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Government funding incentives and study program capacities in public universities: theory and evidence*

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Abstract

Objectives aimed at increasing higher education productivity have stimulated use of performance-based funding (PBF) of higher education institutions both in Europe and the US. On theoretical grounds PBF is expected to speed-up study program capacity adjustments. We find from Norwegian data that study program capacities are adjusted favorably to productivity only if there is competition for students. Strengthened PBF does not affect the adjustments. Instead, admissions seem to adjust to secure full enrollment. The results provide an explanation of why very few positive effects of PBF in higher education are found in the literature. Given continued use of PBF to enhance productivity, a likely policy implication is to pay more attention to the overall allocation of study places to higher education institutions.

JEL Classification numbers: H52, I23, I28, L51

Keywords: Higher education funding, performance funding, study program dimensioning, incentives, regulation

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1. Introduction

During the last three to four decades higher education institutions (HEIs) in many countries have met new forms of output or performance-based funding (PBF hereafter). For many European universities this is closely connected to the 1999 Bologna Process and its European Higher Education Area, establishing throughout Europe a common degree structure, with the paramount goal of increased productivity in terms of credits per student and number of degrees.[1] This process has stimulated PBF in higher education in Europe (Jongbloed, 2010; Esterman et al., 2013; Jongbloed and Vossensteyn, 2016). State appropriations to US universities also use PBF models, for example with number of degrees as a performance indicator. However, it is hard to find evidence that public PBF has increased study program output and productivity. This applies to US universities (Shin, 2010; Dougherty et al., 2014, 2016a, 2016b; Tandberg and Hillman, 2014; Hillman et al. 2014, 2015; Ward and Ost, 2021), and to European universities, with a noticeable exception of Agasisti et al. (2021) who, using Russian data, find some positive short run effects of PBF on national entrance exam scores. Jongbloed and Vassensteyn (2016) gives a descriptive analysis on data from OECD countries 1995-2012 concluding "that we still know relatively little about the impact of performance-based funding […]" (p. 593).[2] Given the strong focus and large amounts of resources spent on the reforms in terms of money and people involved in many countries, this is both curious and disappointing, and makes it the more important to understand and find possible explanations.

Our approach is to analyze study program capacity adjustments, and particularly how they are affected by PBF. Capacity decisions affect the number and quality of enrolled students for several years, thus productivity. For a funding maximizing HEI the capacity elasticities in every program must equal one, meaning that a one percent increase in capacity increases the

[1] See, *e.g.*, http://www.wg.aegee.org/ewg/bolognadeclaration.htm Last accessed 29 Oct 2021.

[2] Research incentives may be more effective, see Aghion et al. (2010), Bolli et al. (2016) and Mathies et al. (2020).

number of enrolled students by one percent. An elasticity below one implies that it is optimal to re-allocate capacity from the given program to other programs. Our identification strategy is to test empirically whether the HEIs adjust to this condition, and to what extent more PBF affects the speed of adjustment. Our theoretical model also provides other predictions of importance for the empirical modelling.

We use data from Norway in the empirical analysis, which has the advantage that it is possible to construct from a centralized, common data base rather long time series at the study program level making it possible to test short and long run adjustments. Moreover, Norway implemented a complete PBF model in 2006 which is rather easy to communicate and understand. Not least, Norwegian HEIs have the autonomy to change their study program capacities and structure.

The main conclusion from the empirical analysis is that the HEIs adjust capacity efficiently if there is competition for students and/or internal competition for capacity. Moreover, the 2006 PBF model seems not to have affected capacity adjustments. Instead of adjusting capacities, we find evidence that the HEIs adjust admissions to meet targets of full enrollment. For one program the PBF model has affected *admissions* in the intended direction. The results imply that measures aimed at higher productivity in terms of more credit points per student, such as PBF or other measures, are undermined or less effective because resources are used to handle and secure full enrollment. Understanding the adjustment mechanisms informs policy design. With the given productivity objectives, the likely policy implication is to implement means incentivizing better capacity utilization, or by directly impose tighter governmental restrictions on the number of study places to the HEIs.

The paper contributes to the literature on HEIs adjustments and how they are affected by incentives and PBF schemes. Particularly, we take inertia in the adjustment processes explicitly into account, which is important because it takes a long time to adjust study program portfolios, and hence productivity. For example, the time dependent enrollment contracts between the HEIs and the students give bindings on the program portfolio from which admitted students may choose courses to compose their final degree. The actual composition of staff and infrastructure hindrances may impose delays, and dynamics may also capture formation of expectations.[3]

The paper is organized as follows. The next section gives more detailed motivation for the paper and institutional background. The theoretical and empirical models are presented in sections III and IV, respectively. Section V describes data and Section VI presents the results. Discussion and conclusions appear in sections VII and VIII, respectively.

2. Institutional context

In a comprehensive discussion of responses to reduced funding to public universities in the US, Fethke and Policano (2012) underline the importance of a strategic attitude towards study program dimensioning, admissions and enrollment of students.[4] They state that universities should, for must strategic reasons, ask the questions, "What programs should we offer? What programs should we not offer?", concluding that "Areas of unsatisfactory quality and low productivity can be considered for downsizing or even elimination" (*ibid*, p. 47). Most European universities are public and do not charge tuition,[5] but there is no reason why the leaderships of European universities should not ask these questions, particularly when facing increasing PBF. The implication is that more PBF should not only improve productivity within

