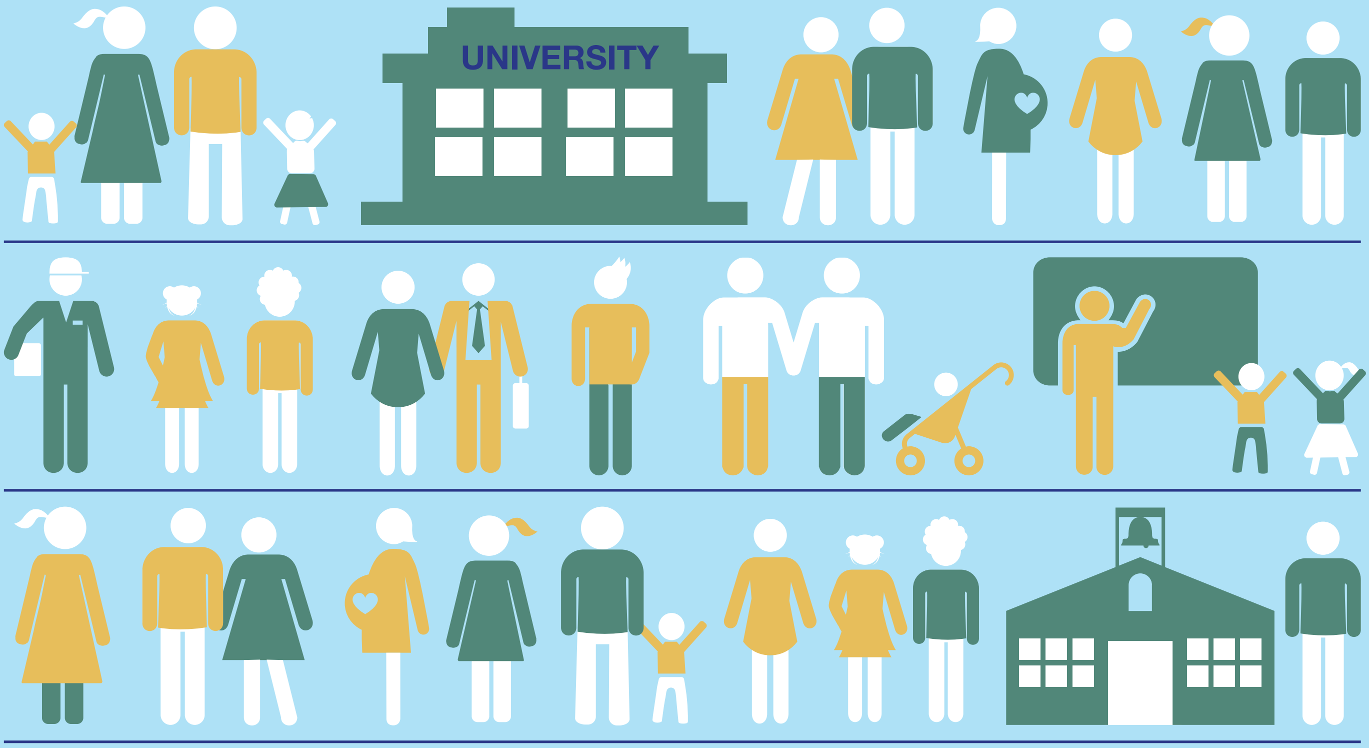
STATE OF THE NATION: A REVIEW OF EVIDENCE ON THE SUPPLY AND DEMAND OF QUANTITATIVE SKILLS

Geoff Mason, Max Nathan
and Anna Rosso



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National Institute of Economic and Social Research (NIESR) and Centre for Learning and Life Chances in Knowledge Economies and Societies (LLAKES)

A report to the British Academy

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Among other projects in recent years, he has led research on productivity, innovation and skills in the UK, US, France and Germany; employer demand for skills in the UK; and a comparative study of vocational education and training systems in seven European countries. This work has been funded by academic research councils, foundations and government departments in the UK, US and New Zealand and by European Union agencies.

His research projects have led to many different publications, ranging from academic articles in refereed journals and book chapters to government department research reports and occasional newspaper articles in the Financial Times and The Guardian. Recent academic publications include articles in *Economics of Innovation and New Technology, Labour Economics*, *Education Economics*, *Journal of Education and Work*, *Research Policy* and the *British Journal of Industrial Relations.*

Geoff Mason's work on productivity, skills, training and labour markets has been widely cited in UK public policy debates and contributed to his being invited to work as Research Advisor to the National Skills Task Force and to serve on the Royal Society Working Group on Higher Education. He has also served on academic panels for the UK Commission for Employment and Skills and the Cabinet Office's Workforce Development Project.

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He has over 12 years' public policy experience in think tanks, consultancy and government, with a particular interest in urban public policy, most recently at the *Department for Communities and Local Government* (DCLG) as an ESRC-DCLG Senior Policy Adviser. Max also co-founded the Centre for Cities, where he ran the research programme for three years.

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At the What Works Centre he leads a series of systematic reviews of local economic development interventions, and is working on a range of projects to improve policymakers' quantitative skills and evaluation capacities. He also co-organised a recent doctoral training session on evidence-based policy at Warwick University, and is speaking in the ESRC 'Spaces of Evidence' series on economic evidence, big data and randomised controlled trials (RCTs). Max's wider interests include the economics of innovation, clusters and industrial policy: he is currently working on a NESTA-funded project that uses big data to map the UK's digital economy.

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She obtained her PhD from the Department of Economics at University College London and previously worked as a Research Officer for the Centre for Research and Analysis of Migration (CReAM) mainly working with individual level datasets. She has worked on several projects on the effects of emigration on the economies of sending countries.

Executive summary

Scope of report

1. This report reviews existing evidence on current levels of demand for quantitative skills (QS) in the UK and the extent to which this demand is matched by supply. As part of this assessment, we discuss how reliable and well-founded this evidence is and draw attention to important gaps in the current evidence base. In carrying out this work, we adopt a broad definition of QS set out by the British Academy which covers both a wide range of different types (or categories) of QS and a wide range of QS levels, referring to the different depths of understanding of quantitative techniques that individuals may possess. We also use the term 'numeracy' to refer to the ability to apply mathematics knowledge in appropriate and accurate ways in particular situations, not just the ability to apply basic arithmetic skills.

2. The report focuses on two key areas of demand for QS, namely, employer demand for QS in different industries, both in the private and public sectors; and demand for students entering higher education (HE) and other post-secondary courses to possess QS appropriate to the level and subject of study. When assessing the potential supply of QS that might meet employers' requirements, we distinguish between the existing stocks of QS in the economy (held by individuals already in the workforce) and annual new *flows* of QS (held by new entrants to the labour market). An important reason for giving equal attention to the stocks of QS as well as flows is that annual flows of newly-qualified persons with QS entering employment can only ever form a small part of the workforce. The largest contributions of QS to economic performance – and the most serious effects of any deficiencies in QS – will always derive from adult workers already in employment who constitute a large majority of the workforce.

International comparisons of QS

3. Recent international surveys suggest that mathematics attainments in secondary education in England and Northern Ireland (NI) are middle-ranking among industrialised nations. But the same is not true of survey findings relating to the quantitative skills of the wider population. According to the 2012 Survey of Adult Skills (SAS), proficiency in numeracy in England/NI was significantly below average among 22 participating countries. Among other things England/NI was found to be the only one of 22 countries where 16–24 year olds had lower proficiency in numeracy than did 55–64 year olds.

4. These comparisons have implications for UK economic performance because QS requirements are pervasive in industrialised economies.

About seven in ten employees in the UK economy say that QS are essential or important to carry out their work. Roughly three out of ten jobs primarily require basic arithmetical skills (such as adding, subtracting, multiplying or dividing numbers or using decimals, percentages or fractions). Another four out of ten jobs require the ability to apply QS at a 'more advanced' level than basic arithmetic, ranging from use of descriptive statistics to highly complex mathematical procedures.

QS requirements in UK workplaces

5. According to periodic Skills Surveys, the 40% share of jobs requiring 'more advanced' QS in 2012 was up by about ten percentage points compared to 1997. Other evidence of rising QS requirements in recent years has been provided by extensive case study research. Among other things the growth in demand for QS reflects the impact of increasing competitive pressures to improve efficiency and quality standards and engage in innovation, all of which require constant monitoring and interpretation of data of different kinds. At the same time the widespread use of Information Technology (IT) in workplaces has not reduced the need for QS but rather changed the nature of the skills required (for example, with employees needing to understand the underlying models used by computer software in order to make effective and accurate use of it).

6. The range of QS covered by the term 'more advanced' in the Skills Surveys can be understood as follows. At the upper end of the QS spectrum, estimates derived from the Labour Force Survey suggest that about 5–6% of all people in employment are classified to occupations which can be regarded as intrinsically relying on high levels of QS: professional engineers, scientists and IT specialists; actuaries, economists and statisticians; and chartered and certified accountants. Many people in these occupations hold university degrees in 'numerate subjects' and/or occupation-specific professional qualifications. Below these upper layers of QS, case studies of workplaces point to a wide range of occupations and activities in which accuracy in measurement and data analysis is vital to organisational performance and sometimes critical for public health and safety.

7. Examples include hospital staff calculating dosages of medications and patients' nutritional requirements; production operators' using statistical process control (SPC) methods of data collection and analysis; financial services staff advising customers on mortgages and making underwriting decisions; chemicals laboratory technicians preparing solutions to specified concentrations; railways staff responsible for monitoring track quality; managers in many industries making cases for capital investments; and civil servants responsible for reviewing evidence on the effects of government policies. In many organisations these different functions rely on a division of labour between small numbers of employees who can develop (or at least modify) computer software packages to meet organisation-specific objectives and a much larger number of employees who need to be able to interpret and make use of the resulting statistics.

Difficulties in applying mathematics knowledge in workplace settings

8. With the exception of highly numerate and technical jobs, the QS requirements of most workplaces should in principle be covered by the mathematics contained in the GCSE curriculum. However, applying basic mathematical skills in the 'complex settings' of workplaces appears to pose challenges for many employees even if they did once gain a formal qualification at GCSE Grade C or equivalent level.

9. A substantial body of case study research suggests that many employees fail to understand fully the quantitative techniques they are using and lack the ability to recognise obvious errors in their work. This is consistent with evidence from the Skills for Life 2011 Survey in England that as many as 75% of 16–65 year olds in employment were classified at a level of numeracy suggesting that their QS might not be sufficient 'to compare products and services for the best buy or work out a household budget'.

10. One implication of these findings is that individuals should preferably study mathematics to a higher level than they are likely to encounter in their jobs in order to be able to apply mathematics with confidence to deal with unexpected issues and problems in work settings.

Labour market returns to mathematics knowledge and to QS

11. The strength of employer demand for QS is also shown by relatively high salary returns to mathematics as a subject of study at both A level and Bachelor degree level. However, researchers tend to find mixed evidence when salary returns to QS are compared with other types of skill such as computing skills, high-level communication skills, client communication skills and planning skills. This may reflect the very high correlation which is found between QS and computing skills, and the fact that QS are rarely used in isolation and often need to be combined with other generic skills. For example, employees with QS are often expected to be able to explain the results of quantitative analyses to non-specialist colleagues and show their relevance to decision-making within their organisations.

12. When basic numeracy skills are considered separately in other studies, there is clear evidence that individuals are better off in terms of employment and earnings if they possess such skills rather than being innumerate.

13. Taken together, the evidence from case studies and from analyses of labour market returns to mathematics as a subject of study in the UK points to strong employer demand for QS (in conjunction with other skills), with several indicators that the currently available supply of QS may be insufficient to meet demand. But when we turn to employer surveys as a third source of information on demand for QS in workplaces, the evidence is more mixed.

Employer survey evidence on mismatches between QS supply and demand

14. Annual surveys of employers carried out for the Confederation of British Industry (CBI) find high proportions of employers reporting weaknesses in basic numeracy among some employees and among school and

college leavers. However, the CBI surveys are based on relatively small samples which are not nationally representative in nature and it is therefore hard to know how far their findings can be generalised to the wider population of employers.

15. In fact, the much larger biennial UK Commission's Employer Skills Survey (UKCESS) points to different conclusions. In 2013 it was based on a fully representative sample of just under 92,000 UK establishments across all sectors of the economy. According to this survey, the reported incidence of QS deficiencies (defined in various ways) is much smaller than that conveyed by the CBI surveys.

16. But there are several reasons for believing that the UKCESS is not an adequate source of information on the balance between supply and demand for QS. The term 'numeracy skills' is not explicitly defined in the UKCESS and it is not a key purpose of this survey to probe employers in detail about their use of QS or the connections between QS and other types of skill. In addition, estimates derived from the Skills for Life 2011 Survey in England suggest that many managerial respondents to surveys such as UKCESS (and indeed the CBI surveys) may be poorly equipped to assess QS or judge the need for them.

17. For these reasons a new nationally representative survey of employers with a specific focus on QS issues is needed – in conjunction with in-depth interviews with multiple respondents in workplaces – to make a better assessment of the extent of problems identified by case studies and the CBI surveys.

18. Any new survey of the ways in which employers meet their QS needs should pay particular attention to the role of skilled migrants. Many jobs requiring high-level QS and other technical skills are filled by migrants brought into the UK as internal transfers within multinational firms operating in skill- and innovation-intensive industries. The reasons for this reliance on migrants with QS include difficulties in recruiting workers with STEM (science, engineering, technology and mathematics) skills from within the UK.

Low take-up of mathematics study after age 16

19. A contributing factor to the limited supply of UK-resident STEM workers is the relatively low proportion (by international standards) of the population in England, Wales and Northern Ireland which has studied mathematics beyond the age of 16. The reasons for this are not just the structure of the A levels curriculum – obliging students to narrow down to a small number of subjects – but also students' concerns about their own abilities to do well in the subject and perceptions (apparently justified) that mathematics is a relatively difficult subject in which to obtain high grades. Ultimately, constraints such as many students lacking confidence in their ability to do well in mathematics reflect deep-rooted shortcomings in primary and early secondary mathematics education, in particular, shortages of specialist mathematics teachers.

20. Early specialisation in secondary education creates an additional problem in that many students who drop mathematics at age 16 have effectively forgotten much of the mathematics that they once knew by the time they enter the labour market or go to university.

Universities' responses to students' QS weaknesses

21. One consequence of weakness and variability of QS among student intakes to universities is that many university departments have modified degree courses in a non-quantitative direction in order to cope with the students' lack of QS. This applies even to subjects such as chemistry, bioscience, geography and sociology for which an emphasis on quantitative techniques would normally be considered essential for their disciplines. In some cases these changes in course design reflect weaknesses in university teachers' own QS as well.

22. At the same time as many degree courses have evolved in a non-quantitative direction in order to cope with students' QS deficiencies, considerable resources have been devoted to efforts to try and remedy those weaknesses through compensatory teaching. Much of this is uncoordinated between departments but various initiatives are now seeking to make such compensatory activity more systematic. Examples include the Q-Step programme which aims to start a process of institutional change in university social science teaching. Reflecting the problems caused by so many students having dropped mathematics study at age 16, it will focus on basic statistical literacy as well as on more advanced training.

23. Clearly, it will take time for such initiatives to make a significant dent in QS-related deficiencies in university course design and teaching. Thus, in the short term at least, many university departments may be unable to deliver the mix of QS and other skills and knowledge that employers increasingly require of their graduate employees. The depth and breadth of these skill requirements become apparent when examining trends in employer demand for high-level QS in both the private and public sectors.

Trends in employer demand for high-level QS combined with other skills

24. For example, growing numbers of firms are now committed to data-driven decision-making, making use of the increased availability of 'Big Data', that is, datasets that have millions or even billions of observations, can be accessed in real-time or close to it and are multi-dimensional, including phenomena that were previously hard to observe quantitatively. Such firms have urgent need of university graduates with 'hybrid skill sets' combining quantitative, computing and analytical skills with business understanding.

25. Other examples of the need for graduates to possess hybrid skill sets including QS can be found in the very different world of government departments. The drivers for more civil servants to possess high-level QS include a strong emphasis on evidence-based policymaking and the continual shaping and reshaping of government functions, particularly in periods of austerity when there is a need to 'do more with less'. In addition, more and more resources are now devoted within government to impact evaluations using quantitative techniques such as randomised control trials that seek to identify the causal effects of policy interventions. The resulting skill demands include a need for more policymakers to possess a strong grasp of quantitative and qualitative evidence, and to have the means to deploy this in strategic and policy decision-making.

26. These examples from the worlds of Big Data usage and government policy-making highlight the massive challenges that many UK universities face in respect of QS development. On the one hand, they need to be able to equip graduates in a range of disciplines with the mix of QS and other skills that are increasingly sought in the graduate labour market. On the other hand, as described above, many university departments are confronted with weak QS among both students and teachers. Hence, they find it hard to ensure that the quantitative content of their courses is appropriate to their disciplines, much less sufficient to form part of the hybrid skill sets that are increasingly sought by employers.

Implications for secondary education and vocational training policy

27. In general, the evidence reviewed in this report provides further support for arguments long made in support of a broader upper secondary curriculum which will produce, not just a larger cohort of prospective HE entrants who have studied pure mathematics at A level or equivalent, but other cohorts of students who have participated in courses emphasising statistics and problem-solving as well as improving mathematical fluency.

28. At intermediate skill levels (below graduate level), much more attention needs to be given to co-ordination between pre-employment education in mathematics and employment-based training in the application of QS. This applies mainly to initial training for new entrants to the workforce (especially through apprenticeship training) but is also relevant to continuing training for adult workers.

29. As noted above, many employees have difficulty in applying mathematics knowledge gained through formal education to work-related issues and problems. The traditional apprenticeship model of skills development – combining employment-based training with part-time attendance on job-related vocational education courses – constitutes one of the few mechanisms by which one can imagine ever bridging the present gap between mathematics education in classroom settings and the practical application of QS in workplaces. Hence, those with interests in the development of usable QS should give serious thought to how to take advantage of the current government's recently-declared support in principle for off-the-job study in mathematics to be mandatory for all apprentices who have not already attained GCSE Grade C or above in mathematics.

