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The impact of individual factors on definitions of academic success at an Austrian University

Abstract

Many different operationalisations of academic success are used in the literature, but hardly any study or project can be found comparing the outcomes by identifying factors influencing academic success using different definitions of the construct. This study fills this gap by systematically analysing different operationalisations of academic success using secondary data of three bachelor study programmes at the University of Vienna. Both classical regression analysis and random forest models were used to investigate the impact the methodological approach may have on the outcomes of the studies.
Results demonstrate that the individual factors influencing academic success depend on three dimensions: First, they may differ for each study programme. Second, they may differ depending on the chosen definition of academic success. And third, they may differ depending on the applicable statistical model. This article highlights the importance of viewing the construct academic success as a multidimensional construct that has to be investigated within institutions and within study programmes. It contributes to the understanding of institutional study success in Austria and may also have broader implications.

Keywords

study success, academic success, academic analytics

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1 Introduction

Studierbarkeit (engl. "structural studiability") refers to the study programme structures and curricula and describes to which extent it is possible, that the curriculum can be mastered under the given challenges and within a given time period (see e. g. BUSS, 2019b). According to Buß' understanding of structural "Studierbarkeit", organisational elements of a study programme will influence student learning behavior (BUSS, 2019b). Furthermore, it describes "whether a study programme creates good study conditions, which allow a diverse student body to finish their studies in an adequate period of study, and with adequate learning outcomes'' (BUSS, 2019b, p. 306). Studierbarkeit is often evaluated through academic success (see e. g. KREMPKOW, 2020).

Although there has been a lot of research on factors influencing academic success, the trend of systematically analysing study-programme-specific differences is still an emerging field. In this article, we research and compare factors influencing academic success for different bachelor study programmes by conducting an analysis of different operationalisations. If the outcome on a study programme level indeed depends on different operationalisations of an ill-defined construct of "academic success", arbitrary differences might have serious consequences in an increasingly data-driven higher education system.

According to recent literature, there is a strong demand for further research into the specifics of academic success on the study programme level (e. g. see KREMPKOW, 2020; BÜLOW-SCHRAMM, 2018; BIRKE, BLÜML, & MEZNIK, 2019). If different factors are relevant for academic success in different study programmes, support measures must also be programme-specific.

2 Review of literature

2.1 Operationalisation of academic success

In general, academic success can be seen as a multidimensional construct, although scientific articles often are only taking into account one aspect of it. STEBLER (2000) discriminates between institutional, marked-based and personal academic success. Institutional, academic success refers mainly to how fast students are studying and therefore, how effective they are studying in the view of the institution. Marked-based academic success means to which degree successfully completing a study programme leads to success after the degree (STEBLER, 2000). Personal academic success is another aspect referring to how satisfied someone is with the study programme at their respective stage of life and can be considered as important (see e. g. UNGER, WROBLEWSKI, LATCHEVA, HOFMANN, & MUSIK, 2009).

In his recent theoretical work, SARCLETTI (2020) distinguishes academic success in a narrow sense from academic success in a broader sense. Indicators measuring study satisfaction belong to academic success in a broader sense and can be measured as subjective indicators (SARCLETTI, 2020). Personal and individual academic success is defined as success in the narrow sense. He categorises the marked-based approach as academic success in the broader sense. Furthermore, SARCLETTI (2020) highlights the importance of taking into account more than one approach in an empirical study. LORSON, LUBINSKI, NICKEL, & TOEBE (2011) were trying to summarise the understanding of academic success in the German-speaking area by doing an empirical study and came up with an individual, institutional and a social operationalisation of the construct. Those concepts are very similar to what STEBLER (2000) was describing. KREMPKOW (2020) was taking into account institutional and marked-based definitions of academic success: Study duration and income, job satisfaction and leadership positions.

Regarding the institutional definition mentioned above, dropout rates (see e. g. HINKELMANN, MAUCHER & SEIDL, 2016; HEUBLEIN et al., 2017), final examination grades or finishing a study programme within the given duration of a programme are often used as a dichotomous definition to model academic success. HOFFMEISTER & WESSELS (2018, p. 86) describe academic success as "... to

have the degree certified with a corresponding certificate, against the decision to drop out of the study programme.'' The authors are using the number of successful degrees, the number of dropouts and the sum of credit points over the study course. ALESI AND NEUMEYER (2017) were using three different dependent variables: study duration, final examination grade and study satisfaction. According to SARCLETTI (2020), these types of indicators are called outcome-oriented indicators. By making use of these definitions, it is only possible to use data of students who already completed their studies (or dropped out). Therefore, current developments cannot be modelled. Referring to SARCLETTI (2020), credit-based approaches of academic success can be seen as process-related definitions, as they can be modelled while people are still studying.

