Do business schools in Norway accept students with a background in the wrong type of mathematics from secondary upper schools?

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Abstract

Purpose – The purpose of this paper is to determine whether the type of mathematics skills developed at secondary school matter for students' later success in business studies. At many business schools in Norway, more students are applying than there are places available. The ranking of applications depends on the grade point average (GPA) level, irrespective of the level or type of mathematics studied at secondary school, where the students are free to choose practically orientated or theoretical mathematics.
Design/methodology/approach – A quantitative analysis (regression model) was applied using data for undergraduate students enrolled in business studies over a three-year period (2012–2014).
Finding – Students with a non-theoretical background in mathematics obtain systematically lower grades on many courses, especially in core business school subjects. Ranking applicants to business studies courses based on their GPA scores irrespective of their level of mathematics may lead to the admission of less able students.
Research limitations/implications –There is little information available concerning why students choose different paths in mathematics at upper secondary school, but the decision students make has an influence on their grades in business courses.
Originality/value – By requiring more knowledge of theoretical mathematics, students' performance at business school will improve. Changing the admission criteria could improve the quality of graduates and reduce the dropout rate.

Keywords Business school, Mathematical background, Admission rules, Student performance, Quantitative analysis.

Paper type Research Paper

Introduction
Møen and Tjetla (2010) demonstrated that the Norwegian School of Economics and Business Administration rejects the wrong student applicants due to different grading practices at regional colleges. This paper adopts another approach. The ranking of students is not only important for higher education programmes, but also for admission to higher education institutes from upper secondary school. This paper focuses on the allocation system of applicants to business schools in Norway. The study aimed to identify the role mathematics background plays in explaining performance in business courses. Nasser (2012) found no significant effect of mathematics courses on performance at university. This paper aims to determine whether the effects of mathematics background differ limiting the sample to courses in business studies.

Taking a course in mathematics is mandatory at upper secondary school in Norway and students can select from two main paths in mathematics. One is practical and includes calculation, working with percentages and fractions, some geometry, elementary statistics, using graphs, etc. The other is theoretical mathematics and includes more advanced aspects, such as abstract algebra, functional analysis, differentiation, etc. This type of mathematics is supposed to be more appropriate as a foundation for study at business school. However, many students choose the former path, offering the minimum requirement for qualification. The mathematics grade achieved contributes to the student's grade point average (GPA).

Few colleges and universities in Norway specify a prerequisite level of skills in mathematics

studies for admission to courses in economics and business administration. At most Norwegian business schools, admittance is based on the GPA scores from upper secondary school. The enrolment pattern will have an influence on the students' expected outcomes (Stanley and Oliver, 1994).

Among students in upper secondary school, Thorsen (2015) found that 83% consider the probability of attaining a higher GPA score increases if one takes the examination in practical mathematics. Another reason for choosing the practical route might be the ability to handle theoretical mathematics. Many students find mathematics difficult to learn and have problems solving basic problems. Moreover, due to lack of motivation or skills, some simply seek the easiest way to pass the requirement for qualification in mathematics. This also gives them the opportunity to spend more time on other subjects. Some might just have a negative attitude towards mathematics. However, most of applicants to business studies courses have a background in theoretical mathematics, perhaps because of interest, motivation, skills, or the wish to be better qualified for further studies.

This study does not focus on the factors determining the students' choice of mathematics course at upper secondary school. The diverse portfolio of courses in business schools requires different kinds of skills. In methodology and quantitative courses, knowledge of mathematics is more critical than in accounting and administration courses. Since the portfolio is heterogeneous, a student facing difficulties on some courses may enjoy benefits in others. This depends on personal characteristics and background.

This study sought to understand the impact of the students' choice at upper secondary school on performance in business courses. The data were drawn from the Norwegian University of Science and Technology (NTNU) Business School and covered a period of three years (2012–2014). Our basic research question was whether two students who had chosen different mathematics courses at upper secondary school, but were otherwise similar across observable factors (GPA, gender), would face different probabilities of success at business school. Using data on observed choices, it is difficult to deal with the counterfactual that success at business school might have differed had the student selected a different mathematics course at upper secondary school.