30. It is also positive that the current government has recently accepted one of the recommendations from the 2011 Wolf Review of Vocational Education that students who are under 19 and do not have GCSE A*–C in English and/or Maths should be required to make progress towards acquiring such qualifications. However, this approach to funding will face many difficulties in raising mathematical attainments among 16–19 year olds who did not fare well in GCSE mathematics at age 16.

31. One possible source of hope for QS development among adult workers is that the UK tends to be well ahead of other European countries on measures of employer-provided training per hour worked. However, as yet there is very little information available about the extent to which current employer-provided training specifically addresses QS improvement needs. Further research is needed in this area before any suggestions can be made as to how such QS-specific training for adult workers could be increased.

Future research agenda

This review has identified several gaps in current knowledge about the imbalances between demand for and supply of QS in the UK. The main questions which deserve to be investigated through new research include:

1. What is the true extent and nature of QS deficiencies identified by case studies and the CBI surveys?

2. To what extent do employers essentially adapt to poor QS (perhaps by organising work in such a way that the effects of employees' QS weaknesses are minimised)?

3. To what extent does employer-provided training seek to upgrade the QS of existing employees and/or new recruits?

4. To what extent does any such QS training provision by employers amount to 'remedial' teaching filling gaps in employees' skills and knowledge which they might have been expected to acquire during their formal education?

5. How widespread is the phenomenon of university departments in physical and social science disciplines evolving in a non-quantitative direction in order to cope with students' QS deficiencies and with university teachers' own deficiencies in QS?

6. What is the success to date of efforts to improve university students' QS through compensatory teaching and other initiatives within higher education?

7. To what extent is the current apprenticeship training system succeeding in raising QS levels?

8. What cost-effective policy options are available to government to try and encourage adult workers to invest in developing their own QS and employers to support them in doing so?

In most cases these questions would ideally be addressed through the use of both quantitative and qualitative research techniques. For example, a new nationally representative survey of employers with a specific focus on data skills and QS issues in general is needed to assess the true extent and nature of QS deficiencies in UK workplaces. This new survey should seek detailed information on the demand for and utilisation of QS in workplaces and the extent to which employers either adapt to poor QS or seek to upgrade QS through providing training for their employees.

The main survey in this case would need to be structured in design so as to provide data suitable for quantitative analysis. However, a smaller number of semi-structured in-depth interviews should also be carried out at workplace level, first, to inform the design of questions in the main survey and, second, to follow-up that survey with in-depth probing of some respondents about the answers given to survey questions and the value of their assessments. In as many workplaces as possible, multiple respondents should be interviewed (including workers as well as managers) so that inferences about QS demand and utilisation in each workplace do not depend on the views of a single respondent. It would also be helpful to interview training providers who are working with some of the employers participating in the main survey.

Chapter one

Introduction

The principal aim of the present report is to review and assess existing evidence on current levels of demand for quantitative skills (QS) in the UK and the extent to which this demand is matched by supply. As part of this assessment, we discuss how reliable and well-founded this evidence is and draw attention to important gaps in the current evidence base. We also draw on available evidence that sheds light on potential future mismatches between QS supply and demand.

In carrying out this work, we adopt a broad definition of QS as set out by the British Academy:

> *'The ability to reason using numbers and quantitative values: understanding the world requires development of hypotheses and interpretation of numbers and data to make observations, analysis and forecasts. A diverse range of skills relevant to specific disciplinary, applied or research contexts are needed to understand and interpret numbers and data. This includes an understanding of mathematics, probability and statistics, models, hypothesis construction and testing, and the challenges of the sound measurement of empirical variation so that generalisable conclusions may be drawn. Among other things, the possession of these skills allow for: confidence in the manipulation and interpretation of numbers and data; an understanding of possibilities and limits of measurement; and understanding the role of evidence in testing and modifying models.'* [1]

This definition covers both a wide range of different types (or categories) of QS and a wide range of QS levels, referring to the different depths of understanding of quantitative techniques that individuals may possess. Furthermore, in assessing the supply of and demand for QS, it is important to distinguish between the apparent possession of QS (as attested by certificates or diplomas) and the ability to put them into practice. Hodgen and Marks (2013:7) argue that many jobs require only a 'simple' level of mathematics (in principle no higher than GCSE standard) but additional skills, knowledge and experience are usually required to apply this level of mathematics in the 'complex settings' of workplaces.

This point also arises in discussion of what 'numeracy' means. This term is often associated primarily with basic arithmetic skills but it is also not uncommon for specialised mathematics-based academic disciplines to be referred to as 'numerate disciplines' (Coben et al, 2003). There is now a measure of agreement in the mathematics education literature that to be numerate means having the ability to make appropriate and accurate use of mathematics knowledge in particular situations (Coben, 2000; ACME, 2011;

1 British Academy, private communication, 6 March 2015

Hodgen and Marks, 2013). In principle, therefore, the term numeracy can refer to the ability to apply QS at many different levels of complexity and its precise meaning needs to be made clear whenever the term is used.

In this report we focus on two key areas of demand for QS:

1. Employer demand for QS in different industries, both in the private and public sectors

2. Demand for students entering higher education (HE) and other post-secondary courses to possess QS appropriate to the level and subject of study

As shown in Table 1, when assessing the potential supply of QS that might meet employers' requirements, we need to distinguish between the existing *stocks* of QS in the economy (held by individuals already in the workforce) and annual new *flows* of QS (held by new entrants to the labour market). Employers can seek to increase the QS available to them either by external recruitment (of experienced workers or newly-qualified persons) or by providing training in QS areas to existing employees (which amounts to upgrading the stocks of QS in the economy). In the case of university and FE college demand for appropriate levels of QS among course entrants (including apprentices attending part-time vocational education courses), the main source of supply is flows of leavers from courses in lower levels of education. However, a proportion of course entrants may be drawn from the stocks of workers already in employment or from adults who are not currently in work.

An important reason for giving equal attention to the stocks of QS as well as flows is that annual flows of newly-qualified persons with QS entering employment can only ever form a small part of the workforce. The largest contributions of QS to economic performance – and the most serious effects of any deficiencies in QS – will always derive from adult workers already in employment who constitute a large majority of the workforce.

Table 1: Key areas of demand for and supply of quantitative skills (QS)

Demand for QS	Supply of QS
Employers / workplaces: • Private sector firms • Civil service • Other public sector organisations • Non-profit, non-governmental organisations	External recruitment: • Experienced workers [STOCKS] • New entrants to labour market [FLOWS] Improvements to QS held by existing employees [STOCKS]
• Higher education (HE) courses • Further Education (FE) courses • Apprenticeships and other vocational training programmes	Applicants / entrants to HE and FE courses and vocational training programmes • School and college leavers [FLOWS] • Adult applicants/entrants to education and training courses [STOCKS]

Although this report focuses primarily on the demand for and supply of QS, we also draw to some extent on research evidence relating to two broader categories of skill in which QS are included alongside other skills:

- Science, Technology, Engineering and Mathematics (STEM) skills; and
- 'Employability' skills (generic skills that are expected to enhance individuals' employment prospects throughout their careers, including communication skills, computing skills, planning skills and problem-solving skills as well as QS)

The report is ordered as follows. In Section 2 we review evidence on how QS in England compare with QS in other industrialised nations. Section 3 presents detailed information on the current utilisation of QS in workplaces across the whole UK economy, including new estimates derived from the 1997, 2001 and 2006 Skills Surveys and the 2012 Skills and Employment Survey. In order to assess the extent and nature of employer demand for QS, we first investigate how the salary returns to QS in the labour market compare to those for other types of skill (Section 4). We then go on in Section 5 to review survey evidence and other information on mismatches between employer demand for QS and the supply of QS in the UK economy, including the supply of QS made available through inward migration. In Section 6 we assess evidence on the difficulties that universities have in recruiting course entrants with the required levels of QS; the steps taken by universities to try and deal with any deficiencies in the QS held by students; and the ability of universities to meet demand for high levels of QS in areas such as data-driven decision-making within firms and evidence-based policy-making within government. Section 7 examines QS issues in further education and in vocational education and training. Section 8 summarises our main findings and presents recommendations for future research on QS.

Chapter two

International comparisons of quantitative skills

Some indications of how QS in England and other parts of the UK compare with QS in other countries can be gleaned from international surveys run by the International Association for the Evaluation of Educational Achievement (IEA) and the Organisation for Economic Cooperation and Development (OECD). These include the IEA's Trends in International Mathematics and Science Study (TIMSS) and the OECD's Programme for International Student Assessment (PISA), both of which seek to compare student attainments but in very different ways: TIMSS asks respondents to demonstrate how much they have learned in different areas of the mathematics curriculum while PISA tends to concentrate on testing real-world applications of mathematics. In addition to these two tests of student attainments, the OECD's Survey of Adult Skills seeks, among other things, to compare adult workers' proficiency at different levels of numeracy.

International comparative exercises of this kind can be criticised on many grounds. For example, practical difficulties are likely to arise in ensuring equivalence between countries in the ways that survey questions are translated and that samples of individual students or adults are drawn. In addition, the country rankings along a single scale that emerge from surveys such as PISA can be criticised for ignoring the many dimensions in which national education systems tend to differ from each other (Goldstein, 2004, 2013).

However, other researchers find that the cross-country comparisons stand up to scrutiny well in certain ways. For example, Brown et al (2007) examine findings from four different surveys (including TIMSS and PISA) and find considerable agreement between the different sources on cross-country averages in test scores and measures of dispersion among children and young people. Hanushek and Woessmann (2011) note that TIMSS and PISA test scores are highly correlated at the country level even though the two surveys vary greatly in the content and focus of their questions, 'suggesting that [such tests] are measuring a common dimension of skills' (ibid, p100).

In the light of such evidence, we draw here on cross-country mathematics test scores to try and assess the UK's comparative position on QS but with due acknowledgement of the potential shortcomings of such measures. Since we are mainly interested in the quantity and quality of QS across the whole UK economy, we refer only briefly to recent TIMSS and PISA survey findings on student attainments before going on to discuss results from the 2012 Survey of Adult Skills in more detail.

Analysis of TIMSS 2011 suggests that the mathematics attainments of 13–14 year olds in England were well behind those in several East Asian countries and the Russian Federation and slightly behind Finland but were much the same as in the United States, Hungary and Australia and ahead of countries such as Italy, New Zealand, Sweden and Norway (Mullis et al, 2012, Exhibit 1.2).

PISA 2012 results refer to England and Northern Ireland (henceforth England/NI) rather than England alone and suggest that the mathematics attainments of 15 year olds in England/NI were well behind East Asian countries and also some way below countries such as Switzerland, the Netherlands, Finland and Germany. However, the England/NI mean score in mathematics was only slightly below Australia and New Zealand, much the same as in France and above the United States and other countries such as Norway, Italy, Spain, the Russian Federation and Sweden (OECD, 2014, Figure 1.2.22).[2]

Thus, taken together, the TIMSS and PISA findings suggest that mathematics attainments in secondary education in England and Northern Ireland are middle-ranking among industrialised nations. But the same is not true of survey findings relating to the QS of the wider population.

'In most countries women tend to perform on average less well than men in tests of proficiency in numeracy, partly reflecting gender inequalities in society as well as cultural influences'

Indeed, the 2012 Survey of Adult Skills (SAS) found that in England/NI proficiency in numeracy was significantly below average among 22 participating countries (OECD, 2013, Figure 2.5). The SAS assesses proficiency in numeracy at six different levels (described in Table 2.1 below) which range from the use of basic arithmetic skills (at 'Below Level 1' and Level 1 itself) to the interpretation and use of basic statistics at Level 3 and the use of progressively more complex mathematical procedures at Levels 4 and 5.

Table 2.1 shows that an estimated 11% of 16–65 year olds in England/NI attained Levels 4 or 5 which places England/NI at 14th among the 22 countries. At Level 3 England/NI's ranking falls to 17th with 30% of 16–65 year olds graded at this level. At the lower end of the scale it is notable that England ranks sixth highest on the combined share (24%) of 16–65 year olds graded as Level 1 or Below Level 1.

Even allowing for justified caveats regarding methodological shortcomings in surveys of this kind, these and other SAS findings should raise serious concerns for UK policy-makers. Among other things England/NI was found to be the only one of 22 countries where 55–64 year olds had higher proficiency in numeracy than did 16–24 year olds. In part this reflected the fact that numeracy among 55–64 year olds in England/NI was relatively high compared to other countries but England/NI was still among the lowest for numeracy among 16–24 year olds. The skills of the younger population in England/NI were also characterised by high levels of inequality as well as relatively high 'social gradients' (the link between skill and parental background – an inverse indicator of social mobility). The relationship between parental background and numeracy among 16–24 year olds in England/NI was second strongest of the 22 countries (OECD, 2013; BIS, 2013a; Green, A. et al, 2014).

As is well known, in most countries women tend to perform on average less well than men in tests of proficiency in numeracy, partly reflecting gender inequalities in society as well as cultural influences (Marks, 2008; Else-Quest et

2 Note that Switzerland, the Netherlands, Finland, Germany, France and Spain did not participate in TIMSS 2011 tests of 13–14 year olds.

al, 2010). The SAS 2012 findings suggest that England/NI ranks sixth highest of 22 countries in terms of male-female differences in unadjusted mean scores in numeracy proficiency (OECD, 2013, Figure 3.4). However, England/NI declines to 13th in the ranking when these gender differences are adjusted to take account of variables such as age, education, migration status, language background, social class and occupation (ibid).

Table 2.1: Description of proficiency levels in numeracy in 2012 Survey of Adult Skills

Below Level 1: Tasks at this level require the respondents to carry out simple processes such as counting, sorting, performing basic arithmetic operations with whole numbers or money, or recognising common spatial representations in concrete, familiar contexts where the mathematical content is explicit with little or no text or distractors.
Level 1: Tasks at this level require the respondent to carry out basic mathematical processes in common, concrete contexts where the mathematical content is explicit with little text and minimal distractors. Tasks usually require one-step or simple processes involving counting, sorting, performing basic arithmetic operations, understanding simple percents such as 50%, and locating and identifying elements of simple or common graphical or spatial representations.
Level 2: Tasks at this level require the respondent to identify and act on mathematical information and ideas embedded in a range of common contexts where the mathematical content is fairly explicit or visual with relatively few distractors. Tasks tend to require the application of two or more steps or processes involving calculation with whole numbers and common decimals, percents and fractions; simple measurement and spatial representation; estimation; and interpretation of relatively simple data and statistics in texts, tables and graphs.
Level 3: Tasks at this level require the respondent to understand mathematical information that may be less explicit, embedded in contexts that are not always familiar and represented in more complex ways. Tasks require several steps and may involve the choice of problem-solving strategies and relevant processes. Tasks tend to require the application of number sense and spatial sense; recognising and working with mathematical relationships, patterns, and proportions expressed in verbal or numerical form; and interpretation and basic analysis of data and statistics in texts, tables and graphs.
Level 4: Tasks at this level require the respondent to understand a broad range of mathematical information that may be complex, abstract or embedded in unfamiliar contexts. These tasks involve undertaking multiple steps and choosing relevant problemsolving strategies and processes. Tasks tend to require analysis and more complex reasoning about quantities and data; statistics and chance; spatial relationships; and change, proportions and formulas. Tasks at this level may also require understanding arguments or communicating well-reasoned explanations for answers or choices.
Level 5: Tasks at this level require the respondent to understand complex representations and abstract and formal mathematical and statistical ideas, possibly embedded in complex texts. Respondents may have to integrate multiple types of mathematical information where considerable translation or interpretation is required; draw inferences; develop or work with mathematical arguments or models; and justify, evaluate and critically reflect upon solutions or choices.

Source: OECD (2013), Table 2.3

Table 2.2: Numeracy proficiency among 16–65 year olds, 2012, selected countries

Ordered by proportion graded at Levels 4/5

	Below Level 1	Level 1	Level 2	Level 3	Levels 4/5	No information	Total
	% of 16–65 year olds scoring at each proficiency level in numeracy						
Finland	3	10	29	38	19	0.0	100
Japan	1	7	28	44	19	1.2	100
Sweden	4	10	29	38	19	0.0	100
Norway	4	10	28	37	17	2.2	100
Flanders (Belgium)	3	10	28	37	17	5.2	100
Netherlands	3	10	28	39	17	2.3	100

Denmark	3	11	31	38	17	0.4	100
Germany	5	14	31	35	14	1.5	100
Austria	3	11	33	37	14	1.8	100
Australia	6	14	32	33	13	1.9	100
Slovak Republic	3	10	32	41	13	0.3	100
Canada	6	16	32	32	13	0.9	100
Czech Republic	2	11	35	40	11	0.6	100
England/N. Ireland (UK)	6	18	33	30	11	1.4	100
Estonia	2	12	36	38	11	0.4	100
United States	9	20	33	26	8	4.2	100
Poland	6	18	38	30	8	0.0	100
France	9	19	34	29	8	0.8	100
Ireland	7	18	38	29	8	0.5	100
Korea	4	15	39	35	7	0.3	100
Italy	8	24	39	24	5	0.7	100
Spain	10	21	40	24	4	0.8	100

Source: Survey of Adult Skills, 2012 (OECD, 2013, data underlying Figure 2.5)

Notes: Cyprus is omitted from this table due to its relatively high proportion (17.7%) of respondents classified as 'No information'.

Percentages may not sum to 100 due to rounding.

According to OECD (2013:5), 'sample sizes [in each country] depended primarily on the number of cognitive domains assessed and the number of languages in which the assessment was administered. The achieved samples ranged from a minimum of approximately 4500 to a maximum of nearly 27300'.