To sum it up, the majority of the definitions of academic success are taking into account the completion of a degree (or dropout) or some kind of credits or grades. Some of the definitions are combining this approach with study satisfaction and/or with specified learning outcomes.

In Austria, several large projects are already applying one of the definitions of academic success mentioned above. It is important to note that the specific situation in Austria has yielded an additional, policy-based (see UG 2002 §12 Abs.2. and §59a) de facto definition of academic success: The project STUDMON is using current student data and is defining academic success as continuous student activity, which is defined as not receiving less than 16 credit points (ECTS) per year (IHS, 2020).

The Student Social Survey (IHS, 2021) focuses on certain characteristics (e. g. living conditions) of students in Austria. Connected to the marked-based definition of academic success is the Statistics Austria project ATRACK, which is tracking students after their graduation (STATISTIK AUSTRIA, 2021). And very recently, the Austrian Federal Ministry of Education (BMBWF, 2021) has approved funding for two network projects, "Predictive Analytics Services for academic success management" (PASSt) and "Learning Analytics – Students in Focus". Both projects aim to enhance academic success, and this article is part of the latter project.

2.2 Factors influencing academic success

Which factors are influencing the various definitions of academic success according to the literature? According to KREMPKOW & BISCHOF (2010) and KREMPKOW (2020), one has to distinguish individual from institutional factors and contextual factors. Institutional factors mainly refer to the concept "Studierbarkeit" mentioned in the previous chapter. HEUBLEIN et al. (2017) use a different differentiation. They discriminate between internal and external factors. Internal factors represent factors which are directly influenceable by students (e. g. study behaviour, grades). External factors refer to matters outside of the students' influence, like their living conditions or existing mentoring offers.

KREMPKOW (2020) is mentioning for instance age, gender, parents' education, the grade of the school leaving exam, migration background, professional training before studying as **individual factors**. The grade of the final school-leaving exam was one of the most influential indicators (KREMPKOW, 2020). WESSELS (2018) found, that the more credit points students are gaining in their first year, the more likely they are to be successful in their studies. ARENS et al. (2017) were using the following individual factors as predictors: demographics, educational background, study behaviour with respect to time and financial resources, academic integration and motivational aspects. LEDERMÜLLER, MITTERAUER, SALMHOFER & VETTORI (2015) argued that social background (both educational background of the parents and job of the parents) has an influence on academic success as well as other indicators such as students having a job. Personality traits (e. g. conscientiousness & extraversion), self-esteem, self-concept and self-efficacy also play a role in academic success, but are not within the scope of this article (see e. g. ZEEH & LEDERMÜLLER, 2015; LÖSCH et al., 2017).

On top of these individual factors, KREMPKOW (2020) lists **contextual factors** such as a study programme change, a semester abroad, employment or caregiver duties. In line with the concept of Studierbarkeit, KREMPKOW (2020) also mentions **institutional factors** like quality of teaching, specialisation options and study satisfaction. ARENS et al. (2007) included the type of university, type of the degree, field of study and study conditions into their model as institutional factors. HINKELMANN et al. (2016) show that the type of university or programme restriction also plays a central role and argue that a systemic, multi-dimensional data analysis is necessary.

3 Methods

The following research questions are addressed within this article:

RQ1: Are the factors significantly influencing institutional academic success the same for different study programmes?

