for, say, aerospace engineering graduates were higher¹⁵ than for, say, production and manufacturing engineering graduates, then it could presumably be said that if there were enough production and manufacturing engineering graduates for the economy. While this might lead to a view that young people should be generally encouraged to sign up on production and manufacturing engineering degree courses rather than aerospace engineering courses, this consideration cannot be restricted only to engineering (or indeed other STEM) courses and graduates. In principle, the unemployment rates of graduates from all subjects would need to be examined in response to a question about their value to the economy as a whole.

Exploring this line of argument a little further, it is worth remembering that a major initial shift of skills policy announced by the Coalition government in 2010 was an intention to move generally from 'command and control' to 'making the market work better'. While that thrust does not appear to have been fully sustained, it is worth considering what 'market improvement' might mean in this context. Presumably, in principle, the logic would be for those in secondary schools – and others considering what higher education course to apply for – to be provided with all the evidence available on unemployment rates for graduates of all the courses they are interested in. In general, (a) pupils in their last years at secondary school presumably have more information on employment prospects than ever before (though some of this might be more as between different higher education institutions than as between course subjects); and (b) employment prospects will – while increasingly important for young people – continue to represent only one factor in the multifaceted decision with which the young person is presented. Thus, while the 'economically optimal strategy' would appear to be for a young person to choose the subject with the lowest unemployment rate of all subjects, this would take no account of the other factors, in particular the subject(s) of greatest interest to the person making the decision. However, for a young person interested in engineering, the choice of production and manufacturing engineering rather than aerospace engineering because the chances of get-

¹⁵ The unemployment rates were approximately *twice as high* in 2011–12.

ting a job appear to be greater could be a plausible one, and the (any additional) cost of provision of this labour market information could indeed be considered to be a sensible market-catalysing investment. Such an arrangement would, of course, in principle result in 'feedback action' that would be 'market correcting'.

Unfortunately, there is a fundamental drawback to this market-catalysing approach, and this is the fact that the measure leading to the relative incentive and consequent action is invalid by virtue of it relating to *present* market conditions as opposed to the realities of market conditions when it matters for the young person, namely three to four years later, when they are seeking work. The 'learning pipeline duration' of the degree course corresponds to a 'pure time delay' within the overall dynamic system in the language of dynamical systems analysis and control engineering (where, for example, tackling control of the performance of, for example, a conveyor belt poses particularly challenging difficulties). Clearly, what is needed for this feedback to work would be reliable information on the supply–demand balance, and resulting recruitment prospects, for graduates from a subject *in three to four years' time*, and forecasting this with any confidence is, of course, particularly challenging. However, given the realities of changes in labour market demand over time – for example, demand in the information technology labour market has shown a number of particularly large swings over the decades of its development – action based on the current state of demand could, given such swings, prove seriously misguided. In addition, of course, demand forecasting takes place first and foremost within a sectoral framework, and the value of the corresponding assessment of implications for engineering graduate demand will again be hamstrung because of the realities of leakage.

Much of the UK skills policy debate is driven by perceived skill shortages. Few employers enjoy the luxury of immediate applications, in response to vacancy notices for skilled technical people, by several candidates, each of whom could do the job really well. And for employers under pressure to perform and deliver, a good new staff member in place and contributing effectively as soon as possible is what is needed. In particular, in the private sector many UK companies are under considerable competitive pressure, in a global marketplace, and delays in recruiting new staff can limit commercial agility and, so, competitiveness. These realities inevitably result in employers expressing their frustrations, and then, through industry or trade bodies, to strident 'representative voices' complaining of skill shortages and, often, to complaints about the capabilities of those leaving full time education (although labour market entrants are, of course, not the only source of supply of skills to an employer).

The challenge for skills policy, therefore, in identifying an appropriate and effective response, is *distinguishing between* different 'strident voices' reporting skill shortages in their sectors, and assessing, in as objective way as possible, how *serious* supply problems really are in the different parts of the economy.

Labour market conditions in engineering have been frequently reviewed: by researchers (for example, Mason 1999), sectoral skills bodies (for example, Semta 2009), and professional engineering institutions (for example, IMechE 2011). A thorough review of skills supply and demand for UK manufacturing was completed by a consortium of seven sector skills councils in 2012 (UKCES 2012). Generally, evidence of serious skills shortages is limited. IMechE (2011) concluded: 'The evidence available suggests that skills shortages in engineering are running broadly in line with the economy as a whole, despite anecdotal and perceptions-based views to the contrary.'