Literature review

There is some empirical literature on the role of mathematics in business studies. Masui *et al.* (2004) found that pre-university mathematics study is important for handling business studies. Many business and economics students have some fear of statistics and have negative attitudes towards introductory business statistics (Gougeon, 2016). This can be the result of a lack of acquaintance with mathematical thinking. Therefore, higher scores and qualifications in mathematics are positively related to grades for introductory statistics (Choudhury and Radhakrishnan, 2009; Johnson and Kuennen, 2005).

For related subjects, such as economics, accounting and finance, the mathematics effect is strong. Furthermore, students who pass more theoretical mathematics subjects in secondary school show improved outcomes. By selecting more mathematics subjects at secondary school, students are better prepared to study economics and business subjects. The students' gain from choosing more theoretical mathematics is substantial. It seems that mathematics is relevant across different courses at business school, although there is a great variation in subjects. Alcock *et al.* (2008) found a positive link between mathematics skills and performance in all business courses except cost accounting.

Not surprisingly, mathematics and quantitative skills have a considerable effect on students' performance in the principles of economics courses (Allwine and Foster, 2013; Arnold and Straten, 2012; Brown-Robertson *et al.*, 2015; Mallik and Lodewijks, 2010). Ballard and Johnson (2004) found quantitative abilities to be the most important factor for success in introductory microeconomic courses. Mathematics is not used to the same extent in introductory courses in macroeconomics and microeconomics. This might explain why the mathematics background has less effect on performance in macroeconomics compared with microeconomics (Lopus and

Maxwell, 1994). However, mathematics is an important tool in investment courses, which might explain why students with good mathematics ability perform better (Gupta and Maksy, 2014). Students with a strong mathematics background outperform those with weaker mathematical backgrounds in quantitative financial courses (Alcock *et al.*, 2008; Eskew and Faley, 1988).

Regarding accounting courses, the results are more mixed. Some authors report that students' scores and ability in mathematics are positively correlated with performance in accounting (Ujar and Güngörmus, 2011; Yunker *et al.*, 2008). On the other hand, neither Guney (2009) nor Kirk and Spector (2006) suggest such a result. The explanation might be that such courses do not employ as many mathematical tools in the presentation of topics.

A lower-level mathematics student from secondary school will be at a disadvantage in quantitative-orientated business courses. One might expect that students with a weak background in mathematics will catch up in non-quantitative courses, but this does not seem to be the case. A mathematics background is not as vital for a good result in non-quantitative courses as in quantitative business courses, but is still an important factor, especially in business law. Although this is a non-quantitative subject, Alcock *et al.* (2008) found secondary mathematics to be a good predictor for performance in this field. Perhaps higher mathematics skills help the students improve their problem-solving skills and logic.

However, in management science, it seems that the GPA is the strongest variable in explaining performance at business school. This has more influence on results than mathematical skills (Brookshire and Palocsay, 2004). The students receive training in learning strategies without the need to use a great deal of mathematics. Higher GPA scores show academic strengths and are an indicator of engagement in learning and the ability to expand knowledge. Thus, next to mathematics skills, GPA scores are an important determinant of study success.

This study analysed the differential effects of mathematics background on student performance in business courses, based on the students' choice of mathematics level at upper secondary school. Do students who took practical mathematics at secondary school and achieved the same GPA scores as fellow students who took more theoretical mathematics achieve the same level of success at business school? Enhancing knowledge in this area is necessary to determine whether specific content skills or interests should determine the students' selection. There might be a self-selection bias in that those who are naturally skilled in mathematics will choose the advanced path at secondary school. This paper does not address this question, but it is also important.

Data and methodology

This research undertook quantitative analysis to determine if students' mathematics background at secondary school influenced their results in undergraduate business studies. Students' results depend on many factors, i.e. they are multidimensional. The model employed intended to capture how mathematical background influences performance. Other factors were included, although there were certain limitations imposed by the data available.

