Labour Economics 31 (2014) 174–187

Contents lists available at ScienceDirect

Labour Economics

journal homepage: www.elsevier.com/locate/labeco

Causal effects of mathematics

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HIGHLIGHTS

- Random draw of 16 year olds in Norway to examination in mathematics or languages
- Selection for examination in mathematics affects short and long run outcomes
- Decrease high school dropout
- Increase enrolment in natural science and technology programs in higher education
- The effects are somewhat stronger for males than for females

ARTICLE INFO

Article history:
Received 6 March 2014
Received in revised form 22 July 2014
Accepted 30 July 2014
Available online 7 August 2014

JEL classification:
I21
J24

Keywords:
Mathematical training
Intervention
External exit examination
High school graduation
Higher education

ABSTRACT

This paper exploits that students at age 16 in Norway are randomly selected into one compulsory exit exam in either mathematics or languages. A few days before the actual exam day, the students are notified about exam subject. The students have an intensive preparation period, and examination in mathematics relative to languages is found to decrease dropout from high school, increase enrollment in higher education, and increase enrollment in natural science and technology education programs. Overall, the causal effects seem to be somewhat stronger for males than for females, but the analysis indicates that gender differences interact in complicated ways with prior skills in mathematics. We explore several mechanisms that might contribute to the findings.

1. Introduction

It is a general concern that insufficient student skills in mathematics lead to shortages of key competencies in a time with rapid technological change. A number of empirical studies find that test scores in mathematics are important predictors of future earnings and other individual outcomes, see Murnane et al. (1995) and the literature review in Hanushek (2002). Moreover, the recent cross-country studies suggest that aggregate measures of test scores in mathematics and science are important determinants of economic growth (Hanushek and Woessmann, 2008, 2012). While this evidence suggests an important role for mathematical skills, causal evidence on the impact of mathematics relative to other subjects in school is still scarce.

Our paper is related to two further strands of literature. First, a small, but growing literature initiated by Altonji (1995), investigates the impact of high school curriculum on further school and labor market outcomes. The typical finding is that more mathematics courses in high school increase educational attainment and earnings. The identification issue in this literature is not trivial, however, because the choice of coursework is clearly endogenous. Various instruments for coursework choice are used in the literature, but the identification strategies can be criticized (Altonji et al., 2012). Second, recent evidence from the experimental literature suggests that the effects of rewards and interventions are more pronounced for math tests than for reading tests, see Bettinger (2012) and references therein. The econometric analyses on dropout behavior and returns to education in Oreopoulos (2007) also indicate that students are myopic. Recent experimental evidence by Levitt et al. (2012) support this view and suggest that incentives improve test scores only if rewards are offered immediately after effort is exerted.

While our study does not consider the effect of financial rewards, we study the effect of an intervention which can be interpreted as a

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http://dx.doi.org/10.1016/j.labeco.2014.07.016
0927-5371/

treatment consisting of two parts; a training and preparation period in ether mathematics or languages followed by a high stake test in either of these subjects. We consider the former part of the treatment to be the most important for the outcomes studied. At the end of compulsory education in Norway, at the age of 16, about 40% of the students are randomly selected to sit for a high stake external exit examination in mathematics, while the rest of the students have an examination in Norwegian or English language. The students are informed of their exam subject a few days in advance, such that there is a period of intensive preparation with extensive support from teachers. The preparation period varies from 2 to 5 working days in our empirical period 2002–2004.

The experimental setting that we exploit provides evidence on whether the observed stronger relationships between skills in mathematics relatively to languages and educational outcomes represent causal effects or merely student sorting. The observed relationships clearly indicate that even a short, but intensive, training period in mathematics immediately prior to a high stake test can have non-negligible treatment effects. This finding makes sense if students are myopic, and is broadly consistent with evidence from the experimental studies suggesting that educational incentives are most effective when the reward comes immediately. We use the population of Norwegian students from administrative registers in the analysis, and find that treatment in mathematics as opposed to languages significantly decreases dropout from high school and increases enrollment in natural science and technology studies in higher education.

The paper is organized as follows: Section 2 reviews related literature and Section 3 presents relevant institutional settings, data and empirical strategy. The empirical results are presented in Section 4, which includes several robustness and heterogeneity analysis, while Section 5 contains concluding remarks.

2. Related literature

A number of papers have investigated the impact of test scores in mathematics and science on earnings and other individual outcomes. For example Bishop (1989), Murnane et al. (1995), and Altonji and Pierret (2001) find that measures of achievement are important determinants of individual earnings for given educational attainment and observed individual and family characteristics. In a recent paper, Koedel and Tyhorst (2012) use a resume-based field experiment and find that stronger mathematical skills improve labor market outcomes.