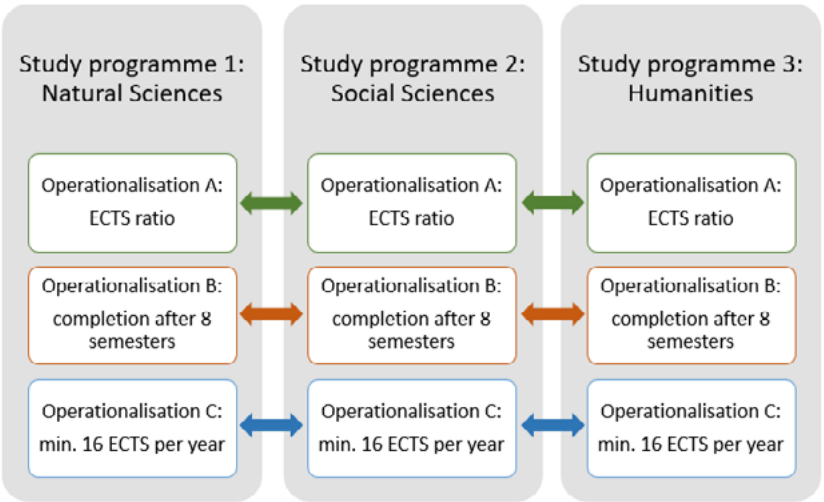

Figure 1: Procedure to analyse RQ1

RQ2: Are the factors significantly influencing institutional academic success the same for the different operationalisations of academic success chosen within a given study programme?

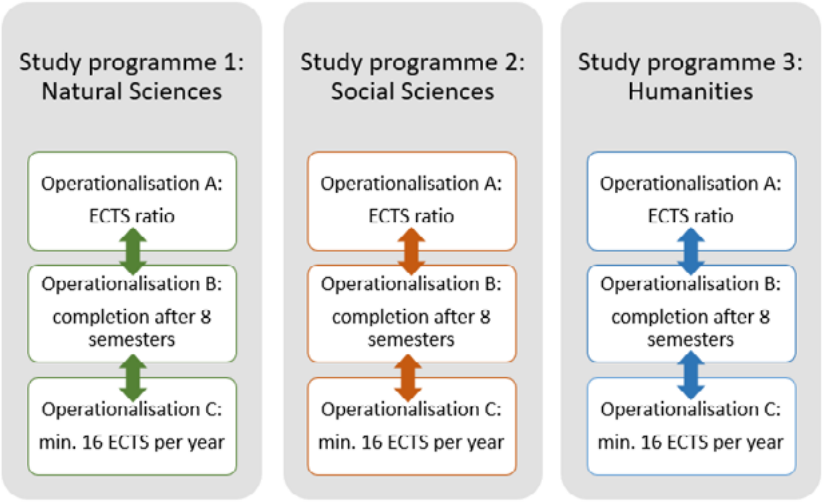

Figure 2: Procedure to analyse RQ2

A list of all potential variables influencing academic success guided by what was found in the literature was created. Admission- and examination data of students first enrolled between 2014 and 2019 for three different study programmes were exported out of the university's data warehouse. The data was prepared and analysed using the program R (R core team, 2020) and an own internal R-package was written. The three programmes chosen differ regarding the discipline and how homogenous the student's enrolled in the programmes might be because of different restrictions (see e. g. HINKELMANN et al., 2016).

The first definition of academic success applied follows a process-oriented approach SARCLETTI (2020) was specifying, and is defined as the ratio of the actual credits

(ECTS) achieved over the credits (ECTS) students should have obtained (as defined by the proposed study path). The second definition applied in this study can be categorised as an outcome-oriented definition (SARCLETTI, 2020): Finishing the programme within the foreseen number of necessary semesters (6 semesters for a bachelor programme) plus 2 tolerance semesters. The third definition is included because it represents an important budget-relevant indicator for Austrian universities. This third operationalisation characterises academic success as continuous student activity, which means to not receive less than 16 credit points per year.

Table 1: Predicted variables

Operationalisation A	Ratio of credit points (ECTS) defined by credit points a student already attained divided by the credit points the student should have obtained defined by the proposed study path.	
Operationalisation B	Was the degree finished within 8 semesters?	yes / no
Operationalisation C	Is there at least one year in which the student gained less than 16 ECTS per year? For calculating this variable credit obtained in the respective study programme were considered.	yes / no

Table 2: Predictors

Ratio of negative grades	All negative grades divided by the absolute number of grades attained in the respective study programme (without aggregated module grades)	
Average grade of positive grades	Average positive grades attained in the respective study programme (without aggregated module grades)	
Age (at study entrance)	Age at study entrance	
Gender	Gender	m / f / d
Semester abroad	At least one semester abroad during the observation period?	yes / no
Secondary studies	Additional study programme in which the student was gaining more credit points during the observation period?	yes / no
Credit points achieved during the first study year	Credit points first study year	
Readmission	Termination and resumption of study programme?	yes / no
School type	Type of school with which the university entrance qualification was obtained; categorized into four Austrian and one international category "others"	AHS, BHS, BRP, Studien-berechtigung, others
Citizenship	Citizenship	AT, DE, others
Migration background	Migration background: yes if a) student's own place of birth is abroad or b) if both parents were born abroad	yes / no

Two performance-based indicators ratio of negative grades and average of positive grades were chosen to be included into the model as independent variables to estimate the impact grades have on study progress (see e. g. study behaviour in ARENS et al., 2017). The educational background of the parents would have been available at our university, but could not be used because of too many missing values. The same predictors were used for all models.

