DISCUSSION PAPER SERIES

No. 6895

THE EFFECTS OF REMEDIAL MATHEMATICS ON THE LEARNING OF ECONOMICS: EVIDENCE FROM A NATURAL EXPERIMENT

Johan N.M. Lagerlöf and Andrew J Seltzer

PUBLIC POLICY

Centre for Economic Policy Research

www.cepr.org

Available online at: **www.cepr.org/pubs/dps/DP6895.asp**

ISSN 0265-8003

THE EFFECTS OF REMEDIAL MATHEMATICS ON THE LEARNING OF ECONOMICS: EVIDENCE FROM A NATURAL EXPERIMENT

Johan N.M. Lagerlöf, University of Copenhagen and CEPR
Andrew J Seltzer, Royal Holloway, University of London

Discussion Paper No. 6895
July 2008

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

CEPR Discussion Paper No. 6895

July 2008

ABSTRACT

The Effects of Remedial Mathematics on the Learning of Economics: Evidence from a Natural Experiment*

This paper examines the effects of remedial mathematics on performance in university-level economics courses using a natural experiment. We study exam results prior and subsequent to the implementation of a remedial mathematics course that was compulsory for a sub-set of students and unavailable for the others, controlling for background variables. We find that, consistent with previous studies, the level of and performance in secondary-school mathematics have strong predictive power on students' performance at university-level economics. However, we find relatively little evidence for a positive effect of remedial mathematics on student performance.

JEL Classification: A22 and I20
Keywords: differences-in-differences, quantile regressions, remedial mathematics and teaching of economics

Johan N.M. Lagerlöf
Economics Department
University of Copenhagen
Studiestræde 6
DK-1455 Copenhagen
DENMARK
Email: johan.lagerlof@econ.ku.dk

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=146648

Andrew J Seltzer
Department of Economics
Royal Holloway
University of London
Egham, Surrey
TW20 0EX
Email: a.seltzer@rhul.ac.uk

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=158285

* We are grateful for helpful comments from the editor Peter Kennedy, three anonymous referees, Joe Clougherty, Tomaso Duso, Wayne Grove, Sebastian Kessing, seminar audiences at Royal Holloway, the Royal Economic Society Annual Conference (Nottingham, 2006), the 61st International Atlantic Economic Conference (Berlin, 2006), the WZB (Berlin, 2007), and the University of Lund (Sweden, 2007). We also thank Joseph Bamidele and Danail Popov for research assistance and the Economics Department at Royal Holloway for financial support. The most recent version of the paper can be downloaded at www.JohanLagerlof.org.

Submitted 24 June 2008

Introduction

The mathematical demands of university-level economics make it a difficult subject for less technically able students. A number of studies have shown a strong link between mathematics background and performance in economics degrees—see, e.g., Reid (1983), Anderson et al. (1994), Butler et al. (1994), Durden and Ellis (1995), Lopus (1997), and Ballard and Johnson (2004). However, the nature of this relationship is not fully understood. Most studies use single measures of mathematics capability such as the American SAT score, which can not distinguish between students' inherent ability in maths and the level to which they studied the discipline prior to starting university. The latter possibility suggests that the implementation of remedial programmes in mathematics may be an important tool in helping students to cope with the demands of university-level economics.

In the United States, the use of remedial education at the university level has been extensive and controversial. According to data from the National Center for Education Statistics, in 2000 71 per cent of all two- and four-year degree-granting institutions offered remedial courses in mathematics. These courses were taken by 22 per cent of entering first-year students.[1] Proponents have argued that the programmes can help less technically able students, who are often from disadvantaged backgrounds, and facilitate their integration into university studies.[2] Critics have argued that remedial programmes are too costly and that tax dollars should not be used in colleges to teach high school courses. In the past decade critics of remedial programmes have been

[1] The White House Social Statistics Briefing Room, http://nces.ed.gov/ssbr/pages/remedialed.asp?IndID=16 (accessed 25 May 2008).
[2] For accounts of these discussions, see e.g. Merisotis and Phipps (2000) and Bettinger and Long (2006).

increasingly influential in public policy debates, and public universities in a number of states (including New York, California, Illinois, and Florida) have reduced students' access to remediation or eliminated their programmes entirely (Merisotis and Phipps (2000) and Bettinger and Long (2006)).

In light of the debate on remedial education, it is important to understand whether and to what extent it actually works. This paper examines the effects of remedial mathematics instruction on students' performance in economics subjects in a British context. We make use of a natural experiment created by the implementation of a remedial maths course for a sub-set of students in the economics programme at Royal Holloway, University of London. Prior to 1999 the Department of Economics did not offer remedial maths to any students. Beginning in 1999 the remedial "Foundations of Mathematics" (henceforth FoM) became compulsory for all single and joint honours students who either did not take A-level mathematics or received a grade C or lower at A-level mathematics.[3] The subject covered a sub-set of the A-level syllabus and was designed to ensure that all students had a basic grounding in the most important mathematical techniques used in an undergraduate economics degree.

We use administrative records of students entering the Department in 1997-1999 to examine the effects of the implementation of FoM on performance in first-year subjects.[4] The data cover individual characteristics, performance at A-level and exam

[3] An A-level (short for "Advanced level") is a qualification that can be taken by students in England, Wales and Northern Ireland, usually in the final two years of their secondary education (at the age of 16 to 18). They are available in a wide range of subjects. The number of A-level exams students take vary, but the minimum number required for university entrance is typically three. A-levels are graded A, B, C, D, E, N and U, with A being the top grade and where N ("nearly passing") and U ("Unclassified") are fail grades.

[4] We do not use the cohorts of students who entered in 2000 or later in our analysis because of a change in College policy that year that reduced the weight of the first year in the overall degree classification

results. We examine students' grades in compulsory first-year subjects ranging from the highly mathematical Quantitative Methods I to the non-mathematical Economics Workshop. As with FoM, these subjects were either compulsory or unavailable to all students in the data set, depending upon their degree programme. We analyse student performance in these classes, examining the results prior and subsequent to the implementation of FoM using a differences-in-differences approach. We also examine possible longer-term effects of remediation using a similar differences-in-differences approach to analyse performance in core second- and third-year courses.

The relatively few previous studies on the topic have found that, in an American context, remedial mathematics seems to work. Johnson and Kuennen (2002) examine the scores of students in introductory microeconomics at a midwestern American university. They find that students who were assigned to remedial maths and actually took the course prior or concurrent to taking microeconomics performed better than students who were assigned to remedial maths but who waited until after taking microeconomics to take the remedial course. This approach leaves open the possibility that Johnson and Kuennen's results are driven by unobserved heterogeneity in the sample—e.g., that students who chose to take the remedial maths course relatively soon after having been assigned to it were on average more motivated than students who waited to take the course.