[3] The topic is also related to studies of central or federal governments realizing goals through decentralized decision-making by subordinate institutions. Regarding education, see, e.g., Cascio et al. (2013), and local government and fiscal decentralization more generally, see, e.g., Baicker et al. (2012). Empirical studies give mixed results, for instance Burgess (2017) on team-based performance pay in the public employment service in the UK. Borge et al. (2014) on Norwegian data find that decentralization improves efficiency and fiscal balance.
[4] Ehrenberg (2014) argues that the analysis also applies to private universities in the US.
[5] UK is the most important exception. Students in Estonia and Latvia pay tuition, but it is lower than the UK. Universities in the Netherlands, Italy and Spain also charge some tuition. See table C5.1, *OECD Education at a glance 2019*, p. 315, https://www.oecd-ilibrary.org/education/education-at-a-glance-2019_f8d7880d-en Last accessed 29 Oct 2021.

given portfolios of study programs (intensive margin), for instance by teaching improvements, but also generate portfolio changes (extensive margin) with capacity expansion of the most productive programs at the cost of less productive ones. The program portfolio decisions have important long run consequences as they affect for several years the composition of enrolled students and consequently productivity development.

Norwegian data are particularly suitable for analyzing capacity adjustments because a complete PBF model was implemented in 2006, common for all Norwegian HEIs, both research-oriented universities and university colleges (Ministry of Education and Research, 2015, p. 28). The PBF model consists of three clearly defined elements; *base funding* independent of achievements in teaching and research, and *performance* funding based on teaching and research achievements. Performance funding from teaching is clear-cut, depending only on credit points (ECTS)[6] and number of exchange students. The model established four performance variables for research: number of PhDs and publications, each with weight 0.3, and research funding from the EU (0.18) and the Research Council of Norway (0.22).

Model evaluations in 2009 and 2010 led to only minor adjustments to the model. A comprehensive revision implemented in 2017 strengthened the performance and incentive part of the model,[7] and the government underlined that this policy would continue, with higher shares of PBF in the future.[8] To illustrate, for the year 2016 the government allocated 69, 25 and 6 percent respectively to base funding, and funding based on teaching and research

[6] The European Credit Transfer System (ECTS) was implemented in Norway in 2003 as part of the Bologna Process. See https://ec.europa.eu/education/resources/european-credit-transfer-accumulation-system_en Last accessed 29 Oct 2021.

[7] In the 2017 revision of the model, number of graduates became a performance variable, reducing the price per credit point but increasing the total performance funding related to teaching. Hence, the credit point prices in 2017 are not directly comparable with previous years, and 2016 is the last year with the old price structure. See Prop. 1 S (2016-2017), p. 285.

[8] Report to the Storting (White Paper): Meld. St. 18 (2014-2015), p. 59. The 2017 revision was based on recommendations from an expert committee that made a guarded conclusion regarding positive effects of PBF in previous years (Ministry of Education and Research 2015, p. 8-9).

performance. Almost all the funding based on teaching achievements come from production of credit points, 99 percent. The model has a clear and easily accessible price structure for credit points, consisting of six different categories, A-F, where category A has the highest and F the lowest price. Relative to each other the prices have stayed almost constant since they were introduced, implying that they are highly correlated over time.[9] As a relevant illustration (see later), the category A price is on average 2.7 times higher than category D, and about four times higher than category F. The HEIs get funding according to these prices, i.e., they are not competing for funding with the other HEIs within a given government budget limit. This is not the case for research funding, where the HEIs compete for funding within a fixed government budget, implying endogenous prices on the performance variables.

Credit points measure number of exams students pass, thus study progression and completion, so stronger and more accurate funding incentives, alongside more institutional autonomy, are expected to increase credit points per student.[10] This does not only relate to teaching incentives but also incentives for research, because changes in research funding should affect how much time staffs spend on teaching and how much on research.

Institutional autonomy is crucial for PBF to work. The government highlights regularly and explicitly that the annual budget allocation to the HEIs gives them scope to make their own strategic choices and priorities.[11] Norwegian HEIs received from 2003 much more freedom and flexibility to establish and close study programs, and to adjust the number of students in the various programs within an overall limit of students set by the government for each HEI.[12] The

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[9] See https://dbh.nsd.uib.no/styringsdata/finans_kategorier_htmlrapport.action?undermeny=finans_kategorier Last accessed 29 Oct 2021. Tyssøy and Wiik (2019, p. 70) report correlation coefficients between 0.98-0.999.

[10] See St.prp. nr. 1 (2001-2002), p. 150, when the reform was first introduced, and the government's budget proposal for 2016 arguing for more incentives in the future (Prop. 1 S (2015-2016), p. 286).

[11] See, *e.g.*, the budget proposal for 2017, Prop. 1 S (2016-2017), p. 281.

[12] For some of the professional studies, such as medicine, there are target figures for credit points settled in the annual appropriation document from the government to each actual HEI. From the year 2014 'credit points' are changed to 'graduates' for these studies, but it is hard to see that this makes a real difference. Measured in units of 60 ECTS, corresponding to one year of fulltime studies, the target figure for the four medicine programs together was 561 in the academic year 2013/14 whereas the target for 2014 was 546 *graduates*. In 2007-2012 the target figures measured in ECTS were constant 541 every year, implying 541 graduates six years after

HEIs decide and report their program capacities in terms of maximum number of students for the coming year to the centralized, national intake authority, Norwegian Universities and Colleges Admission Service (NUCAS), no later than 1 December.[13] The capacities are binding in the sense that all students fulfilling the requirements for a given program are admitted if the capacity limit allows. Hence, *planned study places* is the decision variable for study program dimensioning. If the HEIs emphasize funding maximization, they should become more eager to allocate study places to the most remunerative programs after the change in 2006.