Chapter three

Quantitative skills in UK workplaces

3.1 How widespread is the use of quantitative skills?

As intangible assets, skills are notoriously difficult to measure. Typically, economists make use of proxy measures of skill such as educational level, occupation and wages. Early studies made extensive use of education input measures such as years of completed schooling but this is a measure of attendance rather than attainment. Education output measures such as formal qualifications (certificates, diplomas) have the advantage of capturing something of what has actually been learned while undergoing education but, like the years of schooling measure, they ignore skills acquired in the workplace without formal certification.

Efforts to surmount this problem include quality-adjusted skills measures as, for example, in Jorgenson et al (2005) who make use of education output data (formal qualifications) combined with relative earnings data in order to try and capture differences in relative productivity between different qualification groups. In principle, this approach should help to account for uncertified skills possessed by individual workers as well as their certified skills (Mason et al, 2012). Other approaches include attempts to derive measures of skill such as mathematical ability or hand-eye coordination from analysis of job characteristics (Ingram and Neumann, 2006).

Overall, skills measurement remains difficult and contentious; hence, in this report we review evidence based on a number of different measures of QS, including formal qualifications, test scores of individual proficiency in carrying out tasks requiring numeracy skills and the extent to which different jobs require deployment of different kinds of QS.

In respect of job characteristics relating to QS, a useful contribution has been made in recent years in the UK by a series of surveys of individuals in employment, namely, the Skills Surveys of 1997, 2001 and 2006 and the Skills and Employment Survey 2012. These surveys are nationally representative in nature (typically covering 2,500–7,500 adults in employment) and have served as the basis for several important studies of the supply and valuation of generic skills such as QS in the UK (for example, Green et al, 2001; Dickerson and Green, 2004; Green, 2012).

The Skills Surveys gather evidence on the skills used by individuals in the workplace through a job analysis approach which has its roots in psychological research. The respondents are asked a number of detailed questions about job characteristics, including the importance of 36 different activities. In the case of QS, three of these activities are described as follows:

[Arithmetic-1]
1. In your job, how important is adding, subtracting, multiplying or dividing numbers?
(Note: Using a calculator or computer if necessary.)

[Arithmetic-2]
2. And how important are calculations using decimals, percentages or fractions?'
(Note: Using a calculator or computer if necessary.)

[Advanced maths/statistics]
3. And how important are calculations using more advanced mathematical or statistical procedures?'
(Note: Using a calculator or computer if necessary.)

The response scale for these questions takes the form of:
Essential / Very important / Fairly important / Not very important /
Not at all important or does not apply

As with all surveys attempting to gather information on intangible assets such as skills, these data have to be treated with some caution. The subjective responses of individual employees will vary in their accuracy. However, the same is true of employers' responses to surveys and, in the case of QS used in the workplace, employers will often find it difficult to generalise about the QS needed and/or utilised by several different kinds of employee. By contrast, individual respondents should be well placed to comment on activities connected with their own jobs.

In most analyses of Skills Survey data to date, responses on these three QS-related activities have been combined together in a single measure of 'Number skills'. For our purposes it is more useful to look at the separate responses for each of the three activities. As shown in Table 3.1, just over half of adults aged 20–60 in employment in 2012 reported that adding, subtracting, multiplying or dividing numbers [labelled Arithmetic-1 above] was essential or very important in their work and 40% said the same about the use of decimals, percentages or fractions [Arithmetic-2]. Neither of these proportions changed greatly between 1997–2012. Turning to 'more advanced' mathematical or statistical procedures, 25% of adult workers in 2012 said that such procedures were essential or very important in their work, up from 17% in 1997.

While Arithmetic-1 and Arithmetic-2 broadly correspond to Levels 1 and 2, respectively, in the SAS 2012 measures of proficiency in numeracy (Table 2.1), the category of 'more advanced mathematical or statistical procedures' in the Skills Surveys clearly covers a wide range of activities across SAS 2012 Levels 3–5 and is insufficiently disaggregated for our purposes. However, due to their origins in nationally representative surveys, we believe that Skills Survey findings serve as useful indicators of the extent of QS utilisation in the UK economy.

The proportions shown in Table 3.1 as exercising each type of quantitative skill are clearly overlapping. One way to estimate the highest level of QS used by adults in employment is to impose a rough hierarchy on the different types of response, ranging from 'Advanced mathematics or statistics essential or very important' at the top to 'Arithmetic not at all important' at the bottom. The results (shown in Table 3.2) suggest that the ability to use and understand statistics or undertake mathematical procedures of differing levels of complexity is now fairly important, very important or essential in almost four in ten jobs (up from 29% in 1997 to

38% in 2012). A further 29% of employees in 2012 reported that arithmetical skills were fairly important, very important or essential in their jobs. At the bottom of the QS spectrum, arithmetical skills were regarded as 'not very important' or 'not at all important' in one out of three jobs in 2012 and this proportion remained unchanged throughout the whole period under consideration.

'What should be noticed is that, even in these relatively low-skilled occupations, there are sizeable proportions of job-holders saying that use of arithmetic is fairly important or even very important in their work'

Using this kind of hierarchy of QS-related job activities, a clear picture can be gained of how QS requirements vary between occupations (Table 3.3). Not surprisingly the highest proportions of jobs not requiring arithmetical skills to any great extent (58%) are found in elementary occupations (eg, cleaning, security and storage occupations). Other occupations with relatively high proportions of jobs not requiring arithmetical skills include service and sales workers and plant and machine operators and assemblers (49%). But perhaps what should be noticed is that, even in these relatively low-skilled occupations, there are sizeable proportions of job-holders saying that use of arithmetic is fairly important or even very important in their work – and in some cases this applies to use of statistics as well.

The highest incidence of 'more advanced' use of mathematics/statistics being essential or very important is found among professionals (39%), managers (37%), technicians and associate professionals (29%), clerical workers (24%) and skilled trades (22%). Some idea of what types of jobs fall in to this 'more advanced' category can be gleaned from Table 3.4 which shows the use of QS in different groups of industries, with jobs involving regular use of advanced QS subdivided between three groups of occupations. Jobs involving professionals or associate professionals making essential or very important use of advanced QS mathematics/statistics are most commonly found in financial services (26% of all jobs), business services (20%) education (19%) and metal goods, engineering and vehicles (12%). Jobs involving clerical workers, skilled trades workers and other occupations regularly using QS above the level of basic arithmetical skills account for 17% of jobs in construction, 14% in metal goods, engineering and vehicles and 11% in the wholesale and retail industries.

Table 3.1: Use of quantitative skills in employment, 20–60 year olds, 1997, 2001, 2006 and 2012, population-weighted

A: Adding, subtracting, multiplying or dividing numbers [Arithmetic-1]

	1997	2001	2006	2012
	% of total 20–60 year olds in employment			
Essential	33	33	32	34
Very important	19	20	19	18
Fairly important	18	18	18	19
Not very important	12	16	17	16
Not at all important / does not apply	18	14	14	13
Total	**100**	**100**	**100**	**100**

B: Calculations using decimals, percentages or fractions [Arithmetic-2]

	1997	2001	2006	2012
	% of total 20–60 year olds in employment			
Essential	25	24	26	26
Very important	13	16	14	14
Fairly important	15	16	16	17
Not very important	17	21	20	21
Not at all important / does not apply	30	23	23	22
Total	**100**	**100**	**100**	**100**

C: Calculations using more advanced mathematical or statistical procedures

	1997	2001	2006	2012
	% of total 20–60 year olds in employment			
Essential	10	11	12	14
Very important	7	8	9	11
Fairly important	12	13	13	14
Not very important	22	27	26	25
Not at all important / does not apply	48	41	40	37
Total	**100**	**100**	**100**	**100**
n =	2467	4470	6374	2949

Sources: NIESR estimates derived from Skills Surveys 1997, 2001 and 2006 and Skills and Employment Survey, 2012.

Note: Percentages may not sum to 100 due to rounding.

Table 3.2: Highest level of quantitative skills used in jobs, 20–60 year olds, 1997, 2001, 2006 and 2012, population-weighted

	1997	2001	2006	2012
	% of total 20–60 year olds in employment			
Advanced mathematics/statistics essential or very important	17	19	21	24.6
Advanced mathematics/statistics fairly important	12	13	13	13.6
Arithmetic-2 essential or very important	15	15	13	10.7
Arithmetic-2 fairly important	10	10	10	9.6
Arithmetic-1 essential or very important	8	8	7	5.7
Arithmetic-1 fairly important	4	2	2	3.2
Arithmetic not very important	16	20	20	21.0
Arithmetic not at all important	17	13	13	11.6
Total	**100**	**100**	**100**	**100**
n =	2467	4470	6374	2949

Sources: NIESR estimates derived from Skills Surveys 1997, 2001 and 2006 and Skills and Employment Survey, 2012.

Notes: Percentages may not sum to 100 due to rounding. Column 4 estimates (cited in the main text) are shown to one decimal point to prevent rounded percentages summing to 102.

'Arithmetic-1' refers to adding, subtracting, multiplying or dividing numbers.

'Arithmetic-2' refers to calculations using decimals, percentages or fractions.

Table 3.3: Highest level of quantitative skills used in jobs, 20–60 year olds, 2012, analysed by occupation, population-weighted

	Managers and senior officials	Professionals	Technicians and associate professionals	Clerical	Service and sales workers	Skilled trades	Plant and machine operators and assemblers	Elementary occupations	Total
	% of 20–60 year olds in employment								
Advanced mathematics/statistics essential or very important	37	39	29	24	13	22	7	9	25
Advanced mathematics/statistics fairly important	16	16	13	14	11	22	9	6	14
Arithmetic-2 essential or very important	17	8	12	15	6	12	6	6	11
Arithmetic-2 fairly important	11	7	11	10	6	16	8	9	10
Arithmetic-1 essential or very important	3	3	4	7	10	3	11	7	6
Arithmetic-1 fairly important	2	1	2	3	4	2	11	4	3
Arithmetic not very important	11	22	22	18	31	15	23	25	21
Arithmetic not at all important	3	4	6	9	18	8	26	33	12
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
n =	427	391	446	327	580	299	191	281	2942

Source: NIESR estimates derived from Skills and Employment Survey 2012

Notes: Percentages may not sum to 100 due to rounding.

Skilled trades comprise craft and related workers and skilled agricultural and fishery workers.

Excludes respondents classified to Armed Forces.

Table 3.4: Highest level of quantitative skills used in jobs, 20–60 year olds, 2012, analysed by industry, population-weighted

	Metals, engineeering and vehicles	Other manufacturing	Other production	Construction	Wholesale and retail	Hotels and catering	Transport and communications
	% of 20–60 year olds in employment						
Advanced mathematics/statistics essential or very important – Professionals and associate professionals	12	9	2	2	4	0	4
Advanced mathematics/statistics essential or very important – Managers and senior officials	9	4	6	5	8	7	12
Advanced mathematics/statistics essential or very important – Clerical, skilled trades and other occupations	14	8	5	17	11	6	11
Advanced mathematics/statistics fairly important	16	16	8	22	15	12	13
Arithmetic-2 essential or very important	16	10	22	12	14	10	7
Arithmetic-2 fairly important	7	13	19	13	8	6	7
Arithmetic-1 essential or very important	2	7	2	6	7	22	6
Arithmetic-1 fairly important	3	6	2	2	4	4	5
Arithmetic not very important	11	14	27	15	19	11	15
Arithmetic not at all important	10	13	7	5	11	22	19
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**
n =	192	151	83	183	365	134	161

[Table 3.4 continued]

	Financial services	Business services	Public administration	Education	Health and social work	Other services	Total
	% of 20–60 year olds in employment						
Advanced mathematics/statistics essential or very important – Professionals and associate professionals	26	20	8	19	8	4	10
Advanced mathematics/statistics essential or very important – Managers and senior officials	14	6	4	1	3	9	6
Advanced mathematics/statistics essential or very important – Clerical, skilled trades and other occupations	7	4	9	10	4	7	8
Advanced mathematics/statistics fairly important	12	11	13	14	11	15	14
Arithmetic-2 essential or very important	7	8	9	8	8	15	11
Arithmetic-2 fairly important	10	9	12	10	8	10	10
Arithmetic-1 essential or very important	3	2	8	4	7	4	6
Arithmetic-1 fairly important	5	4	0	2	2	3	3
Arithmetic not very important	15	19	28	27	34	20	21
Arithmetic not at all important	1	15	8	5	16	12	12
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**
n =	106	422	177	324	493	155	2946

Source: NIESR estimates derived from Skills and Employment Survey 2012

Notes: Percentages may not sum to 100 due to rounding.

3.2 Mathematics qualifications and the use of quantitative skills

Recent Skills Surveys have also asked adults in employment: 'What was the highest qualification, if any, that you obtained in mathematics?'. To our knowledge, little use has been made so far of these data and we believe that caution needs to be attached to them for the following reasons. First, upon investigation about 3% of respondents were found to have claimed a highest mathematics qualification which exceeded their claimed highest qualification of any kind (cited in response to another question); these respondents have therefore been included in the 'No information' category for purposes of analysis (Table 3.5). Second, according to the 2012 Skills Survey, about 60% of 20–60 year olds in employment had gained qualifications in mathematics at or above GCSE Grade C or equivalent. This estimate is high compared to an alternative estimate derived from the Skills for Life 2011 Survey in England which suggests that only 49% of 20–60 year olds in employment had gained qualifications in mathematics at or above GCSE Grade C.[3] The contrast between the two estimates is a reminder of the uncertainty attached to many individuals' recall of qualifications gained in what is, for many, a distant past.

3 NIESR estimate derived from Skills for Life 2011 Survey data (population-weighted).

Table 3.5: Highest mathematics qualification, 20–60 year olds in employment, 2012, population-weighted

	% of 20–60 year olds in employment
Mathematics, physics or engineering degree	6
A level or equivalent	11
AS level, BTEC, City & Guilds or equivalent	1
GCSE Grades A*–C or equivalent	42
GCSE Grades D–G or equivalent	14
Other qualifications or no qualifications	19
No information available	7
Total	**100**
n =	2944

Source: NIESR estimates derived from Skills and Employment Survey 2012

Notes: Percentages may not sum to 100 due to rounding.

About 3% of respondents have been reallocated to the 'No information' category because their claimed highest mathematics qualification exceeded their claimed highest qualification of any kind (in response to another question).

In spite of these reservations, analysis of Skills Survey data shows a plausible relationship between the highest mathematics qualification gained and the highest level of QS in use. For example, among employees in professional and associate professional occupations who reported that advanced QS were essential or very important in their jobs, 14% had a degree in mathematics, physics or engineering and another 27% had an A level or equivalent qualification in mathematics (Table 3.6). At the other end of the spectrum, some two thirds of those in jobs where arithmetic was regarded as not at all important held mathematics qualifications below GCSE Grade C or were unable to say what their highest qualification in mathematics was.

At intermediate levels of the occupational distribution there are grounds for concern about whether job-holders' formal education in mathematics has left them well prepared for the QS requirements of their jobs. For example, among clerical, skilled trades and other workers who reported that advanced QS were essential or very important in their jobs, some 45% had a highest mathematics qualification below GCSE Grade C or could not provide information on their highest qualification in mathematics. The same applies to a third of all workers who reported that the use of decimals, fractions or percentages [Arithmetic-2] was essential or very important in their jobs.

Undoubtedly, many adults in employment will have acquired QS through on-the-job training and experience which have not been certificated in any way. This will enable some people not holding mathematics qualifications at GCSE Grade C or above to carry out tasks which require QS above the level of basic arithmetic. Unfortunately, as will be discussed further in Section 5, very little information exists on the extent of uncertificated QS training provided in workplaces. However, given the shortcomings of formal qualifications as a proxy measure of skills, it is important to look at other available indicators such as the task-based proficiency measures reported by the Skills for Life (SfL) 2011 Survey. This survey's findings suggest that a large majority of people in employment have not acquired useful QS through on-the-job training or experience or any other means. As shown in Table 3.7, as many as 75% of 16–65 year olds in employment in England in 2011 were classified below Level 2 on the SfL numeracy performance scale (Table 3.7, Column 1), suggesting that their QS might not be sufficient 'to compare products and services for the best buy or work out a household budget' (BIS 2012, p. xxvii; see also notes to Table 3.7).

Indeed, even if attention is confined to people in work who held a GCSE Grade A*–C pass or equivalent in mathematics, only 35% of them were classified to Level 2 or above on the SfL numeracy performance scale (Table 3.7, Column 2). This is consistent with evidence noted in Section 1 that, in many jobs, possession of a mathematics qualification at GCSE Grade C level does not in itself equip workers to deal with all problems and eventualities that come their way, even if the jobs in questions appear to be relatively low-skilled (Hodgen and Marks, 2013). We now go on to look at other evidence on this potential mismatch between formal education in mathematics and the specific QS requirements found in many workplaces.

Table 3.6: Highest level of quantitative skills used in jobs, 2012, analysed by highest mathematics qualification, population-weighted

	Mathematics, physics or engineering degree	A level or equivalent	AS level, BTEC, City & Guilds or equivalent	GCSE Grades A*–C or equivalent	GCSE Grades D-G or equivalent	Other/no qualif-ications	No information available	Total	n =
Advanced maths/stats essential or very important – Professionals and associate professionals	14	27	2	38	6	12	2	**100**	273
Advanced maths/stats essential or very important – Managers and senior officials	9	19	3	43	9	14	4	**100**	154
Advanced maths/stats essential or very important – Clerical, skilled trades and other occupations	2	9	1	43	20	16	9	**100**	261
Advanced maths/stats fairly important	8	11	3	47	11	14	4	**100**	383
Arithmetic-2 essential or very important	6	12	1	48	13	14	5	**100**	315
Arithmetic-2 fairly important	7	13	1	45	14	15	5	**100**	265
Arithmetic-1 essential or very important	3	7	1	40	17	20	10	**100**	180
Arithmetic-1 fairly important	7	5	1	42	16	27	4	**100**	91
Arithmetic not very important	5	7	1	42	16	20	9	**100**	656
Arithmetic not at all important	1	3	1	27	15	41	12	**100**	366
Total	**6**	**11**	**1**	**42**	**14**	**19**	**7**	**100**	**2944**

Source: NIESR estimates derived from Skills and Employment Survey 2012

Notes: Percentages may not sum to 100 due to rounding.