The data used in this paper concern undergraduate students enrolled in the NTNU Business School, Norway, covering a period of three years (2012–2014). The data include information on the students' gender and grades from upper secondary school. By linking this information to the students' performance in mandatory courses during the first two years of study on the Bachelor's degree in Economics and Business Studies it was possible to determine the influence of mathematical background on performance. The time lag between the results from secondary school and those at business school is one to two years. The sample was limited to include only those who had taken practical or theoretical mathematics at upper secondary school. Including this restriction, the data cover 587 individuals.

The methodology used in this research comprised a linear regression model. Using such analysis provides valuable information concerning the influence of mathematical background on performance in business courses. The basic model tests if mathematical ability has an impact on results at business school. This is done by using a maximum likelihood estimation technique in which Y_i represents the output and X_i the inputs. The model controls for other external factors that

might affect the results. In the model, α_0 is a constant, e denotes stochastic error and α_i are regression coefficients. The linear production function is given by:

$$Yi = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + e$$

where
Yi: Grades on business school courses (0: F, 1: E, 2: D, 3: C, 4: B, 5: A)
α_0: Constant
X_1: Gender (M: 1, F: 0)
X_2: GPA scores
X_3: Grades in mathematics from secondary upper school (on a scale from 1 to 6, where 6 is the highest score)
X_4: Dummy variable for choice of theoretical or practical mathematics at upper secondary school (taking the value of 1 for theoretical mathematics and zero otherwise)

The independent variables selected were gender, GPA score, result in mathematics from upper secondary school and the mathematics pathway selected.

There is a gender difference in the choice of mathematics at secondary school and there might be a gender influence on the result. It is of interest to compare the impact of GPA scores and that of mathematical skills: not only might the choice of mathematical level at secondary school have an effect on the results at business school, but so might the grades achieved at secondary school.

Background data and results
Tables I and II show the descriptive statistics, which include the variables used in the regression model. Table I presents information based on data from upper secondary school, while Table II presents information based on data from mandatory courses at the NTNU Business School. The tables include a standard t-test comparing the means for practical and non-practical mathematics. The school is quite popular and only 1 out of 3 applications is accepted. Around 1/3 of the students have a practical mathematics background and the other 2/3 a theoretical mathematics background. The data reported include around 65% of all enrolled students. More girls than boys (60% and 40% respectively) attend the business school. Female students are more likely to have chosen practical mathematics at upper secondary school (68%) compared to male students, who show a greater tendency to have chosen theoretical mathematics (56% female and 44% male). Approximately 25% of applicants were not included in the sample, mainly comprising mature students who took mathematics at upper secondary school before the existing practical mathematics option was introduced.

[Insert Tables I and II about here]

Table II shows another picture. Although the mean score for the admission criteria (GPA) is the same for the two groups, there is a substantial difference in the performance for the Bachelor's degree students in business courses depending on mathematics background. It seems that there is a link between previously developed mathematics skills and success in most of the courses in economics and business studies. The influence is strongest in quantitative courses.

Business mathematics is on the schedule in the first half-year. Students with a less skilled mathematics background from upper secondary school present poor performance in this course. Even though business mathematics is mandatory, the relationship between students' previous developed mathematics ability and performance in the following courses does not disappear.

The level of mathematics understanding among the students has an impact on their performance in economics and business courses. The students with a theoretical mathematics background outperform students with a practical mathematics background. This effect is strong for courses using quantitative skills, such as Business Economics and Financial Analysis & Investment.

The difference is about ¾ of a grade. The average student without a background in theoretical mathematics from upper secondary school can expect a substantially lower result in these courses. Lower standards in mathematics have a negative influence on success in analytical business subjects. Courses in economics provide the same evidence, but not to the same degree. However, it is still significant at the 1% level using a t-test for the equality of means.

The link between mathematics skills and performance in Accounting and non-quantitative courses is not so strong. The results are more mixed. For Financial Accounting, there is a significant effect, but for Cost Accounting no such impact is observed. The difference is also not significant for the outcome of Organizational Management and Organizational Psychology. On the other hand, it is positive and significant for Marketing and especially Business Law.