Using data from a Principles of Macroeconomics course at Western Michigan University, Pozo and Stull (2006) study the effects of providing a grade incentive for students to complete an on-line maths tutorial and test. The authors use a controlled

from 16.67 per cent to zero per cent. We feel that the effect of this change in policy on students' incentives is sufficiently large to make any comparisons to earlier years meaningless.

experiment to compare the average grades obtained by the (randomly assigned) group of students who were given such an incentive with the grades of a control group of students who were not. The results suggest that the grade incentive had a positive and statistically significant impact (2.6 percentage points) on the grade in a midterm exam. However, the effects of the incentive were short-lived, and Pozo and Stull do not find a statistically significant effect on final exam scores. The remedial maths course that we study is more extensive (lasting seven weeks) than the tutorial in Pozo and Stull's study. However, their result that remediation does not appear to have an effect when the time lag between remediation and exam is somewhat longer is consistent with our findings.

Bettinger and Long (2006) examine remediation in the Ohio public university system using an instrumental variables technique to control for individual-level heterogeneity. They instrument having actually received remedial education with the estimated probability of receiving remediation given students' entry scores and exogenous variation in the choice of school attended, based on distance from home. Their findings indicate that students with a higher probability of being exposed to remediation are *ceteris paribus* less likely to drop out of college and more likely to transfer to a higher-level college and to complete a bachelor's degree. Although Bettinger and Long (2006) are careful to construct a measure of remediation that is unlikely to be related to individuals' ability or motivation, there remain two problems that make it difficult to interpret their results as a pure effect of remedial maths on students' performance. First, their instrument for remediation is based on school-level differences in remedial offerings, which could be correlated with other aspects of the schools' focus on undergraduate education (e.g. availability of tutoring, level of guidance etc). Secondly, they find that students of a given ability who had expressed an interest in majoring in a mathematically-oriented subject prior to entering college and who were assigned to take remedial maths were more likely to graduate, but less likely to do their degree in a mathematically-oriented subject than those not exposed to remediation. This suggests that remediation may have a limited effect in increasing students' mathematical abilities, but helps to match students with appropriate degree subjects.

The design of this study reduces the impact of these concerns. The Foundations of Maths programme was either compulsory or unavailable for all individuals in the data set. Moreover, students required to take FoM all had to take it at the same time and from the same set of lecturers. Similarly, most of the courses taken by the students in our sample were compulsory, as were the times and the lecturers. Thus, it is highly unlikely that the results of this study are driven by selection bias created by unobserved heterogeneity across courses or students. In addition, the students in our sample were required to choose their subject of study prior to beginning their university studies, and could only change subjects by starting another degree from the beginning. Thus remediation is very unlikely to have an effect on matching students with appropriate degrees and would only be effective if it improved students' performance in their chosen degree.

The outline for the remainder of the paper is as follows. The first section describes the Royal Holloway economics programme and the natural experiment created by the implementation of Foundations of Mathematics. The second section describes the data set. The third section outlines our econometric methodology. The fourth section presents the estimation results for the range of compulsory economics courses and presents a variety of robustness checks of these results. The fifth section concludes. Our findings suggest that, consistent with previous studies, the amount of mathematics taken prior to university and the results in A-level mathematics have strong predictive power on student performance. However, we find much weaker evidence that taking remedial mathematics has an effect on student performance. We find a statistically significant effect only in the least mathematical course and the overall average of the first year and no effect in the second or third year of the programme. Moreover, when we do find a statistically significant effect, this is limited to the strongest of the students required to take remedial maths.

1. The Royal Holloway Economics Degree and Foundations of Mathematics

The students contained in the data set were all enrolled in single honours economics, a major in economics, a joint degree in economics or a minor in economics at Royal Holloway, University of London. Once they had selected their degree programme, the set of subjects that students were required to sit in their first year was largely specified by the College's rules. All first-year single-honours students and majors were required to take Principles of Economics, Quantitative Methods I and Economics Workshop. Single-honours students also took a fourth unit, and had the option of choosing that unit in Economics or in another department. Joint-honours students were required to take Principles and Quantitative Methods I. Students with an economics minor were only required to take Principles. Joint students and economics minors took the remainder of their subjects in other departments, and thus did not have the option of taking additional economics courses. The department only ran a single lecture session for each course, which means that all students in a particular subject in a given year went to the same lectures and faced the same assessment.

The FoM module was created in 1999 specifically in response to the observation that students who lacked a solid mathematics background often struggled in the first year of their degree programme, particularly in Quantitative Methods I. Prior to the start of the first term, students were assigned to FoM if they had not taken or failed to attain at least grade B in A-level maths. The FoM module contained an hour of lecture and an hour of tutorial per week and ran concurrently to lectures in the Quantitative Methods I course over the first seven weeks of the first term. The course covered basic algebra, functions, quadratic expressions, inequalities, logarithms, and exponentials. Students were given ungraded assignments for each topic. Students were not given choices of lecturers, seminar leader, or time of day when they took FoM. Because FoM ran parallel to the Quantitative Methods I course, it could not be taken by economics minors.

This set of rules provides an ideal experiment design that enables us to avoid the econometric problems potentially created by self-selection of students into courses based on factors such as mathematics ability. The choice of degree programme was normally made at the time of initial application to university, a year prior to the start of the degree. Although it is possible that students chose their degree programme partly based on mathematics ability, the extent of selection bias in this study is almost certainly less than for other studies in which students had options over which courses to take, and over the lecturer, time of day and point in their college career when to take a given course. Moreover, the Foundations of Mathematics course was made part of the curriculum only after the admissions process for 1999 was well under way and was not well publicized to applicants until the following year, and thus it is highly unlikely that it entered into the application decisions of prospective students.

The nature of FoM meant it was, at best, an imperfect substitute for A-level maths. The FoM module covered only a selection of topics from the full syllabus of A-level mathematics deemed most relevant to an economics degree, and ran over seven weeks, rather than the two years for A-level maths. There was no examination or other assessment for FoM, which may have meant that students lacked incentives to put in much effort into FoM. However, the relevant comparison for this study is between students who have taken FoM and otherwise similar students who have not taken FoM, rather than between those with FoM and those with A-level maths. We believe that, at a minimum, the implementation of FoM exposed students to more maths teaching than they otherwise would have received. Students who did not attend FoM lectures or tutorials potentially could have been penalized by failure for the entire Quantitative Methods I unit, which would result in an inability to progress to the second year of their degree. It is possible that a longer and more comprehensive remedial maths programme would be more effective than FoM; however, such a programme would also have higher costs in the form of additional teaching time, difficulties with scheduling alongside other courses, and diverting students' time away from their other subjects.