However, the most thorough and rigorous assessment in the UK of comparative levels of skill shortage across the economy has been provided over recent years by the work of the Migration Advisory Committee (MAC), whose official shortage occupation list is based on the most objective measures possible from currently available data sources. The MAC's approach to the comparative assessment of skill shortages between occupations and sectors is described in some depth in a number of Committee publications (the assessment methodology was thoroughly reviewed in MAC 2010), and it is notable that a number of limitations to the analysis are still acknowledged, in particular arising from the limits as to how fine-grain the occupational survey data is.

The debate thus far in UK skills policy about problems with the supply of engineering and other STEM graduates has generally been driven by often unsubstantiated assumptions that there is, or will in the coming years be, a shortage of graduates with the relevant skills/knowledge. Anecdotal evidence gained at Semta (the Sector Skills Council for Science, Engineering and Manufacturing Technologies) in recent years suggests that (a) few smaller employers recruit graduates; and (b) the larger employers who regularly recruit graduates generally do not report significant shortages of supply of engineering graduates of adequate 'quality'. Certainly, demand for people with these skillsets can change and will generally rise with periods of economic growth, but the evidence of Section 8 suggests this labour market has not been particularly tight over 10 years.

The MAC recently (September 2014) consulted on a further review of the official shortage occupation list. The existing list was published in February 2013, and the report describes claims made in the preceding months by a number of engineering employers and industry bodies ('bottom up' evidence¹⁶), not all of which were supported by the objective ('top down') evidence at the MAC's disposal and consequently accepted. In general, (a) employers and employer groups call for help with recruitment of skillsets that represent only a part of the 4-digit SOC categories for which objective (empirical) data is available; and (b) the 'job titles' considered by the MAC within each SOC category are generally only accepted onto the list within the specific subsectors represented by those arguing for recognition of shortage.

The position as of 2012–13 with engineering occupations is shown in the following tables: the occupations/subsectors shown were approved for the official shortage occupation list (MAC 2013).

Job titles in the 'civil engineer' category	Subsectors
'Geotechnical engineer' and 'tunnelling engineer'	Construction-related ground engineering industry
'Petroleum engineer', 'drilling engineer', 'completions engi- neer', 'fluids engineer', 'reservoir engineer', 'offshore and subsea engineer', 'control and instrument engineer', 'process safety engineer', and 'wells engineer	Oil and gas industry
'Senior mining engineer'	Mining sector

¹⁶ There were, in the MAC's February 2013 report, no engineering occupation categories assessed as being in shortage (irrespective of sector) from the (objective) 'top down' evidence.

MECHANICAL ENGINEERS

(All) Mechanical engineers in the oil and gas industry

ELECTRICAL ENGINEERS

(All) Electrical engineers in the oil and gas industry

Job titles in the 'electrical engineer' category	Subsectors
'Power system engineer, control engineer and protection engineer'	Electricity transmission and distribution industry
'Electrical machine design engineer' and 'power electronics engineer'	Aerospace industry

ELECTRONICS ENGINEERS

Job titles in the 'electronics engineer' category	Subsectors
'Signalling design manager', 'signalling design engineer', 'sig- nalling principles designer', 'senior signalling design checker', 'signalling design checker', and 'signalling systems engineer'	Railway industry
'Specialist electronics engineer'	Automotive manufacturing and design industry

DESIGN AND DEVELOPMENT ENGINEERS

Job titles within the 'design and development engineer' category	Subsectors
'Design engineer'	Electricity transmission and distribution industry
'Product development engineer', 'product design engineer'	Automotive manufacturing and design industry
'Integrated circuit design engineer', 'integrated circuit test engineer'	Electronics system (manufacturing) industry

PRODUCTION AND PROCESS ENGINEERS

(All) Chemical engineers

Job titles within the 'production and process engineer' category	Subsectors
'Manufacturing engineer (process planning)'	Aerospace industry
'Technical services representative'	Decommissioning and waste management areas of the nuclear industry

ENGINEERING PROFESSIONALS NOT ELSEWHERE CLASSIFIED (N.E.C.)

