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Advanced mathematics: An advantage for business and management administration students

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A R T I C L E I N F O

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A B S T R A C T

In the current context of a "mathematically intensive" job market, we aim to assess whether the educational policies that recommend Social Sciences tracks to access Business and Management Administration degrees are the most appropriate. A new case study for the European Higher Education Area is provided. We apply different econometric analyses to an educational production function to test whether there is a significant relationship between mathematical skills and academic performance in Business degrees. We analyse a set of indicators, including a complete disaggregation by subject. Our findings lead us to recommend advanced mathematics for access to these degrees, preventing students without enough maths skills from enrolling. This could improve both the transition to university and academic performance, as well as facilitating the incorporation of graduates into the current labour market.

1. Introduction

The current labour market increasingly more demands professionals with a technological profile, where mathematical competence has become essential. According to Eurostat (2019), in the EU-15 about 40% of jobs are "mathematically intensive". Business and Management are no stranger to this phenomenon, having turned mathematics into a strategic asset accelerating growth (REM, 2019). Studies quantifying the impacts of "mathematical intensity" on the economy concluded that in the United Kingdom, France and the Netherlands the direct impact on employment is between 10 and 11% and the contribution to added value is between 13 and 16% (Deloitte 2012, 2014). In the Spanish economy these impacts are lower: 6% of employment and 10% of added value (REM, 2019).

Despite the growing importance of mathematics for economy, students accessing university degrees in Business and Management Administration mostly come from Social Science secondary education tracks. These tracks include less demanding maths subjects than Science tracks. This explains why the mathematics profile of the majority of students in Business and Management Administration degrees (LOMCE, 2013) is not the most suitable either to take advantage of them successfully or to facilitate their incorporation into the current job market. It is frequent to find students who chose the Social Sciences track because they are averse to mathematics subjects (Gil et al., 2006).

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In view of the above, in this paper we consider assessing whether the educational policies that recommend the Social Sciences track for access to Business and Management Administration degrees are sending the wrong signals. It has been observed that many of these students have difficulties facing the demands of these degrees and obtain much lower results than their expectations. This leads, in some cases, to abandon their studies. In 2016, the university dropout rate in the countries of the European Union was 10% (Eurostat, 2019) and in Spain it was 18%, and in Social Science and Law University studies was 16.8% (CRUE, 2019).

In addition, many students who manage to complete the degree have trouble accessing the labour market due to quantitative shortcomings in their training. There are many jobs that have traditionally been occupied by economists that today are being carried out by mathematicians or engineers. In fact, the Business and Management Administration analyst are being replaced by the Data Scientist who designs, develops and implements complex mathematical algorithms (Infojobs & ESADE, 2018).

These problems, which are common to the education systems of many countries, have been worsening in recent decades with the changes produced in the global labour market by the 4th Industrial Revolution. More and more information is generated and it is necessary to have professionals capable of both processing and analysing it in order to reach conclusions that allow a better knowledge of reality and prediction of future trends (digitalisation, big data, financial globalisation, artificial intelligence, and so on). "In the era of digital transformation and with the advent of big data, digital literacy and data literacy are becoming increasingly essential, as are physical health and mental well-being" (OECD, 2018:4).

Our work aims to contrast the approaches described above. To do this, we carried out an empirical study supported by data from all first-year students enrolled in the 2016–2017 academic year in the Business and management Administration degree at the University of Seville (Spain). From different econometric analyses, we test whether there is a significant relationship between the mathematical skills developed in high school and academic performance in the first year of the Business and Management Administration degree. We also analyse whether these relationships are maintained in all subjects. To approximate academic success, we jointly analyse the first-year general performance indices and the breakdown of all subjects: grade point average and dropout rates. On the other hand, we analyse the relationships between university performance indicators and the study of Economics, Management and Business in secondary education, in order to compare them with the results of the mathematical background. The results achieved are robust as they are maintained for a wide range of indicators, different specifications and econometric analyses.

The findings of this research have relevant theoretical contributions and practical implications. Providing a new case study, the research expands the scientific literature on the role of mathematical skills background in the success of university Business and Management Administration studies. In the current context, broadening the knowledge in this field is crucial to contribute to improving the competitiveness of both business and management administration professionals and the economy in general. The Spanish case is especially relevant since both the employment and mathematical intensity rates are much lower than those of the EU as a whole. According to Eurostat, the unemployment rate in Spain in December 2020 was 16.2%, while in the EU it was 7.5%.

Thus, the analysis carried out provides empirical evidence to evaluate the suitability of Social Science tracks in secondary education, with less demanding mathematics, to access university degrees in Business and Management Administration. It can therefore be useful to educational policy makers for future reforms.

The rest of the paper is structured as follows. Section 2 includes a literature review and institutional framework. The dataset and methodology are set out in Section 3. Section 4 presents the results and discussion. Finally, Section 5 contains the concluding remarks.