4 Results

4.1 Differences between operationalisations within study programmes

First, the model quality is reported by means of explained variance by the predictos (adjusted R^2) and by an estimation of prediction error (Akaike information criteria – AIC). For modelling operationalisation B (degree within 8 semesters) it was only possible to use the data of students who were already studying at least 8 semesters. For each model (degree programme and operationalisation) all model assumptions could be considered to be fulfilled. First, the standardised regression coefficients and whether or not a significant effect was found were analysed within study programmes and between the three different definitions.

4.1.1 Study programme 1: Natural Sciences

After excluding an outlier, the prerequisite could be assumed to be fulfilled to run model 1 (operationalisation A: Ratio of ECTS). Because missing values were not imputed and only whole datasets were used, the model below is based on n = 1354 observations. The results of the multiple regression analysis of operationalisation A indicated that the predictors explained around 50% of the variance (= .50, $F(15, 1257) = 84.39$, $p < .01$). The AIC of the model was $AIC = 33$. The results of model 2 (operationalisation B: completion after 8 semesters) are based on data of only those students who first enrolled earliest in 2014 and who were already studying at least eight semesters. The logistic regression model is based on the data of n = 807 students with $AIC = 573$. The results of model 3 (operationalisation C: 16 ECTS) are based on data of only those students who first enrolled earliest in 2014 and who were

already studying at least two semesters. This logistic regression model is based on data of n = 1274 students with *AIC* = 1094.

Table 3: Standardised regression coefficients – Natural Sciences

Predictor	**Model 1: ECTS Ratio**	**Model 2: Completion after eight semesters**	**Model 3: 16 ECTS**
Ratio of negative grades	-0.59*	-2.45*	-1.40*
Average grade of pos. grades	**0.06***	0.15	**-0.29***
Age	-0.18*	-0.65*	-0.37*
Gender (female)	-0.04	-0.22	-0.08
Semester abroad (yes)	-0.03	0.05	-0.04
Secondary studies (yes)	**-0.33***	**-1.02***	**-0.45***
Credit points first year	**0.17***	-0.03	**0.32***
Readmission (yes / no)	**-0.09***	**-0.44***	-0.12
School type BHS	0.00	-0.11	0.01
School type BRP	0.04	0.02	0.00
School type Studienberechtigung	**0.04***	0.08	**0.16***
School type others	0.06	0.25	-0.10
Citizenship DE	0.00	-0.06	0.09
Citizenship others	**0.07***	0.11	0.19
Migration background (yes)	-0.07*	-0.53*	0.26*

***p* < .05**

The average grade of the positive grades revealed a significant (although not a large) impact in model 1 and model 3, but not in model 2. A similar, but larger effect was found for the ECTS received during the first year. A readmission showed a

Table 4: Standardised regression coefficients – Social Sciences

Predictor	**Model 1: ECTS Ratio**	**Model 2: Completion after eight semesters**	**Model 3: 16 ECTS**
Ratio of negative grades	-0.33*	-0.77*	-1.06*
Average grade of pos. grades	-0.01	**-0.15***	0.01
Age	-0.14*	-0.43*	-0.31*
Gender (female)	**0.06***	0.02	**0.11***
Semester abroad (yes)	**0.09***	**0.16***	**-0.09***
Secondary studies (yes)	**-0.28***	**-0.33***	**-0.42***
Credit points first year	0.31*	0.31*	0.53*
Readmission (yes / no)	-0.02	-0.04	-0.08
School type BHS	0.00	0.02	**0.12***
School type BRP	-0.01	-0.02	0.07
School type Studienberechtigung	**0.04***	0.09	0.05
School type others	**0.15***	0.28	0.12
Citizenship DE	0.03	0.11	-0.05
Citizenship others	-0.01	0.10	-0.02
Migration background (yes)	-0.13*	-0.55*	0.20*

***p* < .05**

significant and not negligible effect in model 2 (also significant, but small effect in model 1), but no effect in model 3. In case of model 3, even some opposite effects were found.