The students apply for higher education by setting up a prioritized ranking of a maximum of 10 study programs at specific HEIs. The application deadline is 15 April but the applicants may re-order their prioritization after that date until the end of June, when the application closes. In the second half of July admissions (enrollment offers) are emitted, and the so-called supplementary admission starts. The applicants are ranked according to their high school grades. Applicants with more grade points than a program's admission point limit (APL) get admission, and more study places in a program will normally reduce a program's APL, ceteris paribus.[14]

Despite the extensive reforms, we do not see noticeable changes in credit points (ECTS) per student over a long period of time. The average number of credit points per student in Norway was 42.3 in 2003, and 44.9 in 2020, which is 75 percent of a student following normal study progression defined as passing of exams equal to 60 ECTS per year.

The almost constant average credit point rate over several years do not necessarily imply that PBF is ineffective. Several counteracting mechanisms are possible, for instance that more

enrollment given normal study progression. Hence, the government expected five more graduates than previous years' capacities imply, indicating that it wanted to catch up slack in study progression. This is also consistent with observed study progression, see later. Documents referring to the various years can be found here: https://www.regjeringen.no/no/tema/utdanning/hoyere-utdanning/orientering-om-forslag-til-statsbudsjett-for-universiteter-og-hoyskoler/id619675/ Last accessed 29 Oct 2021.

[13] The deadline for withdrawing an application alternative the coming year is 15 December.

[14] See Wallgren Sohlman (2021) for an analysis of the importance of APL and admission probabilities for applicants to higher education in Norway.

students now – as compared to the past – do not to follow normal study progression but do part-time work besides studying. Moreover, teaching effort among academics may have declined, thus generating lower rates, because of heavier total workload (Leišytė et al., 2009; Leišytė, 2016; Horta et al., 2012), or because of stronger preferences and individual incentives for research than teaching (Cummings and Shin, 2014; Geschwind and Broström, 2015; Chen, 2015; Christensen et al., 2020). Funding incentives not getting through to the lowest organizational units, where academic staff teach, may also explain reduced teaching output (Dyrstad and Pettersen, 2017). Weak positive interaction between student ability, student effort and teaching effort is another explanation (Cantillon et al., 2011). Dougherty et al. (2016a, 2016b) list responding obstacles to PBF, such as student composition, inappropriate metrics, insufficient institutional capacity, institutional resistance to PBF, and insufficient knowledge of performance.

With this as background we ask, what would be a HEI's answer to the question of how many study places to allocate to its different study programs, given that it seeks an equilibrium and is only interested in maximizing government funding? The obvious equilibrium is that the number of enrolled students equals the number of study places offered in every program. The answer to the question is that the HEI allocates study places to its different programs such that the elasticities of enrolled students with respect to planned study places, the capacity decision variable, in every program equals one. If this *capacity elasticity* is less than one in any program, it will be optimal to reduce study places in these programs.

Empirically we analyze short and long run study program capacities and admissions adjustments in Norwegian public HEIs, which are almost 100 percent publicly funded (Barr, 2004). We do this by testing whether the HEIs in the long run adjust according to the outlined elasticity rule, and particularly whether more PBF increases speed of adjustment towards long run equilibrium by investigating effects of the 2006 PBF model.

We need reliable and valid data for the empirical analyses, from identically defined study programs across institutions, covering a sufficient long period so it becomes possible to test short and long run adjustments. Another selection criterion is that the programs should represent a subject scope of higher education programs, of importance for model validity assessment, and thus generalization of results. These criteria are demanding, first and foremost because the range and number of study programs in Norway have increased enormously in the actual time span, from a total of about 800 in 1999 to nearly ten times higher in 2007. From this peak, the number has fallen to about 6,400 programs in 2017.[15] Over the years 2000-2005 the annual average increase in programs was close to 14 percent, and from 2005 to 2006 the increase was almost 50 percent. These increases are due to the national follow-up of the Bologna Process to establish more structured and labor market directed study programs, and resulted in more heterogenous study program portfolios, and more frequent adjustments of program content.

It is challenging in this setting to establish data sets for programs that have the same syllabus across institutions and over a long period of time. However, we have been able to establish reliable and valid program level panel data covering (at the most) the period 1999-2017 for two groups of bachelor's programs (23 similar business administration and seven similar history programs), and two integrated master's programs (16 five-years engineering programs[16] and four six-years medicine programs). These four groups span a scope of study programs, regarding discipline and professional content (social science, the Humanities, science and technology, and health/medicine), study lengths, marginal costs, productivity, degree of government regulation, study program size, not least competition for students and study places. They also differ very much regarding funding rewards. The medicine programs belong to the

[15] Source: Norwegian Centre for Research Data, https://dbh.nsd.uib.no/statistikk/ Last accessed 29 Oct 2021.
[16] This is Master of Science in Engineering programs, specializing in 16 different technologies, see the list of programs in Appendix A.

highest funding category A (see above), the engineering programs to category D, and the two bachelors programs to the lowest category F. The groups can be seen as representatives for four different program traditions withing higher education. An important reason for choosing the 16 engineering programs is that they all belong to one university. This means that they are exposed to competition for study places with each other, as allocation of more study places to a program is likely to reduce study places in other engineering programs, for instance due to infrastructure constraints for these programs.

The program variations make the established data set suitable for estimating our parameters of interest but is also helpful when it comes to model evaluation, as the adjustment processes of for instance medicine should be different as compared to the other programs. The institutions included in the analysis also differ in many respects, as there are comprehensive and specialized universities, and a diverse group of university colleges. They also vary according to age, size, location, and mergers during the estimation period.

3. Theoretical model

In this section we outline a theoretical model for study program capacity decisions of a funding maximizing HEI with credit points as the performance metric. More credit points can be achieved either by enrolling more students, which normally gives more credit points (extensive margin), or by increasing number of credit points per student (intensive margin).[17] Hence, the HEI's problem is to find the optimal balance between enrolling more students and their ability to produce credit points.