About 3% of respondents have been reallocated to the 'No information category' because their claimed highest mathematics qualification exceeded their claimed highest qualification (in response to another question).

Table 3.7: Estimated Skills for Life Survey (SfL) numeracy levels of persons in work aged 16–65, England, 2011, analysed by possession or lack of Mathematics GCSE A*–C pass, population-weighted

	All in work	Holders of Mathematics GCSE A*–C or equivalent	Does NOT hold Mathematics GCSE A*–C or equivalent
SfL 2011 Numeracy Level:	% of all persons in work aged 16–65		
Entry Level 1 or below	5	2	8
Entry Level 2	14	7	20
Entry Level 3	24	19	29
Level 1	32	37	28
Level 2 or above	25	35	15
Total	**100**	**100**	**100**
Unweighted n =	3966	1916	2050

Source: NIESR estimates derived from Skills for Life 2011 Survey data

Notes: Percentages may not sum to 100 due to rounding.

Based on all survey respondents aged 16–65 and in work for whom numeracy scores could be obtained.

Numeracy skill levels

These are as set out in the National Qualifications Framework for England, Northern Ireland and Wales in 2011 (BIS, 2012, p. xxvii):

- *Entry Level 1* is the national school curriculum equivalent for attainment at age 5–7.
- Adults with skills below Entry Level 1 may not be able to select floor numbers in lifts.
- *Entry Level 2* is the national school curriculum equivalent for attainment at age 7–9.
- Adults with skills below Entry Level 2 may not be able to use a cash point to withdraw cash.
- *Entry Level 3* is the national school curriculum equivalent for attainment at age 9–11.
- Adults with skills below Entry Level 3 may not be able to understand price labels on pre-packaged food or pay household bills.
- *Level 1* is equivalent to GCSE grades D–G. Adults with skills below Level 1 may not be able to read bus or train timetables or check the pay and deductions on a wage slip.
- *Level 2* is equivalent to GCSE grades A*–C. Adults with skills below Level 2 may not be able to compare products and services for the best buy, or work out a household budget.

3.3 Growth in demand for quantitative skills in workplaces

As shown in Table 3.2 above, Skills Survey findings point to increased demand for QS in workplaces in recent years. Between 1997–2012 the proportion of adults in employment reporting that 'more advanced mathematical or statistical procedures' were essential, fairly important, very important or essential in their jobs rose from 29% to 38%. This evidence of rising QS requirements has been supported by extensive case study research during this period.

For example, Hoyles et al (2002:13) drew on 21 case studies in a mix of manufacturing and service sectors (carried out in 2001–02) to conclude that: 'Because of the pressure of business goals and the introduction of IT [Information Technology], the need for mathematical skills is being progressively extended throughout the workforce'. In their assessment the key drivers of this development included increasing competitive pressures to improve efficiency and quality standards and engage in innovation – all of which required constant monitoring and interpretation of data on within-firm performance, changing customer requirements and preferences and trends in product markets. They observed that the widespread use of IT in workplaces had not reduced the need for QS but rather changed the nature of the skills required (for example, with employees needing to understand the underlying models used by computer software in order to make effective and accurate use of it).

Almost ten years later ACME (2011:2) carried out 25 case studies in diverse sectors and observed that, with the plenitude of data which could be generated by the use of IT, it was now 'commonplace' for firms and other organisations to work with mathematical models which employees 'need to be able to understand, interpret, interrogate and use advantageously'. Examples of mathematical modelling in these cases included tracking production costs and monitoring the performance of machinery and equipment in manufacturing plants, risk assessment in the offshore oil and insurance industries and predictions of customer demand in the water industry.

'Case studies of workplaces point to a wide range of occupations and activities in which accuracy in measurement and data analysis is vital to organisational performance and sometimes critical for public health and safety'

These and other qualitative research studies also shed light on the range of QS covered by the term 'more advanced mathematical or statistical procedures' in the Skills Surveys. At the upper end of the QS spectrum, estimates derived from the Labour Force Survey suggest that about 5–6% of all people in employment are classified to the following occupations which can be regarded as intrinsically relying on high levels of QS: professional engineers, scientists and IT specialists; actuaries, economists and statisticians; and chartered and certified accountants.[4] Many people in these occupations hold university degrees in 'numerate subjects' and/or occupation-specific professional qualifications. Such qualifications are also held by people working in other occupations but are hard to identify in available datasets.

Below these upper layers of QS, case studies of workplaces point to a wide range of occupations and activities in which accuracy in measurement and data analysis is vital to organisational performance and sometimes critical for public health and safety. Examples include hospital staff calculating dosages of medications and patients' nutritional requirements; production operators' using statistical process control (SPC) methods of data collection and analysis; financial services staff advising customers on mortgages and making underwriting decisions; chemicals laboratory technicians preparing solutions to specified concentrations; railways staff responsible for monitoring track quality; managers in many industries making cases for capital investments; and civil servants responsible for reviewing evidence on the effects of government policies (Hoyles et al, 2001; Hoyles et al, 2002; Bakker et al, 2011; ACME, 2011; Hodgen and Marks, 2013; Shepherd, 2014). In many organisations these different functions rely on a division of labour between small numbers of employees who can develop (or at least modify) computer software packages to meet organisation-specific objectives and a much larger number of employees who need to be able to interpret and make use of the resulting statistics (ACME, 2011).

4 NIESR estimate derived from LFS 2012 (April–June quarter), population-weighted.

In a recent review of more than 50 research studies of the use of QS in workplaces, Hodgen and Marks (2013: 7) argue that:

> *'...For all but the most highly numerate and technical jobs.... the academic level of the mathematics required [in most workplaces] is almost wholly within the GCSE curriculum, covering the core areas of:*
> - *Number, particularly mental maths, approximation, estimation and proportional reasoning*
> - *Using and interpreting calculators and spreadsheets*
> - *Statistics and probability, including data collection, interpretation and representation*
> - *Algebra, particularly graphical representation and diagrams*
> - *Geometry and measures, including 2D and 3D representation'*

However, they point out that applying these basic mathematical skills in the 'complex settings' of workplaces poses challenges for many employees even if they did once gain a formal qualification at GCSE Grade C or equivalent level. In the course of their literature review, they report finding:

> *'....many examples of people in the workplace using a 'black-box' approach to some mathematical techniques, where they lack the mathematical knowledge to understand fully the techniques they are using, to control the technology, and to understand and use the outputs' (ibid, p5)*

Under these circumstances the employees concerned may not only make mistakes but may lack the ability to recognise obvious errors in their work. This is one of several reasons for the suggestion by ACME (2011:1) that individuals should preferably study mathematics to a higher level than they are likely to encounter in workplaces in order to acquire 'the confidence and versatility to use mathematics in the many unfamiliar situations that occur at work'.

Another recurrent theme in the research literature is that QS are rarely used in isolation and often need to be combined with other generic skills such as communication skills and with business knowledge and understanding. For example, employees with QS are often expected to be able to explain the results of quantitative analyses to non-specialist colleagues and show their relevance to decision-making within their organisations (Hoyles et al, 2002; Porkess, 2013)

Although case study investigations shed considerable light on QS requirements in workplaces, they are only one type of evidence on employer demand for QS. We now turn to two other information sources in this area, namely, studies of labour market returns to mathematics and related qualifications and skills (Section 4) and employer survey findings on the extent of any mismatches between QS supply and demand (Section 5).

Chapter four

Labour market returns to mathematics-related qualifications and to quantitative skills

4.1 Returns to mathematics compared with other subjects of study

As is well known, average salary levels vary sharply between different subject areas at Bachelor degree level and other formal qualification levels. To the extent that mathematics is one of the subjects attracting above-average salary premia in competitive labour markets, this can be seen as reflecting a relatively high level of employer demand for the skills and knowledge associated with mathematics. At the same time, above-average salary premia for mathematics qualifications should help to encourage individuals to study mathematics and thus, over time, increase the supply of people holding qualifications in this area. However, differences in salary returns to different subjects may persist over long periods of time due to the length of time required to gain many qualifications, lack of information about salary prospects among intending students and lack of lower-level qualifications regarded as prerequisites for studying high-earning subjects.

In economic theory there are two main competing explanations for why average salary levels might vary between subject areas. On the one hand, human capital theory suggests that some subjects of study enhance individual productivity more than other subjects do. On the other hand, signalling theory suggests that some subjects of study provide stronger signals to employers of the innate ability of individuals gaining qualifications in those subjects than other subjects do (Spence, 1973; Weiss, 1995). This debate poses challenges for empirical researchers since much evidence of the relationship between salary premia and subjects of study is consistent with both these theories and it would be no surprise if both mechanisms (human capital development and signalling) were at work to varying degrees in many labour markets.

One key outcome of this debate is that researchers carrying out multivariate regression analysis of factors influencing salary levels pay great attention to ways of controlling for (that is, hold constant) the effects on salaries of individual ability levels, with the aim of isolating other potential influences on salary such as the content of different subjects of study. In reviewing this evidence we pay particular attention to whether studies have grappled seriously with this issue or whether for some reason (perhaps the limitations of their dataset) they have not been able to do so.

Because A level students in England and Wales have the option to drop mathematics when they enter post-compulsory schooling, there is considerable interest in investigating the effects of their subject choices on future labour market outcomes.[5] The most useful datasets for this purpose are longitudinal in nature such as the National Child Development Study (NCDS) which has interviewed a cohort of people born in a single week of 1958 at ages 7, 11, 16, 23, 33, 42, 46, 50 and 55. Thus it is possible to use reading and numeracy test scores from young ages as proxy measures of innate ability in analysis of labour market outcomes. Making use of the NCDS, Dolton and Vignoles (2002) estimate that, after controlling for ability in this way (along with a number of other potential influences on earnings such as qualifications gained, work experience and social class), male 33 year olds with A level mathematics earned about 10% more per year in 1991 than did other males of the same age with A levels in other subject areas but not including maths.[6]

'For men the marginal returns to Bachelor degrees in mathematical and computer sciences are third highest of 20 subject groups, slightly below those associated with law and well behind those associated with medicine and dentistry'

Although Dolton and Vignoles are unable to reject the signalling hypothesis with certainty, they note that other 'hard' subjects such as physics which tend to be chosen by high-ability students did not attract a positive salary premium in the same way as mathematics did. This finding is cited as evidence in support of an argument that 'it is the specific skills and knowledge provided by A level mathematics that attract a wage premium in the labour market' (2002:125).

One mechanism by which A level mathematics might enhance earnings prospects is by equipping individuals to undertake higher education (HE) studies in relatively high-earning subjects that require mathematics. Dolton and Vignoles (2002) explore this issue using a 1986 survey of university graduates who had graduated six years earlier. They find significantly positive effects of A level mathematics on earnings for both male and female graduates even after controlling for degree subject, class of degree and type of HE institution (university or polytechnic). However, they conclude that the relatively high salary returns to studying mathematics at A level probably do reflect to some extent the access that this A level subject gives to HE studies in mathematics, physics, engineering and other quantitatively-based disciplines.

Several studies compare the returns to HE qualifications by subject area using Labour Force Survey (LFS) data which have large enough sample sizes to permit considerable disaggregation by subject area but have the disadvantage of not offering any variables which could serve as measures of innate ability. Estimates based on LFS data for 1996–2009 suggest that marginal earnings returns to Bachelor degrees in mathematical and computer sciences are approximately 41% higher than earnings accruing to people whose highest qualifications are two or more A levels (Conlon and Patrignani, 2011). For men the marginal returns to Bachelor degrees in mathematical and computer sciences (37%) are third highest of 20 subject groups, slightly below those associated with law (39%) and well behind those associated with medicine

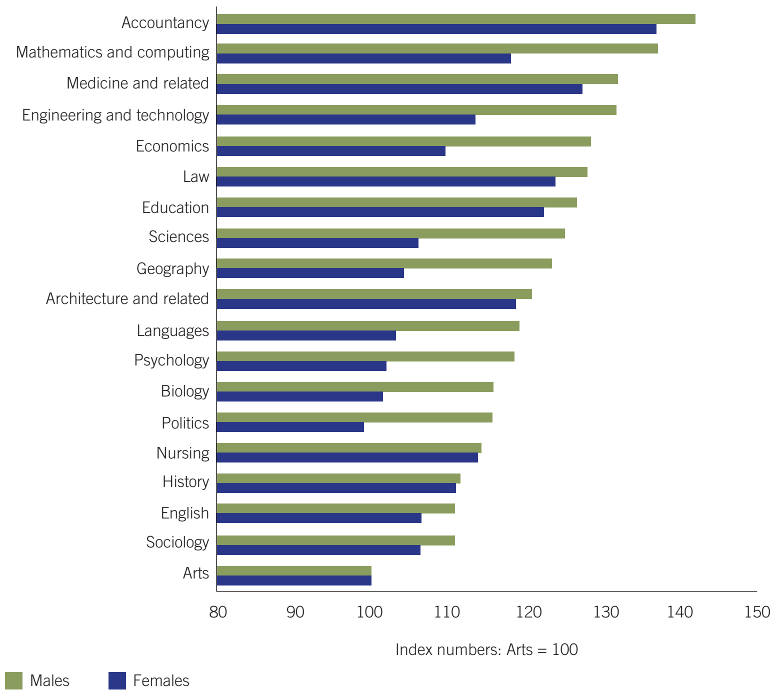
5 Dolton and Vignoles (2002) note that similar studies would not be feasible in countries such as the US where high school students rarely have the option to drop mathematics before leaving secondary education.

6 The analysis is confined to males because of the relatively small number of females in employment at age 33 in the NCDS dataset.

and dentistry (70%). For women the marginal returns to Bachelor degrees in mathematical and computer sciences (48%) are second highest behind medicine and dentistry (92%) (ibid).[7]

In another study of earnings returns to different subject areas at Bachelor degree level, O'Leary and Sloane (2005) also make use of LFS data but seek to adjust their estimates for ability bias using an index of student quality at subject level devised by Leslie (2003) which uses data on university applicants' grades to rank subjects on the assumption that more able students will select more difficult courses. As shown in Figure 4.1, their estimates suggest that the earnings premium attached to mathematics and computing ranks second highest among 19 subject areas for male graduates and sixth highest for female graduates. Several other quantitative degree subjects such as accountancy, medicine and engineering and technology are also highly ranked by this measure. Among subjects that can be regarded as quantitative social sciences, earnings premia are fairly highly ranked for economics (males) and nursing (females) but not for either males or females in psychology.[8]

Figure 4.1: Indices of earnings returns to Bachelor degrees, 1994–2002, analysed by subject area (Index numbers: Arts = 100)



Source: O'Leary and Sloane (2005, Tables 7–8)

7 International comparisons suggest that salary returns to university degrees in science and technology subjects (broadly defined to include mathematics) are also relatively high in other countries such as Germany and the US. However, literature reviews in this field do not refer to comparisons relating specifically to mathematics study (see, for example, Machin and McNally, 2007).

8 ACME (2011) classifies the following subjects as 'social sciences with significant mathematics': psychology, sports science, nursing, economics and finance.

4.2 Returns to quantitative skills compared to other types of skill

Although earnings returns to mathematics as a subject of study are relatively high at both A level and Bachelor degree level, researchers tend to find mixed evidence when QS are compared with other types of skill. Using Skills Survey data for 1997 and 2001, Dickerson and Green (2004) find that – after controlling for gender, work experience, highest qualification level, sector, region and a number of job characteristics – hourly wage premia are significantly positive for computing skills, high-level communication skills, client communication skills and planning skills but not for 'number skills' (broadly defined as a mix of arithmetical skills and more advanced mathematical and statistics skills).

Dickerson and Green (2004) suggest that this result for number skills may reflect the very high correlation which is found between number skills and computing skills. In addition, following the discussion of Skills Survey data in Section 3.1 above, it is possible that more could be learned about the earnings returns to QS if arithmetical skills and more advanced mathematical and statistics skills were entered separately into analysis of labour market returns to different types of skill.

Another explanation for the apparently low earnings returns attached to QS could be that, as discussed in Section 3.3, QS are rarely used in isolation and often need to be combined with other generic skills such as computing skills and communication skills. In later analysis of Skills Survey data from 1997–2006, Green (2012) finds that – in common with several other generic skills – number skills are significantly positively related to innovative forms of work organisation in which employees have some involvement in decision-making and some degree of task discretion.

When basic numeracy skills are considered separately in other studies, there is clear evidence that individuals are better off in terms of employment and earnings rates if they possess such skills rather than being innumerate, as shown in analysis of 1990s UK labour market data in Dearden et al (2000) and McIntosh and Vignoles (2001). In a later analysis of data from the British Cohort Study (1970 cohort) carried out in 2004, Vignoles et al (2011) find that – after controlling for age, gender and indicators of family background – the earnings of 34 year olds in employment are significantly and positively related to basic numeracy skills.[9] These results are also robust to controls for scores achieved in cognitive skills tests undertaken when survey respondents were aged five which is probably a stronger measure of innate ability than test scores derived at older ages after some years of schooling. Vignoles et al also find that labour market returns to basic numeracy skills remained stable during the late 1990s and early 2000s when the supply of people with basic numeracy skills was increasing. This is consistent with a rise in employer demand for basic numeracy skills over this period.

9 In the BCS follow-up survey in 2004, numeracy was assessed through tasks ranging from simple adding-up to use of a 24 hour clock in using a video recorder and extraction of information from graphs and timetables (Parsons, 2012).

BOX 1: Social returns to quantitative skills

All of the studies surveyed in Section 4 have focussed on the private returns to different subjects of study and different types of skill, without reference to the social returns. This is because a central purpose of this review is to evaluate the extent to which mismatches exist between employer demand for QS and the available supply of QS, and private returns shed light on the strength and nature of employer demand for different types of skill. However, it is useful to briefly summarise evidence relating to the social returns to QS.