2. The Data Set

The data set used in this study is constructed from administrative records kept by the Economics Department.[5] These records contain end-of-year exam results for all students entering in years 1997-99. We have linked these records to admissions records for students who took A-levels prior to entering University and who graduated in July 2000 or were still enrolled in the Department in August 2000. The admissions records contain information on age, sex, A-level results and results from all subjects taken at university. We do not have this data for students who began with the 1997, 1998 or 1999 cohorts and withdrew prior to August 2000, and thus we exclude these students from our analysis. The inclusion of only students who were present in August 2000 in the data means that our analysis only captures the effects of remediation on the group of students who are infra-marginal—at a comparative disadvantage in mathematics, but nevertheless unlikely to drop out of university. Thus we cannot replicate Bettinger and Long's (2006) analysis on dropping out. However, in the European context where drop-out rates are much lower than in the US it seems more natural to focus on exam results.[6] Most withdrawals occurred early in the first year, well prior to students sitting any exams.[7] Anecdotally these withdrawals were more likely to be due to financial or personal reasons than due to difficulties with the subject.

---

[5] Royal Holloway, Department of Economics, UCAS Forms (various years); Royal Holloway, Department of Economics, Economics Sub-board: Provisional Rank Sorted Classification Grid (various years); Royal Holloway, Department of Economics, Annual Monitoring (various years).

[6] In typical years over 90 per cent of students remaining in the programme until December of their first year went on to graduate. Royal Holloway, Annual Monitoring (various years).

[7] Our statistics on enrolments and drop-outs are very incomplete. For each cohort we have a count of all students (including those with entry qualifications other than A-levels) enrolled in January and those sitting end-of-year exams. Thus we do not observe the number of drop-outs during the first few months of the programme.

For the purposes of our analysis the collection of data at a single survey date raises concerns about survival bias. The FoM programme may have had the effect of enhancing weaker students' performance enough so that they were able to stay in the programme, but nevertheless did not perform particularly well on their exams. This would lead to a downwards bias in the estimated effects of Foundations of Mathematics. We are not able to directly test for this effect in the data; however, we do note that aggregate statistics do not reveal a substantial change in the pattern of first-year withdrawals over the period of this study.[8] A second concern is that the full sample of students in the data set are not comparable across years. Students entering in 1997 may have sat their first-year exams, but been excluded from the sample due to withdrawing during their second or third years at University. Similarly, students entering in 1998 may have withdrawn after their second year. Since we do not observe all students who entered in 1997 or 1998 and sat their first-year exams, we have excluded from the sample all students who withdrew before sitting their final-year exams in order to ensure that the sample is comparable across years.

Table 1 provides descriptions of the main variables and summary statistics (means, standard deviations and the number of observations) for the sample as a whole and separated into four categories based on whether FoM would have been available and/or required.[9] The first four variables ($GRADE_m$, where $m=PE$, $QM1$, EW, EA) are our main dependent variables. The first three of these are the students' grades in the three courses mentioned previously. The fourth variable, $GRADE_{EA}$, is the students'

[8] The percentage of first-year students (including those with entry qualifications other than A-levels) dropping out between January of the first year and graduation was 8.9 per cent and 7.4 per cent respectively for 1998 and 1999 entrants. Royal Holloway, Annual Monitoring (various years). We do not have similar figures for 1997 entrants.

[9] As the students' degree programmes differ and they accordingly did not all take the same courses, the number of observations is not the same for all variables. Table 1 reports the number of observations for students taking Principles of Economics, the largest course in the Department.

overall average grade across first-year economics courses. Note that $GRADE_{EA}$ is not simply a linear combination of the other variables, as the set of first-year courses can include additional optional courses other than the three previously mentioned. The scale used for the grade in all courses is the usual one, running between 0 and 100.

Next in Table 1, we summarize the main independent variables in the regressions. The variable *WEAKMATH* is a dummy variable that takes the value one if a student, who may belong to any cohort, is (i) not an economics minor and (ii) either did not take A-level maths at all or did take A-level maths but failed to obtain grade A or B. In other words, the students for which *WEAKMATH* equals one satisfy the criteria for being assigned to FoM, and the sub-set of these students who belong to the 1999 cohort (when the remedial course was introduced) were indeed assigned to FoM. The variable *ALEVEL* is a summary measure of the students' A-level results. In coding this variable, we followed the standard approach for UK university admissions prior to 2002, summing up each student's points in their three best A-levels, where A = 10, B = 8 etc.[10] We have also separated out A-level results in mathematics and economics. The variable *FoM* is central to our analysis. It is the dummy variable that gives us the differences-in-differences estimate. It takes the value one if a student entered in 1999 (the year FoM was introduced) and was assigned to FoM. For some of the regressions we also disaggregate students taking FoM into two and three groups, respectively, based on whether they took A-level maths and their grade in that subject.

[10] We have followed standard admissions practices when coding the A-level scores for this paper. Thus an AS-level (advanced subsidiary) result is counted as half of an A-level result. We have also excluded A-levels that would not have been counted for an admissions decision, i.e., general studies and native language. The alternative approach would be to use a set of dummy variables for different A-level results. However, this approach has a significant cost in terms of degrees of freedom and the number of observations in many of the cells would be very small. Thus the resulting regression estimates are likely to be imprecise.

Finally Table 1 contains information on background variables such as gender, degree programme and year of entry.

We can use Table 1 to come up with a first estimate of the effects of FoM. To this end, let $GRADE_{W,C,t}$ denote the average grade in course C of students belonging to cohort t and to the group for whom WEAKMATH equals 1; the latter group is indicated by the subscript W and consists of the students (belonging to any cohort) who failed to attain grade A or B at A-level maths and who were not economics minors. From Table 1, the difference in grades between the cohort that was exposed to FoM (i.e., 1999) and the previous two cohorts (i.e., 1997/98), for the "W students" in the course Principles of Economics, is $(GRADE_{W,PE,99} - GRADE_{W,PE,97/98}) = 52.86 - 56.49 = -3.63$. In other words, it appears that the cohort taking FoM did somewhat worse than previous cohorts. However, it is possible that this difference is due to differences in the difficulty of the exams, marking, or other factors unrelated to FoM. These factors would have affected all students in the 1999 entry cohort, regardless of their performance in A-level maths or exposure to remediation. Thus to eliminate these year effects we compute differences-in-differences $[(GRADE_{W,PE,99} - GRADE_{W,PE,97/98}) - (GRADE_{NW,PE,99} - GRADE_{NW,PE,97/98})]$, where the NW subscript denotes that for these students WEAKMATH equals 0 (i.e., they achieved grade A or B at A-level maths or were economics minors). We calculate the raw difference-in-differences for Principles of Economics to be (52.86 - 56.49) - (54.05 - 61.98) = 4.3. Using this approach we calculate the difference-in-differences for Quantitative Methods I, Economics Workshop, and Economics Average to be 5.4, 5.33, and 8.03, respectively.