Figure 1 shows the grade distribution for some courses depending on mathematics background at upper secondary school. The students with poorer mathematics knowledge tend to get lower grades and the opposite occurs for students with good grades. The graph confirms differential effects on the courses due to skills ability in mathematics.

[Insert Figure 1 about here]

Using multivariate data and including control variables in the model, it is possible to identify more clearly the relationship between mathematical skills and performance in business courses. The results are shown in Table III.

[Insert Tables IIIa and IIIb about here]

The effect of studying theoretical mathematics at upper secondary school and the influence of other independent variables on results in business courses are given in Tables IIIa and IIIb. A student who took theoretical mathematics at upper secondary school is likely to get higher grades in most of the courses on the programme. Skills in mathematics are strongly related to success in subsequent quantitative courses. The evidence is solid and positively significant for Business Mathematics, Business Statistics, Business Economics and Financial Analysis & Investment. A student with a background in theoretical mathematics can expect to achieve at least one grade better. The impact is also substantial for Microeconomics. Among the quantitative courses, the effect is smaller for Macroeconomics, but still highly significant.

It should also be noted that the mathematics factor has a significant influence on student performance in non-quantitative courses, especially in Business Law. On the other hand, Organizational Management presents no significant coefficient.

The results for accounting courses are mixed. There is a positive and significant link between background in mathematics and success in Financial Accounting, but not for Cost Accounting.

The regression model presents some other results of interest. First, grades in mathematics from secondary upper school are more important than GPA in explaining success in Business Studies. Second, male students outperform female students in some of the courses. In Macroeconomics, for instance, women obtain more than a half grade less than men at a 1% significance level.

Discussion
The results in this analysis support and are consistent with the findings of Alcock *et al.* (2008). Students with a higher level of secondary mathematics achieve higher grades in most of the business courses. This is very strong in Business Mathematics and Business Statistics and in quantitative courses, such as Business Economics, Financial Analysis & Investment and Microeconomics. The students who chose theoretical mathematics at upper secondary school present significantly better results than the students with a practical mathematics background. This is not surprising. Students with basic theoretical mathematical skills outperform those with a practical mathematics background as mathematics is an important tool for learning and understanding these fields. The result backs the findings in the international literature. Even though

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the course in Business Mathematics is mandatory, the gap in skills between the two groups does not disappear.

Empirical studies have documented a link between mathematical abilities and performance in Financial Accounting, but not in Cost Accounting, consistent with the finding in this analysis.

The correlation between mathematical knowledge and performance is not only apparent for quantitative courses, but also in Marketing and Business Law. The connection between mathematical skills and success in Business Law and other non-quantitative courses is not as obvious. There is no mathematics in the textbooks or in the presentation of the lectures. However, strength in mathematics might give the students an idea of basic concepts for organization and analysis in other fields also requiring analytical abilities. They are more able to develop a better systematic structure, discuss and solve the problems. Analytical abilities give a student a conceptual advantage for success in Business Law. With a weak mathematical background, one might lack the basic skills to perform well in this course. The same effect, but not to the same degree, is found in Introduction to Marketing and Organizational Psychology.

Students are offered admission to the business school based on their GPA scores. Students with good GPA scores demonstrate the ability and the skills to solve problems in many subjects (Brookshire and Palocsay, 2004). However, the results in this paper suggest that skills and capacity in mathematics play a more important role. Indeed, the study reveals a significant correlation between mathematical skills and performance in business studies. Higher mathematics skills improve the students' success in most courses. In contrast GPA level does not seem to be a good indicator for determining those best qualified to attend the business school. Mathematics background and performance in mathematics at upper secondary school are more closely associated with success on business courses than GPA scores. This has implications for the criteria used to enrol students. By requiring theoretical mathematics for acceptance from upper secondary school, it would be possible to have a more homogeneous student population, thus making the work of professors easier in terms of teaching, especially in quantitative courses. It can be difficult for students with a weak background in mathematics to make up ground in many topics and professors may be tempted to present their topics using fewer mathematics applications. By emphasizing mathematics aptitude over GPA scores, there may well be an improvement in students' outcomes. Moreover, it is likely that the dropout rate will fall and the success rate will increase.

