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Foreword

This report is one of a series of reports commissioned by the Higher Education Academy STEM team to look at mathematical and statistical skills in a range of discipline areas. The report seeks to contribute to existing knowledge about this area within the context of Economics.

At the start of the study a list of areas for consideration was provided by the Higher Education Academy. These encompassed the way in which mathematical and statistical skills form part of the discipline landscape, the signalling higher education provides about the need for these skills, sector requirements within the discipline (e.g., from accreditors and Quality Assurance Agency subject benchmark statements), the use of diagnostic testing and the support provided for students to improve and develop their mathematical and statistical skills. The methods used in the study in Economics consisted of (i) a literature review; (ii) a desk-based review; and (iii) a discussion event.

The mathematical requirements of an Economics degree are often quite demanding. However, in some instances the mathematical entrance qualifications for Economics degrees can be comparatively low and many Economics students are surprised by the weighting of the mathematical and statistical content of their degree programmes. These observations provide particular challenges in Economics which have been recognised for a long time. The present study aims to consider the issues and to provide evidence to inform future discussion and development work in the discipline.

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I Summarised findings and recommendations

1.1 Introduction

Economics relies heavily on Mathematics and Statistics which play a prominent role in the research culture of the discipline. Within undergraduate curricula in Economics, attention has been paid both to the development of standalone modules and to integrating quantitative skills into other core modules throughout the degree programme. This contrasts with the way Economics is taught and assessed in the secondary sector, where there appears to be much less emphasis on mathematical and statistical techniques. Consequently a concern emanating from the higher education sector for some time has been the extent to which students are prepared for the mathematical content of their Economics degrees.

A related problem concerns the extent to which students who enrol on undergraduate degree programmes in Economics come from a variety of different (mathematical) backgrounds. Having a diverse intake of students has notable implications both in terms of the design and delivery of curricula but also the investment in facilities and resources that institutions and departments need to have in place to support students.

The Higher Education Academy (HEA) Science, Technology, Engineering and Mathematics (STEM) project was undertaken to draw together the research findings on these problems and on Mathematics-related issues encountered by students at the transition from pre-university to degree programmes in several disciplines. In Economics, a desk-based review was used to consider the content and level of Mathematics and Statistics within undergraduate Economics degree programmes, the extent to which students enrolling on Economics degree programmes come from different mathematical backgrounds and the strategies adopted by some departments in dealing with these issues.

A literature review was undertaken at the start of the study. Primary data collection took place in an online review of current Economics degree programmes. The last strand of the work was an HEA STEM Tackling Transition event. For the Economics discipline, the event provided an opportunity for staff working in both Economics and in Business and Management in higher education to meet and discuss the areas of interest with colleagues in the pre-university sector and other key stakeholders in the discipline. The discussions were recorded and collated with the other data obtained during the work.
1.2 Findings and recommendations

1.2.1 Notable findings †

1. The Mathematics entrance qualification for some undergraduate degree programmes in Economics is at the level of grade C GCSE Mathematics or equivalent.

2. Survey evidence (from the Economics Network Student Survey) suggests that over 80% of students stated there was much more Mathematics involved in their Economics degree programme than they expected.

3. A number of Economics departments have implemented different strategies (extra support, streaming, bridging modules) to address the challenges presented by the varied mathematical and statistical backgrounds of their students.

4. Students whose highest attainment in Mathematics is at GCSE level (or equivalent) and not at A-level (or equivalent) face a steep learning curve when starting their undergraduate studies in Economics.

† The HEA STEM online review and event had small samples. Attendees at the event were self-selecting and the samples for the online review were determined on the basis of information in the public domain. Detailed information is given in Section 4.

1.2.2 Recommendations

1. GCSE grade C (or equivalent) in Mathematics provides only limited preparation for the demands of an undergraduate degree in Economics where, in the majority of cases, there is considerable emphasis on algebra and calculus. Staff with responsibility for managing degree programmes in Economics should review the mathematical entry requirements for their degree programmes.

2. Key stakeholders in Economics should provide better signalling to the pre-university sector about the amount of Mathematics in Economics degree programmes. Staff with responsibility for Economics degree programmes should provide transparent and detailed information about the mathematical content in their degree programmes.

3. Key stakeholders in the Economics discipline should engage with developments related to post-16 qualifications in Mathematics (e.g. A-level Mathematics, “Core Maths”).
2 Background

Mathematics and Statistics are an integral part of the Economics discipline in higher education. The mathematisation of economic theory is well established, has a long history (Weintraub, 2002) and was seen by many leading scholars as a way of legitimising the discipline and making it more scientific in its approach. This dependence of Economics on Mathematics is most readily identified in the academic literature; nowadays few studies in mainstream peer-reviewed journals get published without formal mathematically/statistically-based analysis.