To put these figures into perspective, we have also calculated raw differences-in-differences between 1999 and 1997 and between 1999 and 1998, respectively, for the four courses. The figures we obtain are 11.27, 8.16, 6.65, and 10.45 for the 1999-1997 comparison and –1.29, 3.90, 4.52, and 6.15 for the 1999-1998 comparison (where the results for the four courses are listed in the same order as before). It is somewhat surprising that the latter set of figures appear to be substantially lower than the former set of figures, because there were no changes to the teaching programme between 1997 and 1998. The explanation for this may be that the raw differences-in-differences are driven by unmeasured differences in student quality, a subject that we now address using regression analysis.

3. The Econometric Model

The raw differences-in-differences suggest that FoM may have been successful at improving students' performance in the first-year courses. However, these raw figures do not control for systematic differences in characteristics (ability, degree programme, etc.), which may have varied systematically across cohorts as well as individuals. We use regression analysis to introduce these controls. The model underlying our OLS differences-in-differences regression is:[11]

$$Y_i = \beta_0 + \beta_1 WEAKMATH_i + \beta_2 TIME_i + \beta_3 FoM_i + \sum_{k=4}^{K} \beta_k X_{k,i} + u_i$$

where:

Y_i is the grade attained in a particular class or the overall average;
$WEAKMATH_i$ is the dummy variable described above;
$TIME_i$ is a time dummy for 1999 (the year in which FoM was offered);
FoM_i is a dummy for taking FoM (the interaction of $WEAKMATH_i$ and $TIME_i$);
$X_{k,i}$ (k=4,…, K) are additional control variables;

[11] See Stock and Watson (2007) for more on the differences-in-differences approach.

u_i is a normally distributed error term.

The underlying idea of the model is that there are likely to be systematic differences between those who did not attain grades A or B in A-level mathematics and those who did.[12] There is also likely to be systematic effects based on *TIME*, for example year-to-year differences in the difficulty of the exams or marking. After controlling for *WEAKMATH* and *TIME*, the coefficient on *FoM* identifies the effect of remediation. If FoM was successful at improving students' performance, by improving their maths skills, then $\beta_3>0$. We also expect $\beta_1<0$, that is, that students who either did not take or fully master A-level mathematics will have worse results at university economics, particularly in the more mathematical subjects.

The additional controls $X_{k,i}$ include the variables summarized in Table 1. While the primary focus of this study is on the effects of mathematics background on university-level economics performance, we are also interested in the effects of economics background, which we test with either a dummy for having previously studied the subject at A-level or a series of dummies for performance at A-level.

It is possible that remediation affected different groups of students differently. We speculate that students who had never seen the topics at A-level may have benefitted more than those who had previously studied the material but not fully mastered it. Alternatively, the lack of assessment in FoM may have meant that only the strongest of the students required to take the module were sufficiently motivated to put in enough effort to benefit from it. We test the first of these propositions using interaction terms in the original regression model, i.e.

[12] Students with an economics minor could not take FoM, as it was part of the Quantitative Methods I course, which was not taken by minors. Accordingly, we have included minors with the group for whom WEAKMATH is zero. We have also run the regressions excluding minors altogether, and found no qualitative changes to any of the results.

$$Y_i = \beta_0 + \beta_1 WEAKMATH_i + \beta_2 TIME_i + \beta_3 FoM_i + \beta_4 WEAKMATH_i * GROUP_i$$
$$+ \beta_5 FoM_i * GROUP_i + \sum_{k=6}^{K} \beta_k X_{k,i} + u_i$$

We test the second proposition using quantile regressions.

4. Empirical Results

Table 2 reports single-equation OLS regressions with $GRADE_m$ (grades in first-year subjects) as the dependent variable. For each subject we estimate two specifications: Specification 1 which is relatively parsimonious (measuring the students' A-level economics background by the dummy variable *AECON*), and Specification 2 which is richer (using dummies for the different grades at A-level economics). The main result from Table 2 is that, after controlling for other factors, the regressions do not provide particularly strong evidence that Foundations of Mathematics was successful in raising the students' grades. The estimated coefficients on *FoM* are significant at the five per cent level in the regressions on Economics Workshop and overall average. The effect for Economics Workshop may well be spurious, as the Workshop course was assessed by two essays and was essentially non-mathematical. On the other hand, consistent with earlier work, the regressions do provide evidence that maths background prior to university has a significant effect on performance (see, e.g., Reid (1983), Anderson et al. (1994), Butler et al. (1994), Durden and Ellis (1995), Lopus (1997), and Ballard and Johnson (2004)).[13] The coefficient on *WEAKMATH* is significantly negative at a one per cent level for the Quantitative Methods I grade and

[13] One exception is Cohn et al. (1998), who measure maths background using (i) a 30-item multiple-choice maths test and (ii) a dummy variable indicating whether the student has taken a calculus course. Neither measure is statistically significant in their regressions, which have results in a Principles of Economics course as the dependent variable. A possible reason why our results differ from those of Cohn et al. is that the Principles course that we study is more quantitative than is the norm in the US.

for the overall average and at a ten per cent level in one of the specifications for Principles of Economics.

There are two possible interpretations of our finding that taking remedial mathematics has a limited effect on student performance in the more mathematical subjects, and we can not fully distinguish between these explanations. The first, and most obvious, explanation is that the existing Foundations of Mathematics programme did little to affect student ability in mathematics. The second explanation is that the remedial programme actually did have a positive impact on the students' maths skills, although the students, realizing that this improved ability would make it easier for them to achieve a particular grade in the more mathematical subjects, chose to substitute time and effort from their studies in these subjects to the workshop essays or to non-academic activities. Given that we do not have access to data on the amount of time the students spent on their studies, we can not rule out the second explanation.[14] Still, even under this scenario, the conclusion that introducing a remedial maths programme may not be helpful in improving performance in technically demanding economics subjects would still be valid, although for a different reason than one perhaps first would think.