Job titles within the 'n.e.c.' category	Subsectors
'Project engineer' and 'proposals engineer'	Electricity transmission and distribution industry
'Aerothermal engineer', 'stress engineer', 'chief of engineer- ing', and 'advanced tool and fixturing engineer'	Aerospace industry
'Operations manager', 'decommissioning specialist manager', 'project/planning engineer', 'radioactive waste manager', and 'radiological protection adviser'	Decommissioning and waste management areas of the civil nuclear industry
'Nuclear safety case engineer', 'mechanical design engineer (pressure vessels)', 'piping design engineer', 'mechanical design engineer (stress)', and 'thermofluids/process engineer'	Civil nuclear industry

QUALITY CONTROL AND PLANNING ENGINEERS

Job titles within the 'quality control and planning engineer' category	Subsectors
'Planning/development engineer' and 'quality, health, safety and environment (QHSE) engineer'	Electricity transmission and distribution industry

ENGINEERING TECHNICIANS

Job titles within the 'engineering technician' category	Subsectors
'Commissioning engineer' and 'substation electrical engineer'	Electricity transmission and distribution industry

METAL-WORKING PRODUCTION AND MAINTENANCE FITTERS

Job titles within the 'metal-working production and maintenance fitter' category	Subsectors
'Licensed and military certifying engineer/inspector technician'	(Aerospace Industry?)

LINE REPAIRERS AND CABLE JOINERS

Job titles within the 'line repairer and cable joiner' category	Subsectors
'Overhead linesworker (high voltage only)'	Electricity transmission and distribution industry

It is worth noting that shortages reported to the MAC by employers are generally articulated as relating to the need for experienced engineers (as shown, in some cases 'senior' engineers), and in no cases were graduate engineers (or engineering graduates) put forward for consideration as being in shortage.

As will be seen, there is great specificity in the majority of the above categories (more specialised than any of the 'finest grain' SOC categories used by the MAC, generally only applying to specific sectors or subsectors, and even more technically specialised than the different work areas shown in the appendix). In addition, given the great importance in recruitment of practical experience, and understanding beyond academic bodies of knowledge, for many of the roles ('job titles'), (and in some cases the considerable

narrowness of the subsectors) it is really not surprising that the reported skills demand, and the shortages of supply reported to and accepted by the MAC, relate to something very different from a new graduate.

This is not entirely surprising, and the annual surveys of the Institution of Engineering and Technology (for example, IET 2014) confirm that twice as many respondents (~200 employers of engineering and information technology staff in the UK) experience problems in recruiting senior engineers as problems taking on engineering graduates. The general recruitment market is essentially something different from the graduate recruitment market. It is therefore crucial for policymaking to think carefully before trying to link the two.

In a different approach to these issues, the Royal Academy of Engineering examined (in RAEng 2012) the state of 'the market for engineering graduates' by reference to graduate premium estimates. Irrespective of the questions around the robustness of the graduate premium measure (in particular whether those who take engineering higher education courses would have earned less well *without* a degree), such calculations take no account of, and inherently say nothing about, the (supply/demand) state of the wide range of labour markets for engineering skills.

This is because – in addition to the significant amount of initial leakage evident from the HESA DLHE data – graduate premium calculations (can only) pick up the estimated lifetime earnings of engineering graduates, in whatever sectors and occupations these earnings are won. Thus, the career of an engineering graduate who starts work in engineering occupations and/or sectors may well involve, over the years, moves beyond either – the most obvious being into general management roles, but there are, in today's more flexible, less 'linear', careers, many more. This does not reduce the value of an engineering degree (if the assumptions about the premium calculation are accepted), but nor does it tell us anything about the state of the labour markets in the engineering occupations where the knowledge and understanding acquired in the degree course are directly used, and even less about labour market conditions in such occupations within engineering companies.

More broadly, a recent book on the science and engineering labour market realities in the US over recent decades by a respected demographer with extensive experience in the careers of engineers and scientists¹⁷ (Teitelbaum 2014) raises fundamental questions about claims of shortage, and suggests a number of reasons why shortage claims continue, in spite of evidence to the contrary: in particular pointing at effective lobbying by those with vested interests in a policy narrative of shortage in the skill area of importance to *them* (see Section 10).

Overall, the greatest risk in policy debates around this issue arises from the compounding of generally unsubstantiated *'supply shortage' concerns in a sector* by the default conclusion that what is then needed is to take steps to try to encourage more (young) people to apply to the relevant higher education courses. The above evidence proves that – should there be a shortage of supply of relevant 'graduate skills' into the industries being considered – in this case engineering – to state it baldly, as in the initial example of 'Electronic engineering' graduate flows into the 'Manufacturing of Electronic products':

¹⁷ Teitelbaum is senior fellow at, and former vice-president of, the Sloan Foundation, and former acting chairperson of the US Commission on International Migration.

