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The impact of GCSE Maths reform on progression to mathematics post-16

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Abstract:
In England, GCSE (General Certificate of Secondary Education) qualifications offered to students aged 14–16 were recently reformed. For mathematics specifically, the new GCSE aimed to be more demanding, provide greater challenge for the most able students, and support progression to post-16 mathematics. However, there have been concerns that the new GCSE could deter students from further education in the subject and, to date, there has been little research on its impact on participation in and learning of mathematics post-16.

This research compared progression to and performance in post-16 mathematics pre- and post-GCSE reform and found that, contrary to fears about reduced uptake, progression generally increased following the reform. In particular, the increase was higher among those who achieved top grades in their mathematics GCSE than for students with just a pass. Performance in post-16 mathematics was, in contrast to teacher expectations, lower post-reform.

The impact of GCSE Maths reform on progression to mathematics post-16

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Introduction

Students in England aged 14–16 study GCSE (General Certificate of Secondary Education) qualifications in a range of subjects, and generally sit GCSE assessments at age 16. Since GCSEs in English and in mathematics are a prerequisite for most post-16 courses, and for many training programmes and jobs, GCSEs in these subjects are taken by almost all young people. In February 2013, the Secretary of State for Education in England announced his intention to reform GCSE qualifications "to ensure they are rigorous and robust, and give students access to high quality qualifications which match expectations in the highest performing jurisdictions" (Gove, 2013).

For mathematics, in particular, the new GCSE would "focus on ensuring that every student masters the fundamental mathematics that is required for further education and future careers", and, in particular, it would "be more demanding" and "provide greater challenge for the most able students" (Gove, 2013).

The new GCSE in mathematics has, therefore, a revised content framework and aims to better prepare students for progression to future education and employment. It was first assessed in summer 2017. Key changes to the qualification were a greater emphasis on problem-solving and more demanding content, together with a new grading scale from 9 to 1 (with 9 being the highest grade). More details about the subject content and the main assessment features of the new GCSE can be found in DfE (2013) or Ofqual (2017).

Background research

Prior to the GCSE reform, there were longstanding concerns about how well the GCSE in mathematics prepared students for progression to AS and A level[1] study in the subject.

1 GCE AS and A levels are level 3 subject-based academic qualifications available to students aged 16 and above in England.

Hernandez-Martinez et al. (2011) reported, drawing on interviews with students, that the GCSE in mathematics was inadequate preparation for many students with pass grades (especially grade C, but increasingly also grade B) for AS level study, with algebra being mentioned as the key problem. Similarly, Noyes and Adkins (2016) showed that the numbers (and proportions) of GCSE Maths grade C students completing any advanced mathematics were relatively small. In fact, around 99 per cent of students achieving a grade C in 2010 did not complete any advanced mathematics over the following three years.

Rushton and Wilson (2014) carried out a survey of teachers to identify the areas of mathematics that were problematic for students who had just completed the GCSE and wanted to study the subject further at A level. They showed that teachers believed that students were prepared adequately for AS and A level courses in most areas of mathematics, but they also identified other areas (e.g., algebra) where GCSEs were considered not to prepare students well.

In a more recent study exploring the perceptions and experiences of the transition between GCSE and AS level in mathematics of a small group of students, Rigby (2017) reported that the majority of students believed that the GCSE syllabus prepared them for the AS level syllabus but not to the extent they would have hoped. It was believed that a gap existed between the mathematics necessary to pass a GCSE and the mathematics that students need to be able to start AS or A level. As a result, most schools were requiring high grades for entry onto A level Maths courses to make sure students were prepared for the transition: for example, students often had to have achieved a grade B at GCSE or even a grade A in order to be accepted for an AS or A level in mathematics (Noyes & Sealey, 2012). In Rigby's research (Rigby, 2017), one of the suggestions to improve the transition between GCSE and AS level was to change the GCSE syllabus to a more rigorous one, by including more AS level material (this has now been implemented within the reformed GCSEs).

The balance between revising the GCSE qualification to be better preparation for the AS and A levels and ensuring that it was appropriate for students who were not intending to continue to further study was problematic as, for example, including more rigorous content could have undesired effects on the transitions of some students, particularly middle- and low-attaining students.

Despite the A level in mathematics having a period of sustained growth in entries in the years prior to the GCSE reform (see, for example, Gill and Williamson (2016) and Gill (2018)), concerns about participation in post-16 mathematics have emerged in recent years. Stakeholders and researchers worried that a particular combination of structural changes (the decoupling of AS and A level qualifications, curriculum changes to the A level in mathematics, and changes to Key Stage 5 funding) would lead to a reduction in the uptake of mathematics at level 3 (e.g., ALCAB, 2014; Lee et al., 2018; Redmond et al., 2020). Changes to GCSE Maths aimed to encourage students to better manage the transition to the A level. However, the number of entries in A level Maths fell by around 3.5 per cent in

2019[2] (DfE, 2019; 2020), with suggestions from school leaders that students might have been losing confidence in their abilities in the subject or being less inclined to take it as it was perceived as quite hard.

To date, there has been little published research on how the reform of GCSE Maths has affected mathematics learning and, in particular, on how it affected progression to further education (e.g., entries to A levels) or performance in level 3 qualifications in mathematics (e.g., AS and A level Maths; AS and A level Further Maths).

One of the few studies that considered this issue in some detail was carried out by Howard and Khan (2019). They conducted interviews with A level Maths teachers with experience in teaching students who had studied the legacy GCSE in mathematics and students who had studied the reformed GCSE. The interviews explored their perceptions of how the legacy and reformed GCSEs prepared students for A level study. In general, teachers were positive about the extent to which the reformed GCSE prepared students for A level and the majority commented that the reformed GCSE prepared students at least as well, if not better, than the legacy GCSE. Humphries et al. (2017) also carried out a small qualitative study involving a sample of teachers (in 12 schools) who were engaged in delivering the new GCSE. Participating teachers expressed the view that “students sitting the reformed mathematics GCSE would be leaving Key Stage 4 with more mathematical knowledge than previous cohorts”, and that this would apply across all attainment levels. This was an important point as it is well documented that participation in A level Maths has been skewed towards those with high GCSE grades in the subject.