4.1.2 Study programme 2: Social Sciences

For model 1 (operationalisation A: ECTS ratio) three outliers had to be removed and the data of n = 3065 students was used for building the linear regression model. The predictors explained around 34% of the variance (= .34, $F(15, 3049) = 105.3$, $p < .01$) and AIC = -208. To predict the variable "completion after eight semesters" (operationalisation B, model 2) n = 2226 and for model 3 (operationalisation C: 16 ECTS) n = 3068 observations were used. The AIC of model 2 was AIC = 2643 and the AIC of model 3 was AIC = 3333.

In comparison to model 1 and model 3, gender had no significant impact in model 2, but the average of positive grades had a negative influence. Two of the school type categorizations only revealed a significant impact in model 1 and one additional categorization was found to be significant in model 3. Again, model 3 was revealing opposite effects.

4.1.3 Study programme 3: Humanities

In case of the study programme Humanities, the assumption of normally distributed residuals was not fulfilled and therefore, fitting a linear multiple regression analysis was not appropriate. The variable importance was analysed by random forest machine learning algorithm and the results are displayed in chapter 4.3. The Data of n = 973 students served as a basis of the logistic regression model 2 (operationalisation B) and AIC = 1071. The results of model 3 (operationalisation C) are based on n = 2089 observations. AIC was AIC = 2552). Small differences in significant predictors were found in two cases: Semester abroad and readmission. Also opposite effects were found in model 3.

Table 5: Standardised regression coefficients – Humanities

Predictor	**Model 1: ECTS Ratio**	**Model 2: Completion after eight semesters**	**Model 3: 16 ECTS**
Ratio of negative grades	-	-0.49*	-0.60*
Average grade of pos. grades	-	**-0.42***	**-0.15***
Age	-	-0.45*	-0.22*
Gender (female)	-	0.11	0.03
Semester abroad (yes)	-	**-0.16***	0.08
Secondary studies (yes)	-	**-0.30***	**-0.49***
Credit points first year	-	0.89*	0.64*
Readmission (yes / no)	-	**-0.19***	-0.10
School type BHS	-	0.07	-0.06
School type BRP	-	0.00	0.01
School type Studienberechtigung	-	-0.06	-0.05
School type others	-	0.18	-0.18
Citizenship DE	-	-0.10	-0.05
Citizenship others	-	-0.02	0.02
Migration background (yes)	-	-0.13	0.03

***p* < .05**

4.2 Differences between study programmes using the same operationalization

4.2.1 Operationalization A: ECTS Ratio

Figure 3 compares the influencing factors detailed in the previous section by comparing the standardised regression coefficients where a linear regression analysis could be modelled. The visualisation functions were written making use of the R package *ggplot2* (WICKHAM, 2016). Slightly different effects between the study programmes could be determined between the influences of the variables on the dependent variable.

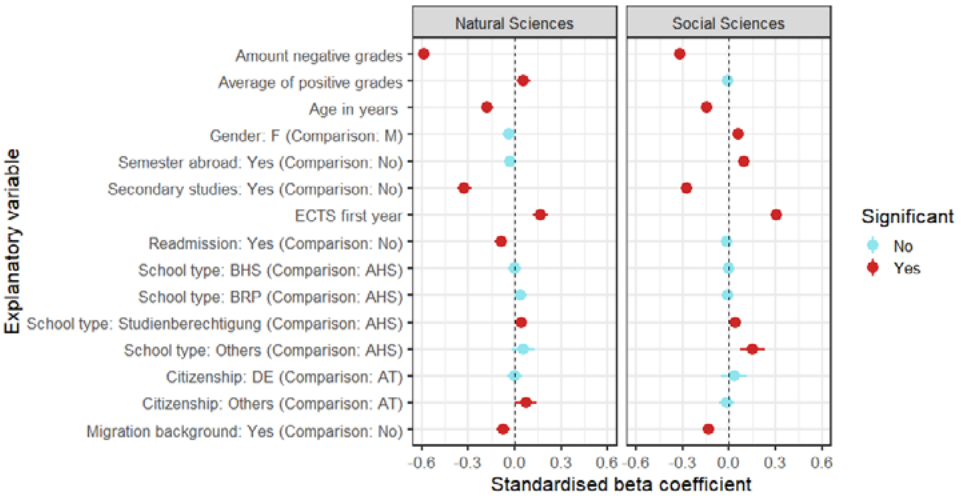

Figure 3: Standardised regression coefficients of two programmes

4.2.2 Operationalisation B: Completion after eight semesters

For the logistic regression outcomes, the odds ratio are displayed in Figure 4. It can be seen that the tendencies and effect sizes are quite similar, although the significance values are not the same, which might be an artefact of different sample sizes.