A considerable literature exists on the social benefits of higher education which take the form of both economic benefits (eg, higher tax revenues, increased productivity of co-workers employed alongside university graduates and higher levels of innovation) and non-economic benefits (eg, reduced crime, increased social trust and tolerance and greater political stability). This literature is reviewed extensively in BIS (2013b) but no distinction is made between social returns to mathematics study and those to other subjects.

By contrast, available evidence on the social benefits of lower levels of education focuses in detail on the acquisition of basic numeracy skills. For example, in a recent study of adult learners in the UK, those gaining skills in numeracy reported improvements in their ability to help children with homework and in their physical health and mental well-being (BIS, 2013c, 2013d). These wider benefits were in addition to improvements in private returns in the form of higher employment and earning rates (in line with evidence noted in Section 4.2).

Numeracy and statistical understanding are also widely recognised as desirable elements of citizenship that are important for negotiating everyday life and engaging in public life. For example, a great deal of the current debate about the NHS is driven by statistical claims and other forms of quantitative evidence, both on spending levels and on the effect of treatments and organisational changes on patient outcomes. 'Ordinary' citizens need to be able to engage with these issues; equally, the media and elected politicians need to be clear on what is being claimed and how robust the evidence being marshalled actually is. These are important issues which are promoted by, for example, the GetStats campaign organised by the Royal Statistical Society[10] and the Campaign for Social Science.[11]

10 www.statslife.org.uk/; https://twitter.com/rssgetstats, accessed 27 January 2015.

11 http://campaignforsocialscience.org.uk/, accessed 27 January 2015.

BOX 2: Quantitative skills and economic performance

As shown in Section 3.1, QS requirements are pervasive in industrialised economies. In the UK economy about seven in ten employees say that QS are essential or important to carry out their work. The extensive case study evidence reported in Section 3.3 suggests that, in a wide range of occupations and activities, accuracy in measurement and data analysis is vital to performance within firms and other organisations (as well as sometimes being critical for public health and safety). The most highly-skilled among QS-based occupations have also been found to contribute disproportionately to productivity performance within the UK. Deloittes (2012) define a category of 'mathematical science research occupations' which includes professional mathematicians and statisticians, engineers, physical scientists, IT professionals, social scientists, finance professionals, medical practitioners, administrators and senior managers. People in these occupations are estimated to account for 10% of jobs and 16% of gross value added in the UK economy.

On the face of things, therefore, it might be thought that cross-country differences in the QS held by people in employment should be readily identifiable as contributing to international differences on measures of economic performance such as productivity and competitiveness. However, this is not the case for two main reasons.

First, most discussion of the relationship between skills and economic performance focusses on broad categories of skills, including QS but not specifically referring to QS. For example, the Global Competitiveness Report 2014–15 published by the World Economic Forum identifies high-quality education and training as one of several 'pillars' of competitiveness at national level. Its measures of this variable are enrolment rates in secondary and tertiary education as a whole and business leaders' evaluations of the quality of education and training in their own country (WEF, 2014).[12]

Second, skills of any kind can only contribute to economic performance when they are applied in combination with other production inputs. A standard approach in economic analysis is to model economic performance (eg, growth in labour productivity) at national level as a function of capital (eg, machinery, equipment, buildings and land), skilled labour, unskilled labour, raw materials and other inputs and then to seek to evaluate the contribution of each type of input to performance through multivariate regression analysis which enables the effects of other inputs on performance to be held constant. In a survey of the econometric literature in this area, Sianesi and van Reenen (2003) concluded that, while the evidence of a positive effect for human capital was 'compelling', the empirical evidence was nonetheless 'still weak at various crucial points' (ibid: 192). In particular, they emphasised the many methodological issues that remained unresolved in this field such as how best to measure skills (discussed in Section 3.1 of this report) and how to model possible channels of influence of skills on economic performance (for example, the role of skills in supporting the introduction of new technologies).

Very few studies of this kind have focussed on QS rather than skills in general but an exception can be found in Hanushek and Woessmann (2008, 2012) who combined mathematics and science test scores from TIMSS and PISA surveys (and predecessors to TIMSS) over a 40 year period to generate a proxy measure of cognitive skills at country-level (see Section 2 for further details on these surveys). This measure of cognitive skills was found to be significantly

12 The Executive Opinion Survey administered by the World Economic Forum includes a question focussing specifically on the perceived quality of mathematics and science education but the responses to such a question can only be subjective in nature. Business leaders are asked to respond on a seven-point scale to the following question: 'In your country, how would you assess the quality of math and science education? [1 = extremely poor—among the worst in the world; 7 = excellent—among the best in the world]'

and positively related to growth in real output per capita between 1960–2000 across 50 countries.[13]

Note that this finding reflects the average contribution of cognitive skills (including QS) across the countries concerned once the contributions of other production inputs have been held constant through multivariate regression techniques. There is no suggestion that the strength or weakness of any country on measures of QS and other cognitive skills will automatically feed through to its ranking in terms of productivity performance. For example, the United States has been found to have relatively modest attainments in average test scores for mathematics and science (Mullis et al, 2012). However, it has still enjoyed world productivity leadership over several decades because its weakness on this measure of skill has been more than offset by advantages such as greater scope for economies of scale in production and heavy investments in research and innovation (O'Mahony and van Ark, 2003; van Ark, O'Mahony and Timmer, 2008).

Other evidence of links between QS and economic performance comes from analysis at the level of individuals rather than countries. As shown in Section 4.1, employers' perceptions of the economic value of QS account in part for relatively high salary returns to mathematics as a subject of study at both A level and Bachelor degree level. However, even at individual level, the evidence is more mixed when salary returns to QS are compared with other types of skill such as computing skills, high-level communication skills, client communication skills and planning skills. In general, QS are rarely used in isolation and only become economically productive when they are combined with other generic skills as well as with other production inputs.

13 The main reason for combining student mathematics and science test scores over such a long period is to try and measure the stocks of cognitive skills in each country which have built up over time as successive waves of students have entered employment (and older workers have retired). See Hanushek and Woessmann (2011) for details of how test scores are standardised before they are aggregated over time (Section 5.3) and a review of evidence suggesting that cross-country differences in sample selection should not seriously bias their multivariate regression findings (Section 3.2). The authors argue that this latter point applies even though there may be legitimate grounds for concern about mismeasurement of country mean performance.

Chapter five

Survey evidence on employer demand for quantitative skills

5.1 Mismatches between QS demand and supply: CBI and NESTA surveys of employers

Taken together, the evidence from case studies and from analyses of labour market returns to mathematics as a subject of study in the UK points to strong employer demand for QS (in conjunction with other skills), with several indicators that the currently available supply of QS may be insufficient to meet demand.

Some of the most widely-cited survey evidence on deficiencies in the QS of British employees comes from annual surveys of employers carried out for the Confederation of British Industry (CBI). These surveys are based on relatively small samples which are not nationally representative in nature and it is therefore hard to know how far their findings can be generalised to the wider population of employers. However, the CBI surveys ask very useful questions about QS demand and supply which have no parallels in larger and more representative employer surveys, and this adds interest to their findings.[14]

In the last four years CBI survey samples have ranged in size from 291–566 employers with combined employment of 1.4 million to 2.2 million people (Table 5.1). Around half of employers in these samples consistently report weaknesses in basic numeracy among some employees and 30–40% report equivalent concerns about school and college leavers. In general, the CBI samples tend to over-represent large and medium-sized firms and manufacturing firms and public sector workplaces. At the same time some large service sectors such as retail, hospitality and business services are under-represented. Hence it cannot be assumed that similar findings would emerge from a nationally representative random sample of UK employers. Nonetheless, these high levels of reported concerns are consistent with the case study evidence reviewed in Section 3.3, in particular, the assessment by Hodgen and Marks (2013) that many employees using IT equipment lack the mathematical knowledge to understand fully the techniques they are using and the statistical outputs of those techniques. They are also consistent with findings from the 2011 Skills for Life Survey that 43% of all persons in work aged 16–65 have numeracy skills below the Level 1 grade (BIS, 2012, Table 8.15) and thus 'may not be able to... check the pay and deductions on a wage slip... [or] work out a household budget' (see notes to Table 3.7).

14 As with all employer surveys relating to QS, there must also be concerns about how well qualified some managerial respondents are to assess QS requirements in their organisations given the evidence of QS weaknesses among a significant proportion of managers themselves (see, for example, BIS, 2012, Table 8.15). This point is discussed further below in Section 5.2.

Table 5.1: CBI survey findings on QS weaknesses among employees and employer-provided 'remedial' training in numeracy, 2011–14

	2011	2012	2013	2014
	% of employers in survey			
% reporting weaknesses in basic numeracy in some employees	48	56	51	53
% providing 'remedial' training in numeracy for adult employees	13	13	13	13
% dissatisfied with basic numeracy among school/college leavers	35	30	39	38
% providing 'remedial' training in numeracy for school/college leavers	21	18	14	19
n =	566	542	294	291
Employment coverage (mn)	2.2	1.6	1.24	1.4

Source: CBI (2011, 2012, 2013, 2014)

In this context the CBI survey findings on employer-provided 'remedial' training in numeracy are also of interest because we have not been able to find other surveys of employers that collect detailed information on the extent to which employer-provided training specifically aims to improve QS. As shown in Table 5.1, between 2011–14 about 14–21% of CBI survey employers said that they provided training in numeracy for school and college leavers and 13% in each year said they provided such training for adult employees. These proportions are notably lower than those reporting QS weaknesses among employees, suggesting that many employers feel they can 'get by' with having some employees with limited QS (perhaps by organising work in such a way that the effects of their QS weaknesses are minimised; more evidence is needed on the extent of such responses by employers).

At the other end of the QS spectrum, a series of reports from NESTA (National Endowment for Science, Technology and the Arts) has explored the skills requirements of firms that seek to make intensive and sophisticated use of online data (for example, gathering information from website pages viewed, online sales data or inquiry forms, or via packages such as Google Analytics). These studies are based on a survey of 500 UK firms that were identified in advance as having active on-line business operations. The survey sample was confined to firms with 50 or more employees and covered a range of service and manufacturing sectors (Bakshi and Mateos-Garcia, 2012; Bakshi et al, 2014a).[15]

'Internal skill deficiencies were outweighed as barriers by problems with legacy systems, inflexible business processes within the firms and concerns about customer privacy and data security'

Only 18% of these firms were found to be relying mainly on data and analysis for their decisions about how to try and improve their sales growth, for example, using techniques such as data/text mining, forecasting or randomised control trials (for example, switching on/off website features or advertisements). The remaining firms tended to make less intensive use of on-line customer data and rely much more on experience and intuition. The firms relying mainly on data and analysis for strategic decision-making were labelled as 'datavores' and were found to enjoy

15 The sector coverage of this sample is described as 'broadly similar' to that of all firms with 50-plus employees in the FAME database which served as a sampling frame, except for financial services being under-represented and information and communications firms being 'slightly over-represented' (Bakshi and Mateos-Garcia, 2012: 13).

advantages in both productivity and profitability over other firms which did not engage systematically in data-driven decision-making (Bakshi et al, 2014a).

When non-datavore firms were asked about the barriers to making intensive use of on-line customer data, just under a quarter (23%) of them said that they lacked the necessary skills within their businesses. But internal skill deficiencies were outweighed as barriers by problems with legacy systems, inflexible business processes within the firms and concerns about customer privacy and data security (Bakshi and Mateos-Garcia, 2012, Figure 15).

Greater concerns regarding skills emerged from 45 follow-up interviews conducted with managers and data scientists working for datavore firms (Bakshi et al, 2014b). In this study the emphasis shifted from the skills of existing staff to the difficulties experienced in recruiting new 'data talent' in the UK. About four in five of these interviewees reported a lack of job candidates with the right mix of coding and analytical skills and the 'commercial nous to create business impacts'. The policy recommendations emerging from these interviews included more professional development for people already in the workforce, better access to recruits from overseas and more attention to the development of 'hybrid skill sets' by UK universities (ibid, p30). We return to these high-level skills issues in Section 6.3.

5.2 Mismatches between QS demand and supply: nationally representative employer skills surveys

Although the CBI and NESTA surveys shed a great deal of light on different kinds of QS deficiency in the UK economy, they do not purport to be nationally representative in nature. Therefore, we now turn to the biennial UK Commission's Employer Skills Survey (UKCESS) – formerly known as the National Employer Skills Survey (NESS) – which is based on fully representative samples of UK employers across all sectors of the economy (private, public and charitable). In 2013 there were just under 92,000 respondents in total, covering establishments (as opposed to firms) with at least two staff (including both employees and working proprietors). Telephone interviews were conducted with the most senior person at each site who had responsibility for recruitment, training and human resource issues (Winterbotham et al, 2014). Typically, in larger establishments, these respondents were senior managers in human resource or personnel departments; in smaller establishments they tended to be owners or general managers.

UKCESS gathers information which enables three different indicators of skill deficiency to be estimated at establishment level:

1. External recruitment difficulties attributable to skills-related factors (such as reported lack of skills, qualifications and/or work experience among job candidates)

2. Internal skill gaps (defined as existing employees lacking full proficiency in their jobs)

3. Skills in need of updating and improvement among existing employees within the next 12 months

Table 5.2 shows a broadly similar incidence of such deficiencies across all establishments in 2011 and 2013. Focussing on 2013, only 4% of establishments reported having skills-related external recruitment difficulties at the time of the survey (just over a quarter of all establishments which had a job vacancy of any kind at that time). This is quite a narrow way to define skills-related external recruitment difficulties: if establishments had been asked about their experience in filling vacancies over a longer period (say, 3, 6 or 12 months) then a larger proportion of them would probably have reported having difficulties in recruiting people with the skills that they were seeking.

In the case of internal skill gaps, about 15% of establishments reported having some existing staff who lacked full proficiency in their jobs. In total, about 5% of all people employed in surveyed establishments were reported to fit this description. However, many more employees were regarded as proficient in their jobs but still in need of having their skills updated or improved. Overall, some 71% of establishments reported having some employees with such skill updating needs (Table 5.2).

Table 5.2: Indicators of skill deficiencies in UK Commission's Employer Skills Surveys, UK, 2011 and 2013, population-weighted estimates

	2011	2013
% of establishments with any vacancies	14	15
% of establishments with any hard-to-fill vacancies	4	5
% of establishments with skills-related external recruitment difficulties	3	4
% of establishments with any staff not fully proficient in their jobs	17	15
Staff not fully proficient as % of employment	6	5
% of establishments which expect some employees to need skills updated or improved within the next 12 months		71
All establishments: unweighted n =	87572	91729

Source: UKCESS 2013 (Winterbotham et al, 2014, pages 8, 51)

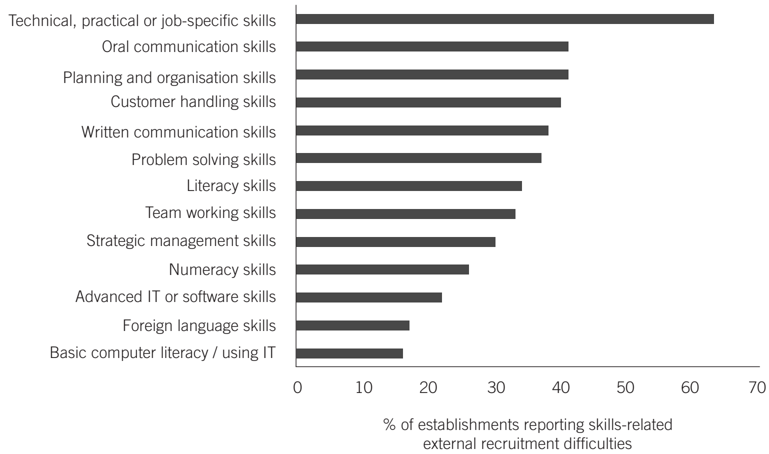
Note: UKCESS 2011 did not include questions on skills updating.

These three types of skill deficiency have very different implications for firm performance. Analysing similar data from the 2009 version of this survey, Mason (2011) found that internal skill gaps appeared to constrain the adoption of high value added innovation-intensive product strategies. However, skills-related external recruitment difficulties and the incidence of skills updating needs among existing employees were both positively related to measures of product strategy and innovation. In general, they were indicators of high levels of vacancies in the first place (due to rapid growth), relatively high standards being set for skills both in recruitment and internal staff development and a more dynamic approach to identifying skill improvement needs which could be addressed through training.

Further information on the types of skill associated with each type of deficiency suggests that QS were by no means uppermost in the minds of survey respondents. In the case of the small minority (4%) of establishments reporting skills-related external recruitment difficulties, only one in four of these establishments attributed their problems to lack of 'numeracy skills' (Figure 5.1). Much higher proportions (37–63%) were concerned about job applicants lacking technical, practical or job-specific skills or generic skills such as planning and organisation skills, oral and written communication skills, customer handling skills or problem-solving skills. These types of skill also featured more prominently in connection with internal skill gaps than did numeracy skills (Figure 5.2).

In the case of skill updating needs, it is worth considering in some detail how the estimates were derived before looking at how strongly QS featured. Respondents were first asked whether they expected that, over the next 12 months, any of their employees would need to acquire new skills or knowledge as a result of specific factors such as new products, new technologies, new work practices, new legislative or regulatory requirements or increased competitive pressures. Those who responded affirmatively to at least one type of skills updating need were then asked to identify the single occupation most affected by such needs, and to indicate which different types of skills were most in need of improvement for the occupation they had selected.