If a program's capacity restriction is binding, the number of enrolled students depends on the program's number of study places, i.e., capacity. To arrive at the HEI's objective function, we start by analyzing the relationship between student enrollment and program

[17] Number of credit points may also increase by reducing requirements to pass exams, meaning that the production of credit points is a direct decision variable (Frølich and Strøm, 2008). By assumption, we rule out this possibility in the following.

capacity. Next, we analyze the relation between enrollment and the students' ability to produce credit points, and finally how maximization of government funding affects program capacity.

3.1 Student enrollment and program capacity

In the following, let S_p, be the number of *enrolled students* in study program *p*. Changing a program's number of study places (*capacity*), $\hat{S}_p$, will only influence number of enrolled students if there is a sufficiently large number of *applicants* to the program, A_p, which means that capacity restricts demand. The number of applicants facing the HEI is assumed to be an increasing concave function of program capacity with $\partial A_p/\partial \hat{S}_p > 1$ for 'low' levels of $\hat{S}_p$, and $\partial A_p/\partial \hat{S}_p = 0$ for very high levels of $\hat{S}_p$. The motivation for the relation between capacity and applications, is that the more study places a program offers, the more likely it is to get an offer and being enrolled in the program, see Section II. The limits $\hat{S}_p = 0$ gives zero applicants and $\hat{S}_p \to \infty$ a constant number of applicants.[18] The number of applicants also depends on other factors. Factors that the HEIs can control include teaching quality, student accommodation, and working conditions for students, whereas labor market conditions, e.g., earnings and the possibility of finding a job after graduating (Becker, 1964; Black et al., 2005; Reiling and Strøm, 2015), and the attractiveness of the area in which the HEI is located, cannot be controlled by the HEI. We simplify and denote these shift factors X. Number of applicants, which corresponds to demand for study places, is given by the application functions $A_p = A_p(\hat{S}_p, X)$ with $A_p = A_p(0, X) = 0$, $\partial A_p/\partial \hat{S}_p \geq 0$ and $\partial^2 A_p/\partial \hat{S}_p^2 \leq 0$.

Capacity is binding if $A_p(\hat{S}_p, X) > \hat{S}_p$, implying that $S_p = \hat{S}_p$ and $\partial S_p/\partial \hat{S}_p = 1$, saying that an increase in study places (capacity) increases the number of students by the same number. If $A_p(\hat{S}_p, X) \leq \hat{S}_p$, then all qualified applicants are admitted, i.e., $S_p = A_p$. An increase in capacity

[18] If $\hat{S}_p$ is 'very large' it is possible that a further increase in the program capacity reduces the number of applicants because it would signal a poor 'cash cow' program.

will in that case affect enrollment according to the application function, so $\frac{\partial S_p}{\partial \hat{S}_p} = \frac{\partial A_p}{\partial \hat{S}_p} < 1$. Thus, a one-to-one relation between capacity and enrolled students requires $A_p(\hat{S}_p, X) > \hat{S}_p$. On this background we formulate the enrollment function as equation (1), with derivatives as indicated depending on the number of applicants relative to program capacity:

$$S_p = S_p(\hat{S}_p, X), \tag{1}$$

where $(i)\ \frac{\partial S_p}{\partial \hat{S}_p} = 1\ if\ A_p \geq \hat{S}_p$ and $(ii)\ 0 \leq \frac{\partial S_p}{\partial \hat{S}_p} < 1\ if\ A_p < \hat{S}_p$.

In case *(i)*, capacity restricts demand, and in case *(ii)* the opposite applies. *Equilibrium* in a program requires no vacant study places ($S_p = \hat{S}_p$) and corresponds to case (i), so the capacity elasticity $\frac{\partial S_p}{\partial \hat{S}_p}\frac{\hat{S}_p}{\hat{S}_p} = 1$. If $S_p = A_p < \hat{S}_p$, there is excess supply of study places, and a capacity elasticity less than one. Figure 1 illustrates the relationships between program capacity, enrollment, and applicants.

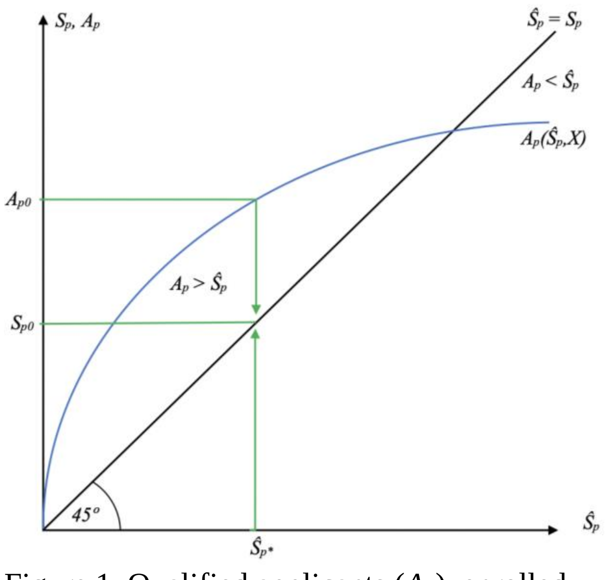

Figure 1. Qualified applicants (A_p), enrolled students (S_p) and program capacity ($\hat{S}_p$).