Grima and Golding (2019) and Pearson Education (2019), who carried out a programme of research looking at the introduction of the new GCSE Maths, reported similar findings to those outlined above. However, although the general consensus was that the new GCSE prepared students well for A level, there were concerns about how the weaker students (those with a grade 5 or 6) would feel about their abilities in mathematics. This was also mentioned by the participants in a study by Lee et al. (2018) who reported on a large-scale survey of post-16 mathematics teachers carried out by MEI (Mathematics in Education and Industry). The participants in this study additionally suggested that they had seen a reduction in mathematical confidence for students at a grade 7 level, observing that “with only 52 per cent of the marks[3] required for a grade 7 it may be the case that students who would feel confident and capable of studying maths with a grade A in the past may no longer feel as confident and therefore as motivated to study the subject”.

2 Students taking the A level Maths in 2019 would have studied the reformed GCSE Maths.

3 This percentage (52 per cent of the marks required for grade 7) was lower post-reform (in 2019) than in pre-reform years. However, it should be borne in mind that grade boundaries in the first year(s) of reformed qualifications, as it is the case here, are usually lower than in pre-reform years and they gradually increase and stabilise over time to account for candidates’ drop in performance (Cuff et al., 2019).

Aim of the research

The current research aimed to add to the qualitative existing research described above by approaching the question on how the reform of GCSE Maths affected progression to further education (e.g., entries to A levels) or performance in level 3 maths and in maths-related subjects (e.g., achieving at least grade A at A level) via quantitative analysis of entries and performance data. In particular, the main research question was:

> *How does overall performance in GCSE Maths relate to progression to and subsequent attainment in level 3 mathematics, pre- and post-GCSE reform?*

The outcomes of this research will increase understanding of how recent reforms to the qualification have affected students, teachers and schools, and contribute evidence towards further understanding of progression from GCSE to level 3 mathematics.

Data and methods

Data

This work addressed the research question using national results data available in the National Pupil Database (NPD).

The NPD is a longitudinal database for children in schools in England, linking pupil characteristics to school and college learning aims and attainment. It holds individual pupil-level attainment data for pupils in all schools and colleges who take part in the exams, and pupil and school characteristics (e.g., age, gender, ethnicity, special educational needs, eligibility for free school meals, etc.) sourced from the School Census for maintained schools only.

Students who achieved a GCSE Maths in each of the years in Table 1 below (June sessions only) were followed up for two years and data for their level 3 qualifications in the four exam sessions before the end of Key Stage 5 were included. For example, students who achieved a GCSE Maths in 2015 were followed up in 2016 and 2017 and their AS and A level results identified. Note that later cohorts could not be included because end-of-course exams were cancelled in 2020 and 2021 due to the COVID-19 pandemic.

The analyses were restricted to students who were 16 years old at the end of each academic year. This age restriction was made to have a set of "typical" candidates at the end of Key Stage 4.

Table 1: GCSE Maths cohorts included in the research.

GCSE exam year	A level completion	GCSE Maths	Number of students achieving the GCSE
2014	2016	Legacy (A*–G)	505 962
2015	2017	Legacy (A*–G)	544 984
2016	2018	Legacy (A*–G)	521 772
2017	2019	Reformed (9–1)	530 482

As shown in Table 1, the GCSE grades awarded in the period of study belonged to two different grading scales: A*–G for the legacy qualifications, and 9–1 for the reformed GCSEs. For some of the analyses in this study, the GCSE Maths grades pre- and post-reform were converted to a common numerical scale using the Department for Education's conversion values[4] for 2017 and 2018 performance table calculations (DfE, 2016).

Progression from GCSE Maths to A level Maths, A level Further Maths and Core Maths[5] was investigated.

Methods

Descriptive statistics were produced on the number and proportion of GCSE Maths students progressing to the qualifications mentioned above during pre-reform (2014–16) and post-reform (2017) years. Progression was investigated overall and by GCSE grade. Pre- and post-reform grade distributions were also produced for all qualifications above, overall and for each GCSE Maths grade. To further explore the effect of GCSE reform on progression to and performance in level 3 mathematics, while controlling for students' backgrounds, multilevel logistic regression analyses were carried out. The outcomes (dependent variables) of the regressions were as follows:

- progression to A level Maths, Core Maths, and A level Further Maths
- achievement of at least grade A in A level Maths, Core Maths, and A level Further Maths
- achievement of at least grade C in A level Maths, Core Maths, and A level Further Maths.

The independent variables in the regression models included: the year GCSE Maths was achieved (this is an indicator of pre-reform (2014 to 2016) or post-reform (2017)), GCSE grade (using the common GCSE grade scale as described above), gender, overall prior attainment, level of deprivation and school type.

4 GCSE 9–1 grades kept their face value (i.e., 9=9, 8=8, etc.), and A*–G grades were mapped as follows: A* = 8.5, A = 7, B = 5.5, C = 4, D = 3, E = 2, F = 1.5, G = 1.

5 Core Maths is a level 3 qualification aimed at students who have passed GCSE Maths at grade 4 or above, but who have not chosen to study AS/A level Maths. It helps students consolidate and extend their mathematical knowledge and provides them with transferable mathematical skills to support their other level 3 subjects (e.g., psychology, geography, business-related courses, sports, social sciences, …) and their transition to employment and further study. For more details see, for example, https://www.ocr.org.uk/qualifications/core-maths/.

The level of attainment at Key Stage 4 (prior attainment) was measured by an average GCSE and equivalents point score per entry (for details on how this was calculated, see DfE (2017)). The average GCSE and equivalents point score per entry, which ranges from 0 to 9, was used to divide students into three approximately equally sized groups: low attainment, medium attainment and high attainment. In each year, these terciles were based on the full Key Stage 4 cohort of students.

The level of income-related deprivation of the students was measured by the Income Deprivation Affecting Children Index (IDACI). This index is based on the student's home postcode and describes the percentage of children in a very small geographical area (Lower Layer Super Output Area or LSOA) living in low income families (more details about the IDACI can be found here: https://www.gov.uk/government/publications/english-indices-of-deprivation-2015-technical-report). It varies between 0 and 1 and indicates the level of income deprivation in the area in which a student lives. It cannot, however, indicate the level of income deprivation affecting an individual student. This measure was used to divide students into three approximately equally sized groups: low deprivation (more affluent), medium deprivation and high deprivation. As above, in each year, these terciles were based on the full Key Stage 4 cohort of students.

We classified schools into five groups: comprehensive schools, secondary modern schools, independent schools, selective schools, and other. *Comprehensive* and *secondary modern* schools (which include free schools and academies) do not select their intake on the basis of academic achievement or the wealth of the parents of the students they accept. *Selective* schools are state-funded schools that admit students on the basis of some sort of selection criteria, usually academic. *Independent* schools are fee-charging private schools, independent from many of the regulations and conditions that apply to state-funded schools. *Other* schools included, for example, sixth form and further education colleges, special schools, pupil referral units, tutorial colleges, and training centres.