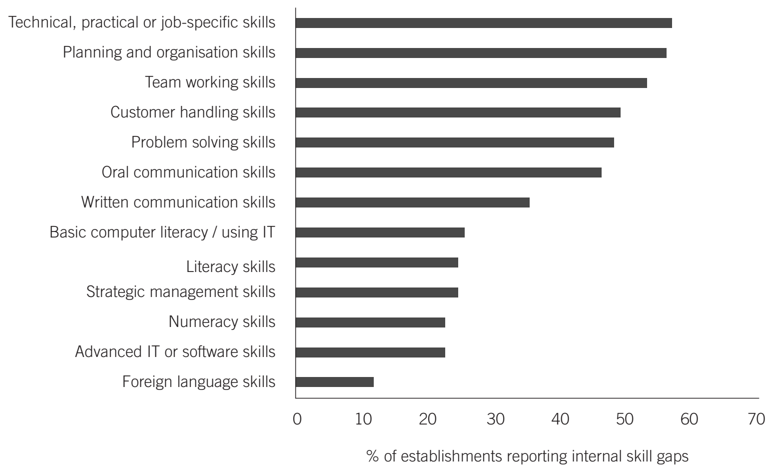
Figure 5.1: Skills lacking among job applicants, UK establishments reporting skills-related external recruitment difficulties, 2013, population-weighted estimates



Source: UKCESS 2013 (Winterbotham et al, 2014, Figure 2.3)

Note: Based on all establishments reporting skills-related external recruitment difficulties: unweighted n = 4987

Figure 5.2: Skills lacking among employees reported as lacking full proficiency in their jobs, UK establishments reporting internal skill gaps, 2013, population-weighted estimates



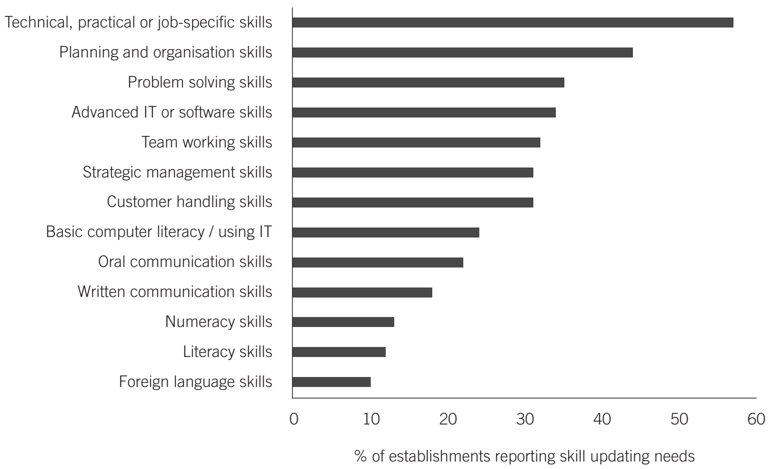
Source: UKCESS 2013 (Winterbotham et al, 2014, Table 3.4)

Note: Based on all establishments reporting internal skill gaps: unweighted n = 20228

The occupation group most commonly reported as having skill updating needs was professionals with 40% of establishments which employed professionals citing the need for updating of some of their skills (Winterbotham et al, 2014, Figure 3.3). They were followed by caring and leisure occupations (37%), managers (32%), skilled trades (31%), associate professionals (29%) and sales and customer service occupations (29%). Thus it is clear that employees in a wide range of occupations have skill updating and improvement needs, reflecting the pace of change in workplaces and the intensity of market competition. Overall, as noted above, as many as seven in ten of all establishments reported that at least some employees need upskilling.

When asked about the specific nature of the skills that needed updating for their most important single occupation affected by such needs, respondents again ranked numeracy skills fairly low. Only 18% of establishments affected by upskilling needs cited numeracy skills compared to 57% mentioning technical, practical or job-specific skills and 35–44% mentioning planning and organising skills and problem-solving skills (Figure 5.3). The relatively low ranking of numeracy applies across all occupation groups. For example, in the case of establishments where professionals were the most important single occupation in need of upskilling, numeracy skills were mentioned by only 11% of respondents compared to 70% citing technical, practical or job-specific skills (Table 5.3, Column 2).

Figure 5.3: Skills needing updating or improving in the next 12 months, UK establishments reporting skill updating needs, 2013, population-weighted estimates



Source: UKCESS 2013 (Winterbotham et al, 2014, Figure 3.4)

Note: Based on all establishments reporting skill updating needs, excluding those where main occupation is unknown: unweighted n = 32630

Table 5.3: Skills needing updating or improving in the next 12 months, UK establishments citing single occupations most affected by skill updating needs, 2013, population-weighted estimates

	Managers	Professionals	Associate professionals	Administrative and clerical	Skilled trades	Caring, leisure and other services	Sales and customer service	Machine operatives	Elementary occupations
	% of establishments reporting upskilling needs relating to each occupation group								
Technical, practical or job specific skills	49	70	75	55	71	61	55	70	59
Planning and organising skills	44	43	43	41	38	53	50	34	47
Problem solving skills	32	32	35	34	35	41	44	31	44
Advanced IT or software skills	36	48	51	49	23	20	26	17	14
Team working skills	28	30	28	27	28	53	43	30	50
Customer handling skills	25	24	31	31	26	43	56	21	51
Strategic management skills	39	32	27	27	18	24	27	12	20
Basic computer literacy / using IT	24	18	17	29	23	32	28	24	25
Oral communication skills	18	17	18	22	18	35	34	20	38
Written communication skills	15	17	19	20	16	36	21	15	23
Numeracy skills	11	11	7	16	10	18	14	11	23
Literacy skills	10	11	8	15	11	23	15	10	18
Foreign language skills	11	10	8	10	5	10	12	5	11
Unweighted base size (establishments with upskilling needs in each occupation group)	11552	3369	1666	2602	3423	2562	3966	1469	2021

Source: UKCESS 2013 (Winterbotham et al, 2014, Table A.3.8)

Note: Based on all establishments reporting skill updating needs for single occupations most affected by such needs

To what extent do these findings from a large-scale nationally representative survey cast doubt on the evidence of widespread QS deficiencies that emerges from case study investigations (Section 3.3) and smaller, admittedly unrepresentative surveys such as the CBI surveys (Section 5.1)?

Before considering this question, several points need to be made. First, the term 'numeracy skills' is used in the UKCESS questionnaire without being defined in any way and without any attempt to differentiate between basic numeracy skills and more advanced numeracy skills. This contrasts with the approach to computing skills in the questionnaire for which a distinction is made between 'Basic computer literacy / using IT' skills and 'Advanced IT or software skills'. Thus it is unclear how the term 'numeracy' was interpreted by the majority of respondents.

Second, recall the Skills Survey evidence that QS are highly correlated with other generic skills such as computing skills in respect of job requirements (Section 4.2) and the case study evidence that QS are rarely used in isolation and often need to be combined with other generic skills such as computing skills and communication skills (Section 3.3). It is difficult for surveys such as UKCESS (trying to cover a lot of ground in a short time by listing separate skill categories) to do justice to these interconnections between skill requirements.

Third, it can be argued that mathematics study actually helps to develop other generic skills such as logical thinking and problem-solving that are highly ranked among employers' skill requirements (Dolton and Vignoles, 2002). If we consider the wider category of STEM skills, Bosworth et al (2013) report evidence of a 'problem' perceived by some STEM employers that a large and apparently growing proportion of STEM graduates now work in non-STEM jobs and industries. One of the drivers of this diffusion of STEM graduates throughout the wider economy is that they are widely seen as possessing desirable skills in mathematics and in 'logical approach[es] to solving problems' (BIS, 2011: 7). Thus some employers may implicitly rate QS highly but not identify them separately in response to survey questions.

Fourth, estimates derived from the Skills for Life 2011 Survey in England suggest that as many as 58% of people in 'higher managerial and professional' occupations do not have numeracy skills at Level 2 or above (BIS, 2012, Table 8.15).[16] Thus many managerial respondents to the UKCESS may be poorly equipped to assess QS or judge the need for them.

For these reasons we suggest that a new nationally representative survey of employers with a specific focus on QS issues is needed to assess the true extent of problems identified by case studies and the CBI surveys. This new survey should seek detailed information on the demand for and utilisation of QS in workplaces and the extent to which employers either adapt to poor QS or seek to upgrade QS through providing training for existing employees and/ or new recruits. Such a survey would ideally make use of both quantitative and qualitative research techniques and would seek to interview multiple respondents (including workers as well as managers) in each workplace. We elaborate further on these suggestions in Section 8.2 below.

5.3 Foreign sources of QS supply: UK employers' reliance on inward migration

Any new survey of the ways in which employers meet their QS needs should pay particular attention to the role of skilled migrants who are becoming an increasingly important element in global labour movements, especially to more developed nations. Between 2000–01 and 2010–11, for example, OECD countries saw total migrant stocks rise by over 20% to about 100 million people. During the same period, the number of tertiary-educated migrants rose by 70%, over three times faster than the global count, reaching 27.3 million in 2010/11 (UN-DESA/OECD, 2013). Skilled migrants now comprise nearly 29% of all migrants in OECD countries, up from 24% in 2000–01.

Highly-qualified workers with QS make up an important component of this labour flow which reflects patterns of employer demand as well as macro conditions in sending and receiving countries and migration policy regimes in the latter. For example, estimates based on the Labour Force Survey (LFS) suggest that in 2014 about 21% of employees in QS professional occupations (defined as professional engineers, scientists and IT specialists; actuaries, economists and statisticians; and chartered and certified accountants) had been born outside the UK compared to 16% in other professional occupations (Table 5.4, Column 5) and 15% in all non-professional occupations.[17] Among the foreign-born QS professionals, about one in three had been born in countries belonging to the European Economic Area (EEA, defined here as all European Union member states in 2014 plus Iceland, Liechtenstein, Norway

16 Recall from Section 3.2 above that 'adults with skills below [SfL] Level 2 may not be able to compare products and services for the best buy or work out a household budget' (see notes to Table 3.7).

17 NIESR estimates derived from Labour Force Survey 2014 (all quarters).

and Switzerland).[18] The remaining two thirds of foreign-born QS professionals had been born outside the EEA.

The biggest differences between QS and non-QS professional occupations in terms of national origin are shown in younger age groups. For example, almost a third of 30–39 year olds in QS occupations had been born outside the UK. Of these just under two thirds had arrived in the UK within the previous ten years, with non-EEA nationals in this category outnumbering EEA nationals by two to one (Table 5.4, Part A, Column 2). By contrast, in non-QS professional occupations, the proportion of foreign-born employees was 20%, just over half of whom had been in the UK for ten years or more by 2014. Of those who had arrived in the UK within the previous ten years, a majority were non-EEA nationals but not to the same extent as for foreign-born QS professionals (Table 5.4, Part B, Column 2).[19]

This disproportionate share of non-EEA migrants among QS professionals in the UK appears to reflect both difficulties in recruiting QS and other STEM workers from within the UK (MAC, 2013; Broughton, 2013) and the distinctive qualities of some non-EEA migrants such as their language skills and knowledge of foreign markets and cultures (George et al, 2012). Many such migrants are brought into the UK as internal transfers within multinational firms operating in sectors such as oil and gas extraction; chemicals and pharmaceuticals; telecommunications services; computer services; aerospace manufacturing; architectural and engineering services; and computer, electronic and optical engineering (ibid).

Table 5.4: Employees in professional occupations, analysed by age band and country of birth, UK, 2014, population-weighted averages

A: QS professional occupations (professional engineers, scientists and IT specialists; actuaries, economists and statisticians; and chartered and certified accountants)

Age band:	20–29	30–39	40–49	50–64	Total
	% of employees in QS professional occupations				
Country of birth:					
UK	81	68	80	85	79
EEA, arrived before 2004	1	3	3	4	3
EEA, arrived 2004–09	2	5	1	1	2
EEA, arrived since 2009	5	2	2	0.4	2
Non-EEA, arrived before 2004	4	8	10	9	8
Non-EEA, arrived 2004–09	4	7	2	1	4
Non-EEA, arrived since 2009	4	6	2	1	3
Total	**100**	**100**	**100**	**100**	**100**
Unweighted n =	1407	3101	293	4966	9767

18 Although Switzerland is not a member of the EEA, one effect of bilateral treaties between Switzerland and the EU is that Swiss nationals have the same rights to live and work in the UK as do other EEA nationals.

19 The differences in foreign-born shares of employment between QS professionals and non-QS professionals are statistically significant at the 1% level for both the 30–39 age group (p<0.001; n = 9973) and the 20–29 age group (p<0.001; n = 4551) and for all employees aged 20–64 (p<0.001; n = 34791).

B: Other professional occupations

Age band:	20–29	30–39	40–49	50–64	Total
	% of employees in other professional occupations				
Country of birth:					
UK	87	80	79	86	84
EEA, arrived before 2004	1	3	2	3	3
EEA, arrived 2004–09	2	3	4	0.5	1
EEA, arrived since 2009	3	1	0.4	0.1	1
Non-EEA, arrived before 2004	3	8	11	9	8
Non-EEA, arrived 2004–09	2	4	4	1	2
Non-EEA, arrived since 2009	2	1	0.5	0.3	1
Total	**100**	**100**	**100**	**100**	**100**
Unweighted n =	3144	6872	732	14276	25024

Source: NIESR estimates derived from Labour Force Survey 2014 (all quarters)

Notes: Percentages may not sum to 100 due to rounding. See main text for definition of the EEA = European Economic Area.

The UK is not alone in such heavy reliance on foreign-born QS professionals. For example, firms in the US also employ sizeable numbers of foreign-born IT and other QS-related professionals (Kerr et al, 2013; Ghosh et al, 2014). Clearly, this is a market where many workers with high-level QS are internationally mobile, not least through international transfers within multinational firms. Further research would be needed to gain a detailed understanding of how the UK compares against other countries in terms of both inward flows of foreign-born QS professionals and outward flows of UK-born QS professionals. For purposes of this report, the main inference we draw from the LFS-based evidence described above is that access to foreign-born QS professionals acts as an important safety valve for UK-based employers who might otherwise report higher levels of QS-related recruitment difficulties to surveys such as the UKCESS.

Chapter six

Higher education and quantitative skills supply and demand

6.1 Mathematics attainments in upper secondary education

Universities' demand for incoming students to possess QS appropriate to their intended levels and subjects of study is typically discussed in terms of both the quantity of entrants who have studied mathematics beyond the age of 16 and the quality (or standard) of the skills and knowledge that they have gained in the course of such study. We examine each of these issues in turn.

The relatively low proportion of students in England, Wales and Northern Ireland who study mathematics at A level has been lamented for decades but with no decisive action taken to avoid this outcome. Hodgen et al (2010, Table 6) show that England, Wales and Northern Ireland are alone among 24 advanced industrial nations in having fewer than 20% of upper secondary students participating in mathematics study (referring to continued study in basic mathematics as well as advanced studies covering topics in pure mathematics and/or statistics).

In spite of Scotland's preservation of a broader upper secondary curriculum than is found in the rest of the UK, it is one of only three other countries with fewer than half of upper secondary students continuing with mathematics study. Eight of the 24 countries have 95%-plus participation rates and another six are in the 81–94% category. The four UK countries also compare unfavourably in terms of advanced mathematics study at upper secondary level, with Scotland again ahead of England, Wales and Northern Ireland but only regarded as middle-ranking compared to other countries (ibid).

These inter-nation differences do not just reflect varying degrees of compulsion to study mathematics after the age of 16 but also differing levels of encouragement to study a broad range of subjects and differences in the availability of courses that permit advanced study of statistics without embarking on pure mathematics topics such as calculus (Hodgen et al, 2013).

In England, Wales and Northern Ireland the low take-up of mathematics post-16 is attributed not just to the structure of the A levels curriculum – obliging students to narrow down to a small number of subjects – but to concerns that students have about their own abilities to do well in the subject (Vidal Rodeiro, 2007; Mendick, 2008) and perceptions (apparently justified) that mathematics is a relatively difficult subject in which to obtain high grades (Brown et al, 2008; Coe et al, 2008). In addition, efforts to develop alternatives to A or AS level mathematics for post-16 students have met with limited success (Hillman, 2014).

Ultimately, constraints such as many students lacking confidence in their ability to do well in mathematics reflect deep-rooted shortcomings in primary and early secondary mathematics education. In 2009 a House of Commons Public Accounts Committee report concluded that, in spite of increased public expenditure on a National Strategy to improve performance in primary mathematics under the then Labour government, primary mathematics test results levelled off between 2000–08 and just over one in five primary school pupils were still 'starting secondary school without a secure foundation in mathematics' (HoC, 2009:3). A key factor contributing to this outcome was reported as a lack of primary teachers 'who could combine strong [mathematics] subject knowledge with good interpersonal skills and the ability to engage children in the subject' (ibid: 13).

More recently, new initiatives have sought to address teacher quality issues and to generate improvements in mathematics teaching methods, for example, by increasing access to mathematics-specific continuing professional development for teachers at all levels of education (including primary education)[20] and establishing a national network of 'maths hubs' that will seek to learn from mathematics teaching methods practised in East Asian countries such as Japan, Singapore and China.[21]

However, for the foreseeable future mathematics teaching standards will remain of concern, in part because of the cumulative effects of past shortcomings in mathematics teaching which have inevitably fed through into subsequent shortages of suitable candidates for mathematics teacher training (Royal Society, 2007). In a recent report on the science and mathematics teaching workforce, Smithers and Robinson (2013) cite continuing evidence of mathematics teacher training providers 'struggling to fill places' (p38).

Although the take-up of mathematics study after the age of 16 remains low by international standards in most parts of the UK, A level mathematics entries did grow by just over two thirds between 2003–04 and 2013–14 in England, Wales and Northern Ireland and now account for about 10.7% of total A level entries, up from 6.9% ten years earlier (Table 6.1). At the same time AS level mathematics entries rose even faster and are now 80% higher than A level entries.[22] However, similar growth occurred over this period in A level entries in other QS-intensive subjects such as physics and chemistry so it is not clear how much this growth in mathematics entries signified expanded numbers of students taking mathematics/science combinations as compared with expanded numbers of students combining mathematics with non-quantitative subjects.[23]

In Scotland there has been much slower growth in post-16 mathematics entries in the ten years to 2013–14 but it took place from a higher base than in the rest of the UK. Mathematics now accounts for 15.4% of total entries at Advanced Higher level in Scotland and 11.4% at Higher level (Table 6.2).