2. Background

2.1. Determinants of academic performance: the role of maths skills in Business and Management Administration Degrees

The theoretical and empirical literature on the determinants of university academic performance is large (see, e.g.: Hattie, 2009 and Robbins et al., 2004, for a meta-analysis. Hanushek, 1986; Hendy & Biderman, 2019 and Van den Berg & Hofman, 2005, for a literature review). Academic performance is a complex concept that is characterised by its multidimensionality (Opstad, 2018; Salas-Velasco, 2019; Tuero et al., 2018). There are numerous conceptual variables that are included in these studies, such as: gender, people living in the family household, family responsibilities, parents' studies level, non-local, worker, Erasmus or grants (Asián Chaves et al., 2020; Bartoli & Polanec, 2018; Beattie Laliberté & Oreopoulos, 2018; Covarrubias et al., 2018; El Massah & Fadly, 2017; Glocker, 2011; Millea et al., 2018; Nuñez et al., 2019; Whalen et al., 2009).

Although there are many factors that determine it, there is a broad consensus in considering academic variables as the main predictors. More specifically, the variables linked to the qualifications and characteristics of pre-university studies (Cyrenne & Chan, 2012; Hattie, 2009; Marcenaro & Navarro, 2007; Masui et al., 2014; Robbins et al., 2004; Strayhorn, 2013; Wood et al., 2012).

The literature on success in University Business and Management Administration studies is scarce, but it reaches conclusions very similar to the aforementioned, highlighting the previous academic factors (Alcock et al., 2008; Arnold & Rowaan, 2014; Arnold & Straten, 2012; Asián Chaves et al., 2020; Beattie et al., 2018; Becker, 1997; Lagerlöf & Seltzer, 2009; Silva et al., 2016; Swope & Schmitt, 2006).

Although, among the academic factors, previous mathematical skills play a fundamental role for success in Business and Management Administration degrees, empirical studies on this topic are still scarce and have important limitations.

On the one hand, most of them have focused on the analysis of the qualifications of a specific subject (see, e.g.: Choudhury & Radhakrishnan, 2009; Green et al., 2009; Johnson & Kuennen, 2006, for Statistics. Anderson et al., 1994; Ballard & Johnson, 2004; Brown-Robertson et al., 2015; Mallik & Lodewijks, 2010, for Microeconomics or Introductory Economics. Guney, 2009; Ujar & Güngörmu, 2011, for Accounting). Some papers have jointly analysed several subjects (Dolado & Morales, 2009, for Mathematics, Introductory Economics and Economic History; Lagerlöf & Seltzer, 2009, for Principles of Economics, Quantitative Methods I and

Economics Workshop), but there are still very few investigations that study all the subjects (the compulsory subjects of the first year are analysed by Alcock et al., 2008 and Opstad, 2018) or a course's global indicators of academic performance (Asián Chaves et al., 2020; Arnold & Rowaan, 2014; Arnold & Straten, 2012) or degree (Swope & Schmitt, 2006). The results of these partial empirical studies are hardly generalisable, which reduces their usefulness in the evaluation of educational policy actions.

On the other hand, a large part of these works are specific case studies of US (e.g.: Ballard & Johnson, 2004; Brown-Robertson et al., 2015; Choudhury & Radhakrishnan, 2009; Green et al., 2009; Johnson & Kuennen, 2006; Swope & Schmitt, 2006) or Australian universities (Alcock et al., 2008; Holmes et al., 2018 and Mallik & Lodewijks, 2010), where the particularities of pre-university systems and university access make it difficult to extrapolate the results.

Complete studies that allow a rigorous analysis of the European Higher Education Area remain limited. Dolado and Morales (2009) carry out a rigorous econometric analysis for the Carlos III University (Spain), but only consider the grades of three subjects. On the other hand, Arnold and Rowaan (2014) and Arnold and Straten (2012) analyse several indicators of academic performance of the first course at the Erasmus University Rotterdam (Netherlands), but do not disaggregate by subject. Similarly, for the Seville University (Spain), Asián Chaves et al. (2020) analyse the academic success of the first year but do not disaggregate by subject.

In addition, the works on this topic usually approximate the mathematical background through the grades obtained in high school (Ballard & Johnson, 2004; Lagerlöf & Seltzer, 2009; Mallik & Lodewijks, 2010 and Swope & Schmitt, 2006) or with a mathematical skills test designed ad hoc (Laging & Voβkamp, 2017). The works that explicitly analyse the different maths options that can be taken in the upper secondary school are very rare and do not consider the case of not having taken mathematics.

The papers reviewed find a significant and positive relationship between the mathematical skills background and the academic performance in the Business and Management Administration degree, which is more intense in quantitative subjects. Several of these studies jointly analyse the effects of mathematical skills and having studied economics, management, and business subjects in secondary school (Alcock, Cockcroft & Frank, 2008; Asián Chaves et al., 2020; Dolado & Morales, 2009 and Mallik & Lodewijks, 2010). Alcock et al. (2008); Asián Chaves et al. (2020) and Dolado and Morales (2009) find that greater maths skills are a powerful predictor of success in Business and Management Administration studies, but this is not the case of the economic knowledge developed in higher secondary schools. These results question the suitability of the high-school Social Sciences track, which is the one that is mostly recommended for access to university degrees of the Business-Management Administration-Economic area.