The importance of quantitative skills in Economics is recognised and, in higher education, attention has been paid both to the development of standalone modules and to integrating quantitative skills into other core modules throughout the undergraduate curriculum. This appears to be very different to the way A-level Economics is taught and assessed, where there appears to be much less emphasis on mathematical and statistical methods. A concern emanating from the higher education sector for some time now has been the extent to which students are prepared for the mathematical content of their degrees, not only in Economics but in other disciplines too (Engineering Council, 2000).

A second problem concerns the extent to which students enrolling on undergraduate degree programmes do so from a variety of different (mathematical) backgrounds and the implications this has in terms of the design and delivery of curricula and the support provided to these students.

Using a desk-based review the extent of these problems in the Economics discipline is considered and some of the strategies which some institutions and departments of Economics have adopted to help overcome these problems are outlined.
3 Research objectives and methodology

3.1 Objectives

The work described in this report focuses on the content and teaching of Mathematics and Statistics within Economics in the UK higher education sector. Attention is restricted to undergraduate programmes with a specific focus on the transition into higher education. Specifically, it considers:

• the entry requirements;
• mathematical and statistical content and delivery;
• the attitudes and expectations of students and lecturers in higher education;
• a discussion of the main issues and challenges.

3.2 Methodology

The HEA STEM study in Economics involved a desk-based review of academic literature and existing reports together with primary data collection from an online review of current provision at higher education institutions, which is referred to here as the HEA STEM online review. A similar approach has previously been adopted by Pomorina (2013). The starting point for the HEA STEM online review involved a keyword search on the UCAS website (8 November 2012) using “economics” in the tag line, which generated a total of 1,128 programmes. In order to keep the review manageable, degree programmes titled Economics “with” or “and” were excluded and the analysis was restricted to the following 'single' honours programmes: Economics, Applied Economics, Business Economics, Development Economics, Financial Economics, International (or European) Economics and Management (Managerial) Economics. This search generated a total of 120 degree programmes from 62 institutions in England, Wales and Northern Ireland and a further 18 degree programmes from 8 institutions in Scotland. The programmes that appeared most were: Economics (offered by 55 institutions) and Business Economics (offered by 32 institutions). Although not part of the current review, it is notable that 38 institutions across the sector offer joint degree programmes in Mathematics and Economics.

In the second part of the HEA STEM online review, information was extracted from UK university websites on the specific content of programmes with a focus on the content of year one modules. The initial aim was to use a random stratified sample method based on minimum entry requirements. However it became apparent early on that there were a notable number of institutions in which information, particularly detailed module content, was only available to current students and existing members of staff. This is not unusual, as an earlier study carried out by Riethmuller and Thompson (2008) also had limited access to information. The analysis presented in this report is therefore restricted to the 37 universities in which information on programme and module content was readily, and publically, available. Nonetheless, the sample in this report includes institutions from the main university groupings (based on information correct as of November 2012): 1994 Group (6), Alliance (5), Million + (1) and Russell Group (14), drawn across the different entry requirements for Mathematics and across each of the main geographical regions of the UK.
Finally the attitudes and expectations of students and academic staff were compiled from secondary sources, namely the surveys undertaken by the Economics Network. This information was supplemented with comments and discussions at the HEA STEM Tackling Transition event in Business and Management and Economics, held in Hatfield, in April 2013. 23 delegates attended the event, consisting of representatives from the secondary and higher education sectors, the HEA and examination boards, with delegates drawn from the Economics discipline and the Business and Management discipline. The delegates received a brief introduction to the project and presentations about (i) Business and Management and (ii) Economics. The attendees were then split into focus groups to consider the mathematical knowledge and skills of students when they commence their undergraduate studies, and discuss how these skills are developed and enhanced within Economics, Business and Management programmes within higher education institutions. The discussions were recorded and later transcribed.
4 Main findings

4.1 Mathematical and statistical requirements

While no single honours Economics programme has professional accreditation, the importance of quantitative skills is emphasised in the Quality Assurance Agency (QAA) subject benchmarking statement in Economics (Quality Assurance Agency for Higher Education, 2007). As can be seen from Table 1, students who have attained either the threshold or typical level are expected to have achieved a level of competency in quantitative skills.