3.2 Credit point production and student enrollment

A study program's total production of *credit points*, CP_p, depends on the students' ability to acquire new knowledge. The intake process ranks students according to their previous achievements, so the students' average ability is assumed to be a decreasing function of the number of ranked applicants. This means that there is a positive but decreasing relationship between number of enrolled students and total number of credit points:

$$CP_p = CP_p(S_p, Z), \quad \frac{\partial CP_p}{\partial S_p} > 0, \; \frac{\partial^2 CP_p}{\partial S_p^2} < 0 \tag{2}$$

Quality of teachers, lectures, organized teamwork, seminars and assignments, and the availability of reading rooms, etc., may affect production of credit points. Factors external to the HEI may also have a direct impact on the number of produced credit points. For instance, a tight labor market may intensify students' effort (Reiling and Strøm, 2015), whereas high student cost of living may work in the opposite direction because part-time work to earn money reduce study time. The implication is that there are both external and internal factors affecting the average number of produced credit points *directly*, which we capture by the shift variable Z in equation (2).

3.3 Pure monetary objective function

We assume that a HEI allocates capacity to its study programs such that *net* government funding, F, is maximized. The HEI knows the application functions $A_p = A_p(\hat{S}_p, X)$, for instance based on previous experience. To begin with, we assume that the HEI maximizes without restrictions on its total number of study places. More students in a program are assumed not to affect credit point production in other programs, so its net funding function becomes

$$F = \sum_{p=1}^{P} [q_p CP_p(S_p(\hat{S}_p, X), Z) - c_p S_p(\hat{S}_p, X)], \tag{3}$$

where q_p is the price per CP from study program p in the government's funding model, and c_p is the short run constant marginal cost of one more student. Maximizing funding with respect to capacity, $\hat{S}_p$, the first order conditions (FOC) can be written as

$$\frac{\partial F}{\partial \hat{S}_p} = q_p r_p \frac{\partial S_p}{\partial \hat{S}_p}\left(\varepsilon_p - \hat{c}_p\right) = 0, \qquad \forall p \tag{4}$$

where r_p is the average number of credit points per student in program p, CP_p/S_p. The credit point elasticity $\varepsilon_p = \partial CP_p/\partial S_p \times S_p/CP_p$ gives the percentage change in credit points when the number of students increases by one percent, and $\hat{c}_p = c_p/q_p r_p$ is the *effective* or net marginal cost of one more student. For a given marginal cost (c_p), a higher price (q_p) and/or a higher average number of credit points per student (r_p), the lower is $\hat{c}_p$.[19] In equilibrium the first order condition is satisfied if income from more credit points balances the effective cost of one more student ($\varepsilon_p = \hat{c}_p$).[20]

3.4 Restricting total number of students

Binding restrictions on the total number of study places, for instance because of infrastructure constraints or because the government sets a cap on the HEI's total number of students, will affect capacity dimensioning. Hence, when optimizing program capacities, the HEIs must take these restrictions into account. To discuss this, we assume that there is an overall capacity limit $\hat{S}$, so that the restriction for a given HEI becomes $\sum_{p=1}^{P} \hat{S}_p \leq \hat{S}$, where P is the total number of study programs.

An interior solution requires that the funding rate of substitution between all pairs of program capacities i and j equals one,[21] as the HEI's restriction implies $\Delta\hat{S}_i = -\Delta\hat{S}_j$:

[19] If the HEI aims at maximizing credit points instead of funding, e.g., as a measure of teaching quality or effectiveness, $q_p = 1$ in (3) and (4). The interpretation of the FOC is qualitatively the same.

[20] The compressed expression $\varepsilon_p - \hat{c}_p$ can be written $S_p/CP_p \times (\partial CP_p/\partial S_p - c_p/q_p)$. Formally, $\partial S_p/\partial \hat{S}_p = 0$ satisfies FOC but this cannot correspond to an equilibrium, cf. equation (1).

[21] This requires full substitutability between two or more programs, which is the case except for some professional programs (e.g., physician, psychologist, dentist, pharmacist).

$$-\frac{\mathrm{d}\hat{S}_i}{\mathrm{d}\hat{S}_j} = \frac{q_j r_j \frac{\partial S_j}{\partial \hat{S}_j}}{q_i r_i \frac{\partial S_i}{\partial \hat{S}_i}} \times \frac{(\varepsilon_j - \hat{c}_j)}{(\varepsilon_i - \hat{c}_i)} = 1 \tag{5}$$

In *long run equilibrium* all study places are filled, implying $\partial S_p/\partial \hat{S}_p = 1$ $(\forall p)$, so equation (5) becomes

$$q_j r_j(\varepsilon_j - \hat{c}_j) = q_i r_i(\varepsilon_i - \hat{c}_i) \tag{6}$$

To illustrate, assume that we have two programs *i* and *j* where prices, credit point rates and marginal costs are the same ($q_i = q_j$, $r_i = r_j$, $c_i = c_j$). In this case it is only credit point production that matters, and (6) says that the HEI is optimally adjusted if study places are allocated such that $\varepsilon_i = \varepsilon_j$. If $\varepsilon_i > \varepsilon_j$ ($\varepsilon_i < \varepsilon_j$) then study places – and students, as this is long run equilibrium – should be taken from program *j* (*i*) and given to program *i* (*j*).