Note that some of the variables described above are collected as part of the annual school census, which is only compulsory for state-maintained schools (and optional for independent schools). This can lead to high levels of missing data, particularly among independent school students, for some variables (e.g., IDACI deprivation). Students with missing data in any of the independent variables were not included in the regression analyses.

With logistic regression models such as the ones fitted in this research, estimates are hard to interpret directly because they are log odds of the outcome (e.g., progressing to A level; achieving at least a grade A). But, in simple terms a positive parameter estimate (for a categorical variable) means that being in that category is associated with a higher probability compared to being in the reference category. Negative values mean a reduction in probability. A positive parameter estimate for a continuous variable means that the increase in that variable is associated with an increase in the probability of the outcome. To aid interpretation, alongside the tables with the results from the regression analyses, figures are presented showing the probability of the outcome for different GCSE Maths grades and broken down by the GCSE year.

To ensure confidentiality of the data, statistical disclosure controls have been applied to the results (tables and graphs). In particular, counts below 10 and percentages based on counts below 10 have either been suppressed or merged with other counts/percentages.

Results

Progression to level 3 qualifications in mathematics

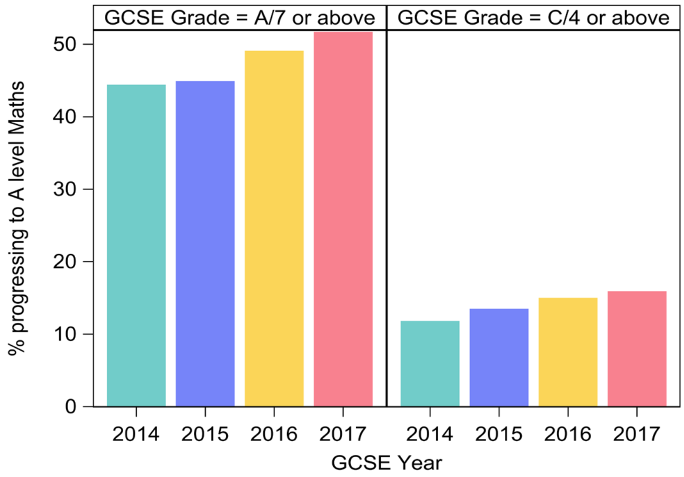
Table 2 below shows the overall progression to level 3 qualifications in mathematics of students who achieved a GCSE Maths pre-reform (2014 to 2016) and post-reform (2017).

Progression to A level Maths increased post-reform. However, this increase could be the continuation of a trend already present pre-reform (as shown in Table 2, progression to A level Maths had been increasing year on year in the last three years prior to the GCSE reform). Progression to Core Maths and A level Further Maths also increased post-reform, but it is worth noting that progression to both qualifications continued to be low in absolute terms.

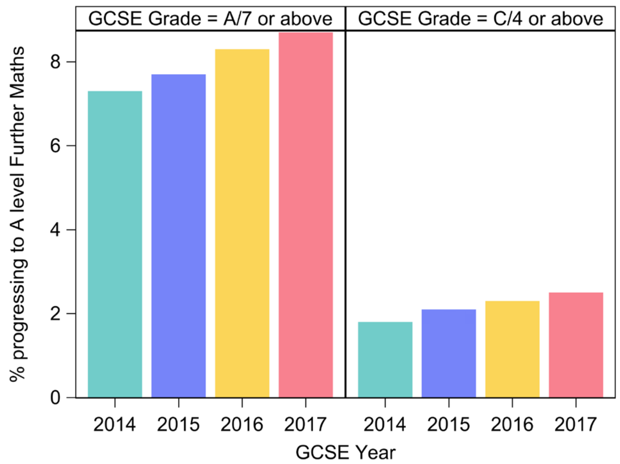
Table 2: Overall progression to level 3 qualifications in mathematics.

GCSE year	Progression	A level Maths		A level Further Maths		Core Maths	
		N	%	N	%	N	%
2014	No	465 271	92.0	499 823	98.8	504 848	99.8
	Yes	40 691	8.0	6139	1.2	1114	0.2
2015	No	492 946	90.5	536 819	98.5	542 088	99.5
	Yes	52 038	9.5	8165	1.5	2896	0.5
2016	No	465 586	89.2	513 115	98.3	517 297	99.1
	Yes	56 186	10.8	8657	1.7	4475	0.9
2017	No	470 651	88.7	521 135	98.2	525 400	99.0
	Yes	59 831	11.3	9347	1.8	5082	1.0

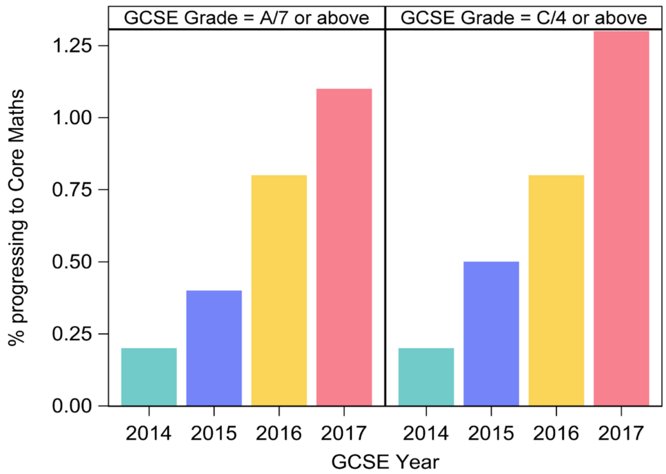
Figure 1 shows the progression to level 3 qualifications in mathematics broken down by achievement in GCSE Maths, pre- and post-reform. For A level Maths and A level Further Maths, progression increased post-reform for all students. The increase in progression rates was higher among those who achieved at least grade A/7 than for students with at least grade C/4. For Core Maths, although progression also increased post-reform for all students, the increase was slightly lower among students who achieved at least grade A/7 than among students who achieved at least grade C/4 in their GCSE Maths.