Another striking observation from Table 2 is that, although all the grades that we try to explain are in economics courses, most of the coefficients on the A-level economics variables are not statistically significant. In particular, for Specification 1, the *AECON* coefficient is never statistically significant. In Specification 2, the

[14] Dolton, Klein and Weir (1994) offer some evidence that students who are provided with improved teaching resources substitute time away from self-studies. The authors study a group of undergraduate first-year economics students who were offered assistance in their computer training from paid peer-counsellors. Compared to a control group who did not have access to counsellors, these students spent less time working with computers in classes and in preparing assessed work.

economics variables are rarely significant, except for the counterintuitive result that students attaining grade D did very well.[15] Although it is not possible to formally test why these students performed so well, we can offer a couple of speculations. It is possible that these students were admitted to the programme on the basis of some compensating strengths on their UCAS application that are unobservable to us. Alternatively, these students, being aware that they had been admitted to an economics programme in spite of a poor grade in that subject, may have been motivated to put in extra effort to show that they deserved their place in the programme.

The results reported in Table 2 show only short-term outcomes. It is possible that remedial maths increased students' mathematical abilities, and that this did not immediately translate into much better exam results but nevertheless had an effect on longer-term educational outcomes. Taking the remedial course took time away from the students' regular courses in their first term at university. Even if they learned important maths skills in FoM, this may have been offset by an associated loss in study time for their regular subjects, reducing the net benefit in the first year. However, in their second and third years of the programme, these students did not have to spend any time on remedial mathematics but may have still benefitted from any maths knowledge they have acquired by taking FoM previously. Alternatively, in line with the findings of Pozo and Stull (2006), the effects of FoM may have been only short-term and not continued to the second and third years. We have tested these hypotheses by looking at whether FoM improved performance in core second- and

[15] The raw data show that nine students were admitted with grade D at A-level Economics over the three years. Of these students three performed extremely well, maintaining first year averages over 70 per cent (the cut-off for first-class honours) and seven exceeded the overall average for students in the data set (56.7).

third-year subjects. In particular, we ran OLS differences-in-differences regressions for grade in Microeconomics (core for all second-year economics students), Macroeconomics (core for all second-year single honours, major and joint students), Quantitative Methods II (core for second-year single honours and majors) and the final-year dissertation (core for all third-year economics students). Table 3 shows partial results of regressions of grades in these courses on the same set of independent variables as in Table 2. The results are consistent with those in Table 2. A-level mathematics is an important determinant of performance: the coefficient on *WEAKMATH* is significantly negative in the regressions on grades in the Micro and Macro courses (and weakly so in Quantitative Methods II). However, the results also strongly suggest that the effects of FoM were limited to the short-term. The coefficient on FoM is never significant in any of the regressions in Table 3, and frequently has the wrong sign.

The approach taken above implicitly assumes that students taking FoM were a homogeneous group. However, in reality the students were heterogeneous in terms of both ability and maths background (some took A-Level maths and performed poorly, some did not take A-level maths). It is possible that the effects of FoM differed across groups, but these effects are obscured by aggregation. As a further robustness check of our results in Table 2, we first run regressions with the remedial students divided into sub-groups according to their maths background and, secondly, run quantile regressions to examine the effects of FoM at different points of the distribution.

The regressions with the remedial students divided into sub-groups according to their maths background are shown in Table 4. We show partial results from OLS regressions with the WEAKMATHS students split into *two* separate groups (A-level maths C, D, or E and no A-level maths) and from regressions with *three* separate groups (A-level maths C, A-level maths D or E, and no A-level maths). An interesting result from Table 4 concerns the coefficients on the additional A-level maths variables. Most of the coefficients on the dummies for attaining a relatively poor grade in maths A-level are positive and statistically significant, suggesting that most of the performance gap between the "W" and "NW" groups is a gap between students who had taken A-level maths and those who had not.[16] As with Table 2, the evidence from Table 4 to suggest that remedial maths had a significant effect on student performance is limited to Economics Workshop and the overall average. There is evidence of different effects only in the quantitative methods course, where the coefficients on FoM*AMATHDE and FoM*AMATHCDE are negative and significant at a ten per cent level. This suggests that students who had taken A-level maths and done poorly benefitted less from remediation than the students who had not taken A-level maths at all.

Another interesting possibility is that FoM may have had an impact on the performance of students at non-central parts of the ability distribution, which would not necessarily be captured by the OLS regressions reported in Table 2. We explore this possibility by running quantile regressions with the scores in our first-year

[16] Consider column 8 of Table 4. Students in the WEAKMATH group scored an average of 8.199 points worse than those in the NOT WEAKMATH group. Students in the "W" group who took A-level maths scored an average of 6.674 points better than those who did not take A-level maths, largely offsetting their disadvantage relative to the "NW" group. However, all else equal, these students also had a lower total A-level score than those in the "NW" group because of their lower score in A-level maths (8.59 average vs. 5.33 average). Thus, all else equal, the regressions imply that the "NW" group scored 8.199 points better than students without A-level maths and 3.426 points better than students with A-level maths grade C, D, or E [8.199-6.674+.583(8.59-5.33)].

courses as dependent variables.[17] Partial results for such regressions—at the 0.25 and the 0.75 quantiles—are reported in Table 5 (all right-hand side variables are as in the Specification 1 versions of the regressions in Table 2). For the 0.25 quantile, the *FoM* coefficient is not significant for any of the courses. However, for the 0.75 quantile the FoM coefficients are all positive and the coefficient is significant for Principles, Workshop, and the overall average.

Figure 1 shows the results for a range of further quantile regressions on grades in Principles of Economics, Quantitative Methods I, Economics Workshop, and Economics Average (as before, all right-hand side variables are as in the Specification 1 versions of the regressions in Table 2). Each panel depicts point estimates of the *FoM* coefficient (the solid curve) and 90 per cent confidence intervals (the grey area above and below the solid curve) for all quantiles. In addition, each panel shows an OLS point estimate (the dotted line). A couple of observations can be made from Figure 1. First, for all four courses, the *FoM* coefficient is never positive and statistically significant for the bottom half of the distribution. Secondly, in the three mathematically-intensive courses (Principles, QM, and Economics Average) the solid curve that connects the quantile point estimates of the *FoM* coefficient tends to be upward-sloping, and the point estimates for the higher quantiles are positive and statistically significant for at least part of the distribution. This suggests that to the extent that remediation has any effect, that effect is likely to be concentrated on the

[17] For other studies of the determinants of academic performance using the approach of quantile regressions, see e.g. Eide and Showalter (1998) and Dolado and Morales (2007). On quantile regressions in general, see e.g. Koenker and Hallock (2001) and Koenker (2005).

relatively stronger students.[18] In other words, remediation seems to be least effective for the students who are marginal and thus in most need of help.