From the funding function (3), a constant level of net funding gives iso-funding curves showing combinations of study place allocations to different pairs of study programs. The slope of these curves, $d\hat{S}_i/d\hat{S}_j$, are negative irrespective of $A_p > \hat{S}_p$ (and $\partial S_p/\partial \hat{S}_p = 1$), or not. An interior solution requires that the slopes of the iso-funding curves are convex, which they are in long run equilibrium, given that $CP_p(S_p, Z)$ is a concave function of S_p, cf. equation (2).[22] The iso-funding curves become steeper when the price q_j, or the number of credit points per student, r_j, increase, saying that it becomes costlier to reduce $\hat{S}_j$ in terms of $\hat{S}_i$, because the HEI gets more funding per enrolled student in program *j* relative to program *i*. The opposite applies if q_i and r_i increase. On the other hand, higher (lower) marginal costs, c_j, makes it less (more) costly to reduce $\hat{S}_j$ in terms of $\hat{S}_i$, and the same applies symmetrically to $\hat{S}_i$ if c_i increases. A high credit

[22] In long run equilibrium the second order derivative becomes
$\frac{d^2\hat{S}_i}{d\hat{S}_j^2} = \frac{\partial^2 CP_j}{\partial s_j^2}\left(q_i \frac{\partial CP_i}{\partial S_i} - c_i\right) - (q_j \frac{\partial CP_j}{\partial S_j} - c_j) q_i \frac{\partial^2 CP_i}{\partial S_i^2} \frac{\mathrm{d}\hat{S}_i}{\mathrm{d}\hat{S}_j} / \left(q_i \frac{\partial CP_i}{\partial S_i} - c_i\right)^2 > 0.$

point elasticity in program j, ε_j, also makes the iso-funding curve steeper because a reduction of study places, thus students, in that program gives a large reduction in credit points, and consequently funding. For a higher elasticity in program i we get the opposite.

The adjustment mechanism in long run equilibrium is illustrated in Figure 2: Suppose that the HEI has allocated the number of study places such that the substitution rate is larger than one, illustrated by point *a* in Figure 2. Then it is possible to re-allocate study places to, e.g., point *b*. At allocation *b*, government funding is the same, F^0, but the study place restriction is not binding. However, with an allocation such as *a* in Figure 2, the HEI will optimize its government funding by moving to *c* giving $F = F^1 > F^0$. Outside equilibrium, i.e., $\partial S_j/\partial \hat{S}_j < 1$, an increase in $\partial S_j/\partial \hat{S}_j$ towards one in equation (5) also will make the iso-funding curve steeper, so it becomes costlier to reduce $\hat{S}_j$ in terms of $\hat{S}_i$. Analogously, an increase in $\partial Si/\partial \hat{S}_i$ gives the opposite result.

Theoretically, corner solutions cannot be ruled out. If $\partial S_j/\partial \hat{S}_j = 1$, marginal costs close to zero, and credit points per student and credit point elasticities equal ($r_i = r_j$ and $\varepsilon_i = \varepsilon_j$), it follows from equation (6) that the iso-funding curves are linear with slope q_j/q_i, so program dimensioning will depend only on the relative prices in the government's funding model. If the price of credit points in program j is higher than in program i, the whole capacity will be allocated to program j. However, $\partial S_j/\partial \hat{S}_j$ sufficiently below one may change this conclusion, even to the opposite.

For a given program p, we summarize the above discussion by equation (7), where the sign of the partial derivatives are indicated below each argument:

$$\hat{S}_p = \underset{+}{f(q_p}, \underset{+}{r_p}, \underset{-}{c_p}, \underset{+}{\varepsilon_p}, \underset{+}{\partial S_p / \partial \hat{S}_p}) \qquad (7)$$

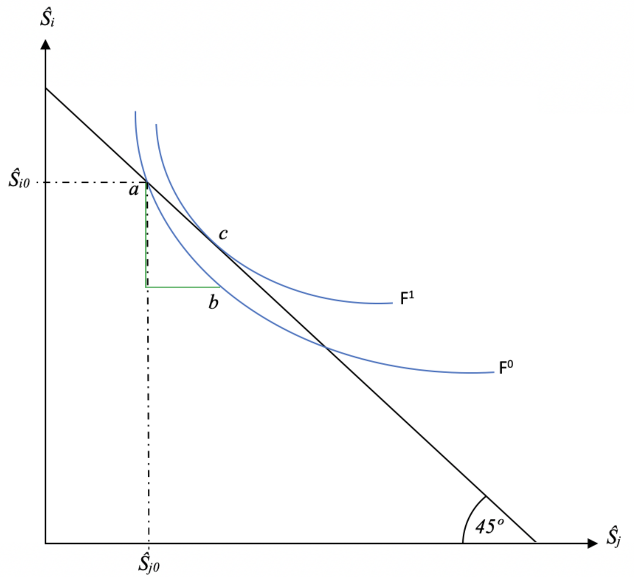

Figure 2. Allocation of study places between two programs, $\hat{S}_i$ and $\hat{S}_j$.

4. Empirical modelling

The theoretical model gives the empirically testable prediction that the elasticity of planned study places with respect to enrolled students – the capacity elasticity – equals one in the long run. One may argue that irrespective of the introduction of a PBF model, the institutions would adjust according to this condition to secure optimal use of resources. We estimate how the HEIs adjust to deviations from the predicted long run relation between capacity and enrolled students, and whether adjustments change after the implementation of the PBF model in 2006. The theoretical model also provides other unambiguous predictions, cf. equation (7), which are used when assessing the results. In this section, we first formulate the model for testing long run adjustments and short run dynamics, and next explain how to use the other predictions.

4.1 Long run equilibrium and short run dynamics

The predicted long run equilibrium relation between planned study places and enrolled students motivates the use of an Equilibrium-Correction Mechanism (EqCM) model. We use the same variable notation as in the theoretical model.