<table>
<thead>
<tr>
<th>A graduate in Economics who has attained the threshold level should:</th>
<th>A graduate in Economics who has attained the typical level should:</th>
</tr>
</thead>
<tbody>
<tr>
<td>demonstrate knowledge of economic concepts and principles</td>
<td>demonstrate understanding of economic concepts and principles</td>
</tr>
<tr>
<td>demonstrate knowledge of economic theory and modelling approaches</td>
<td>demonstrate understanding of economic theory and modelling approaches, and their competent use</td>
</tr>
<tr>
<td>demonstrate awareness of quantitative methods and computing techniques appropriate to their programme of study, and show an appreciation of the contexts in which these techniques and methods are relevant</td>
<td>demonstrate proficiency in quantitative methods and computing techniques and know how to use these techniques and methods effectively across a range of problems</td>
</tr>
<tr>
<td>display knowledge of the sources and content of economic data and evidence and appreciate what methods might be appropriately applied to the analysis of such data</td>
<td>display understanding of the sources and content of economic data and evidence and of those methods that might be applied appropriately to the analysis of such data</td>
</tr>
<tr>
<td>know how to apply economic reasoning to policy issues</td>
<td>know how to apply economic reasoning to policy issues in a critical manner</td>
</tr>
<tr>
<td>demonstrate knowledge in an appropriate number of specialised areas in Economics</td>
<td>demonstrate knowledge in an appropriate number of specialised areas in Economics, as well as an appreciation of the research literature in these areas</td>
</tr>
<tr>
<td>display awareness of the possibility that many economic problems may admit of more than one approach and may have more than one solution.</td>
<td>display familiarity with the possibility that many economic problems may admit of more than one approach and may have more than one solution.</td>
</tr>
</tbody>
</table>

Table 1: Economics subject benchmark standards - threshold and typical levels (Quality Assurance Agency for Higher Education, 2007).
Quantitative skills are also prominent in the subject knowledge section of the Economics subject benchmark statement where there is explicit discussion of the role of Mathematics as a mechanism for developing understanding of key economic principles:

- “relevant quantitative methods and computing techniques. This would include appropriate mathematical and statistical methods, including econometrics. Students should have exposure to the use of such techniques or actual economic, financial or social data, using suitable statistical or econometric software;

- a knowledge and appreciation of the nature, sources and uses of economic data, both quantitative and qualitative;

- understanding of relevant mathematical and statistical techniques;

- a critical understanding of analytical methods, both theory and model-based;

- understanding of verbal, graphical, mathematical and econometric representation of economic ideas and analysis, including the relationship between them. Appropriate techniques to enable manipulation, treatment and interpretation of the relevant statistical data, may also be relevant.”

Implicit in these points is the importance of applying statistical methods in developing students’ understanding of statistical software and applications using “real-world” data.

4.2 Minimum Mathematics entry requirements

Given the importance of quantitative skills in Economics, it comes as very little surprise that the academic literature reports results showing that those with a stronger mathematical background did better in their Economics degrees. Drawing upon data from American institutions, Anderson et al. (1994), Ballard and Johnson (2004) and Cohn et al. (1998) all found that mathematical skills are important determinants of success in introductory Economics modules, particularly microeconomics. This is consistent with more recent studies that have investigated the determinants of student performance in first year Economics modules in other countries, including the Netherlands (Arnold and Straten, 2012), Italy (Cappellari et al., 2012) and Australia (Mallik and Lodewijks, 2010). Deficiencies in mathematical skills have also been considered an important reason why Economics students drop out of university (Arnold and Straten, 2012; Mallik and Lodewijks, 2010).

With specific focus on the UK, Naylor and Smith (2004) looked at students enrolled on Economics degree programmes who graduated in the academic years 1984-85 to 1992-93. They also carried out a similar analysis for those students who graduated during the academic year 1997-98, following the expansion of the higher education sector. They found that degree performance is positively and statistically significantly related to having previously studied Mathematics. In contrast they found no effect associated with having previously studied Economics. Lagerlöf and Seltzer (2009), drawing on data from administrative records of students entering the Department of Economics at Royal Holloway in the period 1997-99, also found performance in secondary school Mathematics enhanced performance at university. As a third example, Jones and Wheeler (2011) also found mathematical background was important but unlike Naylor
and Smith (2004) found an Economics background to be quantitatively more important. It is unclear however whether or not this is a reflection of changes to higher education Economics programmes (curriculum, teaching and assessment) in the period between the two studies that might lead to an Economics background being more useful in recent years.

In evaluating the minimum Mathematics entry requirements for Economics degree programmes, information was extracted from the UCAS website and cross-checked with departmental websites and prospectuses. For the purpose of this work, the focus was on GCSE and A-levels for entry to institutions in England, Wales and Northern Ireland. For entry into Scottish institutions the focus was on Standard Grade, Intermediate Grade, Scottish Highers and Advanced Highers.

A key finding from the HEA STEM online review was the number of undergraduate degree programmes in England, Wales and Northern Ireland that required GCSE (at grade A, B or C) rather than AS or A2-level Mathematics. As Figure 1 shows, 39% (47 out of 120) programmes require a grade C in GCSE Mathematics whereas less than 10% (11 out of 120) require A2-level Mathematics at Grade A or A*.