5. Concluding Remarks

The effectiveness of remedial programmes has important policy implications. The British Government has targeted expansion of participation in Higher Education from about 43 per cent in 2002 to 50 per cent by the end of the decade, while at the same time raising tuition fees for British and EU students from approximately £1100 to £3000. This increase in costs makes it likely that much of the demand for new university places will come in subject areas that offer good future earnings prospects, such as economics.[19] However, despite the earnings potential of an economics degree, recent growth in enrolment in economics programmes has lagged behind the overall growth of student numbers, perhaps partly due to the mathematical demands of the subject and recent declines in enrolment in A-level mathematics.[20] In this context, a successful remedial mathematics programme might not just improve the performance of currently enrolled students, it might also increase the demand to study the subject.

---

[18] This is in contrast to the results in Pozo and Stull (2006), who conclude that it is primarily the *weaker* students who benefit from the remediation.

[19] Jessica Shepherd, "Careerist Mentality Rises with Top-ups", Times Higher Education Supplement, 17/2/2006, pp. 1, 4; also available at http://www.timeshighereducation.co.uk/story.asp?sectioncode=26&storycode=201363 (accessed 25 May 2008). See Dolton and Makepeace (1990) and Bratti and Macini (2003) on the earnings of graduates in different subject areas.

[20] On enrolment in different degree subjects see Rebecca Smithers, "Maths 'crisis' as exam entrants tail off", Guardian Unlimited, http://education.guardian.co.uk/alevels2002/story/0,,774698,00.html and "Media studies overtakes physics", BBC News website, http://news.bbc.co.uk/1/hi/education/4162230.stm on the decline of enrolment in A-level maths (both accessed 25 May 2008).

In addition, successful remedial mathematics programmes may be an important tool to help meet the Government's Widening Participation targets.[21]

In light of the policy implications, it is perhaps surprising just how little evidence there is on the effectiveness of these programmes. This paper examines the impact of the implementation of a remedial mathematics programme for students' performance in a variety of compulsory economics courses at Royal Holloway, University of London. These courses differed considerably in their use of mathematics. For each course, we examined the results prior and subsequent to the implementation of the remedial mathematics course, using a differences-in-differences approach to analyse student performance. In line with a large body of existing literature, we found that, for a range of courses, the amount of mathematics taken prior to university and the results in secondary-school mathematics have strong predictive power on student performance. However, we find relatively little evidence that taking remedial mathematics has an effect on student performance. We find a significant effect only for a subset of the first-year programme and this seems to be confined to the strongest group of students required to take remediation.

[21] These targets involve making higher education more accessible to traditionally underrepresented groups, such as those from poor areas and weaker schools, mature students and students without standard A-level qualifications.

References

Anderson, Gordon, Dwayne Benjamin, and Melvyn A. Fuss (1994). "The Determinants of Success in University Introductory Economics Courses", *Journal of Economic Education*, Vol. 25(2), pp. 99-119.

Ballard, L. Charles and Marianne F. Johnson (2004). "Basic Math Skills and Performance in an Introductory Economics Class", *Journal of Economic Education*, Vol. 35(1), pp. 3-22.

BBC News (2005), "Media Studies Overtakes Physics", *BBC News website*, http://news.bbc.co.uk/1/hi/education/4162230.stm (accessed 25 May 2008).

Bettinger, Eric P. and Bridget Terry Long (2006). "Addressing the Needs for Under-Prepared Students in Higher Education: Does College Remediation Work?", mimeo, Case Western Reserve University and Harvard Graduate School of Education.

Bratti, Massimiliano and Luca Mancini (2003). "Differences in Early Occupational Earnings of UK Male Graduates by Degree Subject: Evidence from the 1980-1993 USR", IZA Discussion Paper 890, Institute for the Study of Labor (IZA).

Butler, J.S., T. Aldrich Finegan and John J. Siegfried (1994). "Does More Calculus Improve Student Learning in Intermediate Micro and Macro Economics Theory?", *American Economic Review (Papers and Proceedings)*, Vol. 84(2), pp. 206-210.

Cohn, Elchanan, Sharon Cohn, Richard E. Hult, Jr., Donald C. Balch, and James Bradley, Jr. (1998), "The Effects of Mathematics Background on Student Learning in Principles of Economics", Journal of Education for Business, Vol. 74(1), pp. 18-22.

Dolado, Juan Jose and Eduardo Morales (2007). "Which Factors Determine Academic Performance of Undergraduate Students in Economics? Some Spanish Evidence", CEPR Discussion Paper No. 6237.

Dolton, Peter, J. Douglas Klein, and Ivan Weir (1994). "The Economic Evaluation of Peer Counselling in Facilitating Computer Use in Higher Education", *Education Economics*, Vol. 2(3), pp. 313-326.

Dolton, P.J. and G.H. Makepeace (1990). "The Earnings of Economics Graduates," *The Economic Journal*, Vol. 100, pp. 237-250.

Durden, Garey C. and Larry V. Ellis (1995). "The Effects of Attendance on Student Learning in Principles of Economics", *American Economic Review (Papers and Proceedings)*, Vol. 85(2), pp. 343-346.

Eide, Eric and Mark H. Showalter (1998). "The Effect of School Quality on Student Performance: A Quantile Regression Approach", *Economics Letters*, Vol. 58, pp. 345-350.

Johnson, Marianne and Eric Kuennen (2002). “Does Remedial Math Matter? Evidence of the Cross-Disciplinary Effects of Requiring Remedial Math”, mimeo, University of Wisconsin Oshkosh and University of Wisconsin Stout.

Koenker, Roger (2005). *Quantile Regression*, New York NY: Cambridge University Press.

Koenker, Roger and Kevin F. Hallock (2001). “Quantile Regression”, Journal of Economic Perpsectives, Vol. 15, No. 4, pp. 143-156.

Lopus, Jane S. (1997). “Effects of the High School Economics Curriculum on the Learning in the College Principles Class”, *Journal of Economic Education*, Vol. 28(2), pp. 143-153.

Merisotis, Jamie P. and Ronald A. Phipps (2000). “Remedial Education in Colleges and Universities: What’s Really Going On?”, *Review of Higher Education*, Vol. 24(1), pp. 67-85.