This research aims to solve the aforementioned shortcomings of the previous literature, so that their results can be useful to guide educational policies in the European Higher Education Area. In this sense, we jointly analyse the global performance indicators for the first year of the Business and Management Administration degree (average grades and credits passed) and, for each subject, both the average grades and the dropout (not having taken the subject exam). We conducted an analysis focused on the results of the first year, since all the previous literature concludes that the academic performance of the first year is a powerful predictor of the final results (Alcock et al., 2008; Arnold & Rowaan, 2014; Arnold & Straten, 2012; Lagerlöf & Seltzer, 2009; Nuñez et al., 2019). Likewise, we consider all the possibilities provided by the Spanish education system in relation to mathematics subjects for access to Business and Management Administration studies: not having studied mathematics, having taken mathematics through Social Sciences or Advanced Mathematics.

In addition, unlike previous works, we detail the Spanish institutional context in order to extrapolate the conclusions of the empirical analysis for Spain to other countries.

2.2. Institutional framework

In Spain the majority of students enter the university after passing two high school courses (*Bachillerato*) and an entrance exam (*PEvAU*).

Bachillerato students can choose one of the three possible tracks: Social Sciences, Technology and Arts and Humanities. The subject of the mathematical content of the Technological track [Maths(A)] is stronger than of that of Social Sciences [Maths(SS)].

The *PEvAU* is divided into a mandatory and a voluntary part. In the latter, the student can take up to a total of four subjects of the second year of *Bachillerato* (which may include the two subjects of mathematics). The two highest grades obtained from these four subjects, weighted with a coefficient ranging from 0 to 0.2, are considered for the *PEvAU* final grade. The value of this coefficient depends on the suitability of the content of the subject with that of the university degree chosen. Specifically, for the Business and Management Administration degree, the two mathematics subjects have the same weighting coefficient, 0.2.

Although it is possible to access the Business and Management Administration degree from any kind of *Bachillerato*, it is generally recommended to do so from the Social Sciences track that includes economics, management and business subjects. In this sense, most of the students who enter the Business and Management Administration degree have studied Maths(SS). This is due to several factors. On the one hand, in many high schools it is not possible to combine subjects from different tracks, so a student of the Social Sciences track cannot do Maths(A). Furthermore, even in those high schools where this is possible, the majority of students choose Maths(SS) instead of Maths(A). This is because the former is easier and they can achieve higher grades, which allows them to better position themselves to enter their preferred university degree.

3. Data and empirical strategy

3.1. Data

In addition to the analysis of frequencies and correlations, we used regression methods (OLS, Quantile regression, Logit) and tested

Table 1
Description and range of the variables.

Variable	Description	Range
DEPENDENTS: Academic Performances 1st year		
TC	Passed Credits in 1st, 2nd and 3rd calls (1st year)	0–60
GPA	Grade Point Average of subjects enrolled in the 1st year of the degree (*)	0–10
S1 Stat	Grade Point Average of Subject 1 (Statistics) during the 1st year of the degree	0–10
S2 Fin	Grade Point Average of Subject 2 (Finance) during the 1st year of the degree	0–10
S3 Acc	Grade Point Average of Subject 3 (Accounting Fundamentals) during the 1st year of the degree	0–10
S4 EH	Grade Point Average of Subject 4 (Economic History) during the 1st year of the degree	0–10
S5 Law	Grade Point Average of Subject 5 (Private Law) during the 1st year of the degree	0–10
S6 Ec	Grade Point Average of Subject 6 (Introduction to Economics) during the 1st year of the degree	0–10
S7 Bus	Grade Point Average of Subject 7 (Introduction to Business and Management Administration Economics) passed during the 1st year of the degree	0–10
S8 Mark	Grade Point Average of Subject 8 (Introduction to Marketing) during the 1st year of the degree	0–10
S9 Mat I	Grade Point Average of Subject 9 (Maths I) during the 1st year of the degree	0–10
S10 Micr	Grade Point Average of Subject 10 (Microeconomics) during the 1st year of the degree	0–10
Dropout_S_i	1 if the student takes the exam of subject i, 0 if she/he does not take it	0 and 1
EXOGENOUS		
NoMaths	1 if NoMaths has been examined in University Entrance Exam, 0 if some Maths	0 and 1
Maths(A)	1 if Maths(A) has been examined in University Entrance Exam, 0 in the other case	0 and 1
Gender	1if female, 0 if male	0 and 1
AG	Access Grade to University	5–14
GPA(*PEvAU_MP*)	Mandatory phase mark of the University Entrance Exam	5–10
Motivation	1 if students have chosen the degree in their 1st option, 0 in the other case	0 and 1
ECO (*PEvAU*)	1 if Economics, Management and Business has been examined in the University Entrance Exam, 0 if not	0 and 1

Note: Given the dummies defined, the value which is taken as the base in the models is: a woman, who has studied Social Sciences Mathematics and has chosen the degree as her first option.

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the presence and magnitude of the effects of the type of mathematics skills developed at high school on university academic performance measured through different indices. We jointly analyse first-year general performance indices and disaggregation for all subjects: average grades and dropout rates.

The case study analysed included the data of all the students who enrolled in the degree in Business and Management Administration at the University of Seville in the 2016–2017 academic year (454 students). The data were provided by the Corporate Applications Area of the Computing and Communications Service of the University of Seville. We made an average profile of the student who accessed this degree as follows: male (66.9%), who has studied the subjects Social Sciences Mathematics (56%) and Economics, Management and Business in upper secondary school (67.6%), has obtained an average access grade of 8.85 and has chosen his studies as his first option (73.3%).