![Figure 1: Undergraduate degree programmes by minimum Mathematics entry requirement (England, Wales and Northern Ireland) based on a sample of 120 degree programmes from 62 institutions.](image)

The main types of qualification offered are a BSc and a BA. BSc programmes are typically designed for students with stronger backgrounds in Mathematics and Statistics and they tend to follow a pathway that has a considerable amount of quantitative content. In contrast, in BA programmes there is typically less emphasis on the quantitative side. Consequently a BSc is often seen as being more technical than a BA, but this is not always the case. Cambridge and Oxford, for example, almost exclusively award BA degrees (Pomorina, 2013). Some institutions offer Economics routes with distinct BSc and BA routes that have been designed to cater for the different backgrounds and interests of students.
Programmes in Scotland are typically a year longer (four years) compared with their counterparts in England, Wales and Northern Ireland. However, advanced entry level (direct entry into year two) is often possible, so both types of programme were considered in the study. In the HEA STEM online review, 83% (15 of 18) of four year programmes (from eight institutions) require Standard Grade 1, 2 or 3 in Mathematics. On the basis that Standard Grades are broadly equivalent to GCSEs (Quality Assurance Agency for Higher Education, 2013), the minimum Mathematics requirement for entry into Scottish institutions is broadly the same as those entering institutions in England, Wales or Northern Ireland. 56% of four year programmes (10 out of 18) require Standard Grade 1 or 2 and 28% (5 out of 18) require Standard Grade 3, whereas the Higher Grade is only required in 17% (3 out of 18) of programmes.

### 4.3 Mathematical and statistical content

This section presents quantitative and qualitative analysis on the institutions in which information on module profiles and content is publicly available.

The general findings presented here are consistent with evidence reported elsewhere, confirming the importance of quantitative methods to the Economics discipline. For example, Monteiro and Lopes (2007), in a survey of undergraduate Economics majors in top-ranked departments in Europe and the USA, found modules in Mathematics, Statistics and econometrics were offered by the majority (over 75%) of universities.

The HEA STEM online review found that in first year undergraduate programmes in England, Wales and Northern Ireland, Mathematics and Statistics are taught as separate modules in two-thirds (44 out of 66) of the programmes sampled. Where they are not taught separately they are generally taught in separate semesters, with Mathematics typically taught during the Autumn and Statistics in the Spring.

The HEA STEM online review also found that Mathematics and Statistics modules constitute around 25% of year one undergraduate degree programmes (sample of 75 programmes). This figure tends to increase as the minimum Mathematics entry requirements increase. For programmes in which the minimum Mathematics requirement is GCSE A or B (a sample of 34 programmes across 18 institutions) Mathematics and Statistics modules make up about 38% on average of year one programmes. For those programmes which require AS or A2 Mathematics, the proportion is higher still (around 40%, based on a sample of 17 programmes across 13 institutions).
<table>
<thead>
<tr>
<th>Minimum Mathematics entry requirement</th>
<th>GCSE grade C</th>
<th>GCSE grades A, B</th>
<th>A-level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mathematics syllabus</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Basic Algebra</td>
<td>Basic Algebra</td>
<td>Basic Algebra</td>
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<tr>
<td>Linear Functions</td>
<td>Linear Functions</td>
<td>Linear Functions</td>
<td></td>
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<tr>
<td>Logarithms and Exponentials</td>
<td>Logarithms and Exponentials</td>
<td>Logarithms and Exponentials</td>
<td></td>
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<tr>
<td>Financial Mathematics</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Differentiation</td>
<td>Differentiation</td>
<td>Differentiation</td>
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</tr>
<tr>
<td>Partial Differentiation</td>
<td>Partial Differentiation</td>
<td>Partial Differentiation</td>
<td></td>
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<tr>
<td>-</td>
<td>Optimisation</td>
<td>Optimisation</td>
<td></td>
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<tr>
<td>-</td>
<td>-</td>
<td>Integration</td>
<td></td>
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<tr>
<td>-</td>
<td>-</td>
<td>Matrices</td>
<td></td>
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<tr>
<td>-</td>
<td>-</td>
<td>Difference Equations</td>
<td></td>
</tr>
<tr>
<td><strong>Statistics syllabus</strong></td>
<td></td>
<td></td>
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<tr>
<td>Descriptive Statistics</td>
<td>Descriptive Statistics</td>
<td>Descriptive Statistics</td>
<td></td>
</tr>
<tr>
<td>Probability</td>
<td>Probability</td>
<td>Probability</td>
<td></td>
</tr>
<tr>
<td>Point and Interval Estimation</td>
<td>Point and Interval Estimation</td>
<td>Point and Interval Estimation</td>
<td></td>
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<tr>
<td>Hypothesis Testing</td>
<td>Hypothesis Testing</td>
<td>Hypothesis Testing</td>
<td></td>
</tr>
<tr>
<td>Basic Regression Analysis</td>
<td>Basic Regression Analysis</td>
<td>Regression Analysis</td>
<td></td>
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<tr>
<td>-</td>
<td>-</td>
<td>Non-parametric techniques</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Typical content of Mathematics and Statistics modules in year one undergraduate Economics categorised by minimum Mathematics entry requirement (England, Wales and Northern Ireland), as found in the HEA STEM online review.