(a) A level Maths



(b) A level Further Maths



(c) Core Maths

Figure 1: Progression to level 3 qualifications in mathematics, by GCSE year (pre-reform: 2014 to 2016; post-reform: 2017) and achievement of GCSE grade thresholds: A/7 or above and C/4 or above

To further explore the effect of GCSE reform on progression to A level Maths, while accounting for students' backgrounds, multilevel logistic regression analyses were carried out. The focus of the regression analyses was on the effect of the GCSE exam year (proxy for GCSE reform) and its interaction with the GCSE Maths grade. Students' background characteristics were included as controls. Table 3, which shows the results of the regression model looking at progression to A level Maths, indicates that the GCSE year was a statistically significant predictor of progression to A level Maths, and that its effect varied significantly by grade as shown by the interaction term included in the regression model (see the four bottom rows in Table 3).

To aid the interpretation of the results from the regression model, Figure 2 shows the probability of progressing to A level Maths according to GCSE exam year and GCSE Maths grade. The graph shows the probability values for a "reference candidate" (a female student, of medium prior attainment, medium level of deprivation, and in a comprehensive school). For students with different background characteristics, a similar picture is expected: the relationship between GCSE exam year, GCSE Maths grade, and progression to A level Maths does not change, although the actual probability values might be slightly higher/lower.

Figure 2 shows that the probability of progression post-reform (the solid red line) is below the probability of progression pre-reform for the low GCSE grades, but above for the high GCSE grades – so, towards the top of the GCSE distribution, the progression to A level becomes very slightly higher for students who achieved the GCSE in 2017 (post-reform). In particular, Figure 2 shows that a reference candidate with grade A/7 in GCSE Maths had a similar probability of progression pre- and post-reform: a probability of 0.12 to progress to A level Maths pre-reform (taking 2015 as an example, but very similar for the other pre-reform years) and a probability of 0.11 after the reform. However, the very top candidates had different probabilities of progression pre- and post-reform: a reference candidate with grade A* pre-reform (2015, A*=8.5) had a probability of progression of 0.56, while a reference candidate with grade 9 post-reform had a probability of 0.78.

Table 3: Progression to A level Maths, regression analysis results (N=1 761 038).

Variable		Estimate	Standard Error	P-value
Intercept		-16.361	0.073	<.0001
Gender	Male	0.951	0.008	<.0001
	[Female]	.	.	.
Deprivation	Medium	0.005	0.009	0.5890
	High	0.087	0.012	<.0001
	[Low]	.	.	.
Prior Attainment	Medium	2.827	0.050	<.0001
	High	3.432	0.048	<.0001
	[Low]	.	.	.
School Type	Independent	-1.028	0.594	0.0836
	Other	-0.259	0.143	0.0706
	Secondary Modern	-0.057	0.059	0.3357
	Selective	-0.160	0.045	0.0004
	[Comprehensive]	.	.	.
GCSE Maths Grade		1.641	0.007	<.0001
GCSE Exam Year	2014	1.041	0.075	<.0001
	2015	1.237	0.071	<.0001
	2016	1.557	0.069	<.0001
	[2017]	.	.	.
GCSE Maths Grade * GCSE Exam Year	2014	-0.151	0.011	<.0001
	2015	-0.166	0.010	<.0001
	2016	-0.190	0.010	<.0001
	[2017]	.	.	.

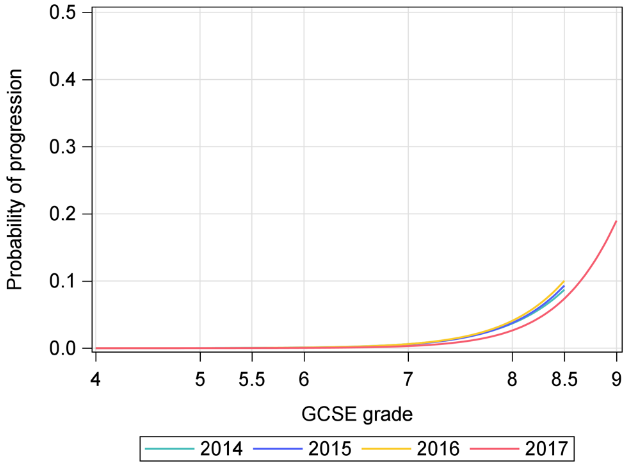
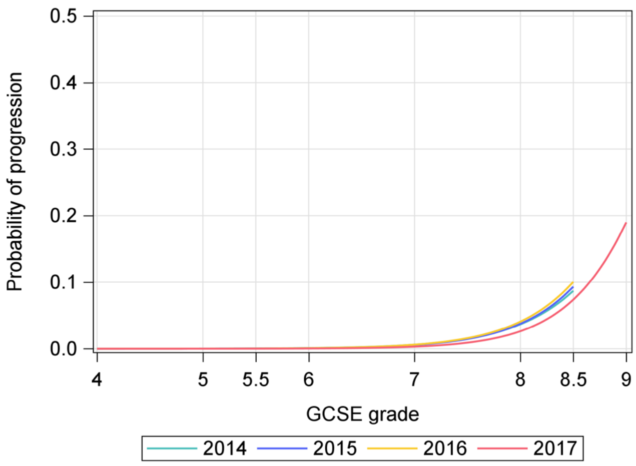
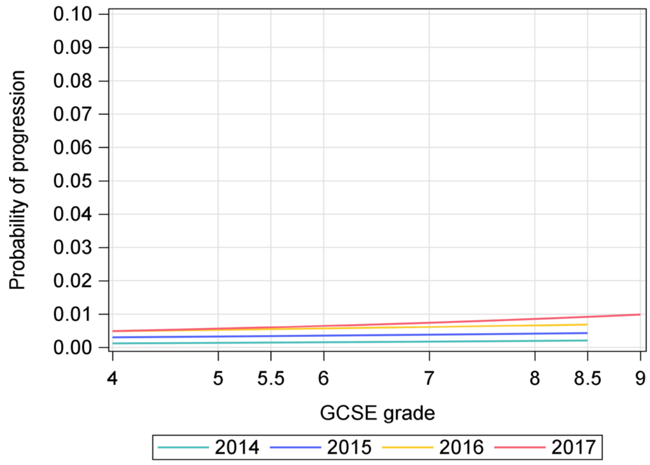


Figure 2: Probability of progression to A level Maths, by GCSE year and GCSE Maths grade (Gender=Female; Prior attainment=Medium; Deprivation=Medium; School type=Comprehensive)

The results of the regression models looking at progression to A level Further Maths and Core Maths are shown in Figure 3 (full outputs from the regression models are given in Table A1 in the Appendix). Note that, when looking at the probability graphs in Figure 3 the Y-axis scales differ.