Table 1 provides a summary of the variables chosen, as well as the indexes selected to measure them and their range.

(*) To calculate the GPA for both the 1st year and each subject we have done the following: if the subject is passed, the mark of the call in which it has been passed is taken; in the case of failing, the highest mark obtained in the calls to which it has been submitted is taken; if the exam has not been taken in any call, a value of 0 is assigned.

Source: University of Seville. Computing and Communications Service (Corporate Applications Area).

The literature analysed in the preceding section supports that the outcomes achieved in the first year constitute a reliable predictor of degree academic performance. For that reason, we compute the *academic performance of the university* from two indicators linked with the results of the first year of the degree: (1) the number of credits passed in the three calls which the student of the University of Seville has to pass (making up the total of 60 credits of the whole year) 'TC', and (2) the average grade of the first year, 'GPA'. Additionally, for each first-year subject, we consider two indicators to approximate academic performance (average grade) and dropout (whether or not the student has taken the exam).

Taking into account the objectives of the research, the core *explanatory variables* measured are the mathematics skills of the student who accesses studies of Business and Management Administration. We operate the official data of the *PEvAU*; precisely, the type of mathematics examined: none 'NoMaths', Advanced Mathematics 'Maths(A)'or Social Sciences Mathematics 'Maths(SS)'.

The *Control variables* are selected from the main determinants of university academic success mentioned in the literature review. Three indicators are chosen to approximate the pre-university characteristics and qualifications: the grade of access to the degree 'AG', the average grade of the mandatory phase 'GPA(*PEvAU_MP*)' and whether the economics, management and business subjects have been studied in upper secondary school 'ECO(*PEvAU*)'. We use, as a motivation proxy, the variable: priority in the option of access to the degree ('Motivation'). The 'Gender' is also considered.

3.2. Empirical strategy

Firstly, the Student's *t*-test and the Kruskal-Wallis test, depending on the type of variables, are used to verify if there are differences of means in the variables. Secondly, we perform Ordinal Least-Squares regressions (OLS) to test if there is a significant link between the mathematics subject studied in upper secondary school and the indicators of academic performance of the first university year (overall and disaggregated by subject). Then, we apply Quantile Regression (QR) to verify the relation between the mathematics and the university performance in different ranges of values of academic performance. Furthermore, a Logit model is used in order to analyse the influence of mathematics on the likelihood (or not) of taking the exam of each subject in any call (dropout by subjects).

The formulation followed to estimate the *Ordinal Least-Squares regressions* is (1):

$$Y_i = \beta_0 + \beta_1 \, NoMaths_i + \beta_2 Math(A)_i + \beta_3 \, X_i + \varepsilon_i \tag{1}$$

We consider an academic performance production function (see Dolado & Morales, 2009; Mallik & Lodewijks, 2010) where: Y_i is a performance indicator (overall and disaggregated by subject), NoMaths and Maths(A) refer to the type of mathematics studied in upper secondary school, X_i is a vector of the control variables. β_0 is the constant, $\beta_{1,2,3}$ are the regression coefficients and ϵ is the random error term. We estimated two models introducing different control variables. In Model 1 we controlled the variables which the literature has traditionally linked with academic performance (gender, prior marks and motivation). In Model 2, we added the economics, management and business knowledge developed at upper secondary school. In the analysis by subject, we have only considered Model 2.

Quantile Regression (QR) presents important advantages (Koenker & Bassett, 1978; Koenker & Hallock, 2001; Koenker, 2015). Because of this, we concluded the study running QR estimations at three points (the quantiles 0.25, 0.50 and 0.75) in addition to the average, and the quantile 0.90 to analyse the higher performance levels. The QR model from the previous linear regression equation is:

$$Y_{ij} = \beta_{0j} + \beta_{1j} \, NoMaths_{ij} + \beta_{2j} Math(A)_{ij} + \beta_{3j} \, X_{ij} + \varepsilon_{ij} \tag{2}$$

where the variables and the coefficients are defined in an analogous manner to those of the linear regression expressed, particularised in each of the five quantiles according to the value of j (j = 0.25, 0.50, 0.75, 0.90). Quantile analysis was done both for the indicators of overall performance of the degree and for the grades of the different subjects and for Model 2.

Finally, for the binary variable "dropout by subjects" we estimated a *Logit model* (Johnson, 2000; Peng et al., 2002; Pérez, 2004) and computed marginal effects at the means of the regressors. The likelihood of dropout conditioned by the characteristics of each subject is calculated following the formulation (3):

$$P(dropout_i = 1 \;/\, x) = p_i = \frac{e^{\,\beta_{0i} + \beta_i \overline{X}_i}}{1 + e^{\,\beta_{0i} + \beta_i \overline{X}_i}} = \frac{1}{1 + e^{-\,\beta_{0i} - \beta_i \overline{X}_i}} \tag{3}$$

where β_0 is the independent term, and $\beta_i \overline{X}_i = \beta_{1i}\, NoMaths_i + \beta_{2i} Math(A)_i + \beta_{3i}\, X_i$.[1]

4. Results and discussion

4.1. Overall results for Business and Management Administration Degree

Table 2 shows the results of the descriptive analysis and the comparison tests of the means according to the type of mathematics studied in upper secondary school for the variables related with aspects prior to entering University. The same analysis for the variables of university performance is in Table 3.