Planned study places in year t ($\hat{S}_{p,t}$) is the capacity decision variable, and the HEIs make their decisions the year before the study programs starts ($t-1$). Thus, the last available information at the time of decision is from year $t-1$, but number of applicants, enrolled students and planned study places in previous years give information of likely importance in the decision process. This motivates the inclusion of lagged differences to capture short run dynamics. On this background, we use the following *general* EqCM model for planned study places:[23]

$$\begin{aligned}\Delta ln\hat{S}_{p,t} &= const + \boldsymbol{\alpha_1} EqCM_{p,t-1} + \boldsymbol{\alpha_2} EqCM_{p,t-1} \times F_{2006} + \beta_1 F_{2006} + \beta_2 \Delta F_{2006} \\ &+ \sum_{s=1}^{3} \gamma_{1s}\, \Delta ln\hat{S}_{\,p,t-s} + \sum_{s=1}^{3} \gamma_{2s}\, \Delta lnS_{p,t-s} + \sum_{s=1}^{3} \gamma_{3s}\, \Delta lnA_{p,t-s} \\ &+ Merger\ dummy\ variables + \ Program\ FE + error\ term\end{aligned} \tag{8}$$

In eq. (8), ln denotes log-transformation, Δ denotes first difference, and the subscript p and t are indicators for program and year.[24] The dependent variable $\Delta ln\hat{S}_{p,t}$ is growth in number of planned study places from year $t-1$ to t. The explanatory variable $\Delta lnS_{p,t-s}$ is enrollment growth, $\Delta lnA_{p,t-s}$ is growth in number of primary applicants, and $\Delta ln\hat{S}_{p,t-s}$ growth in planned study places, all referring to previous years. The dummy variable F_{2006} represents the change in government funding in 2006, equal to one from 2006, otherwise zero. The equilibrium correction term, $EqCM_{p,t-1} = ln\hat{S}_{p,t-1} - lnS_{p,t-1}$, corresponds to a long run relation with an imposed elasticity of one between $\hat{S}_{p,t}$ and $S_{p,t}$, lagged one year. *Merger dummy variables* capture possible effects at the program level of institutional mergers, and/or changes in status from university college to university. As each of the medicine and history programs are offered only by one HEI, *Program FE* captures characteristics of the study programs, and the institutions and locations (campuses) to which they belong. For engineering, the fixed effects correspond

[23] Three years lags were chosen to ensure as rich as possible short run dynamics. Equation (8) and (9) are general specifications simplified to parsimonious models during the modelling process.
[24] Study programs are cross section units and identical to institution, except for the business administration programs where six HEIs have more than one program due to mergers. More details in the data section below.

solely to program as all these programs belong to the same university, located at the same campus. Data are presented in Section V.

The parameters α_1 and α_2 are our primary interest, both assumed to be negative as they measure speed of adjustment from disequilibrium to equilibrium. If the number of planned study places is larger (smaller) than the number of enrolled students *last* year, less (more) study places will be allocated to the program *this* year. Hence, the program capacity will move towards equilibrium where capacity equals number of students. The same arguments applies for α_2, as we expect that the funding change in 2006 made it even more important to tighten gaps between planned and enrolled students.

As explained in the Introduction, the intake process is centralized at the national level in Norway but the respective HEIs decide during this process the number of admissions. Admissions are binding offers of study places which directly influence utilization of the study program capacities. Most students accepting an admission enroll when the semester starts. However, some reject the offer of a study place, or accept but do not show up. In other words, the relation between admissions and enrollment has a random component, which the institutions are aware of when they decide admissions. If the HEIs do not allow for those not enrolling, qualified students with lower priority get their acceptance later in the fall and lose the first weeks of lectures.[25] Hence, all HEIs offer more admissions than planned study places. Particularly, study programs that have problems utilizing the decided capacity may admit much more students than their allocated capacity allows. One reason for this could be fear of losing study places in the future. So instead of allocating study places to other programs, they are possibly filled with less qualified students than otherwise would have been the case. Therefore, it is interesting to see if admission practices are consistent with the empirical results from the

[25] NUCAS informs on their website that over-admissions in the respective programs is based on the fraction of accepted students that register (enroll) at semester start.

analyses of study places. This is the background for estimating the following general EqCM model:

$$\Delta lnAdm_{p,t} = const - \boldsymbol{\theta_1} EqCM_{p,t-1} - \boldsymbol{\theta_2} EqCM_{p,t-1} \times F_{2006} + \lambda_1 F_{2006} + \lambda_2 \Delta F_{2006}$$

$$+ \sum_{s=1}^{3} \mu_{0s}\, \Delta lnAdm_{p,t-s} + \sum_{s=0}^{3} \mu_{1s}\, \Delta ln\hat{S}_{p,t-s} + \sum_{s=1}^{3} \mu_{2s}\, \Delta lnS_{p,t-s} + \sum_{s=0}^{3} \mu_{3s}\, \Delta lnA_{p,t-s} \quad (9)$$

$$+ \; Merger\ dummy\ variables + \; Program\ FE + error\ term,$$

where the dependent variable $\Delta lnAdm_{p,t}$ is growth in admissions. Multiplying the equilibrium correction term in eq. (8) by minus one gives $EqCM_{p,t-1} = lnS_{p,t-1} - ln\hat{S}_{p,t-1}$ in model (9). In analogy to model (8), the parameters θ_1 and θ_2 are of main interest. A positive estimate of θ_1 ($-\theta_1 < 0$) measures speed of adjustment back to equilibrium: If the number of students in the previous year is larger than planned study places ($S_{p,t-1} > \hat{S}_{p,t-1}$), the change in admissions in year *t* must be negative to attain long run equilibrium, and vice versa. Analogous to model (8), we expect θ_2 to be positive as the funding change in 2006 should make it more important to use admissions actively to reach full capacity after the reform. Short run dynamics of the two models are similar, except that $\Delta lnA_{p,t}$ is included in (9) because the HEIs know the number of applicants in year t, when the admission decisions are taken.