20 National Centre for Excellence in the Teaching of Mathematics (NCETM): www.ncetm.org.uk

21 www.gov.uk/government/news/network-of-32-maths-hubs-across-england-aims-to-raise-standards

22 Note that the 17–18 year old age cohort in England, Wales and Ireland was only 1.8% larger in mid-2013 than in mid-2003, according to ONS Population Estimates.

23 Further research would be useful to explore this issue in more detail.

Table 6.1: AS level and A level entries, England, Wales and Northern Ireland, 2003–04 and 2013–14

	2003–04	2013–14	2003–04	2013–14
	AS levels	AS levels	A levels	A levels
Total entries:				
Mathematics	62098	161711	52788	88816
Further mathematics	3980	24530	5720	14028
% of entries in All Subjects:				
Mathematics	6.0	11.4	6.9	10.7
Further mathematics	0.4	1.7	0.7	1.7

Source: Examination Results, Joint Council for Qualifications www.jcq.org.uk/examination-results/a-levels

Table 6.2: Higher and Advanced Higher entries, Scotland, 2004 and 2014

	2003–04	2013–14	2003–04	2013–14
	Higher	Higher	Advanced Higher	Advanced Higher
Total entries:				
Mathematics	19394	21851	2416	3444
Applied mathematics	-	-	234	346
% of entries in All Subjects:				
Mathematics	11.7	11.4	14.1	15.4
A pplied mathematics	-	-	1.4	1.5

Source: Attainment Statistics, Scottish Qualifications Authority, 2004: www.sqa.org.uk/sqa/57563.html, 2014: www.sqa.org.uk/sqa/64717.4239.html

There is some evidence that the recent growth in mathematics A level entries reflects growing awareness among students of the advantages of mathematics in terms of gaining university places and future employment and salary prospects (ACME, 2009). However, as discussed above, the proportion of UK students engaging with mathematics in upper secondary education remains low by international standards and reservations continue to be expressed about the quality of mathematical skills and knowledge that is now associated with a pass at A level.

For example, Engineering Council (2000) reports on diagnostic tests in 60 university departments of mathematics, physics and engineering that point to ‘a steady decline over the past decade of fluency in basic mathematical skills and of the level of mathematical preparation of students accepted onto degree courses’ (p iii). Weaknesses in mathematical preparation have also been identified in reports focussed on other disciplines such as sociology (Williams et al, 2008) and geography (Harris et al, 2013). A key problem affecting a wide range of disciplines is that many students who drop mathematics at age 16 have effectively forgotten much of the mathematics that they once knew by the time they get to university (ACME, 2011).

6.2 University responses to students’ QS deficiencies

In coping with weakness and variability of QS among their student intakes, university departments have two main options available to them. One is essentially to adapt to student weaknesses in QS and modify degree courses in a non-quantitative direction in order to cope with the students’ lack of QS. The other option is to seek to remedy the weaknesses through compensatory teaching. Both types of response can be observed in abundance in UK universities.

Turning first to degree courses being developed in a non-quantitative direction, the 2009 MacInnes Review looked across the social sciences as a whole and reported an 'institutionalised marginalisation' of QS teaching across higher education institutions. In the most extreme cases no QS teaching was provided at all; at the other extreme, QS options were provided as specialist modules, mostly taught in the second year. However, MacInnes also argued that, even when QS teaching appears 'baked in' to degree pathways, teaching 'does not give students enough contact time to develop confidence in their skills, often has an outdated focus on primary data collection, and does not pay enough attention to secondary data analysis' (2009: 2).

'Some teachers may denigrate quantitative methods as 'inaccessible or irrelevant "positivism"... [using] such arguments to legitimise ignorance of their most basic features'

MacInnes points to some demand-side factors in explaining QS provision, in particular 'hostility to numbers from students who have sometimes experienced poor school mathematics teaching, have done no maths for three years (since GCSE), and have never before encountered maths in an applied setting' (ibid). In addition, he highlights many students' lack of information about the labour market advantage of good quantitative methods skills, putting this down in large part to supply-side issues within higher education institutions such as cost pressures and inadequate teaching. Relative to qualitative techniques, QS teaching often needs high staff-student ratios and bespoke material (for example, specialist software): this leaves it vulnerable to cost-cutting, with the Quality Assurance Agency for Higher Education (QAA) failing to support QS teaching in its benchmarking exercises.

MacInnes also criticises course architecture that places QS provision in specialist modules, suggesting that this sends a message to students that quantitative skills are optional and can be ignored in favour of a methods-free or a qualitative focus. This is reinforced by the lack of QS in other parts of the course experience. Over time, this feeds back into poor teaching so that no more than one in six university social science teachers can now be regarded as quantitatively skilled. Some teachers may denigrate quantitative methods as 'inaccessible or irrelevant "positivism"... [using] such arguments to legitimise ignorance of their most basic features' (2009: 3). MacInnes argues that these structural factors have tended to push QS to the margins of social science in UK universities.

This broad picture is backed up by subject-specific studies, albeit with important differences between subject areas. For example, Harris et al. (2013) report on QS in geography using a survey of school teachers, students, university instructors and heads of teaching as well as a systematic review of course content. They are more optimistic than MacInnes although they highlight many of the same challenges. They report that students are typically taught by expert instructors on courses which often have a high QS content. However, 42% of Year 2 students struggle with QS learning, especially those who have not studied mathematics beyond age 16. They also find that quantitative methods are not well-integrated into curricula and that teachers appear to lack confidence in their own QS, especially in relation to specialist bodies of knowledge such as geospatial methods.

An investigation of sociology departments by Williams et al (2008) focuses on demand-side factors, in particular student attitudes, which are explored in focus groups and a survey. They find that QS are almost universally taught in sociology courses, and in 11–20% of cases form the majority of degree units. They also find that a 'sizeable minority' of students enjoy learning QS and do make effective use of them. However they uncover worries about QS among the majority of respondents and evidence of what they dub an 'anti-quantitative' mindset. Many students see sociology as closer to humanities than sciences and are sceptical about the value of QS in the subject.

One might imagine that QS are more deeply embedded in physical science degrees but this is not always the case. In a survey of bioscience academics, Koenig (2012) finds that the majority of students on their courses have only studied mathematics to GCSE level, with nearly half of these attaining B or C grades and 16% scoring below Grade C. 'Fear of maths' attitudes are commonplace with poor QS outcomes at school evidently an important factor in explaining this. Koenig also notes that a majority of UK university departments 'do not extend students past the concepts of GCSE and AS level maths' in contrast to most US bioscience departments 'where calculus and [advanced mathematical] modelling are considered to be an integral part of the undergraduate biology curriculum' (p5).

At the same time as many degree courses have evolved in a non-quantitative direction in order to cope with students' QS deficiencies, considerable resources have been devoted to efforts to try and remedy those weaknesses through compensatory teaching such as through the provision of supplementary courses in quantitative methods and increased integration of QS development into regular teaching of the main discipline in each department. Specific examples include additional tutoring and support for social science undergraduates at the University of Southampton which helped raise the proportion of students undertaking dissertations using quantitative methods (Falkingham et al, 2009) and the development of specialist pathways in quantitative methods for MSc students at Lancaster University.[24] Much of this compensatory activity has been uncoordinated between departments but various initiatives are now seeking to make it more systematic in nature.

In this regard MacInnes (2009) made a number of recommendations. First, he highlighted the potential of cost-reducing ICTs such as web-based tools to access and analyse data and to organise and manage courses. Second, to jump-start the provision of QS within UK higher education, the review suggested a national kitemark for methods teaching, with a co-ordinated lobbying effort led by the ESRC, foundations and others. Third, this effort should include pilot projects in a number of universities, with strong links to schools, a national network of methods teaching; and a national training and placement scheme in secondary data analysis.[25]

In a co-ordinated effort targeted at disciplines where QS shortfalls have been identified, the Nuffield Foundation, ESRC and HEFCE have supported

24 www.lancaster.ac.uk/sci-tech/graduate_school/courses/Quantitative-Methods-for-Science-Social-Science-and-Medicine-MSc

25 These recommendations have been echoed in subject-specific reports on QS issues. For example, Harris et al (2013) recommend that the Benchmark Statement for geography be revised to reflect the important of QS and quantitative methods; they want further exploration into teaching capacity, and better linkages with schools to embed working with data into GCSE and A-Level curricula.

the development of the Q-Step programme which aims to start a process of institutional change in university social science teaching. Reflecting the problems caused by so many students having dropped mathematics study at age 16, the focus is also on basic statistical literacy as well as on more advanced training.[26]

The initiative has three elements. The first and largest element is a network of 15 Q-Step Centres in universities around the UK which took part in a competitive bidding process to become hosts. Winning institutions have been chosen for their existing strengths in QS teaching and research. Each Centre has different specialisms reflecting their host institutions' strengths in research and quantitative methods. For instance, the UCL centre focuses on human geography and demography, political studies and industrial relations, and social anthropology, while Cardiff will cover criminology, education, social policy and sociology.

The Q-Step Centres will aim to improve the recruitment and training of students, both through improved links to schools but also through new QS training techniques. As an alternative to the stand-alone QS provision that currently exists in many social science courses, the Centres will look to embed QS teaching through the whole degree pathway. The funding agreements encourage innovation so this might include sequences of QS modules or, potentially, badged 'quantitative methods' degrees. The Centres will also reach out to employers to organise work placements, applied training and to encourage students towards QS-focused careers (Nuffield Foundation, 2014).

To deliver this, the Centres have been recruiting new staff, and this cohort is intended to be one of the main outputs from the initiative, as they move through academic careers. The collective body of teaching material will form a further important output, and this will be made available more widely. To help achieve this, a second element of Q-Step is a wider support programme that will share resources and expertise across higher education institutions, as well as reaching out to employers and schools (through work experience programmes, course co-design and other tools). A third element will be an information and awareness-raising programme aimed at policymakers, employers, schools and the wider public.

Clearly, it will take time for initiatives such as Q-Step to make a significant dent in QS-related deficiencies in university course design and teaching. The scale of current problems is shown in an ACME (2011) study of entry requirements to courses in ten different subjects across 15 universities and the connections between these entry requirements and course design. The university sample was selected to achieve a mix of 'selecting' institutions (those which can require entering students to have achieved a relatively high standard in previous study of mathematics) and 'recruiting' institutions which would not be able to fill many student places if they imposed similarly high entry requirements. Their enquiries led them to conclude that:

> *'Of those entering higher education in any year, [we estimate that] some 330,000 would benefit from recent experience of studying some mathematics (including statistics) at a level beyond GCSE, but fewer than 125,000 have done so. This places those responsible for many university courses in an impossible position. They cannot require an appropriate*

26 The main social sciences not covered by Q-Step are economics and experimental psychology which are deemed to have relatively strong traditions in quantitative methods. See www.nuffieldfoundation.org/q-step-centres

> *level of mathematics of their applicants and hope to fill their places, and in many cases they are unable to design courses with the level of quantitative demand that would be appropriate for their disciplines.' (p1)*[27]

The departments in recruiting institutions fitting this description included some teaching STEM subjects such as chemistry and computer science as well as others teaching social sciences such as sociology and psychology.

As efforts are made to address these shortcomings, further research using a mix of quantitative and qualitative techniques will be needed to investigate the underlying issues in more detail and on a wider scale and to evaluate the success of new QS initiatives. In the short term at least, the current state of QS teaching and learning in UK higher education raises serious concerns about many universities' ability to deliver the mix of QS and other skills and knowledge that employers increasingly require of their graduate employees. We now go on to illustrate these skill requirements through examples of important and growing areas of employer demand for high-level QS in both the private and public sectors.

6.3 High-level skills demand and its implications for the skills supply-side

6.3.1 Data-driven decision-making within firms

Recall the high-level skill requirements of the 'datavore' firms set out in Section 5.2 above. These are firms that are committed to data-driven decision-making and who have urgent need of university graduates with 'hybrid skill sets' combining quantitative, computing and analytical skills with business understanding.

Such skill requirements derive from the increased availability of 'Big Data', that is, datasets that have millions or even billions of observations, can be accessed in real-time or close to it and are multi-dimensional, including phenomena that were previously hard to observe quantitatively (Einav and Levin, 2013). Many of these datasets have been amassed by private businesses but others have their origins in administrative microdata, especially now that many government datasets can be linked together and made available under secure conditions to non-government users. Specialist skills are needed not just to clean, manage and analyse such data but also to develop specific tools that can cope with some of the more unstructured of these datasets (Varian, 2014).

According to Davenport and Patil (2012), the ideal 'data scientist' is 'a hybrid of data hacker, analyst, communicator and trusted adviser' (p73), who can 'emerge from any field that has a strong data and computational focus' (p74). They argue that the 'scientist' component is more important than the 'data' component, quoting a leading industry recruiter who looks for 'both a skill set – a solid foundation in [mathematics], statistics, probability, and computer

27 ACME's estimate of 330,000 HE entrants per year needing to have studied mathematics beyond GCSE level refers to all UK-domiciled entrants to STEM and social science courses in UK higher education institutions. By ACME's definition, only humanities course entrants are excluded from this level of mathematics requirement, with humanities here comprising: linguistics, classics, European and non-European languages and literature, history and philosophical studies, creative arts and design (ACME, 2011, Chart 3). In future research it would be useful to explore the implications of adopting different definitions of the category of HE courses that are deemed to require mathematics beyond GCSE level.

science – and certain habits of mind.' Further technical development can be achieved through on-the-job training and technology-specific courses.

Demand for 'hybrid skills' arises from the need for computational skills to be combined with 'domain knowledge', for example, in healthcare and retail areas (Dumbill et al (2013). In addition, many firms making use of Big Data not only need a core of highly-competent data scientists but also a larger number of staff who are users rather than creators of Big Data products and services. Mattmann (2013) argues that 'data stewards' are needed with skills in both their subject field and in computing who have the creativity to convert ideas in their field into big data analytical tools.

In some leading US universities these skill demands have led to:

> *'Graduate students in economics, political science, and sociology now regularly learn[ing] computer languages, and… starting to do formal training in computer science as part of their graduate degrees. Associated with this development is computer scientists doing research in what is effectively social science… The social sciences are in the midst of an historic change, with large parts moving from the humanities to the sciences in terms of research style, infrastructural needs, data availability, empirical methods, substantive understanding, and the ability to make swift and dramatic progress. The changes have consequences for everything social scientists do and all that we plan as members of university communities.'*
> King 2014:166, 171

6.3.2 Evidence-based policy-making within government

Other examples of the need for graduates to possess hybrid skill sets including QS can be found in the very different world of government departments. The drivers for more civil servants to possess high-level QS include an emphasis on evidence-based policymaking, which dates back to at least the late 1990s (Solesbury, 2001), and the continual shaping and reshaping of government functions, particularly in periods of austerity when there is a need to 'do more with less'. In addition, as noted above, government is integrally connected to the emergence of Big Data sources and techniques by dint of its own very large, structured administrative datasets that can be creatively linked together and mined for different kinds of information of potential value to external users as well as to policy-makers.

Within government more and more resources are now devoted to impact evaluations using quantitative techniques such as randomised control trials that seek to identify the causal effects of policy interventions. The new network of 'What Works Centres' (focussing on health, education, crime reduction, early intervention, ageing, local economic growth) are at the centre of this, with a mission to generate high quality impact evaluations, translate findings into policy messages and raise policymakers' capacity to design and implement evidence-driven interventions (Puttick and Mulgan, 2013).

The resulting skill demands include a need for more policymakers to possess a strong grasp of quantitative and qualitative evidence, and to have the means to deploy this in strategic and policy decisions (Hallsworth et al, 2011). In a review of 'evidence systems' across all levels of UK government, and the use of evidence in policymaking, Shepherd (2014) identifies shortfalls in evidence generation – in particular, quantitative impact evaluations in social science fields, including parts of economics – and poor translation of results from (academic) researchers to policy actors. Both of these relate to QS capacity within government. The first problem is linked, at least in part, to commissioning practices which may not involve impact evaluations or may fail to implement programmes and studies in such a way that reliable estimates of programme effects can be generated. The second problem – poor translation of research results into policy – is partly due to many officials lacking the technical knowledge to make use of academic material.

Shepherd is clear that this picture varies substantially across policy fields, and that intermediary bodies (such as What Works Centres) have a crucial role to play working with both external researchers and public bodies. Some areas (such as health) have a large body of experimental evidence to draw on, and established intermediary organisations (such as the National Institute for Health and Care Excellence) which perform a translation role. Others (such as local economic growth) have a much smaller quantitative evidence base, newer and less well-resourced translation agencies and policy users who typically lack the knowledge and experience to make use of quantitative findings, and who lack the QS capacity to integrate quantitative evaluation elements into programme design.

6.3.3 Implications for university teaching and the upper secondary curriculum

These examples from the worlds of Big Data usage and government policy-making highlight the massive challenges that many UK universities face in respect of QS development. On the one hand, they need to be able to equip graduates in a range of disciplines with the mix of QS and other skills that are increasingly sought in the graduate labour market. On the other hand, as described in Section 6.2, the reality for many university departments outside the upper layer of 'selecting' institutions is that they find it hard to ensure that the quantitative content of their courses is appropriate to their disciplines, much less sufficient to form part of the hybrid skill sets that are increasingly sought by employers.

A clear prerequisite for more universities to be able to rise to these challenges is an expanded supply of HE entrants who have studied mathematics beyond the age of 16. Thus the evidence reviewed in this report provides further support for arguments long made in support of a broader upper secondary curriculum which will produce, not just a larger cohort of prospective HE entrants who have studied pure mathematics at A level or equivalent, but other cohorts of students who have participated in courses emphasising statistics and problem-solving as well as improving mathematical fluency (Hodgen et al, 2013; Hillman, 2014).

Chapter seven

The development of quantitative skills through vocational education and training

7.1 The balance between high-level and intermediate-level skills development

If poorly-qualified entrants to some universities end up not being equipped with QS appropriate to their disciplines, they are unlikely to match up to employers' skill requirements in their fields and may end up in the lower reaches of the widening graduate salary distribution (Green and Zhu, 2010). This prospect raises further questions about whether – more than 20 years after the transition from elite higher education to mass higher education in the UK – a satisfactory balance between higher education and intermediate-level education has been achieved.