There are also differences in the typical content of these modules. In particular where entry requirements are set at the standard of A-level Mathematics (or equivalent), students are more likely to encounter topics associated with matrix algebra, integration and difference equations (Table 2). Students with A-level Mathematics (or equivalent) are also likely to encounter more advanced statistical techniques (e.g. multiple regression analysis and non-parametric tests) earlier in the curriculum. These findings are comparable with those of Osmon (2010) in a review of the Mathematics modules in Economics at two universities.
Overall the results of the HEA STEM online review show that for the majority of programmes algebra and differential calculus are fundamental topics in first year mathematical modules and inferential statistics and regression analysis are important topics in first year Statistics modules. Students are therefore expected to have achieved a sufficient level of competency in these areas by the end of the first year of undergraduate study.

A common feature of Economics programmes is that mathematical and statistical techniques are embedded into other modules. The importance of embedding is emphasised in the following quotation from Parker (2011):

“Advanced statistical training is of little use if students are never asked to practise or apply it as part of other modules in their subject. The extent to which such skills are embedded in a curriculum will strongly indicate to students how important it is to that discipline. Economics, for example, is considered the most quantitative subject, not just because of its training requirements, but also because its students are most likely to need and use these skills in their coursework throughout the subject.”

This need for mathematical and statistical skills is evident in many of the programmes analysed in this review, particularly in modules associated with principles of Economics. Interestingly, most principles of Economics textbooks, even those pitched at the introductory level, frequently apply mathematical and statistical methods to economic concepts (Lopus and Paringer, 2012).

Although mathematical concepts feature heavily in intermediate and advanced level microeconomics and macroeconomics, and more specialist modules associated with, for example, game theory (Nicholson 2012), perhaps the clearest example of how Mathematics and Statistics are developed beyond the introductory level is in the teaching of econometrics.

Econometrics is the quantitative branch of Economics that studies theoretical and practical aspects of applying statistical methods, principally regression analysis, to economic data for the purpose of testing economic theories and forecasting the future path of economic variables. It typically provides opportunities for students to undertake their own investigations, through research projects and dissertations, using specialist software and to develop skills that are valued by employers (see, for example, Pomorina, 2012; Porkess, 2013). Econometrics therefore plays a key role in many Economics degree programmes (Judge, 2014). Econometrics may be taught with or without using matrix algebra. As indicated in Table 2, the HEA STEM online review found that the use of matrices is a topic included only in degree programmes where the minimum entry requirement is A-level Mathematics. So the content of econometrics modules, and perhaps the number of econometric modules offered, is likely to be influenced by the Mathematics entry requirement for a programme.

In Scotland, based on information from a limited number of institutions and for four year programmes in particular, there are generally no separate Mathematics and Statistics modules taught in the first year – the two subjects are generally taught as separate modules in the second year; typically constituting a similar proportion and content to programmes offered in England, Wales and Northern Ireland. There appears, however, to be more explicit and direct discussion of how mathematical and statistical techniques are integrated in modules on the principles of Economics. As with Economics in other parts of the UK, knowledge of Mathematics and Statistics feeds forward in more advanced principles of Economics modules and in the study of econometrics.
4.4 Transitional issues and challenges

4.4.1 Mathematical backgrounds of students

As the review of Economics programmes has demonstrated, almost all programmes require students to study Mathematics and Statistics during their first year (or second year for students enrolled on four year programmes in Scotland).

The global financial crisis may have contributed to a renewed interest in studying Economics. Concerns have however been raised about the varied mathematical backgrounds of students, and this remains the case despite an increasing trend in the number of undergraduate Economics students entering higher education with A-level Mathematics or equivalent (based on information on the composition of survey respondents to the Economics Network Student Survey over the period 2002-2012).

Table 3 reports the proportion of students with GCE A2 Mathematics and/or GCE A2 Economics (and their equivalents) for students admitted to single honours Economics degree programmes in 2010-11 for institutions in England, Wales, Northern Ireland and Scotland. When considered across all institutions, the results suggest the proportion with A2 Economics is higher than the proportion with A2 Mathematics. When this is broken down by institution grouping there is a larger gap for those in the Million + and Alliance groups and a smaller gap for the 1994 Group and the Russell Group. The Russell Group and those students studying in Scotland are the only groups in which the percentage of students with A2 Mathematics exceeds the percentage with A2 Economics.