(a) A level Further Maths



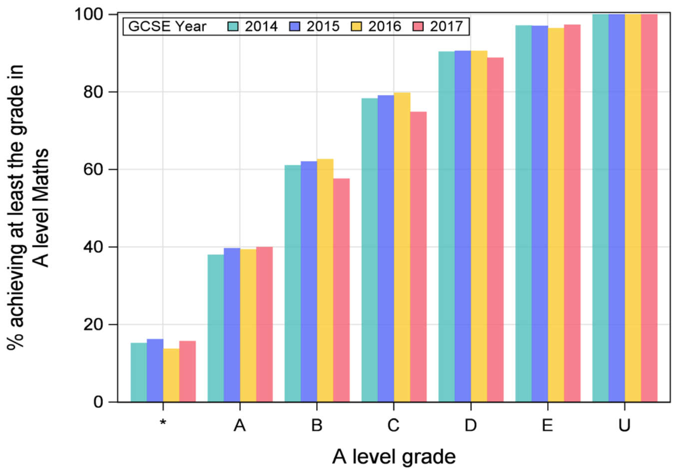
(b) Core Maths

Figure 3: Probability of progression, by GCSE year and GCSE Maths grade (Gender=Female; Prior attainment=Medium; Deprivation=Medium; School type=Comprehensive)

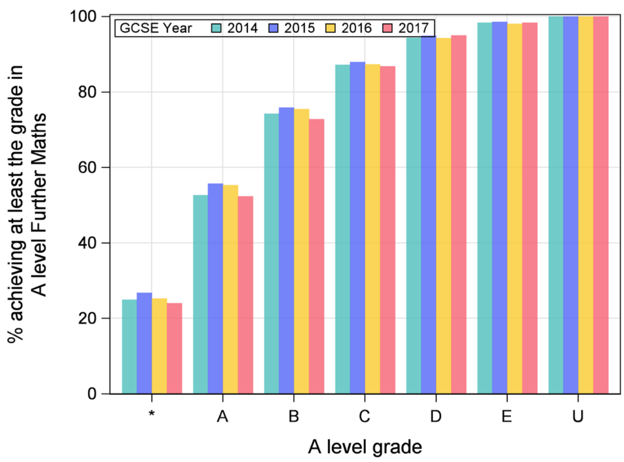
As in the model for progression to A level Maths, the results from the regression models confirmed that the year the GCSE was taken was a statistically significant predictor of progression to A level Further Maths and Core Maths, and its effect varied significantly by grade. Specifically, Figure 3(a) shows that the probability of progression to A level Further Maths post-reform was lower than the probability of progression pre-reform. On the contrary, Figure 3(b) shows that, in line with the results of the descriptive analyses, and although the rates of progression to Core Maths were very low pre- and post-reform, progression was slightly higher post-reform, independent of the grade achieved in GCSE Maths.

Performance in level 3 qualifications in mathematics

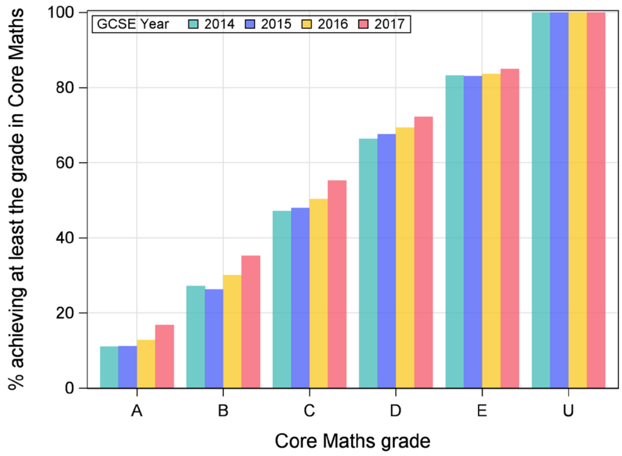
Figure 4(a) shows the A level Maths cumulative grade distribution for the cohorts of students progressing to A level Maths who achieved a GCSE in 2014 to 2016 (pre-reform) and in 2017 (post-reform).



(a) A level Maths



(b) A level Further Maths



(c) Core Maths

Figure 4: Cumulative grade distributions in level 3 qualifications in mathematics, by GCSE year (students progressing from GCSE Maths)

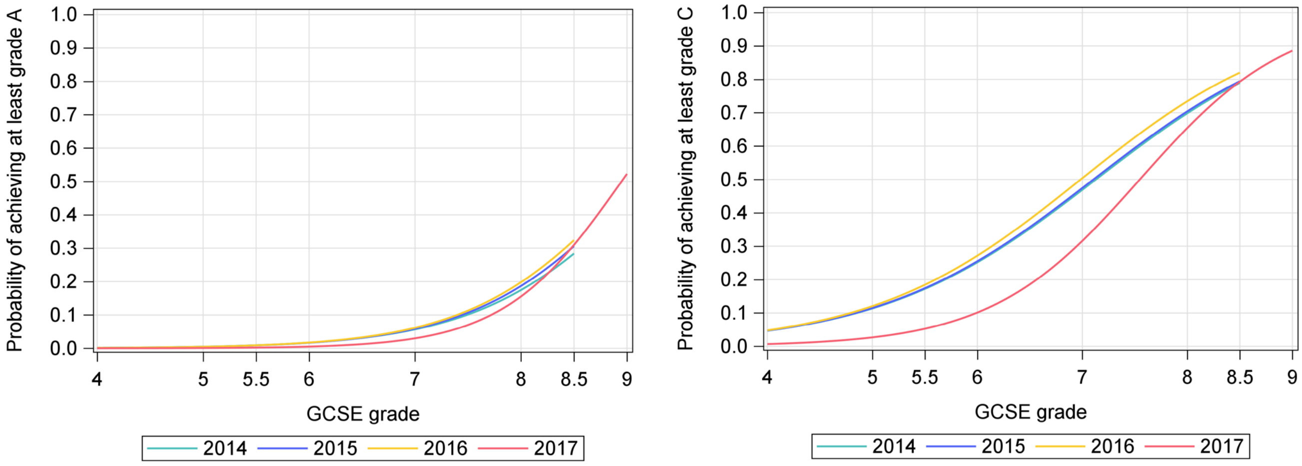
Compared to the last year pre-reform (2016), students who achieved a GCSE Maths post-reform (2017) were more likely to achieve an A* grade and at least grade A in their A level (although it was within the range for pre-reform years 2014 to 2016), but they were less likely to achieve grade B or above. Figure 4(b) shows that, compared to the pre-reform years, students who achieved GCSE Maths post-reform were less likely to get top grades (A*, at least grade A, at least grade B) in A level Further Maths. The picture for Core Maths (Figure 4(c)) was different: students who achieved a GCSE Maths post-reform performed better than students who achieved the GCSE pre-reform.