In a number of industries in the UK, the graduate share of employment has increased sharply in recent years and yet employer demand for associate or 'para' professional and technician-level skills remains strong, for example, in health services, financial services and some branches of advanced manufacturing such as aerospace and electronics and chemicals (Skills for Health, SEMTA and Cogent; 2010; SEMTA 2009). The issue is not just what mix of *levels* of education best meets employers' skill needs (and thus enhances individuals' employment and salary prospects) but what mix of *modes of skill acquisition* should be aimed for. Many skills sought by employers such as practical skills, problem-solving skills and commercial understanding are often best acquired through employment-based training (combined with part-time education, as in technician-level apprenticeships) rather than through full-time education in classroom settings, whether in universities or in schools or colleges (Mason et al, 2009; Mason, 2012).

This point has considerable relevance to the development of usable QS at intermediate skill levels (below graduate level) through vocational education and training. As discussed in Section 2.3 above, research evidence on employer demand for QS in workplaces points to the serious difficulties that many employees have in making practical use of any mathematical knowledge that they have previously gained in the course of formal education. Under these circumstances much more attention needs to be given to co-ordination between pre-employment education in mathematics and employment-based training in the application of QS. This applies mainly to initial training for new entrants to the workforce (especially through apprenticeship training) but is also relevant to continuing training for adult workers. For example, in a five year longitudinal study of adult trainees in 55 different organisations across a range of sectors, Kersh et al (2011) found that numeracy courses delivered in workplace settings were effective in providing trainees 'with skills that they can embed and contextualise in the same settings (in some cases on the same day) within their workplace tasks and responsibilities' (p34).

7.2 Apprenticeship training

A defining characteristic of 'apprenticeship training' is that it combines employment-based training with part-time attendance in vocational education classes or workshops related to the field of training. Thus in principle it is well suited to developing QS which can actually be applied in workplace settings.

In recent years apprentice training levels have grown rapidly across different parts of the UK. For example, in 2012–13 some 510,200 people started apprentice training in England, up threefold in ten years. More than half (57%) of English apprentice trainees were aiming for NVQ Level 2 qualifications while the remainder were aiming for Level 3 or higher qualifications.[28] Much of the growth in apprentice training has occurred in service sectors such as information and communication technology, health, public administration and care and business, administration and law which had little or no previous tradition of apprenticeship training.

The high proportion of apprentice trainees aiming for Level 2 qualifications in England constitutes a weakness since trainees aiming for this level of qualification would not be classified as apprentices in Continental European countries with well-established apprentice training systems such as Germany, Denmark and Switzerland. Another weakness of apprentice training in England and other parts of the UK is that much of the recent growth in apprenticeships has taken the form of adult employees being 'converted' to apprentice status in their existing jobs rather than training provided for young people entering employment. In principle, this could be a positive development but there are concerns (as expressed, for example, in the 2012 Richard Review of Apprenticeships) that some training under the 'apprenticeship' heading for older workers in their existing jobs has amounted to little more than short-duration skills updating or accreditation of existing skills (Richard, 2012; Fuller and Unwin, 2012).

So far as QS are concerned, apprenticeships in England and other parts of the UK have long been notable for much less general education in mathematics and other core subjects being required for trainees than is the case with apprenticeship training in Continental European countries (Steedman, 2010; Wolf, 2011). One of the recommendations from the Richard Review of Apprenticeships was that:

> *'All apprentices should have achieved Level 2 [equivalent to GCSE A*-C] in English and maths before they can complete their apprenticeship. Maths and English taught within apprenticeships should be sufficiently functional in approach to be suitable for an apprenticeship context'*
> Richard, 2012: 18

This recommendation has been accepted in principle by the current government but it is too early as yet to assess the extent and effectiveness of its implementation (Lupton, Unwin and Thomson, 2015).

28 Source: www.gov.uk/government/statistical-data-sets/fe-data-library-apprenticeships (Apprenticeships by sector subject area, age and level 2002/03 to 2012/13)

In general, a traditional apprenticeship model of skills development – combining employment-based training with part-time attendance on job-related vocational education courses – constitutes one of the few mechanisms by which one can imagine ever bridging the present gap between mathematics education in classroom settings and the practical application of QS in workplaces. Therefore, those with interests in the development of usable QS should give serious thought to how to take advantage of the government's support in principle for off-the-job study in mathematics to be mandatory for all apprentices who have not already attained GCSE Grade C or above in mathematics.

Other mechanisms by which the gap between mathematics education and the application of QS can be narrowed, if not bridged, include greater employer involvement in course design and teaching in schools and colleges and in providing work placements for students. However, it is hard to imagine such initiatives having the same impact on the development of usable QS as the provision of employment-based training through apprenticeships.

A further consideration is that available evidence suggests that when good quality apprenticeships are offered, there is no shortage of bright young people who are willing to choose the vocational route. The biggest constraint is on the employer demand side, with only a few employers at present willing to incur the costs of good quality apprenticeship training. As a consequence, applicant numbers for such apprenticeships far exceed the number of trainee places.[29]

7.3 Continuing mathematics education for 16–19 year olds

In a review of vocational education for the present government, Wolf (2011) criticised the reduced proportion of 16–19 year olds in recent years who achieve GCSEs in mathematics by re-sitting examinations in that subject. She also criticised the previous government's introduction of the concept of 'functional skills' (for example, mathematics 'embedded' in real life examples relevant to different types of vocational course) on the grounds that most teachers are poorly placed to deliver such teaching. Accordingly, one of her recommendations was that:

> *'Students who are under 19 and do not have GCSE A*–C in English and/or Maths should be required, as part of their programme, to pursue a course which either leads directly to these qualifications, or which provide significant progress towards future GCSE entry and success.'*
> ibid:15

As of August 2014, this recommendation has been implemented as a condition of government funding for all classroom-based general and vocational education for 16–19 year olds. Clearly, it will be some time before its effectiveness can be evaluated. However, some indications of the difficulties this approach to funding will face can be gleaned from the recent assessment by Lupton et al (2015) of the Coalition Government's record on further education and skills. They point out that the number of young people achieving

29 By 'good quality' apprenticeships, we refer to those providing a substantive training of two years or more and leading to a recognised membership of, and identification with, an occupation. For information on highly regarded apprenticeship schemes having to turn away large numbers of applicants for training places, see: www.telegraph.co.uk/finance/jobs/8710305/School-leavers-scramble-for-apprenticeships.html

Level 2 Maths and English at age 19, expressed as a percentage of those not achieving it by age 16, rose steadily between 2004–05 and 2009–10, but has fallen from 18.1% in 2009–10 to 16.3% in 2012–13. They suggest that:

> *'One possible explanation for this trend is that, as rates of achievement at age 16 continue to rise, those who have not reached expected levels by that age are an increasingly challenging group.'*
> (Lupton et al, 2015: 38)

7.4 Continuing training for adult workers

In general, UK employers are much more willing to provide short courses of continuing training for existing employees than they are to invest in long-duration initial training for new employees. Cross-country comparisons suggest that the UK is well ahead of other European countries on measures of employer-provided training per hour worked (O'Mahony, 2012), although it is not known how much of this training provision relates to remedial training which may be less necessary in other countries.

As discussed in Section 5, there appears to be very little information available about the extent to which current employer-provided training specifically addresses QS improvement needs (apart from the CBI surveys). Further research is needed in this area before any suggestions can be made as to how such QS-specific training for adult workers could be increased.

Chapter eight

Summary and assessment

8.1 Main findings

Recent international surveys suggest that mathematics attainments in secondary education in England and Northern Ireland (NI) are middle-ranking among industrialised nations. But the same is not true of survey findings relating to the quantitative skills (QS) of the wider population. According to the 2012 Survey of Adult Skills (SAS), proficiency in numeracy in England/NI was significantly below average among 22 participating countries. Among other things England/NI was found to be the only one of 22 countries where 16–24 year olds had lower proficiency in numeracy than did 55–64 year olds.

This has implications for UK economic performance because QS requirements are pervasive in industrialised economies. About seven in ten employees in the UK economy say that QS are essential or important to carry out their work. Roughly three out of ten jobs primarily require basic arithmetical skills (such as adding, subtracting, multiplying or dividing numbers or using decimals, percentages or fractions). Another four out of ten jobs require the ability to apply QS at a 'more advanced' level than basic arithmetic, ranging from use of descriptive statistics to highly complex mathematical procedures.

According to periodic Skills Surveys, the 40% share of jobs requiring 'more advanced' QS in 2012 was up by about ten percentage points compared to 1997. Other evidence of rising QS requirements in recent years has been provided by extensive case study research. Among other things the growth in demand for QS reflects the impact of increasing competitive pressures to improve efficiency and quality standards and engage in innovation, all of which requires constant monitoring and interpretation of data of different kinds.

At the same time the widespread use of Information Technology (IT) in workplaces has not reduced the need for QS but rather changed the nature of the skills required (for example, with employees needing to understand the underlying models used by computer software in order to make effective and accurate use of it).

With the exception of highly numerate and technical jobs, the QS requirements of most workplaces should in principle be covered by the mathematics contained in the GCSE curriculum. However, applying basic mathematical skills in the 'complex settings' of workplaces appears to pose challenges for many employees even if they did once gain a formal qualification at GCSE Grade C or equivalent level.

Case studies suggest that many employees fail to understand fully the quantitative techniques they are using and lack the ability to recognise obvious errors in their work. This is consistent with evidence from the Skills for Life 2011

Survey in England that as many as 75% of 16–65 year olds in employment were classified at a level of numeracy suggesting that their QS might not be sufficient 'to compare products and services for the best buy or work out a household budget'.

One implication of these findings is that individuals should preferably study mathematics to a higher level than they are likely to encounter in their jobs in order to be able to apply mathematics with confidence to deal with unexpected issues and problems in work settings.

'The CBI surveys are based on relatively small samples which are not nationally representative in nature and it is therefore hard to know how far their findings can be generalised to the wider population of employers'

The strength of employer demand for QS is also shown by relatively high salary returns to mathematics as a subject of study at both A level and Bachelor degree level. However, researchers tend to find mixed evidence when salary returns to QS are compared with other types of skill such as computing skills, high-level communication skills, client communication skills and planning skills. This may reflect the very high correlation which is found between QS and computing skills, and the fact that QS are rarely used in isolation and often need to be combined with other generic skills.

When basic numeracy skills are considered separately in other studies, there is clear evidence that individuals are better off in terms of employment and earnings if they possess such skills rather than being innumerate.

Taken together, the evidence from case studies and from analyses of labour market returns to mathematics as a subject of study in the UK points to strong employer demand for QS (in conjunction with other skills), with several indicators that the currently available supply of QS may be insufficient to meet demand. But when we turn to employer surveys as a third source of information on demand for QS in workplaces, the evidence is more mixed.

Annual surveys of employers carried out for the Confederation of British Industry (CBI) find high proportions of employers reporting weaknesses in basic numeracy among some employees and among school and college leavers. However, the CBI surveys are based on relatively small samples which are not nationally representative in nature and it is therefore hard to know how far their findings can be generalised to the wider population of employers.

In fact, the much larger biennial UK Commission's Employer Skills Survey (UKCESS) points to different conclusions. In 2013 it was based on a fully representative sample of just under 92,000 UK establishments across all sectors of the economy. According to this survey, the reported incidence of QS deficiencies (defined in various ways) is much smaller than that conveyed by the CBI surveys.

But there are several reasons for believing that the UKCESS is not an adequate source of information on the balance between supply and demand for QS. The term 'numeracy skills' is not explicitly defined in the UKCESS and it is not a key purpose of this survey to probe employers in detail about their use of QS or the connections between QS and other types of skill. In addition, estimates derived from the Skills for Life 2011 Survey in England suggest that many managerial respondents to surveys such as UKCESS (and indeed the CBI surveys) may be poorly equipped to assess QS or judge the need for them.

For these reasons a new nationally representative survey of employers with a specific focus on QS issues is needed – in conjunction with in-depth interviews with multiple respondents in workplaces – to make a better assessment of the extent of problems identified by case studies and the CBI surveys.

Any new survey of the ways in which employers meet their QS needs should pay particular attention to the role of skilled migrants. Many jobs requiring high-level QS and other technical skills are filled by migrants brought into the UK as internal transfers within multinational firms operating in skill- and innovation-intensive industries. The reasons for this reliance on migrants with QS include difficulties in recruiting workers with the required skills from within the UK.

A contributing factor to the limited supply of UK-resident STEM workers is the relatively low proportion (by international standards) of the population in England, Wales and Northern Ireland which has studied mathematics beyond the age of 16. The reasons for this are not just the structure of the A levels curriculum – obliging students to narrow down to a small number of subjects – but also students' concerns about their own abilities to do well in the subject and perceptions (apparently justified) that mathematics is a relatively difficult subject in which to obtain high grades. Ultimately, constraints such as many students lacking confidence in their ability to do well in mathematics reflect deep-rooted shortcomings in primary and early secondary mathematics education, in particular, shortages of specialist mathematics teachers.

Early specialisation in secondary education creates an additional problem in that many students who drop mathematics at age 16 have effectively forgotten much of the mathematics that they once knew by the time they enter the labour market or go to university.

One consequence of weakness and variability of QS among student intakes to universities is that many university departments have modified degree courses in a non-quantitative direction in order to cope with the students' lack of QS. This applies even to subjects such as chemistry, bioscience, geography and sociology for which an emphasis on quantitative techniques would normally be considered essential for their disciplines. In some cases these changes in course design reflect weaknesses in university teachers' own QS as well.

At the same time as many degree courses have evolved in a non-quantitative direction in order to cope with students' QS deficiencies, considerable resources have been devoted to efforts to try and remedy those weaknesses through compensatory teaching. Much of this is uncoordinated between departments but various initiatives are now seeking to make such compensatory activity more systematic. Examples include the Q-Step programme which aims to start a process of institutional change in university social science teaching. Reflecting the problems caused by so many students having dropped mathematics study at age 16, it will focus on basic statistical literacy as well as on more advanced training.

Clearly, it will take time for such initiatives to make a significant dent in QS-related deficiencies in university course design and teaching. Thus, in the short term at least, many university departments may be unable to deliver the mix of

QS and other skills and knowledge that employers increasingly require of their graduate employees.

In general, the evidence reviewed in this report provides further support for arguments long made in support of a broader upper secondary curriculum which will produce, not just a larger cohort of prospective HE entrants who have studied pure mathematics at A level or equivalent, but other cohorts of students who have participated in courses emphasising statistics and problem-solving as well as improving mathematical fluency.

At intermediate skill levels (below graduate level), much more attention needs to be given to co-ordination between pre-employment education in mathematics and employment-based training in the application of QS. This applies mainly to initial training for new entrants to the workforce (especially through apprenticeship training) but is also relevant to continuing training for adult workers.

As noted above, many employees have difficulty in applying mathematics knowledge gained through formal education to work-related issues and problems. The traditional apprenticeship model of skills development – combining employment-based training with part-time attendance on job-related vocational education courses – constitutes one of the few mechanisms by which one can imagine ever bridging the present gap between mathematics education in classroom settings and the practical application of QS in workplaces.

Those with interests in the development of usable QS should give serious thought to how to take advantage of the current government's recently-declared support in principle for off-the-job study in mathematics to be mandatory for all apprentices who have not already attained GCSE Grade C or above in mathematics.

It is also positive that the current government has recently accepted one of the recommendations from the 2011 Wolf Review of Vocational Education that students who are under 19 and do not have GCSE A*–C in English and/or Maths should be required to make progress towards acquiring such qualifications. However, this approach to funding will face many difficulties in raising mathematical attainments among 16–19 year olds who did not fare well in GCSE mathematics at age 16.

One possible source of hope for QS development among adult workers is that the UK tends to be well ahead of other European countries on measures of employer-provided training per hour worked. However, as yet there is very little information available about the extent to which current employer-provided training specifically addresses QS improvement needs.

8.2 Future research agenda

This review has identified several gaps in current knowledge about the imbalances between demand for and supply of QS in the UK. The main questions which deserve to be investigated through new research include:

1. What is the true extent and nature of QS deficiencies identified by case studies and the CBI surveys?

2. To what extent do employers essentially adapt to poor QS (perhaps by organising work in such a way that the effects of employees' QS weaknesses are minimised)?

3. To what extent does employer-provided training seek to upgrade the QS of existing employees and/or new recruits?

4. To what extent does any such QS training provision by employers amount to 'remedial' teaching filling gaps in employees' skills and knowledge which they might have been expected to acquire during their formal education?

5. How widespread is the phenomenon of university departments in physical and social science disciplines evolving in a non-quantitative direction in order to cope with students' QS deficiencies and with university teachers' own deficiencies in QS?

6. What is the success to date of efforts to improve university students' QS through compensatory teaching and other initiatives within higher education?

7. To what extent is the current apprenticeship training system succeeding in raising QS levels?

8. What cost-effective policy options are available to government to try and encourage adult workers to invest in developing their own QS and employers to support them in doing so?

In most cases these questions would ideally be addressed through the use of both quantitative and qualitative research techniques. For example, a new nationally representative survey of employers with a specific focus on data skills and QS issues in general is needed to assess the true extent and nature of QS deficiencies in UK workplaces. This new survey should seek detailed information on the demand for and utilisation of QS in workplaces and the extent to which employers either adapt to poor QS or seek to upgrade QS through providing training for their employees.

The main survey in this case would need to be structured in design so as to provide data suitable for quantitative analysis. However, a smaller number of semi-structured in-depth interviews should also be carried out at workplace level, first, to inform the design of questions in the main survey and, second, to follow-up that survey with in-depth probing of some respondents about the answers given to survey questions and the value of their assessments. In as many workplaces as possible, multiple respondents should be interviewed (including workers as well as managers) so that inferences about QS demand and utilisation in each workplace do not depend on the views of a single respondent. It would also be helpful to interview training providers who are working with some of the employers participating in the main survey.

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