According to the mathematics studied, we find that significant differences exist as to *gender*. There are more men than expected among those who studied Maths (A).

There are significant differences in the *degree access grade (AG)*, being greater than expected in the students of Maths(SS). As we pointed out before, these differences are explained by the higher weighting that the subjects of the track of Social Sciences have for the access to the Business and Management Administration Degree. However, centring on the *average marks of the mandatory phase* of the *PEvAU* or on the subjects of *mathematics*, *economics*, *management* and *business* we note that significant differences do not exist. On the other hand, we found significant differences according to the economics, management and business studied at secondary school, only 2.8% of students of Maths(A) did the exam of Economics, management and business in *PEvAU* (while 81.5% of those that studied Maths (SS) did so).

Although the differences are not significant in the *motivation* variable, there is a lower percentage of students who chose the degree as their first option among those who studied Maths(A) (66.7%) compared to those who studied Maths(SS) (74.8%). This result mirrors the current way of university access in Spain as it recommends and rewards the track of Social Sciences for access to the Business and Management Administration Degree.

Significant differences are observed among the three mathematics options studied both for the *academic performance indicators* of the overall degree and for the more quantitative subjects (Table 3). The students who studied Maths(A) achieve higher results than expected, while those who did not study mathematics obtain worse academic results. The differences are especially significant in the Mathematics subject (S9) where the average grade for Maths(A) students is 7 (3.48 for NoMaths, and 4.55 for Maths(SS)).

The results of the *Regression Analysis* (OLS and Quantile) confirm the previous findings: *there exists a significant relation between the mathematics skills acquired by the student in upper secondary school and the results of the first year of the University studies of the Business and Management Administration degree*. As we show in Tables 4 and 5, there is a positive and significant relation for the students who studied Maths(A) and a significant and negative relation for those who did not study any mathematics (NoMaths).

Notes: The standard errors are in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The Variance Inflation Factors (VIF) are below 2.0. Variables: see Table 1.

The estimation of Quantile Regressions allows some nuances (Tables 4 and 5). In the case of NoMaths, the relationship is significant (and negative) in the highest quantiles. Otherwise, having studied Maths(A) explains better the performances in the lowest quantiles.

The control variables are similar to those in the previously cited studies. There is a positive and significant relation with the previous marks (in every model, indicator and quantile). The relation is also positive with having studied Economics, management and business. We found a positive link between being female and academic performance. The motivation is not significant.

The results are robust for the two models and the two performance indicators.

4.2. Subjects results

Having tested the existence of a link between the basic mathematical skills and the general academic results of Business and Management Administration Degree, we verify whether the relationship is maintained in the ten subjects.

4.2.1. Dropout by subjects

Firstly, we used the Logit model to study the relation between the mathematical skills background and the likelihood of taking the exam in each of the subjects in the first course (proxy-variable of dropping out) (Table 6). The results for Maths(A) are conclusive and significant: having studied Maths(A) makes it more likely to take exams in most subjects. The results for NoMaths are significant only for Marketing (S8), Mathematics I (S9), Microeconomics (S10), and for the latter the relation is negative.

4.2.2. Academic performance by subjects

Having confirmed the relation between the mathematical skills background and the likelihood of taking the exam in each subject, we run the regression models (OLS and QR) to test if those relations are maintained to the average mark of the ten subjects (Tables 7).

These outcomes confirm the Logit model results. The average marks of all the subjects are positively related with having studied Maths(A), the relation in most of them being significant. On the other hand, there is a negative link with NoMaths, although it is significant only in 3 of the subjects.

The last results allow classifying the subjects into three groups:

[1] The Probit results are similar and available upon request.

Table 2
Descriptive statistics for first-year students and the standard test comparing means for different mathematical skills.

	% or Mean	Min	Max	SD	NoMaths	Maths(SS)	Maths(A)	*Difference*(1)
Gender (%F)	36.1%				31.7%	40.9%	22.2%	0.031[a]
Motivation (%1°option)	73.3%				72.6%	74.8%	66.7%	0.563[a]
AG	8.85	5.04	13.36	1.38	7.96	9.41	8.92	0.000[b]
GPA(*PEvAU_MP*)	6.84	5.01	9.55	0.91	6.87	6.81	6.98	0.355[b]
Mark_Maths(*PEvAU*)	6.90	5.00	10	1.23	–	6.94	6.64	0.242[b]
Mark_Eco(*PEvAU*)	7.26	5.00	10	1.32	7.19	7.31	5.25(2)	0.240[b]
ECO(*PEvAU*) (%)	67.6%				60.4%	81.5%	2.8%	0.000[a]
TOTAL	**454**				**164** (36.1%)	**254** (56.0%)	**36** (7.9%)	

Notes: (1) Standard test comparing means difference: a Pearson's Chi-squared; b Kruskal-Wallis. (2) This is not representative because only one student of Maths(A) has a mark in ECO. Variables: see Table 1.