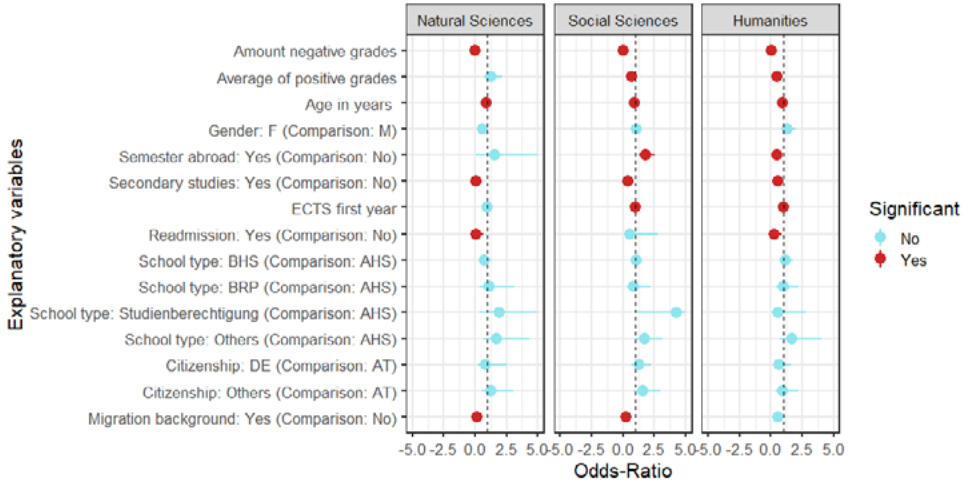

Figure 4: Degree after eight semesters: Odds ratio comparison of three programmes

4.2.3 Operationalization C: 16 ECTS

The odds ratio are also depicted for analysing differences between the three study programmes for the 16-ECTS definition and show a similar picture across the three study programmes.

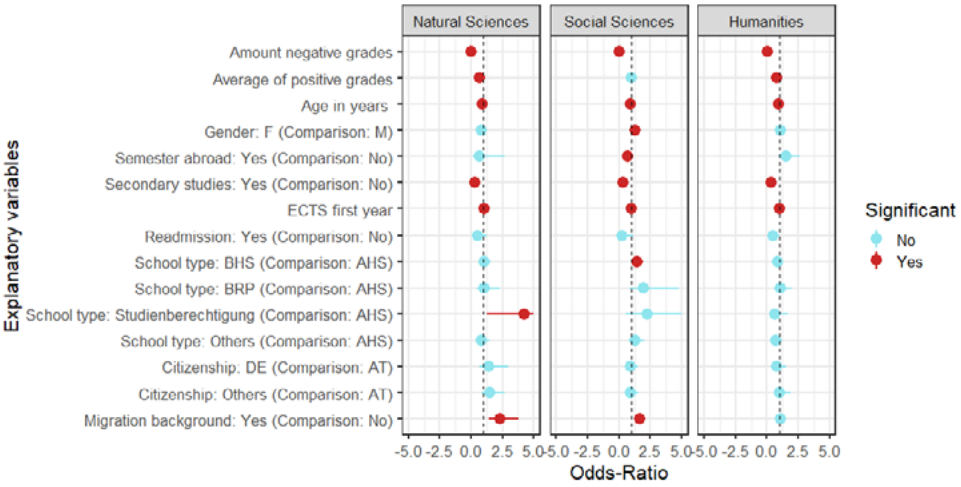

Figure 5: 16-ECTS: Odds ratio comparison of three programmes

4.3 Humanities

Because using an ordinary least squares regression analysis was not possible in case of the study programme Humanities a random forest regression approach was chosen as an additional analysis. For each study programme, the dataset was split into a training (75%) and validation (25%) dataset and 100 trees were used. To impute missing values and to fit the regression trees, the R packages *missRanger* (MAYER, 2021) and *randomForest* (LIAW & WIENER, 2002) were used. In case of the Humanities, around 64% of variance could be explained, in case of the Natural Sciences approximately 77% and in case of the Social Sciences around 49%. Table 6 shows the five most relevant predictors of model 1 (ECTS ratio). For the regression analysis, they were sorted by their absolute value of the standardised regression coefficient, in case of the random forest regression they were ordered by in-node purity (gini importance). Significant predictors are displayed in bold. It can be seen that also the statistical method applied may have an impact on the conclusions drawn.