Table 4 shows the results of the regression analyses looking at the performance in A level Maths (i.e., achieving at least grade A; achieving at least grade C) pre- and post-reform. As for progression to A level Maths, the year the GCSE was taken was a statistically significant predictor of performance in A level Maths, and its effect varied significantly by grade, as shown by the interaction term included in the model (see bottom rows in Table 4).

Table 4: Achievement of grade thresholds in A level Maths, regression analysis results (N=176 398).

Variable		At least grade A			At least grade C		
		Estimate	Standard Error	P-value	Estimate	Standard Error	P-value
Intercept		-14.367	0.183	<.0001	-10.014	0.165	<.0001
Gender	Male	0.405	0.013	<.0001	0.227	0.015	<.0001
	[Female]	.	.	.	.	.	.
Deprivation	Medium	-0.134	0.014	<.0001	-0.156	0.016	<.0001
	High	-0.239	0.018	<.0001	-0.181	0.020	<.0001
	[Low]	.	.	.	.	.	.
Prior Attainment	Medium	-1.472	0.127	<.0001	-0.479	0.118	<.0001
	High	-0.555	0.122	<.0001	0.352	0.116	0.0025
	[Low]	.	.	.	.	.	.
School Type	Independent	0.869	1.194	0.4668	1.660	1.203	0.1677
	Other	0.224	0.213	0.2936	0.544	0.225	0.0155
	Secondary Modern	-0.431	0.066	<.0001	-0.376	0.065	<.0001
	Selective	0.252	0.038	<.0001	0.252	0.044	<.0001
	[Comprehensive]	.	.	.	.	.	.
GCSE Maths Grade		1.785	0.017	<.0001	1.411	0.016	<.0001
GCSE Exam Year	2014	4.364	0.197	<.0001	3.770	0.167	<.0001
	2015	4.079	0.184	<.0001	3.757	0.156	<.0001
	2016	3.992	0.176	<.0001	3.651	0.152	<.0001
	[2017]	.	.	.	.	.	.
GCSE Maths Grade * GCSE Exam Year	2014	-0.528	0.024	<.0001	-0.446	0.023	<.0001
	2015	-0.482	0.023	<.0001	-0.441	0.021	<.0001
	2016	-0.462	0.022	<.0001	-0.409	0.021	<.0001
	[2017]	.	.	.	.	.	.

Once we took into account the background of the students, including their prior attainment and their grade in GCSE Maths, both Table 4 and Figure 5 below show that the probability of achieving at least grade A at A level was lower post-reform (2017) than pre-reform (2014–16), apart from for the students who achieved the very top GCSE grades. In particular, a reference candidate with grade 7 in GCSE Maths had a higher probability of achieving at least a grade A at A level pre-reform than post-reform. The same patterns were found for the achievement of at least grade C.



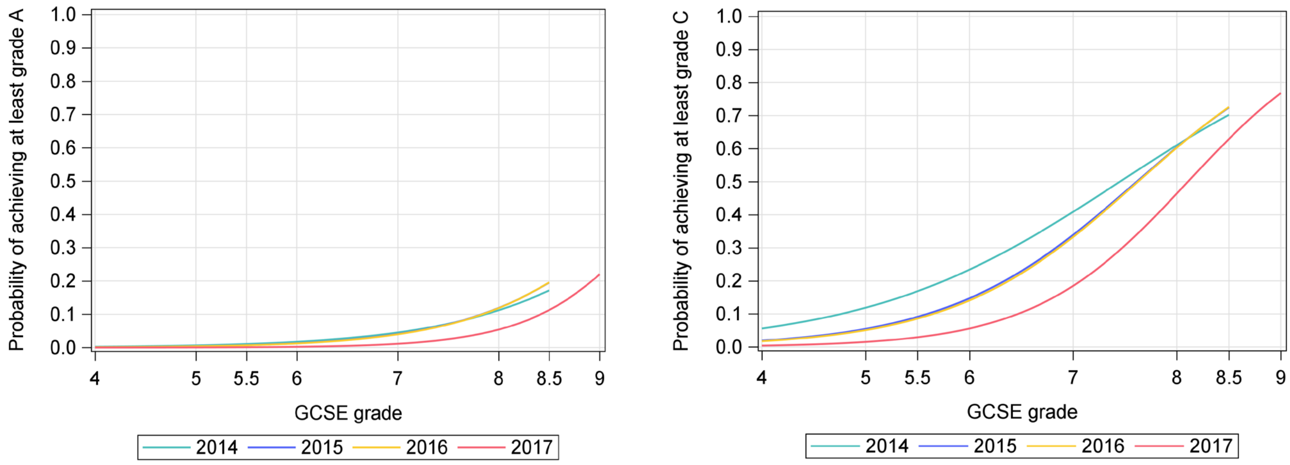
(a) Grade A or above

(b) Grade C or above

Figure 5: Probability of achieving a grade or above in A level Maths, by GCSE year and GCSE Maths grade (Gender=Female; Prior attainment=Medium; Deprivation=Medium; School type=Comprehensive)

The results of the regression models looking at performance in A level Further Maths and Core Maths are shown in Figure 6 and Figure 7, respectively (full outputs from the regression models are given in Table A2 and Table A3 in the Appendix).