If the fraction of graduates who go into the "natural" industry is, say, less than 10%, then, if, as a result of major promotional activities funded from taxpayers' money 100 additional entrants could be found for the relevant course, then – unless the initial employment patterns evident over recent years were to change significantly – the number of new recruits into the natural industry (at least) three years later, when the cohort arrives on the labour market, would be no more than 10.

In the sense of the 'precision' of a policy – or even sector – response, trying to increase flows into the corresponding higher education courses could, not unreasonably, be viewed as comparatively very wasteful.

Indeed the situation is even more unsatisfactory than the above percentages would suggest, since the (three-plus-year) delay arising from the learning pipeline involved means that the additional supply might not even be needed (or indeed might not be *enough*), since labour market conditions – particularly in advanced technology fields – can change substantially over that period of time. If the demand rises faster, that will reduce the relative supply even more, and if the demand eases (as has happened in the past with DTI investments in response to reported skill shortages) some of those who have completed the course may not get jobs.

9.2 Lessons for relevant manufacturing sectors

There are a number of issues influencing the perspectives of employers in specific manufacturing (sub) sectors, and in particular the 'leadership' of such sectors: made up in general of groups of senior representatives of large companies, often working through trade associations or industry bodies, and perhaps with help of some kind from policy.

- Is the problem a shortage of relevant technical skills or a shortage of relevant graduates? As indicated above, it will generally take months, in most cases longer, for labour market entrants perhaps particularly new graduates to be able to fill gaps of technical expertise in a company. In particular, what would be needed (in addition to the graduate developing a range of broader workplace skills) is deeper technical understanding of the specific specialist area for which expertise is needed, and, perhaps most important of all, for *sufficient direct experience* of the practical aspects of handling that technical area. Some employers are in a position both in terms of 'coping with the delay' and in terms of human resource development capability to 'turn a fresh graduate into a professional engineer making a significant contribution'. In general larger employers can do this, smaller ones are less able, and this is consistent with the evidence on fewer small companies recruiting graduates: in neither case does this happen quickly enough for the employer's current needs
- Does the sector have a shortage, or do certain employers within the sector have a shortage? To the extent that the rhetoric of 'staff being a company's most important asset' is true, and that there can be as much competition between companies for the best talent as there is for market share of their prod-

ucts, then the real issue is the *needs of each employer* in the sector,¹⁸ and this will inevitably lead to competitive relationships in relation to recruitment. This matters massively when action is required in terms of coming up with money for investment in promoting *work in the sector*. Does each employer (in particular the larger players) ultimately want the best graduates to perceive work in the sector to be attractive or *work in their company* to be attractive? The essence of free markets is that enterprises are indeed in competition, for human and other resources as well as for market share, and of course the keenest competition is felt with other companies in the sector rather than recruiting employers in other sectors, even though the latter may also be competitors for some of the same graduates

This leads to a fundamental issue about sector leadership in relation to skills. Given the realities of competition for talent within the sector, it is understandable that the sector leadership (whether in a trade association or government-established skills body) would tend to press for greater supply of relevant graduates (and others from the education system) rather than for trying to get companies in the sector to put their hands in their pockets for a publicity campaign to try to improve the attractiveness of the sector as a whole. Most companies would prefer to deploy any funds they might have for this purpose on *their own* promotion, and, if (even significant) major players do not contribute to a sector campaign, they would stand to benefit from the campaign promoting the sector without having contributed.

Overall, in terms of lessons for relevant manufacturing sectors, what this DLHE evidence tells us about what is going on and how employers are recruiting could be summarised in three succinct, practical ways:

- Although many graduates from each engineering discipline go into sectors where the technical understanding they have acquired in their degree can be directly drawn on, there is evidently no simple single 'pipeline' from a specific engineering degree into a single sector, and the data shows that this is particularly true for manufacturing. Arguments that increasing the number of students in that discipline will lead to corresponding increased numbers in that manufacturing sector are therefore naive at best and essentially wrong-headed
- If you want more employees in a particular sector of engineering ('x engineering'), you are likely to have more chance of a successful hiring if you invest in recruitment of *engineering* graduates of some kind rather than *history* graduates, and perhaps but not necessarily even more if you invest in *x engineering* graduates
- In graduate recruitment for an engineering sector, the individual person comes first (in terms of the relative importance of their likely strengths for an overall contribution to the company), their general degree study area (engineering of some kind) comes second, and their precise engineering discipline is least important

¹⁸ Of course, in some cases recruitment problems of individual employers may be the result of unattractiveness of work in that company, whether because of where it is based or the fact that the company offers salaries notably below the going rate.