<table>
<thead>
<tr>
<th>Institution Grouping</th>
<th>Percentage with A2 Mathematics</th>
<th>Percentage with A2 Economics</th>
<th>Percentage with both A2 Mathematics and A2 Economics</th>
</tr>
</thead>
<tbody>
<tr>
<td>England, Wales, Northern Ireland</td>
<td>71.2</td>
<td>78.4</td>
<td>56.8</td>
</tr>
<tr>
<td>(64 institutions)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scotland</td>
<td>80.4</td>
<td>54.7</td>
<td>41.3</td>
</tr>
<tr>
<td>(9 institutions)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Million +</td>
<td>34.9</td>
<td>62.8</td>
<td>23.4</td>
</tr>
<tr>
<td>Alliance</td>
<td>39.1</td>
<td>72.0</td>
<td>27.7</td>
</tr>
<tr>
<td>1994 Group</td>
<td>76.1</td>
<td>80.8</td>
<td>62.0</td>
</tr>
<tr>
<td>Russell Group</td>
<td>84.1</td>
<td>82.2</td>
<td>68.9</td>
</tr>
</tbody>
</table>

Table 3: Percentage of Economics undergraduate students with A2 Mathematics and A2 Economics (and equivalents) by institution grouping, 2010-11 cohorts (author’s calculations based on HESA (2012) data).

Table 3 also reveals a relatively high proportion of students without A2 Mathematics. This is particularly the case for the Million + and Alliance universities, which typically have lower entry requirements, but even for the 1994 and Russell Groups 23.9% and 15.9% of students respectively do not have A2 Mathematics.
4.4.2 Strategies for working with student diversity

The diverse mathematical backgrounds and skills of incoming students clearly presents a challenge to lecturers and those designing curricula. A number of different types of support designed to deal with these challenges were identified in the HEA STEM online review:

- the inclusion of more “revision” material in the first year;
- extra support (remedial classes) or “bridging modules”;
- streaming.

Some of these strategies have been noted elsewhere (e.g. Lawson et al., 2003). Information extracted from the HEA STEM online review indicates that the inclusion of more revision material in the first year appears to be a strategy that is more prominent among those programmes with lower entry requirements for Mathematics.

To avoid compromising the volume and level of Mathematics, some Economics programmes offer additional support (“remedial” classes) for weaker students, and such support featured prominently in the discussions at the HEA STEM Tackling Transition event. Sometimes support is provided in the form of additional modules (or bridging modules) that are delivered intensively at the start of the programme (Jackson, 2012). In other instances they run in parallel with other Mathematics modules (Lagerlöf and Seltzer, 2009).

Lagerlöf and Seltzer (2009) present empirical evidence that suggests remedial classes have no effect on either short-term (year one) or long-term (years two and three) performance. These preliminary Mathematics modules can be designed for students who performed poorly during a diagnostic test set at the start of the programme (typically during the induction period). An example, that includes details of a diagnostic test and syllabus, is provided by Jackson (2012).

Another mechanism that has been used to cope with student diversity is to stream students and teach the less knowledgeable group separately. Streaming appears to be most common among those programmes where the intake of students is the most heterogeneous. Of the 24 programmes where the minimum Mathematics entry requirement is set at GCSE grade A or B (or equivalent), and for which data are available, some form of streaming occurs in 75% of programmes. Some of the streaming is self-selecting, where programmes offer separate pathways based on more quantitative (BSc) routes or less quantitative (BA) routes. In other instances the streaming is based on the mathematical background of the students (i.e. A-level or GCSE Mathematics or equivalents). Where streaming occurs it is almost always used in the delivery of mathematical techniques in Economics degree programmes. In contrast to Mathematics, the HEA STEM online review revealed very few examples in Economics programmes of introductory Statistics being streamed. Jackson (2012) discusses some of the issues associated with streaming, offering strategies to minimise the stigma associated with being in the weaker group.

Clearly providing additional support for those with weaker mathematical skills is likely to require more resources and is more time-consuming. But without such support, students with weaker mathematical skills are more likely to lose confidence, lack motivation and may drop out of university altogether. Compromises however are required to avoid students who have stronger backgrounds in Mathematics becoming disengaged. Jackson (2012) argues that
incentives should be used in order to maintain a high level of engagement from
the stronger students. However it is also acknowledged, “...that a substantial
number of students with strong mathematics and stat ability actually find it more
difficult to apply the techniques to economic problems” (Jackson, 2012).

Because the diversity of mathematical and statistical knowledge and skills of
students is a problem that affects many disciplines, some institutions have
responded by establishing Mathematics and Statistics support centres (Lawson
et al. 2003):

“The term ‘Mathematics Support Centre’ should be interpreted to mean a
facility offered to students (not necessarily of mathematics) which is in addition
to their regular programme of teaching through lectures, tutorials, seminars,
problems classes, personal tutorials, etc. The term should be regarded as an
umbrella term encompassing a wide range of provision (known in different
institutions by various names including Mathematics Workshop, Mathematics
Help, Mathematics Drop-In)’.

In their online material, a number of Economics programmes explicitly mention
the availability of these support centres. There is also a wide range of online
resources. These include: Mathcentre Resources for Economics (Mathcentre,
2014) and Mathematics for Economics: Enhancing Teaching and Learning (METAL)
(Economics Network, 2014). Both websites include a large repository of tutorial
videos, learning and assessment materials (learning guides, worksheets) and
question banks. There are specific case studies about how METAL resources
in particular have been integrated into the teaching of quantitative methods in
Economics programmes (e.g. Kinakh, 2009; Dutton, 2010; Stephenson, 2010).
The overwhelming response to these resources among lecturers and students
has been very positive (Taylor, 2010).