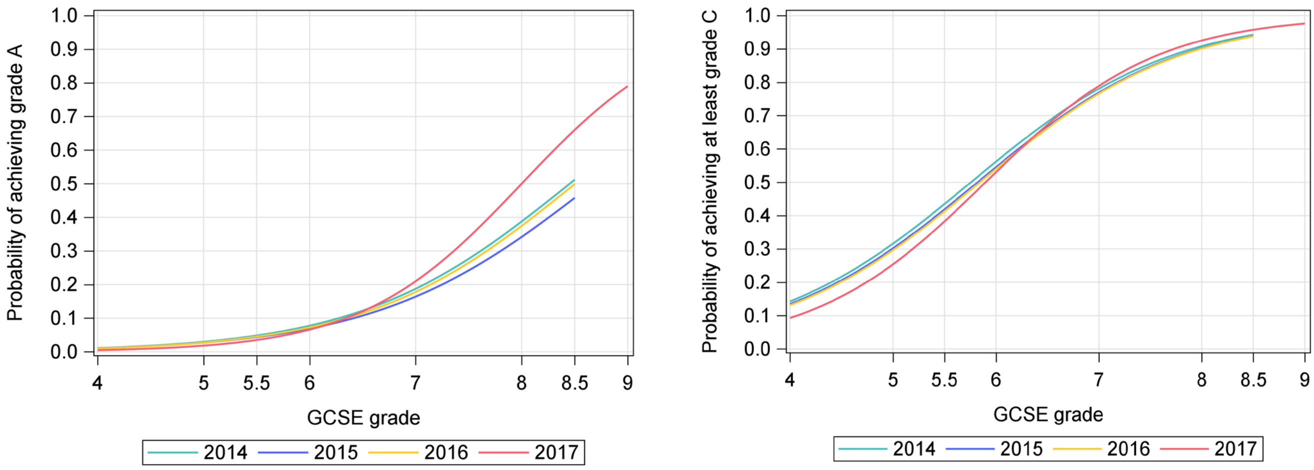
Once we took into account the background of the students, including their prior attainment and their grade in GCSE Maths, Figure 6 shows that the probability of achieving at least grade A or at least grade C in A level Further Maths was lower post-reform (2017) than pre-reform (2014–16), apart from for the students who achieved the very top GCSE grades. Performance in Core Maths was, however, generally higher post-reform (see the red lines for 2017 in Figure 7(a) and Figure 7(b)) than pre-reform.



(a) Grade A or above

(b) Grade C or above

Figure 6: Probability of achieving a grade or above in A level Further Maths, by GCSE year and GCSE Maths grade (Gender=Female; Prior attainment=Medium; Deprivation=Medium; School type=Comprehensive)



(a) Grade A

(b) Grade C or above

Figure 7: Probability of achieving a grade or above in Core Maths, by GCSE year and GCSE Maths grade (Gender=Female; Prior attainment=Medium; Deprivation=Medium; School type=Comprehensive)

Discussion and conclusions

This research has explored how well the GCSE in Maths prepared young people for further study in mathematics in the context of GCSE reform.

Contrary to fears of reduction in the uptake of A level Maths following the reform (e.g., Lee et al., 2018; Redmond et al., 2020) this research showed that progression generally increased post-reform. It should be noted, however, that this increase could be the continuation of a trend already present pre-reform (progression to A level Maths had been increasing year on year in the last three years prior to the GCSE reform). When controlling for students' backgrounds (including the grade achieved in GCSE Maths) the probability of progression post-reform was just below the probability of progression pre-reform for students with low GCSE grades. On the contrary, for students who achieved GCSE grades towards the top of grade distribution, the progression to A level was very slightly higher post-reform.

Performance in A level Maths was, in general, lower post-reform. In particular, the probability of achieving at least grade A or at least grade C in A level Maths was lower post-reform for students with any GCSE grade, apart from the students at the very top of the GCSE grade distribution. This contrasts with the perceptions of A level Maths teachers interviewed in research by Howard and Khan (2019) or Humphries et al. (2017), who commented that the reformed GCSE prepared students for the A level at least as well, if not better, than the legacy GCSE and that students sitting the reformed GCSE would be leaving Key Stage 4 with more mathematical knowledge than previous cohorts. However, it should be taken into account that students taking the reformed GCSE would have also taken the newly reformed A level Maths,[6] and it is well known that student performance tends to dip slightly in the first years of a new qualification (i.e., there is a sawtooth effect, as described, for example, in Cuff et al. (2019)). While the approach to awarding and grading A levels in this context (Newton, 2020) should have smoothed the sawtooth effect when looking at grade distributions, there could still be some evidence of relative under-performance. Furthermore, research showed that the reformed A level specifications were significantly more demanding than legacy specifications (Redmond et al., 2020), and there was concern from some teachers that while more able students may benefit from the more "aspirational" A level, lower performing students may be impacted negatively by the changes.

Progression to other level 3 qualifications in mathematics such as Core Maths or A level Further Maths increased post-reform (although it should be noted that progression to either of these qualifications was quite low both pre- and post-reform). In the case of Core Maths, as suggested by Mathieson et al. (2020), this increase could be seen as the result of the opportunity that this subject provides students for whom there was previously no option to study maths post-16. There were, however, differences in progression by the grade achieved in GCSE Maths: the increase in progression to Core Maths was slightly lower among students who achieved top grades (at least grade A/7) than among students who achieved lower grades (at least grade C/4), while the opposite pattern was found for progression to A level Further Maths. It is worth noting, however, that when accounting for the students' background characteristics, the probability of progression to A level Further Maths post-reform was lower than the probability of progression pre-reform.

Regarding performance in Core Maths and A level Further Maths, students who achieved a GCSE Maths post-reform were more likely to achieve top grades

6 Alongside GCSE reform, A levels have also been reformed. For example, students who sat the reformed GCSE Maths in 2017 (first year of assessments after the GCSE reform) were the first full cohort to sit the reformed Maths and Further Maths A levels in summer 2019 (A level Maths was available after one year of study in summer 2018; however, the entries in summer 2018 were small and were mainly younger students also studying A level Further Maths).

(grades A or B) in Core Maths, compared to students who achieved their GCSE Maths in pre-reform years. On the contrary, compared to the pre-reform years, students who achieved a GCSE Maths post-reform were less likely to achieve both grade A or above and grade C or above in A level Further Maths.

The new GCSE in mathematics also aimed to better prepare young people for further study in subjects with significant mathematical content (e.g., science subjects, economics, psychology). Howard and Khan (2019) reported that the reformed GCSE had positive implications beyond studying A level Maths and that the new GCSE would support students' progression to and performance in other subjects with mathematical content. Further to the research presented here, Vidal Rodeiro and Williamson (2022) investigated the impact of GCSE Maths reform on five maths-related A levels (biology, chemistry, physics, economics and psychology). Compared to pre-reform years, they found that overall progression was higher post-reform in all five subjects. Furthermore, performance in A level science subjects (biology, chemistry and physics) was very similar pre- and post-reform for students with the very top GCSE grades in mathematics, but it was lower post-reform for students with lower grades in GCSE Maths. However, in economics and psychology, performance was very similar pre- and post-reform.

The research discussed in this article is set in the context of recent reforms to GCSEs and A levels and, as with any reforms, changes take time to bed in. Given that this research focused on the first year after the reform (the new GCSE Maths was first assessed in 2017), it is possible that the results do not reflect how the reformed GCSE Maths will impact progression to and performance in level 3 qualifications in mathematics and subjects with mathematical content over the coming years. In the interim, however, the results of this research have raised important issues for the mathematics education community and for policy makers by increasing the understanding of how recent reforms to GCSE Maths have affected students, and contributing evidence on its impact on progression to post-16 study.