Pozo, Susan and Charles A. Stull (2006). “Requiring a Math Skills Unit: Results of a Randomized Experiment”, *American Economic Review, Papers and Procedings*, Vol. 96(2), pp. 437-441.

Reid, Roger (1983). “A Note on the Environment as a Factor Affecting Student Performance in Principles of Economics”, *Journal of Economic Education*, Vol. 14(4), pp. 18-22.

Royal Holloway, Department of Economics (various years). *UCAS Forms*.

Royal Holloway, Department of Economics (various years), *Economics Sub-board: Provisional Rank Sorted Classification Grid*.

Royal Holloway, Department of Economics (various years). *Annual Monitoring*.

Shepherd, Jessica (2006). "Careerist Mentality Rises with Top-ups", *Times Higher Education Supplement*, http://www.timeshighereducation.co.uk/story.asp?sectioncode=26&storycode=201363 (accessed 25 May 2008).

Smithers, Rebecca (2002). "Maths 'Crisis' as Exam Entrants Tail Off", *Guardian Unlimited*, http://education.guardian.co.uk/alevels2002/story/0,,774698,00.html (accessed 25 May 2008).

Stock, James and Watson, Mark (2007). Introduction to Econometrics. Boston: Pearson Education Ltd.

The White House Social Statistics Briefing Room. "Postsecondary Remedial Education", http://nces.ed.gov/ssbr/pages/remedialed.asp?IndID=16 (accessed 25 May 2008).

TABLE 1—VARIABLE DEFINITIONS AND SUMMARY STATISTICS

Variable	Description
$GRADE_{PE}$; $GRADE_{QM1}$; $GRADE_{EW}$; $GRADE_{EA}$	Grade in Principles of Economics, Quantitative Methods I, Economics Workshop, Average grade in all 1st year economics courses.
WEAKMATH	Dummy: 1 if not a minor and failing to get grade A or B at A-level maths
ALEVEL	Points on three best A-level subjects, excluding general studies, A=10, B=8, C=6, D=4, and E=2. (Can take values between 0 and 30.)
AECON	Dummy: 1 if taking economics at A-level or AS-level.
AMATHC; AMATHDE;	Dummy: 1 grade in A-level math is C; D or E.
AECONA; AECONB; AECONC; AECOND	Dummy: 1 grade in A-level economics is A; B; C; D.
JOINTMINOR	Dummy: 1 if taking joint degree or being an economics minor.
CLASS98; CLASS99	Dummy: 1 if entering in 1998; 1999.
FoM	Dummy: 1 if assigned to Foundations of Mathematics.

Variable	All Students	1997,98 entrants A-level Maths (A or B) or econ. minors	Other 1997,98 entrants	1999 entrants A-level Maths (A or B) or econ. minors	Other 1999 entrants
$GRADE_{PE}$	56.70 (14.54)	61.98 (14.80)	56.49 (13.16)	54.05 (10.15)	52.86 (18.29)
$GRADE_{QM1}$	57.70 (13.66)	67.66 (12.33)	52.57 (11.41)	68.13 (9.66)	58.44 (14.67)
$GRADE_{EW}$	60.07 (6.12)	59.85 (4.76)	59.05 (6.68)	58.77 (6.47)	63.30 (4.41)
$GRADE_{EA}$	57.59 (9.40)	61.83 (9.43)	55.74 (8.30)	56.56 (10.25)	58.50 (10.41)
ALEVEL	22.83 (3.30)	23.83 (3.45)	21.98 (3.31)	23.50 (2.50)	23.64 (2.98)
AMATH	0.62	1.00	0.42	1.00	0.53
AECON	0.71	0.59	0.80	0.65	0.67
WEAKMATH	0.69	0.00	1.00	0.00	1.00
AMATHC	0.18	0.02	0.24	0.00	0.28
AMATHD	0.07	0.00	0.09	0.00	0.14
AECONA	0.27	0.27	0.28	0.25	0.25
AECONB	0.27	0.12	0.37	0.15	0.22
AECONC	0.13	0.15	0.13	0.10	0.14
AECOND	0.05	0.05	0.02	0.15	0.06
MALE	0.65	0.71	0.62	0.75	0.58
JOINTMINOR	0.21	0.37	0.16	0.35	0.08
CLASS98	0.37	0.59	0.50	0.00	0.00
CLASS99	0.29	0.00	0.00	1.00	1.00
FoM	0.18	0.00	0.00	0.00	1.00
Sample Size	193	40	97	20	36

Note: Standard deviations shown in parentheses for continuous variables.

TABLE 2—DIFFERENCE-IN-DIFFERENCE REGRESSIONS, PERFORMANCE IN FIRST-YEAR COURSES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	EC1101	EC1101	EC1102	EC1102	EC1103	EC1103	ECONAVG	ECONAVG
FoM	2.205	2.983	4.521	5.103	5.949**	5.890**	6.629**	7.120**
	(4.581)	(4.398)	(4.225)	(4.094)	(2.397)	(2.424)	(2.993)	(2.939)
WEAKMATH	-4.827*	-4.173	-14.30***	-13.73***	-1.396	-1.078	-6.465***	-6.133***
	(2.839)	(2.807)	(2.502)	(2.568)	(1.365)	(1.431)	(1.724)	(1.702)
YEAR=99	-6.915**	-8.803***	-1.120	-2.229	-2.275	-2.504	-5.470**	-6.422***
	(3.169)	(3.147)	(3.326)	(3.365)	(2.203)	(2.296)	(2.389)	(2.428)
YEAR=98	1.280	0.789	-2.634	-2.807	-1.632	-1.697	-0.562	-0.728
	(2.311)	(2.316)	(2.097)	(2.106)	(1.318)	(1.324)	(1.481)	(1.477)
ALEVEL	0.678**	0.718**	0.336	0.240	-0.101	-0.00132	0.407**	0.375*
	(0.306)	(0.324)	(0.284)	(0.316)	(0.167)	(0.175)	(0.185)	(0.192)
JOINTMINOR	-4.960**	-5.757***	-4.962*	-5.550**	-2.916*	-2.578	-6.393***	-6.721***
	(2.494)	(2.193)	(2.989)	(2.783)	(1.557)	(1.584)	(2.157)	(1.992)
MALE	-0.264	-0.294	-0.0867	-0.0926	0.398	0.459	-0.234	-0.279
	(2.233)	(2.133)	(1.884)	(1.828)	(0.958)	(0.992)	(1.368)	(1.311)
AECONA		-1.131		0.106		0.316		-0.0943
		(3.071)		(2.412)		(1.258)		(1.705)
AECONB		-3.342		-3.294		0.522		-2.210
		(2.600)		(2.465)		(1.438)		(1.607)
AECONC		-5.625*		-5.616*		2.582*		-3.722*
		(3.084)		(2.922)		(1.531)		(1.989)
AECOND		12.94***		8.816**		2.102		6.629
		(4.529)		(3.394)		(2.166)		(4.102)
AECON	-1.665		-1.532		0.944		-1.006	
	(2.244)		(1.892)		(1.155)		(1.366)	
Constant	48.06***	47.62***	62.90***	65.14***	62.53***	60.15***	55.53***	56.46***
	(8.280)	(8.404)	(7.521)	(8.113)	(3.805)	(4.052)	(4.676)	(4.801)
Observations	193	193	181	181	155	155	194	194
R-squared	0.089	0.147	0.244	0.284	0.101	0.113	0.154	0.201