Table 6: Predictors ordered: Coefficients and gini importance

	Natural Sciences		Social Sciences		Humanities	
Nr.	**OLS**	**RF**	**OLS**	**RF**	**OLS**	**RF**
1	**Amount negative grades**	**Amount negative grades**	**Amount negative grades**	**ECTS first year**	**-**	**ECTS first year**
2	**Secondary studies**	ECTS first year	**ECTS first year**	**Amount negative grades**	**-**	Amount negative grades
3	**ECTS first year**	Average pos. grade	**Secondary studies**	**Average pos. grade**	**-**	Average pos. grade
4	**Age**	Age	**Age**	**Age**	**-**	Age
5	**Readmission**	Secondary studies	**Migration background**	Secondary studies	-	School type

5 Conclusion & Discussion

With our first research question, we investigated the varying importance of multiple factors influencing academic success on study programme level by comparing different model outcomes using data of three different study programmes at the University of Vienna. Our results demonstrate how the impact of individual factors varies from study programme to study programme and thus support the need for subject-specific model generation for each study programme when attempting to accurately model (institutional) academic success. The relevance of taking the study programme into account is congruent with existing literature (see e. g. ARENS et al., 2007; KREMPKOW, 2020). This observation can have tangible implications for Austria's higher education institutions, as insight into the relative influence of factors such as migration background or the students' school type may be paramount

for developing customized student support programmes on the study programme level. Many such initiatives are currently in development like in case of the project "Learning Analytics – Students in Focus" (see e. g. BMBWF, 2021).

Based on our outcomes we further suggest to build separate models for study programmes. As our analysis shows, a classical ordinary least squares regression may not always be the method of choice, since in one case (study programme 'Humanities'), we had to opt for a more robust approach.

As for our second research question, the results demonstrate that seemingly arbitrary differences in the operationalisation of academic success can decide which individual factors significantly influence the construct; small to middle-sized differences in the standardized regression coefficients were found. Some predictors even show opposite effects (e. g. age). The various differences also include basic individual categories such as gender, school type or the average of positive grades, which could all be considered a significant predictor for academic success or not – based solely on the chosen definition. The effect sizes of some of the predictors (like ECTS gained during the first year) showed small to middle-sized differences between the operationalisations. Since no commonly-accepted operationalisation of academic success exists as of yet, there is indeed a certain degree of arbitrariness inherent in any chosen definition, and researchers (or decision-makers) might be well-advised to include more than just one operationalisation in their analysis of academic success, especially if they would lead to impactful decisions about budget allocations. This observation becomes increasingly relevant in light of the dichotomous de facto definition for academic success as postulated in the University Financing Ordinance (see UG 2002 §12 Abs.2. and §59a), which entails tangible financial consequences for Austria's universities.

A quantification and interpretation of the factors influencing academic success or an individual and accurate prediction of study success were not within the scope of this paper. Many variables that would be needed (e. g. employed students, self-concept, and motivational aspects) could not be included, and it was only possible to include secondary data. A repetition of the analysis making use of primary data and making use of data of additional universities would be beneficial. If additional predictors could be added to the model which are increasing adjusted R^2, confounding could be adjusted better and therefore it would allow for better interpretation of associations.

Furthermore, the impact of the statistical method used must be analysed in more detail and could be investigated in future research. The impact of the statistical method applied was only analysed in this paper, because it was not possible to fit an OLS-regression in case of the Humanities.

As our results demonstrate that even the statistically applicable model can differ from study programme to study programme, we recognize a need for more specific, in-depth analysis if we are to understand individual determinants of academic success and accurately assess Studierbarkeit on the study programme level. Conversely, the oft-desired comparability and easy benchmarking with convenient, one-size-fits-all models across the board may not be applicable to assess academic success.

In conclusion we can say, if universities analyse their students' success, it is necessary taking account both: the study programme and the operationalisation that is considered to be relevant in the specific case. According to the results of this article, even institutional academic success needs more than one operationalisation.

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