The existing enrolment system potentially admits students to the school with inadequate mathematics skills. For this reason, many students who might well succeed in business studies could never get the chance. This also means that resources are not optimally allocated. Furthermore, the labour market might receive less qualified candidates.

There is little information available regarding the reasons why students at upper secondary school choose different paths in mathematics. However, the choice students make might have an impact on their performance in business courses. Academic success probably depends on many factors, such as the degree of effort, motivation and self-discipline (Brookshire and Palocsay, 2004). However, the existing admissions system gives the wrong signals to the students. It is probably easier to get a higher GPA by choosing practical mathematics at upper secondary school as the subject is not as difficult as theoretical mathematics and the time released can be spent in other ways, for instance studying other subjects. A student less qualified for business studies can achieve higher GPA points, sending the wrong signal to students planning to attend business school. However, by selecting the mathematics path that gives the best qualification to study business courses, i.e. theoretical mathematics, students risk not attaining admission. For some students, the reward of making the wrong choice is to gain access to business school.

This study may have an influence on public policy. There is already discussion regarding the existing enrolment system. For instance, the Norwegian School of Economics does not accept applicants with a qualification only in practical mathematics.

Conclusion

The main purpose of this study was to explore the impact of mathematics background gained at upper secondary school on performance in business courses using data from a popular Norwegian business school. There is strong evidence that mathematics matters for studies at business school. Students preferring practical mathematics at upper secondary school will tend to fall behind in many subjects and not only in quantitative courses.

By requiring theoretical mathematics as a criterion for enrolment at business school, performance may well improve and there will a better selection of students given an entry ticket. The existing system is potentially ineffective due to incorrect composition of students. In particular, students who are borderline in terms of acceptance might be incentivized to choose practical mathematics to increase their GPA, even though paradoxically this makes them less qualified to engage in business studies.

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Table I. Descriptive statistics for enrolment, including a standard t-test comparing means for theoretical vs practical mathematics

	Mean	Min.	Max	Std. Dev.	Theoretical mathematics	Practical mathematics	Difference
Gender (male)	0.6	0	1		0.56	0.68	-0.12
GPA	51.9	43.0	67	3.38	52.0	51.8	0.2
Language grade upper secondary school[1]	4.48	2	6	0.64	4.51	4.42	0.09
Mathematics grade upper secondary school[1]	4.47	3	6	0.89	4.26	4.86	-0.6***
N	587				383	204	179

[1] Based on a six-point scale where 1 is the lowest score and 6 is the highest.

*, ** and *** denote significance at the 10%, 5% and 1% levels respectively.

Table II. Descriptive statistics for the results from the NTNU Business School and a standard t-test for equality of means comparing theoretical vs practical mathematics

Course	Mean	Min	Max	Std. Dev.	Theoretical mathematics	Practical mathematics	Difference
Mathematics and Statistics							
Business Mathematics	2.74	0	5	1.75	3.27	1.51	1.76***
Business Statistics	3.07	0	5	1.68	3.36	2.33	1.03***
Quantitative courses in Economics and Business Studies							
• *Business Economics*	2.71	0	5	1.59	2.93	2.21	0.72***
• *Financial Analysis and Investment*	2.48	0	5	1.72	2.70	1.82	0.88***
• *Microeconomics*	3.21	0	5	1.29	3.37	2.81	0.56***
• *Macroeconomics*	3.08	0	5	1.22	3.19	2.81	0.38***
Accounting							
• *Cost Accounting*	3.20	0	5	1.57	3.24	3.10	0.14
• *Financial Accounting*	3.02	0	5	1.56	3.22	2.60	0.62***
Non-quantitative courses in Business Studies							
• *Organizational Management*	2.83	0	5	1.28	2.89	2.69	0.20
• *Organizational psychology*	2.91	0	5	1.13	2.97	2.80	0.17
• *Introduction to Marketing*	2.63	0	5	1.01	2.71	2.45	0.26**
• *Business Law*	2.93	0	5	1.18	3.02	2.63	0.39***

Notes: F:0, E:1, D:2, C:3, B:4, A:5. *, ** and *** denote significance as the 10%, 5% and 1% levels respectively.