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

TABLE 3–REGRESSIONS, PERFORMANCE IN SECOND- AND THIRD-YEAR COURSES

Independent variable	Specification	WEAKMATH	FoM	R^2	N
2nd Year Microeconomics	1	-6.697** (3.007)	1.280 (4.561)	.128	195
2nd Year Microeconomics	2	-5.766* (3.008)	1.838 (4.410)	.188	195
2nd Year Macroeconomics	1	-6.415*** (2.401)	1.890 (3.810)	.085	195
2nd Year Macroeconomics	2	-5.895** (2.439)	2.053 (3.856)	.110	195
2nd Year Quantitative Methods	1	-5.280 (3.006)	-3.165 (4.604)	.290	162
2nd Year Quantitative Methods	2	-4.085 (3.113)	-2.999 (4.610)	.323	162
3rd Year Dissertation	1	-0.853 (2.686)	-1.936 (3.312)	.074	172
3rd Year Dissertation	2	-1.189 (2.829)	-1.219 (3.344)	.100	172

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

TABLE 4–REGRESSIONS WITH SEPARATE WEAKMATH GROUPS

	(1) PE	(2) PE	(3) QM	(4) QM	(5) WS	(6) WS	(7) ECONAV	(8) ECONAV
FoM	3.982	5.153	6.812	6.488	5.196**	5.158**	7.901**	7.776**
	(5.162)	(5.174)	(5.063)	(5.010)	(2.594)	(2.572)	(3.538)	(3.494)
WEAKMATH	-6.983**	-6.945**	-17.96***	-17.63***	-1.445	-1.407	-8.299***	-8.199***
	(2.951)	(2.947)	(2.541)	(2.523)	(1.453)	(1.437)	(1.807)	(1.790)
ALEVEL	0.847***	0.860***	0.595**	0.683**	-0.0825	-0.0727	0.529***	0.583***
	(0.321)	(0.313)	(0.269)	(0.263)	(0.167)	(0.163)	(0.193)	(0.190)
AMATHC	10.51***		13.86***		0.193		7.726***	
	(2.639)		(2.393)		(1.712)		(1.767)	
AMATHDE	-0.0981		8.648***		0.150		3.235*	
	(3.817)		(2.760)		(1.768)		(1.873)	
FoM*AMATHC	-7.244		-7.145		2.464		-3.994	
	(6.359)		(5.156)		(2.551)		(3.642)	
FoM*AMATHDE	-16.26		-11.65*		-0.156		-6.686	
	(11.37)		(6.372)		(2.733)		(4.691)	
AMATHCDE		7.884***		12.59***		0.196		6.674***
		(2.548)		(2.140)		(1.502)		(1.570)
FoM*AMATHCDE		-9.920		-9.046*		1.578		-5.293
		(6.537)		(4.865)		(2.249)		(3.470)
Constant	42.62***	43.53***	56.47***	54.46***	62.09***	61.89***	52.39***	51.20***
	(8.710)	(8.490)	(7.065)	(6.956)	(3.849)	(3.746)	(4.800)	(4.765)
Observations	197	193	181	181	155	155	194	194
R-squared	0.189	0.123	0.357	0.343	0.109	0.105	0.228	0.211

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

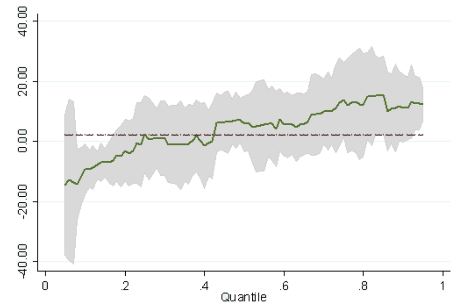
TABLE 5 – QUANTILE REGRESSIONS ON PERFORMANCE IN FIRST-YEAR COURSES

	Quantile	WEAKMATH	FoM	N	Pseudo R^2
PE	25	-7.500* (4.489)	2.500 (7.786)	193	0.0534
PE	75	-9.333** (4.449)	13.83* (7.531)	193	0.0681
QM	25	-12.67*** (4.123)	4.333 (7.245)	181	0.1381
QM	75	-15.00*** (3.805)	10.000 (6.580)	181	0.1591
EW	25	-1.00 (1.656)	4.00 (3.095)	155	0.0659
EW	75	0.00 (0.850)	6.00*** (1.504)	155	0.1331
ECONAV	25	-4.740 (3.001)	0.790 (4.790)	194	0.1316
ECONAV	75	-7.500*** (2.386)	7.430* (4.222)	194	0.0878

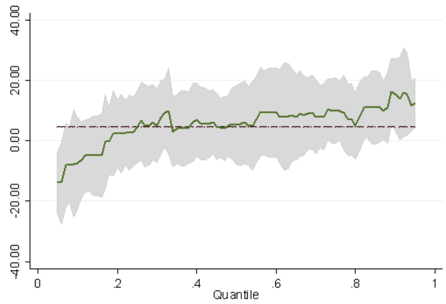
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

FIGURE 1 – QUANTILE REGRESSIONS, FIRST-YEAR COURSES

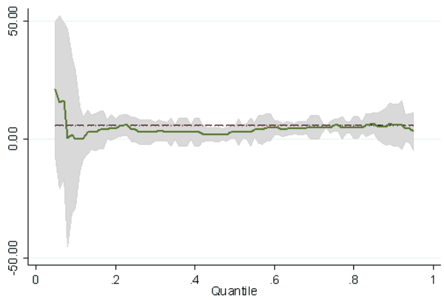
A) Principles



B) Quantitative Methods I



C) Economics Workshop



D) Economics Average