10. LEAKAGE OF GRADUATES WITH STEM DEGREES MORE BROADLY

This paper has examined in some depth the patterns of recruitment of engineering graduates into industry sectors relevant to the substance of the discipline they have studied. The findings – in particular that the majority, sometimes the vast majority, of graduates from 'vocational' degree courses simply do not (want to) go and work in the industries where the substance of their courses is of significant direct relevance – might in principle be relevant to any vocational degree course of a highly technical nature. Work on initial destinations of information technology graduates around the time of the 'millennium bug' (when demand for information technology practitioner skills was at an unprecedented high) found evidence of significant leakage, both in sectoral and occupational terms, in information technology and in the more traditional professions (AISS/ITNTO 1999).

Given the evident value of graduates with a degree 'training' in a technical/scientific area and with broad understanding of, and familiarity with working with, mathematics, it is understandable that public policy has perceived the importance to employers, and so to the economy as a whole, of people with deeper knowledge and understanding of STEM subjects.

However, if the flows of people with STEM qualifications into work that will directly use the knowledge and understanding of that area of science and technology are to be seriously considered, as has been done for certain engineering disciplines in this paper, then, clearly, because of the much greater breadth of the scope of the bodies of knowledge of STEM subjects as a whole,¹⁹ only a very small fraction of the 'first destinations' of such people will turn out to be involved.

So, while STEM qualifications do provide undoubted potential labour market strengths to the 'holder', by bringing together all such qualifications across a massively broad set of bodies of knowledge, the amount of potential heterogeneity (and so the amount of leakage from initial occupations that will directly use the technical body of knowledge acquired in the degree) in the subsequent 'graduate first destination flows' will be even (very considerably) greater than for just engineering.

Figure 31 shows the broad categories of the main elements of STEM higher education courses, together with the 'corresponding' sector(s) that would be assumed for the relevant 'linear pipelines'.

¹⁹ UKCES (2013) acknowledges this heterogeneity, among others, by dividing the field into 'core STEM' and 'medical and related STEM'.

Figure 31: Broad structure of STEM higher education course fields and STEM-intensive sectors

STEM HIGHER EDUCATION COURSE FIELDS (JACS 3 categories)	Broad linear pipelines	CORRESPONDING STEM-INTENSIVE SECTORS (SIC 07 categories)
A - Medicine and dentistry	-	Health care and bioscience sectors (86 Human health activities)
B - Subjects allied to medicine		Health care and bioscience sectors (86 Human health activities; 21 Manufac- ture of basic pharmaceutical products and pharmaceutical preparations; 72.11 Re- search and experimental development on biotechnology)
C - Biological sciences		Health care and bioscience sectors (86 Human health activities; 21 Manufac- ture of basic pharmaceutical products and pharmaceutical preparations; 72.11 Re- search and experimental development on biotechnology)
D - Veterinary sciences, agriculture and related subjects	>	Veterinary profession, agriculture (75 Veterinary activities; A Agriculture, for- estry and fishing)
F - Physical sciences	>	Engineering manufacture (and construction for civil engineering) and professional engineering services (C Manufacturing; F Construction; 71.12 Engineering activities and related technical consultancy; 71.2 Technical testing and analysis; 72.19 Research and experimen- tal development on natural sciences and engineering)
G - Mathematical sciences		 (All sectors involving quantitative calculations and assessment)
H - Engineering		Engineering manufacture (and construction for civil engineering) and professional engineering services (C Manufacturing; F Construction; 71.12 Engineering activities and related technical consultancy; 71.2 Technical testing and analysis; 72.19 Research and experimen- tal development on natural sciences and engineering)
I - Computer sciences		Information and communication technology services, and ICT applications in most other sectors J Information and communication
J - Technologies		<i>Engineering and most other sectors</i> (C Manufacturing; F Construction; 71.12 Engineering activities and related technical consultancy; 71.2 Technical testing and analysis; 72.19 Research and experimen- tal development on natural sciences and engineering)
K - Architecture, building and planning		Construction and urban and rural planning (F Construction)

The arrows show the flows that would occur assuming a linear pipeline for each subject, but, as with engineering, there will inevitably be a wide range of flows beyond those 'straight across to the corresponding sectors'. While the distribution of these flows would – as has been done in this paper for the various engineering disciplines – need to be established in each case, the key policy consideration would relate to the fraction of graduates from each specific STEM discipline who go into the 'expected' directly relevant sectors. Where these turn out to be comparatively low, the same argument – of the comparatively low 'return' for the sectors needing such technical knowledge – would apply to the default assumption of trying to get more (young) people to enrol in these courses.