Overall, the findings indicate that some aims of the curriculum and assessment reform in upper secondary mathematics (in particular, increasing uptake of post-16 mathematics) may have been fulfilled. Going forward, it will be important to monitor the uptake of and performance in different post-16 mathematics qualifications (particularly by mid-attaining students), and continue to triangulate teacher perceptions with trends in attainment.

Acknowledgements

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Appendix

Table A1: Progression to level 3 qualifications in mathematics (A level Further Maths; Core Maths), regression analysis results (N = 1 761 038).

Variable		A level Further Maths			Core Maths		
		Estimate	Standard Error	P-value	Estimate	Standard Error	P-value
Intercept		-23.965	0.250	<.0001	-7.648	0.067	<.0001
Gender	Male	1.183	0.017	<.0001	0.021	<.0001	<.0001
	[Female]	.	.	.	.	.	.
Deprivation	Medium	0.020	0.017	0.2506	0.024	0.3610	0.3610
	High	0.026	0.022	0.2503	0.029	0.0063	0.0063
	[Low]	.	.	.	.	.	.
Prior Attainment	Medium	3.055	0.184	<.0001	0.039	<.0001	<.0001
	High	3.206	0.180	<.0001	0.048	<.0001	<.0001
	[Low]	.	.	.	.	.	.
School Type	Independent	0.310	0.893	0.7285	1.025	0.8374	0.8374
	Other	-0.252	0.278	0.3648	0.243	0.0200	0.0200
	Secondary Modern	-0.529	0.092	<.0001	0.155	0.1528	0.1528
	Selective	-0.177	0.050	0.0004	0.136	<.0001	<.0001
	[Comprehensive]	.	.	.	.	.	.
GCSE Maths Grade		2.160	0.020	<.0001	0.143	0.010	<.0001
GCSE Exam Year	2014	2.976	0.258	<.0001	0.116	<.0001	<.0001
	2015	2.150	0.254	<.0001	0.081	0.0065	0.0065
	2016	2.275	0.244	<.0001	0.072	0.0004	0.0004
	[2017]	.	.	.	.	.	.
GCSE Maths Grade * GCSE Exam Year	2014	-0.329	0.031	<.0001	0.021	0.2477	0.2477
	2015	-0.223	0.030	<.0001	0.014	<.0001	<.0001
	2016	-0.228	0.029	<.0001	0.013	<.0001	<.0001
	[2017]	.	.	.	.	.	.

Table A2: Achievement of grade thresholds in A level Further Maths, regression analysis results (N = 27 386).

Variable		At least grade A			At least grade C		
		Estimate	Standard Error	P-value	Estimate	Standard Error	P-value
Intercept		-14.868	0.716	<.0001	-10.739	0.644	<.0001
Gender	Male	0.162	0.033	<.0001	0.132	0.047	0.0052
	[Female]	.	.	.	.	.	.
Deprivation	Medium	-0.207	0.032	<.0001	-0.299	0.047	<.0001
	High	-0.400	0.040	<.0001	-0.500	0.054	<.0001
	[Low]	.	.	.	.	.	.
Prior Attainment	Medium	-0.578	0.550	0.2934	0.168	0.451	0.7094
	High	0.991	0.538	0.0653	1.398	0.445	0.0017
	[Low]	.	.	.	.	.	.
School Type	Independent	1.187	1.872	0.5258	-1.080	1.770	0.5417
	Other	-0.293	0.419	0.4834	0.057	0.536	0.9157
	Secondary Modern	-0.376	0.148	0.0110	-0.231	0.189	0.2215
	Selective	0.442	0.055	<.0001	0.440	0.082	<.0001
	[Comprehensive]	.	.	.	.	.	.
GCSE Maths Grade		1.599	0.054	<.0001	1.341	0.056	<.0001
GCSE Exam Year	2014	5.705	0.725	<.0001	4.776	0.691	<.0001
	2015	4.334	0.714	<.0001	2.581	0.666	0.0001
	2016	4.185	0.687	<.0001	2.384	0.639	0.0002
	[2017]	.	.	.	.	.	.
GCSE Maths Grade * GCSE Exam Year	2014	-0.614	0.085	<.0001	-0.523	0.084	<.0001
	2015	-0.434	0.084	<.0001	-0.252	0.081	0.0018
	2016	-0.416	0.080	<.0001	-0.228	0.078	0.0032
	[2017]	.	.	.	.	.	.

Table A3: Achievement of grade thresholds in Core Maths, regression analysis results (N = 12 140).

Variable		Grade A			At least grade C		
		Estimate	Standard Error	P-value	Estimate	Standard Error	P-value
Intercept		-11.133	0.466	<.0001	-7.725	0.284	<.0001
Gender	Male	0.297	0.070	<.0001	0.350	0.052	<.0001
	[Female]	.	.	.	.	.	.
Deprivation	Medium	-0.150	0.076	0.0476	-0.134	0.057	0.0188
	High	-0.427	0.092	<.0001	-0.299	0.064	<.0001
	[Low]	.	.	.	.	.	.
Prior Attainment	Medium	0.676	0.282	0.0165	0.787	0.112	<.0001
	High	1.525	0.282	<.0001	1.717	0.119	<.0001
	[Low]	.	.	.	.	.	.
School Type	Independent	-6.107	23.842	0.7978	4.548	26.927	0.8659
	Other	2.270	0.663	0.0006	0.708	0.563	0.2083
	Secondary Modern	-0.287	0.264	0.2778	-0.441	0.189	0.0196
	Selective	0.201	0.197	0.3084	0.397	0.187	0.0333
	[Comprehensive]	.	.	.	.	.	.
GCSE Maths Grade		1.326	0.058	<.0001	1.199	0.047	<.0001
GCSE Exam Year	2014	2.078	0.811	0.0104	1.189	0.535	0.0262
	2015	2.168	0.580	0.0002	1.128	0.391	0.004
	2016	1.959	0.504	0.0001	1.083	0.346	0.0018
	[2017]	.	.	.	.	.	.
GCSE Maths Grade * GCSE Exam Year	2014	-0.317	0.131	0.0153	-0.177	0.101	0.0800
	2015	-0.353	0.093	0.0001	-0.178	0.072	0.0137
	2016	-0.309	0.079	0.0001	-0.174	0.063	0.0058
	[2017]	.	.	.	.	.	.