A Depository of Resources for Statistics in Social Sciences (De-STRESS) has
also been established to promote a similar set of resources for the teaching and
learning of Statistics (De-Stress, 2014).

4.4.3 Attitudes and expectations

This section draws upon secondary data provided in the surveys of academics and
students in higher education undertaken by the Economics Network as well as
discussions that took place at the HEA STEM Tackling Transition event in Business
and Management and Economics.

The perspective of students

Since 2002, the Economics Network has carried out biennial student surveys
(of undergraduate students) and the issue of the mathematical skills of students
in Economics has been a regular feature. In particular students continue to be
surprised by the amount of Mathematics involved in the Economics curriculum.
In the 2012 survey (Economics Network, 2012), 81% of respondents stated there
was much more Mathematics involved than they expected in Economics degree
programmes. One respondent commented:
“I did not anticipate the level of mathematics that took place during an economics degree. If I had known that there would be extensive use I would have chosen to do a mathematics A-level.”

This view is interesting because there are a number of sources that clearly explain the importance of Mathematics in Economics undergraduate degree programmes. For example the Why Study Economics website, which was developed by the Economics Network and has been in existence since 2004, “...is designed to encourage students to study Economics at HE level and supports student transition from school/college to higher education” (Sloman and Pomorina, 2012: 767). The site also seems to be popular, receiving 477,341 page requests in 2009-10 (Sloman and Pomorina, 2012). Other sources include guidance from the Russell Group (2013), which states that Mathematics is usually an essential advanced level qualification for undergraduate Economics degree programmes. A similar message is articulated on Which? University (2014). Clearly the mismatch between these messages and student expectations is something that both the secondary and higher education sectors need to address and appears to be a sector-wide problem (see, for example, Hernandez-Martinez, 2010).

Students have also raised concerns (Economics Network, 2004; Economics Network, 2008; Economics Network, 2012) about the teaching and relevance of Mathematics to the Economics discipline:

“The more maths-orientated aspects tend to be too complex; The maths part does not really, at the moment, relate to general economic aspects, again just random topics.”

“Extremely mathematical theoretical – Should be more focused on what goes on in the real-world; Economics is far too mathematical.”

Students continue to request more support:

“More support for those with weaker maths skills and streaming people with different levels of mathematical training.”

Students have however recognised the difficulties lecturers face in teaching students with a wide range of mathematical knowledge and backgrounds:

“Maths is not challenging enough for post A-level mathematics students but very challenging for non A-level mathematics students.”

“The mathematics component of the module is found incredibly difficult by some and incredibly easy by others which tend to make both groups switch off a little.”

Overall it appears that the teaching of Mathematics and Statistics is an important issue to students. Specifically there appears to be an increasing need to show the relevance of the Mathematics being taught. For example, see the website of the Curriculum in Open-access Resources in Economics (CORE project, 2014).
The perspective of lecturers

Students’ mathematical skills have also featured prominently in lecturer surveys which, like the student surveys, have also been undertaken biennially by the Economics Network. Mathematical skills have been highlighted as either the most important or second most important issue in teaching in recent surveys (Economics Network, 2007; Economics Network, 2009; Economics Network, 2011). Specific comments (Economics Network, 2009; Economics Network, 2011) include:

“Mathematics is a key issue in our department as students are often very weak at mathematics and disengage from the subject early on.”

“At BSc level the clear problem is that an A grade in Mathematics doesn’t signify very much nowadays.”

Lecturers have also identified the more general issue of student motivation and transition:

“Motivation is a particular issue in year one alongside growing difficulties of student transition to university and university learning.”

These sentiments were echoed at the HEA STEM Tackling Transition event. Although the representatives that attended the event were self-selected, the views appear to be consistent with the issues identified in the surveys undertaken by the Economics Network. One delegate, for example, said, “students can do the (mathematical) operations but do not really understand the answer”. Another commented that, “student heterogeneity is the issue; getting the balance (in terms of the content and level of material presented) is more difficult the more mixed the intake is”. The general consensus was that GCSE Mathematics (or equivalent) alone provided limited preparation for an undergraduate degree programme in Economics. It was also the view that A-level (or equivalent) Mathematics was more important as an entry qualification compared to A-level (or equivalent) Economics. Many delegates at the event also highlighted the general problems associated with student motivation and the culture shock at university where there is much more emphasis on independent learning compared to the predominantly guided structure in the secondary sector. It is also likely that across the higher education sector as a whole the extent to which university lecturers are aware of the mathematical and statistical techniques students had been taught prior to university is highly variable (see for example McMahon (2012)).