Table 3
Descriptive statistics for the performance of first-year undergraduates and the standard test comparing means for different mathematical skills.

	Mean	Min	Max.	SD	NoMaths	Maths(SS)	Maths(A)	*Difference*(1)
TC	28.22	0	60	19.82	24.32	29.26	38.50	0.000[a]
GPA	5.19	0	9.43	2.05	4.85	5.30	5.99	0.001[a]
S1 Stat	4.28	0	10	2.67	4.10	4.29	5.03	0.120[b]
S2 Fin	2.63	0	10	2.62	2.36	2.74	3.00	0.227[b]
S3 Acc	2.67	0	9.8	2.64	2.33	2.70	3.79	0.036[b]
S4 EH	3.06	0	10	2.78	2.82	3.11	3.69	0.273[b]
S5 Law	3.90	0	10	1.98	3.72	3.95	4.43	0.217[b]
S6 Ec	3.98	0	10	1.94	3.78	4.03	4.50	0.185[b]
S7 Bus	3.96	0	10	1.94	3.75	4.01	4.64	0.094[b]
S8 Mark	2.44	0	9.0	2.50	1.87	2.60	3.89	0.000[b]
S9 Mat I	4.37	0	10	3.19	3.48	4.55	7.00	0.000[b]
S10 Micr	3.79	0	10	2.67	3.30	3.92	4.98	0.005[b]

Notes: (1) Standard test comparing means difference: [a] Pearson's Chi-squared; [b] Kruskal- Wallis. Variables: see Table 1.

Table 4
Results for first-year performance measured by Grade Point Average (OLS and Quantile regression).

	OLS		q.25	q.50	q.75	q.90
	(1)	(2)				
Intercept	1.286* (0.692)	0.776 (0.730)	2.090*** (0.687)	3.356*** (0.206)	3.745*** (0.510)	4.402*** (0.476)
NoMaths	−0.422** (0.195)	−0.330* (0.199)>	0.114 (0.109)	−0.016 (0.077)	−0.185** (0.110)	−0.160 (0.114)
Maths(A)	0.725** (0.348)	1.075*** (0.384)	0.798** (0.327)	0.673*** (0.127)	0.247 (0.151)	0.059 (0.193)
Gender	0.603*** (0.192)	0.568*** (0.192)	0.346** (0.160)	0.314*** (0.092)	0.269*** (0.096)	0.144 (0.114)
GPA(*PEvAU_MP*)	0.532*** (0.103)	0.558*** (0.103)	0.372*** (0.083)	0.295*** (0.033)	0.361*** (0.076)	0.349*** (0.066)
Motivation	0.203 (0.210)	0.154 (0.210)	0.198 (0.130)	0.096 (0.060)	−0.005 (0.115)	−0.026 (0.126)
ECO(*PEvAU*)		0.464** (0.221)	0.452* (0.234)	0.195 (0.127)	−0.034 (0.110)	−0.268** (0.151)
R^2/Pseudo-R^2	0.114	0.123	0.0499	0.0669	0.0793	0.1192

Table 5
Results for first-year performance measured by Total Credits (OLS and Quantile regression).

	OLS		q.25	q.50	q.75	q.90
	(1)	(2)				
Intercept	−35.752*** (6.206)	−43.435*** (6.494)	−49.202*** (7.995)	−57.147*** (9.210)	−41.810*** (8.802)	2.078 (14.791)
NoMaths	−5.123*** (1.750)	−3.735** (1.771)	−1.863 (2.125)	−3.633 (2.628)	−5.835*** (2.259)	−4.150** (1.954)
Maths(A)	8.604*** (3.121)	13.889*** (3.419)	13.710*** (4.808)	17.524*** (4.670)	16.454*** (4.464)	5.757 (3.557)
Gender	4.161** (1.725)	3.641** (1.709)	6.150*** (2.009)	4.109* (2.170)	2.343 (2.276)	2.978 (2.442)
GPA(*PEvAU_MP*)	9.116*** (0.921)	9.519*** (0.916)	8.161*** (1.226)	11.320*** (1.591)	11.121*** (0.905)	7.142*** (1.706)
Motivation	1.706 (1.881)	0.968 (1.868)	2.387 (1.727)	−0.011 (2.520)	1.298 (2.326)	−0.685 (1.982)
ECO(*PEvAU*)		7.001*** (1.963)	5.546* (3.085)	9.962*** (2.480)	8.641*** (3.048)	1.342 (2.422)
R^2/Pseudo-R^2	0.241	0.262	0.1144	0.1704	0.2002	0.1246

Notes: The standard errors are in parentheses; *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The Variance Inflation Factors (VIF) are below 2.0. Variables: see Table 1.

Table 6
Results for dropout measured by Subject (Logit analysis).