Table IIIa. Regression results for the dependent variable course grade in mathematics, statistics and quantitative courses in business and economics studies

Variable	Business Mathematics	Business Statistics	Business Economics	Financial Analysis and Investment[1]	Micro-Economics	Macro-Economics
Intercept	-4.815	-3.608	-2.906	-5.057	-1.395	-2.472
Gender	0.335**	0.279*	0.203	0.338	0.308**	0.711***
	(0.148)	(0.160)	(0.145)	(0.295)	(0.129)	(0.125)
GPA	0.081***	0.069***	0.049**	0.067	0.042**	0.070***
	(0.023)	(0.025)	(0.021)	(0.050)	(0.020)	(0.019)
Upper secondary school mathematics	0.435***	0.517***	0.522***	0.655***	0.409***	0.319***
	(0.088)	(0.094)	(0.088)	(0.172)	(0.078)	(0.075)
Theoretical mathematics	1.187***	1.044***	1.049***	1.284***	0.713***	0.399***
	(0.169)	(0.183)	(0.163)	(0.348)	(0.150)	(0.141)
R^2	0.270	0.146	0.141	0.188	0.123	0.175
F-value	39.140***	38.586***	17.623***	6.841***	12.822***	16.647***
N	427	393	433	122	371	318

[1] Available data for 1 year. Notes: *, ** and *** denote significance at 10%, 5% and 1% respectively. Figures in parentheses show the standard deviation. The correlations between the independent variables are low. The variance inflation factor (VIF) values are below 2.0.

Table IIIb. Regression results for the dependent variable "course grade" in Accounting and non-quantitative courses in business studies

Variable	Cost Accounting	Financial Accounting	Organizational Management	Organizational Psychology	Introduction to Marketing	Business Law[1]
Intercept	-3.643	-1.825	-0.852	0.362	1.343	-2.556
Gender	0.439**	-0.109	0.060	-0.025	0.095	-0.92
	(0.172)	(0.177)	(0.124)	(0.115)	(0.099)	(0.155)
GPA	0.095***	0.048*	0.046	0.024*	0.001	0.063**
	(0.026)	(0.025)	(0.019)	(0.017)	(0.015)	(0.027)
Upper secondary school mathematics school	0.356***	0.405***	0.256***	0.256***	0.215***	0.427***
	(0.104)	(0.107)	(0.074)		(0.058)	(0.090)
Theoretical mathematics	0.222	0.821***	0.259	0.267**	0.350***	0.558***
	(0.195)	(0.195)	(0.135)	(0.127)	(0.110)	(0.187)
R^2	0.096	0.097	0.050	0.047	0.043	0.163
F-value	18.562***	8.262***	5.479***	5.067***	4.852***	11.716***
N	318	310	420	415	440	209

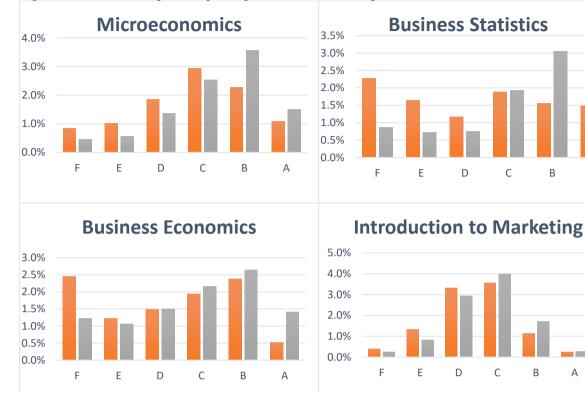[1] Data available for two years. Notes: *, ** and *** denote significance at 10%, 5% and 1% respectively.

Figure 1. Distribution of grades depending on mathematical background