There is nothing in principle to stop an aeronautical engineering graduate going into work in the National Health Service and being successful both for his/her own career and in terms of the contribution to the employer. But that is taking place without (to begin with) the person having any deep understanding of medical matters, or with any prospect of being able to use the very considerable technical knowledge and understanding s/he has acquired through the degree course. Likewise, there is probably little that a Bachelor of Medicine can bring directly from their degree to work in a company building airframes. So, as with engineering graduates, *other STEM graduates make a contribution to UK output and prosperity in many parts of the economy*, but in doing so not all draw directly on the substantive technical understanding derived from their degrees.

To the extent, therefore, that skills policy is interested in helping reduce (future) skill shortages in any particular sector of the economy, a strategy that tries to get more (young) people to take the relevant qualification is likely to be 'even more irrelevant' (or 'wasteful') in relation to STEM overall than it is in relation to engineering.

It would clearly be possible to examine the detailed initial destination flows of graduates with a wide range of technical knowledge and understanding in the many elements of the other (science, technology, and mathematics) elements of STEM in the same way as has been done for engineering to elucidate the specific flow distributions of those fields, but the general message is likely to be the same.

In addition, the question of skill shortage evidence examined above for engineers also applies for STEM skills more broadly. Smith and Godard (2011) raised serious questions about the assumed shortage of scientists; from a physics perspective, Harris (2014) examined the belief that the UK suffers from a shortage of scientists and engineers, and expressed various doubts; and the UKCES 'Skills for the Future' briefing paper (UKCES 2014) admitted that 'The UK is not forecast to have skill shortages for higher level STEM skills' (between now and 2022).²⁰

²⁰ However, the report goes on to remark, '...but supply and demand are often finely balanced so there would be little capacity to meet a sharp increase in demand for STEM skills'. Responding to a 'sharp increase in demand' for STEM (or any other) skills has never been a serious skills policy issue, and – even ignoring the serious leakage realities – is, for graduate supply, always going to be fundamentally limited at professional level by the 'pipeline delay' of the degree duration as well as the subsequent initial professional development.

It is worth noting that the rather thorough recent analysis (Teitelbaum 2014) of the US labour market, over a number of decades, considers STEM skills as a whole, rather than just those for engineering. While examined in the context of a series of boom-and-bust waves of promotion of supply of engineers and scientists in the US, Teitelbaum summarised his conclusions on *shortages* as follows:

- If skill shortages exist, there should be *evidence* generally of a) rising relative wages for STEM occupations (which has not been present); b) faster than average employment growth (which has been present in some, but not all, occupations), and c) relatively low, and declining, unemployment rates (which has also not been present).
- While there were no signs of broad STEM shortages, a) there was evidence of large variations *within* STEM; b) under-supply and over-supply coexisted in some specific fields at certain times, and situations in different fields change (rise and fall of activity in particular disciplines for example, fading of demand for mechanical engineers as US automotive manufacturing declined; and growth in demand for petroleum engineers with the strong rise of fracking activity); c) geographical variations (local 'hot houses' for example, Silicon valley are atypical, there are booms and busts in specific occupations over time, but generalisations are perilous); Examples include i) computer/IT skills: high starting salaries, sub-degree qualified people common, some specific areas are 'hot', some not; ii) Engineers: high starting salaries, but slow increases, careers 'unstable'; iii) Biomedical: lengthy PhD + post-doc; low starting salaries; careers 'unstable'. Are STEM shortage claims over-generalisations?
- Why then do shortage claims 'prevail'?: a) effective lobbying campaigns (led by IT employers, emphasis on temporary visas), b) support from Higher Education (seeking increased funding for specific disciplines); c) substantial support from immigration lawyers (seeking more high-volume temporary visas paid for by employers); d) some Federal agencies (less now – for example, NSF in late 1980s). *Opposition* to shortage claims has been limited (some science and engineering associations – for example, IEEE – already international).
- Science and engineering shortage claims have existed for decades: Quote from *Arrow and Capron* (1959): "Careful reading of such statements indicates that the speakers have in effect been saying: 'There are not as many engineers and scientists as this nation should have in order to do all the things that need doing such as maintaining our rapid rate of technological progress, raising our standard of living, keeping us militarily strong', etc. In other words they are saying (in the economic sense) demand for technically skilled manpower *ought* to be greater than it is it is really a shortage of *demand* for engineers and scientists that concerns them" [Teitelbaum 2014].