	NoMaths		Maths(A)		Pseudo R^2	Correctly classified
	Coef.	EM	Coef.	EM		
Dropout_S1 Stat	0.469 (0.333)	0.621 (0.044)	1.517* (0.797)	0.201* (0.105)	0.0238	83.86%
Dropout_S2 Fin	0.099 (0.244)	0.023 (0.056)	1.147** (0.529)	0.266* (0.110)	0.0174	59.42%
Dropout_S3 Acc	0.546* (0.289)	0.104* (0.054)	0.339 (0.551)	0.064 (0.105)	0.0267	72.92%
Dropout_S4 EH	−0.017 (0.222)	−0.003 (0.048)	0.865* (0.464)	0,188* (0.100)	0.021	65,38%
Dropout_S8 Mark	−0.622*** (0.221)	−0.127*** (0.043)	1.730*** (0.585)	0.353*** (0.116)	0.0775	68.03%
Dropout_S9 Mat I	−0.541** (0.254)	−0.079** (0.036)	2.456** (1.051)	0.362** (0.154)	0.091	79,27%
Dropout_S10 Micr	−0.234 (0.244)	0.390 (0.040)	2.254*** (0.776)	0.374*** (0.126)	0.0899	76.83%

Notes: The standard errors are in parentheses; *p < 0.10, **p < 0.05, ***p < 0.01. ME: marginal effects.

Table 7a
Results for the first-year performance measured by Subject (OLS and QR).

	S1 Stat		S2 Fin		S3 Acc		S4 EH	
	NoMaths	Maths(A)	NoMaths	Maths(A)	NoMaths	Maths(A)	NoMaths	Maths(A)
OLS	−0.175 (0.262)	0.892* (0.502)	−0.316 (0.252)	0.653 (0.487)	−0.181 (0.256)	−0.215 (0.197)	−0.225 (0.282)	0.957* (0.539)
q.25	−0.165 (0.572)	2.740*** (1.057)	0.000 (0.047)	0.000 (0.466)	−0.238 (0.158)	0.328 (0.834)	−3.62e-16 (0.145)	0.700 (0.693)
q.50	−0.148 (0.331)	0.661 (0.742)	−0.410 (0.485)	1.019 (0.779)	−0.410 (0.415)	1.862* (1.071)	−0.521 (0.664)	0.712 (0.795)
q.75	−0.080 (0.261)	−0,052 (0.336)	−0.487 (0.439)	0.499 (0.571)	−0.334 (0.377)	1.357* (0.700)	−0.117 (0.282)	0.310 (0.732)
q.90	-0-077 (0.214)	−0.419 (0.436)	−0.428 (0.301)	0.562 (0.706)	−0.068 (0.578)	2.432*** (0.794)	0.112 (0.272)	1.789** (0.814)

Notes: The standard errors are in parentheses; *p < 0.10, **p < 0.05, ***p < 0.01. The Variance Inflation Factors (VIF) are below 2.0. Variables: see Table 1.

Table 7b
Results for first-year performance measured by Subject (OLS and QR).

	S5 Law		S6 Ec		S7 Bus		S8 Mark	
	NoMaths	Maths(A)	NoMaths	Maths(A)	NoMaths	Maths(A)	NoMaths	Maths(A)
OLS	−0.215 (0.197)	0.673* (0.377)	−0.223 (0.193)	0.681* (0.371)	−0.204 (0.193)	0.812** (0.383)	−0.660*** (0.243)	1.673*** (0.469)
q.25	−0.052 (0.210)	0.093 (0.566)	−0,126 (0.224)	0.728 (0.503)	−0,100 (0.177)	0.760 (0.506)	1.12e-16 (0.155)	2.000*** (0.482)
q.50	−0.433 (0.276)	0.393 (0.585)	−0.398** (0.191)	0.453 (0.463)	−0.368 (0.370)	0.426 (0.791)	−0.930*** (0.261)	2.707*** (0.863)
q.75	−0.118 (0.239)	0.332 (0.787)	−0.144 (0.170)	0.344 (0.580)	−0.138 (0.269)	0.352 (0.832)	−0.774 (0.602)	1.425** (0.607)
q.90	0.114 (0.405)	1.823* (1.091)	0.007 (0.274)	1.854** (0.878)	−0.006 (0.312)	1.921** (0.909)	−0.634* (0.367)	0.880 (0.654)

Notes: The standard errors are in parentheses; *p < 0.10, **p < 0.05, ***p < 0.01. The Variance Inflation Factors (VIF) are below 2.0. Variables: see Table 1.

Table 7c
Results for the first-year performance measured by Subject (OLS and QR).

	S9 Mat I		S10 Micr	
	NoMaths	Maths(A)	NoMaths	Maths(A)
OLS	−0.947*** (0.292)	2.905*** (0.569)	−0.485* (0.252)	1.578*** (0.485)
q.25	−0.914*** (0.317)	4.034*** (0.626)	−0.716 (0.463)	2.792*** (0.690)
q.50	−1.108** (0.507)	3.107*** (0.850)	−0.647 (0.434)	1.163* (0.660)
q.75	−0.675** (0.279)	1.638** (0.767)	−0.467** (0.200)	0.396 (0.526)
q.90	−0.350 (0.320)	1.185*** (0.417)	−0.476 (0.297)	0.727 (0.851)

Notes: The standard errors are in parentheses; *p < 0.10, **p < 0.05, ***p < 0.01. The Variance Inflation Factors (VIF) are below 2.0. Variables: see Table 1.