Another strand of the literature has studied the impact of school curriculum on individual earnings, following the seminal paper by Altonji (1995). These studies typically ask to what extent earnings depend on the number and levels of mathematics and science courses taken in high school. For the US, Altonji (1995), Levine and Zimmerman (1995), and Rose and Betts (2004) generally find a positive impact on earnings of taking more mathematics and science courses. It is a question, however, whether these estimates can be interpreted causally or whether they represent selection effects or omitted variables (Altonji et al., 2012). Given the problem to find credible instruments for students' coursework, or other credible identification strategies, it is not surprising that the results vary somewhat across studies.

Three recent studies apply more credible strategies to identify the impact of curriculum on earnings. Joensen and Nielsen (2009) explore a pilot scheme implemented in some Danish high schools, in which students were allowed to select different combinations of high school courses than students enrolled in other schools. Using this variation as instrument for students' actual choices, they find that taking more advanced mathematics courses has a significant and sizable positive impact on earnings. Their estimates imply that taking one extra course in mathematics increases earnings by 20–25%. The main mechanism seems to be increased likelihood of taking higher education.

Goodman (2012) uses the US state-level changes in high school mathematics requirements as instruments for students' actual coursework and finds that additional mathematics coursework increases earnings, especially for low-skilled students. However it is not entirely clear that the estimated effect reflects only coursework in mathematics since the change in state level math requirements was part of a change toward stricter high school graduation requirements in several subjects.

Cortes et al. (forthcoming) study an algebra policy implemented in Chicago in 2003. Students with achievement below the national median result in an eighth grade exam in mathematics are assigned to algebra courses with double instructional time in ninth grade. Using a regression discontinuity design, they find sizable effects of the double-dosing in algebra on high school graduation rates, college entrance exam scores, and college enrollment rates. The intervention seems to have been most successful for students with relatively low reading skills.

These three studies have different identification approaches, but all find sizable effects of increased coursework in mathematics during the school year. In Joensen and Nielsen (2009) and Cortes et al. (forthcoming), the increased coursework in mathematics is at the expense of coursework in other subjects. Thus, the estimated effects of mathematical coursework are to some extent relative to other coursework. Our study shares this feature, although we do not study coursework per see. The intervention we study differs from the above studies in at least three important ways. First, we study the effect of intensive preparation in a few days without any other school work for the students. Second, the preparation is directly related to a high-stake test very close in time, and third, we are able to estimate average treatment effects because the whole cohort is included in the random assignment of examination subject.

The way the students work on a topic is arguably different in a short intensive preparation period for a high-stake test than during regular teaching. Haeck et al. (2014) investigate the impact of a universal school reform in Quèbec, Canada, that transformed the teaching in mathematics from approaches of memorization and repetition to problem-based and self-directed learning. They find that this change to a socio-constructivist teaching approach reduced student achievement over the whole skill distribution.

Our paper is also related to the growing literature on the impact of instruction time. For example Marcotte and Hemelt (2008) and Hansen (2011) find that reduced instruction time due to more snow-related school day cancelations reduces student performance. In addition, Hansen (2011) finds that variation in the number of instruction days across cohorts implied by state-mandated shifts in test-date is related to student performance. A similar identification strategy is pursued by Carlsson et al. (forthcoming). They exploit the conditionally random variation in the actual date for the test taken by 18 year-old males in Sweden in preparation for military service. They find that 10 days of schooling increases the score on crystallized intelligence by one percent of a standard deviation. Lavy (forthcoming) uses international comparable student tests and exploits variation in instruction time across subjects in a within-student framework. He also finds a positive effect of instruction time on test scores.

Finally, a recent literature is concerned that students have myopic behavior. Levitt et al. (2012) use large field experiments including over 6000 elementary and high school students in Chicago to study student behavior under different incentive schemes. In particular, they study how students perform on a low stake test when rewards are offered immediately after the test compared to when rewards are offered with a delay. They find strong evidence that students have very high discount rates. Incentives increase performance only when the rewards are received shortly after the effort is exerted and is more effective for younger than for older students. Of particular interest is that the effects seem more pronounced for math tests than for reading tests. This is a typical finding in the literature, see Bettinger (2012) and references therein. This evidence combined with myopic behavior motivates us to study whether a short intensive training period followed by a high stake test has different medium- to long-run impact depending on whether the relevant subject is mathematics or a language.