In theory a top-level strategic skills policy objective could be considered in terms of attempting to reduce the cost of future STEM professional skills to UK employers by increasing the supply of STEM graduates even in the expected absence of sufficient directly relevant jobs, since such an over-supply would, in principle, reduce the going rate for such skills. However, such a strategy would have serious drawbacks, in particular:

- It would knowingly 'produce' more graduates than are expected to be needed in the UK labour market, thus leading to higher frustrations and disappointments for many graduates who would be unable to find jobs in the UK involving the work they seek
- The interconnected realities of modern economies would result in both (a) any overall skills cost reduction for UK employers probably being modest in comparison with the cost reductions that can already be achieved by recruiting from overseas; and (b) any corresponding benefit potentially being enjoyed by foreign-owned, and even foreign-based, companies

And, of course, like all attempts to increase supply by changing young peoples' choices in their selection of degree courses and/or initial employment, such an approach would have considerable implementation challenges, since the state's ability to significantly influence the individual choices of young people remains limited.

UK skills policy is in principle aware of the leakage issue for STEM. DBIS (2011) concludes that:

The research has called into question the widespread expectation that a STEM student should become a STEM worker/employee. This "default" career direction is clearly not what many STEM students or graduates have in mind or are adhering to. The situation is more complex and career paths less simple and less predictable than generally thought. The research has also highlighted the fluidity of the students' and graduates' career decision-making (and lack of career thinking in many cases) which lies behind many of the observed individual outcomes.

The executive summary of UKCES (2013) points out that:

LFS data on new graduates shows that in 2011:

- 16 % of employed new Core STEM graduates are working in Core STEM jobs in Core STEM sectors;
- 12 % are working in non-STEM jobs in Core STEM sectors;
- 6 % are working in STEM jobs in non-Core STEM sectors; and

• 66 % are working in a non-Core STEM job in a non-Core STEM sectors (up from 52% in '01). (Thus, in 2011) only **a third** of new Core STEM²¹ graduates worked in either a Core STEM job or a Core STEM sector or both, which was down from 45% in 2001. This drop is partly the result of a change in occupational and sectoral classifications, but also reflects a general trend of dispersion of Core STEM workers from traditional Core STEM occupations and sectors, spreading out throughout the overall workforce.

In terms of supply, demand and market imbalances, UKCES (2013) concludes that:

Estimates of vacancy ratios (the number of vacancies divided by employment) do not suggest a higher vacancy rate for Core STEM vacancies (in all occupations) or for vacancies in STEM occupations only.

and:

Supply and demand calculations for 2020 under both the "2007" (pre-recession) and "2011" (recession) scenarios do not suggest an overall shortage of STEM graduates (in terms of numbers) in most regions or nations of the UK.

With such evidence it is not clear how public investment in promotion of STEM skills can be justified.

²¹ 'Core STEM' in this study comprise biological sciences, agricultural sciences, physical/environmental sciences, mathematical sciences and computing, engineering, technology, and architecture.

11. CONCLUSIONS

This paper has presented comprehensive evidence that the 'linear pipeline assumption' about sectoral destinations of graduates from engineering disciplines that has often been made (generally by default) thus far in relation to flows into work in engineering is fundamentally flawed, and has examined the implications of this reality on the skills policy debate on the supply of engineering skills to the different UK manufacturing sectors.

The evidence produced on these initial flows confirms that public policy would be ill-advised to proceed assuming that the response to reported shortages of supply of engineering graduates in a particular subsector, where substantiated, must be to try to increase the numbers on the relevant engineering higher education courses. It should rather be to find ways of helping any sectors genuinely concerned about shortages to take much more seriously the need to significantly increase the attractiveness of their work to engineering students, and in particular to those in the last and penultimate years of their courses.

The response to engineering employers' concerns about (possible) shortages of engineering graduates that straightforward application of economic theory would suggest – namely, for manufacturing employers to increase their starting salary offers – is shown to be over-simplistic, since employers' ability to increase pay depends on whether they can do so without jeopardising the price(s) of their product(s)/ service(s), and average profitability levels in manufacturing industries are unequivocally lower than in some other sectors with which they compete for such graduates. The paper also flags issues about sectoral leadership, in response to skills supply concerns.