1. The first group consists of Finance (S2), Economic History (S4) and Private Law (S5), where the relationships are not significant either for Maths (A) or for NoMaths (we only find a significant -and positive-relationship in quantile 0.9 for Maths(A) in subjects S4 and S5). These results have been expected since Economic History and Private Law are the subjects with the lowest quantitative content.
2. In the second group, composed of Statistics (S1), Accounting (S3), Introduction to Economics (S6) and Introduction to Business Economics (S7), the relation is significant only with Maths(A), and especially in the highest quantiles. These are quantitative subjects, but more related with the Social Science track (Maths(SS) includes a Statistics section).
3. Finally, we find three subjects in which the relationships are significant for both the NoMaths and Maths(A) cases: Marketing (S8), Mathematics I (S9) and Microeconomics (S10). These subjects have the highest quantitative requirements. In them the student must demonstrate high skills in mathematical analysis. The relationships are more intense in the lower quantiles, demonstrating that previous maths skills are necessary to pass the exams of these subjects.

Additionally, having studied Economics, management and business at high school is not a significant variable either for dropout or for the grade achieved in most of the subjects. This result, together with the previous ones, allows us to question the suitability of the Social Sciences track for access to the Business and Management Administration degree.

5. Concluding remarks

The findings of the empirical analysis carried out corroborate the importance of mathematical skills background for success in university Business and Management Administration studies, both for overall academic performance (Alcock et al., 2008; Arnold & Rowaan, 2014; Arnold & Straten, 2012; Asián Chaves et al., 2020; Swope & Schmitt, 2006) and for first-course subjects (Anderson et al., 1994; Ballard & Johnson, 2004; Brown-Robertson et al., 2015; Choudhury & Radhakrishnan, 2009; Dolado & Morales, 2009; Green et al., 2009; Guney, 2009; Johnson & Kuennen, 2006; Lagerlöf & Seltzer, 2009; Mallik & Lodewijks, 2010; Opstad, 2018 and; Ujar & Güngörmu, 2011).

Not having studied mathematics in upper secondary school has a negative and significant impact on the university academic performance, while having studied Advanced Mathematics has a positive and significant relationship with this performance. These results are robust as they are repeated for all the models built and for all the performance indicators chosen.

From the Quantile analysis it is concluded that not having studied mathematics is especially significant for the higher performance ranges. However, having studied advanced mathematics is significant in the lower ranges.

Regarding the subjects of the first course of the Business and Management Administration Degree, the mathematical skills background explains both the probability of sitting the exam and the qualifications achieved in most of the exams.

As we anticipated, the type of pre-university mathematics studied is decisive for those subjects with higher quantitative requirements (Introduction to Marketing, Mathematics I and Microeconomics). On the contrary, we have not found a relationship for Economic History or for Private Law. These results corroborate those achieved by Dolado and Morales (2009), which find a positive and significant relationship for Introduction to Economics and Mathematics I, but not for Economic History. However, our results contradict those of the works of Alcock et al. (2008) and Opstad (2018) since they find a positive and significant relationship for all quantitative and non-quantitative subjects (with the sole exception of Cost Accounting).

Therefore, the students who have studied Maths(A) have an advantage of passing 80% of the subjects of the first year of Business and Management Administration Degree, which is key for the student to continue studying (Arnold, 2015). The direction of the relation of the control variables is in line with the previous literature.

The results of this research have relevant theoretical contributions and interesting practical implications. On the one hand, the current study expands the scientific literature on the role of the mathematical skills background in the success of university Business and Management Administration studies. Research in this field is particularly scarce for the European Higher Education Area, where knowing exactly the determinants of university success is essential for the achievement of one of the five targets of the Europe 2020 Strategy "at least 40% of the younger generation should have a tertiary degree" (European Commission, 2010, p. 5).

On the other hand, the results achieved can be useful in guiding education policies. Thus, our findings contribute to the debate about the appropriateness of Social Science tracks, with less strict mathematics, to access Business and Management Administration studies. The educational systems that recommend and/or reward these tracks introduce erroneous signals since they attract to the Business and Management Administration degrees a student with a profile that is not the most suitable either to face the demands of the degree or to successfully access the current labour market. In the context of the IV Industrial Revolution, the labour market of the graduates of the Business and management Administration area demands increasingly more professionals with more solid quantitative competences.

In view of the above, we suggest changes both in pre-university studies and in the system of access to Business and Management Administration degrees. We propose creating a specific itinerary in the field of Social Sciences with subjects of Advanced Mathematics for students who seek to access these degrees. We also suggest modifications in the weights for calculating the Access Grade to Business and Management Administration degrees, weighting Advanced Mathematics more than Social Science Mathematics, as well as limiting access to those students without enough prior mathematical training.

For further research, this empirical analysis could be enlarged if it were extended to other Spanish universities and even to foreign ones, with different mathematical options in their pre-university studies. It could also be extended to other courses of the degree in Business Administration and Management and to other degrees in the business economic area such as degrees in Economics or Marketing.

CRediT authorship contribution statement

Rosario Asian-Chaves: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Eva M Buitrago:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Inmaculada Masero-Moreno:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Rocío Yñiguez:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

We have no known conflict of interest to disclose.

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Appendix A. Supplementary data

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