4.4.4 The preparedness of students entering higher education

The results of the HEA STEM online review suggest that while the minimum Mathematics entry requirement for 39% (47 out of 120) of Economics degree programmes is set at GCSE grade C, the reality is that over 70% (Table 3) of students start their Economics programme with A2 Mathematics (or equivalent). Moreover the content of these programmes, with an emphasis on algebra and differential calculus, means that students entering undergraduate programmes in Economics with a GCSE or Standard Grade Mathematics qualification are likely to face substantial challenges.
Another important issue for those students who have not studied Mathematics to A2 (or equivalent) is the length of time that has elapsed since they last studied Mathematics, which for some students can be two or more years. This issue was discussed at the HEA STEM Tackling Transition event. Given that one topic in Mathematics builds on another, this can be problematic and again means that students whose highest attainment in Mathematics is at GCSE or Standard Grade level face a steep learning curve when starting their undergraduate studies.

Equally having an A2 Mathematics qualification (or equivalent) should not been seen as a panacea. While in general students who have studied Mathematics to A or AS-level appear to be better equipped to cope with the demands of the mathematical content in Economics undergraduate degree programmes, it cannot be assumed they all have the same level of conceptual understanding of mathematical and statistical techniques. At the HEA STEM Tackling Transition event there were concerns about the preparedness of students for higher education. It was suggested that students were too focused on assessment and cared less about developing a deep understanding of subject concepts.

It is also the case that for the majority of students the first time they see a systematic integration of Mathematics into Economics is at university. As identified in the previous section, even some students with an A2 Mathematics qualification (or equivalent) appear to have difficulties appreciating how much Mathematics is involved in the content of undergraduate Economics.

A report from the Nuffield Foundation (2012) which analysed the content of Summer 2012 A-level examinations, identified that the five awarding organisations that offer an A-level in Economics set assessments that were largely based on basic Mathematics (use of graphs, percentages, proportions, ratios and basic arithmetic operations). The only areas of Economics that had mathematical content that was taught (but not formally assessed) were elasticities and production possibility curves.

At the time of writing, consultations are underway regarding the revisions to the content of A-level Economics and the development of new qualifications designed for students who have successfully passed GCSE Mathematics and would benefit from continuing to study Mathematics, but would not normally do so (e.g. “Core Maths”).
5 Conclusions

This HEA STEM study has considered the Economics landscape in the learning and teaching of Mathematics and Statistics in the UK higher education sector and the issues associated with transition. Economics relies heavily on Mathematics and Statistics. These subjects play a prominent role in the research culture of the discipline. The importance of mathematical and statistical skills in the discipline at university level are emphasised in the academic literature, and in the QAA subject benchmarking statement (Quality Assurance Agency for Higher Education, 2007).

The HEA STEM online review found that the Mathematics entrance qualification for some undergraduate degree programmes in Economics is at the level of grade C GCSE Mathematics or equivalent. This qualification provides only limited preparation for the demands of an undergraduate degree in Economics where, in the majority of cases, there is considerable emphasis on algebra and calculus (Table 2). Furthermore, as noted at the HEA STEM Tackling Transition event, students whose highest attainment in Mathematics is at GCSE level (or equivalent), may not have studied Mathematics for two or more years and so may find Mathematics a challenge when starting their undergraduate studies in Economics.

The HEA STEM online review also revealed that there is still considerable diversity in the mathematical and statistical skills of students, even though nearly three-quarters of students enter undergraduate degree programmes in Economics with A2 Mathematics (or equivalent). To address the problems raised by such diversity, a number of Economics departments have implemented strategies (such as extra support, streaming and bridging modules). University-wide initiatives such as Mathematics Support Centres have also been introduced and a substantial range of online resources is readily available to help students. However, the biennial Economics Network surveys showed that those delivering higher education teaching continue to have concerns about the challenges of working with students with diverse mathematical knowledge and skills.

Survey evidence (Economics Network, 2012) indicated that over 80% of students stated that there was much more Mathematics involved in their Economics degree programme than they expected. This is in spite of the availability of a range of resources that have been made available to help potential students understand what is involved in studying Economics at degree level. The students’ unrealistic expectations may in part be influenced by the content of the A-level Economics curriculum, which is largely based on basic Mathematics. As a result, for many students, the first time they see a systematic integration of Mathematics into Economics is at university. In spite of the emphasis on the relevance of Mathematics in the QAA subject benchmarking statement in Economics (Quality Assurance Agency for Higher Education, 2007), students undertaking degree programmes, are still concerned that the teaching of Mathematics within Economics degree programmes is insufficiently focused on real-world applications.

Overall, the work has shown that there is a “Mathematics problem” in the Economics discipline, similar to that reported in STEM disciplines. Many students lack the skills needed to cope with the mathematical content of their Economics degree programmes, and although the problem of teaching groups with diverse mathematical and statistical backgrounds is being addressed, more work still remains to be done.
6 References


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