Evidence of the lack of 'tightness' of this recruitment market over recent years is presented, through the unemployment rates of engineering graduates, which further questions default assumptions about the need for more people to enrol in engineering courses.

And, finally, the paper sheds light on the answers to the questions that naturally arise when it becomes clear that most graduates from engineering courses do not 'go on to work in the relevant field of engineering', showing where engineering graduates do go and work, and clarifying other aspects of relevant employers' graduate recruitment.

The sometimes surprising realities that are uncovered by this analysis allow policy analysts to recognise, even more strongly than before, the rather greater complexity in current graduate recruitment patterns than generally assumed, which will enable more valid insights into current behaviour, and so more soundly evidence-based, and thus more effective, future policy responses.

While the DLHE evidence of what is happening is clear, in order to clarify the reasons behind these flows (and so provide more insights as to possible policy implications) serious surveys of both employer experience in recruiting engineering graduates, and employment aspirations and preferences of final and penultimate-year engineering students (including their perceptions of the attractiveness of the 'natural' sector) would be of considerable value.

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Appendix

Examples of Broad Work Areas²² Within Some Engineering Disciplines

²² These tables are only intended to be illustrative – not definitive or comprehensive – and it should be noted that there are often crossover points between the different disciplines (for example, rail signalling work is directly relevant to the rail engineering element in transport, but it would generally be carried out by a telecommunciations engineer or technician). In practice, large engineering projects generally need to bring to bear expertise in a wide range of engineering disciplines.

Broad Work Areas within some engineering 'Disciplines'

(showing some safety-critical/regulated specific activities)

Civil engineering

	Construction	Earthquake engineering	Environmental engineering	Geophysics	Geotechnical engineering	Water Resources	Structural engi- neering	Transport engineering	Surveying	 (other)	(other)
Professional Engineer (theoretical)		(sign-off on new structure safety in E. areas)				(Dam/ reservoir design)	(Tall building/ bridge design sign-off)				
Professional Engineer (applied) / engineering Technologist						(reservoir inspection)		(Rail signalling)			
Professional engineering Technician								(Rail signalling)			
'Skilled Trades'											

Mechanical engineering

	Fluids	Product Design	Hydraulics & Pneumatics	Manufacturing Engineering	Combustion, engines, fuels	Strength of Materials	Computer Aided Design/ CAM	Energy conversion	Mecha- tronics/ Control	 (other)	 (other)
Professional Engineer (theoretical)		(Gaining regulatory approval for aircraft safety)			(Pressure Vessel design)						
Professional Engineer (applied)/ engineering Technologist		(compliance with product regulatory requirements)			(Pressure Vessel design/ manu-facture)						
Professional engineering Technician				(Aircraft Maintenance)	(Pressure Vessel welding)						
'Skilled Trades'				(Aircraft Maintenance)							

Electrical/Electronic engineering

	Power	Control	Electronics	Micro- electronics	Signal Processing	Telecommunications	Instrumentation	Computers	Network Analysis	 (other)	 (other)
Professional Engineer (theoretical)											
Professional Engineer (applied) / engineering Technologist						(Rail signalling)					
Professional engineering Technician						(Air Traffic Control system monitoring/ maintenance)					
'Skilled Trades'											

Marine engineering (inc. Naval Architecture)

	Ship Design, Construction	Marine Safety	Defence/ Naval	Ports & Harbours	Offshore operations	Underwater operations	Marine Leisure	Systems & Equipment	Fishing technology	 (other)	 (other)
Professional Engineer (theoretical)	(Gaining regulatory approval for vessel safety)	(Duties of engineering Officers on board)									
Professional Engineer (applied) / engineering Technologist		(Duties of engineering Officers on board)									
Professional engineering Technician											
'Skilled Trades'											

Building Services engineering

	Energy supply to buildings	Escalators & Lifts	Fire detection & protection	Heating, Ventilating, Air Conditioning	Security & Alarm systems	Water, drainage & Plumbing	Artificial Lighting/ facades	Cabling/ICT systems/ networks	Refrigeration systems	 (other)	 (other)
Professional Engineer (theoretical)											
Professional Engineer (applied) / engineering Technologist											
Professional engineering Technician	(gas equipment installation/ checking)										
'Skilled Trades'	(gas equipment installation/ checking)			(Wiring regulations)				(Wiring regulations)			