4.2 Program differences

The theoretical model predicts that high (low) credit point prices (q_p), high (low) average and marginal credit point production (r_p, ε_p), low (high) marginal costs (c_p), and high (low) responsiveness in student enrollment ($\partial S_p/\partial \hat{S}_p$) increase (reduce) study program capacity. Except from credit point prices, quantitative data on these variables are not available. However, the price series are highly correlated and therefore useless for direct estimation of price effects (c.f. Section II), so we are left with qualitative information which will be used when assessing the empirical results. This becomes possible as the four programs selected for the empirical analysis differ on important dimensions, c.f. criteria for selection of programs. As explained in

Section II we have selected the two integrated master's programs engineering and medicine, and the two bachelor's programs business administration and history.

The professional programs medicine and engineering have the highest credit point prices in the government's funding model (see Section II), reflecting high marginal costs, and they have the highest completion rates,[26] giving the highest averages of credit points per student per year. To get admission, the two programs require high grade point averages (GPA) from high school,[27] so it is likely that both programs have high credit point elasticities. The bachelor's programs in business administration and history have lower completion rates, thus lower averages of credit points per student.[28] Most of these programs have admitted all qualified applicants, only requiring that the formal requirements for admission are fulfilled.[29] On this background, it is reasonable to assume much lower credit point elasticities for business administration and the history programs. As mentioned above, the study programs in medicine face target figures for credit points. This may also apply to engineering although not explicitly

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[26] According to information from NTNU (*Frafall og gjennomføring for teknologiprogram*), 75.5 percent of the students in the 2010 engineering classes at NTNU have completed their degree one year after regulated study time. A report from the Faculty of medicine at the University of Oslo shows that of a representative class of medical students, 80 percent finish one year after regulated study time. (https://www.uio.no/for-ansatte/arbeidsstotte/sta/undersokelser/dokumenter/frafall-ved-det-medisinske-fakultet-sluttrapport-2015.pdf) Last accessed 29 Oct 2021.

[27] The applicants are ranged according to their GPA, multiplied by 10. A program's *admission point limit*, APL (reported by NUCAS, see data section), is the admission point the last student admitted to a given program has. For medicine and engineering, the *average* APL (min, max) in our data set are 60 (57, 65) and 55 (44, 68), respectively. Students having completed courses in mathematics and natural science in high school get additional admission points. Without additional points, the maximum GPA a student can have is six, which gives 60 points. Both medicine and engineering require specified high course levels in mathematics and natural science from high school.

[28] The estimated completion rate for the 2010 classes in the bachelor's programs in business administration in Norway one year after regulated study time (three years) is 54 percent. We have not been able to obtain the corresponding rate for the bachelor's programs in history, but the average rate for all the bachelor's program in the humanities is 36.7 percent. Source: *Tilstandsrapport høyere utdanning*, p. 240 (in Norwegian only), see (https://www.regjeringen.no/contentassets/ff233dff1b2a48359ee92c7e1b4eb876/tilstandsrapport2016_endelig_nettversjon.pdf), Ministry of Research and Higher Education. Last accessed 29 Oct 2021.

[29] Of the 104 history and 364 business administration admission processes from which we use data, respectively 64 and 72 percent admitted all qualified applicants. Calculating *admission point limits* from the intakes where planned study places is a binding restriction, we get 44 (max = 49) and 45 (max = 54) points, respectively.

and formally settled between the government and the university.[30] The distinctive characteristics of the programs are listed in Table 1.

Table 1

Comparison of the programs included in the empirical analysis

	Bachelor's programs		*Master's programs*	
Variables	*History*	*Business administration*	*Engineering*	*Medicine*
Price per credit point (q_p)	Low	Low	Medium	High
Marginal cost (c_p)	Low	Low	Medium	High
Credit points per student (r_p)	Low	Low	High	High
Credit point elasticity (ε_p)	Low	Low	Medium	High
Admission requirements	Low	Low	High	High
Direct government regulation	Low	Low	Medium	High
Admissions per study place	High	High	Low	Low
Applicants per study place	Low	Medium	Medium	High
Student enrollment responsiveness to increases in study places ($\partial S_p / \partial \hat{S}_p$)	Low	Medium	High	High

5. Data

Data are collected from Norwegian Universities and Colleges Admission Service (NUCAS). Because of changes in the study program structure, c.f. Section II, as well as mergers between university colleges, and universities and university colleges, the study program identifying codes for the business administration and history programs changed, even though the programs' contents did not. We prevent misplacing study programs by painstakingly checking the study program booklets available for all the covered years at the web page of the NUCAS. The programs are listed in Appendix A.

Data from the four medicine programs offered by the universities of Bergen, Oslo, Tromsø and Norwegian University of Science and Technology (NTNU) in Trondheim cover

[30] The argument is that the university graduates about 80 percent of all MSc in Engineering in Norway so large (downward) changes in number of graduates would possibly be followed up by the government.

the longest period, 1999-2017. This is a balanced panel data set. For the other programs we have unbalanced panel data. Several of the business administration programs are established after 1999, but only one within the same HEI.[31] For engineering, the analysis is within one university (NTNU). Except the Nano technology program, all the engineering programs are established before 1999. The seven bachelor's programs in history also nearly give a balanced data set covering the period 2003-2017.[32] The starting year 2003 is due to the new bachelor's structure implemented that year.

Indexes of aggregate planned study places ($\hat{S}_{p,t}$) for the four program groups are given in Figure 3, illustrating some striking differences between the groups. Data inspection at the program level reveals much more variation within the groups.[33] The medicine programs are the most stable, with constant number of planned study places for long stretches of time, ending up with a capacity 24 percent higher in 2017 compared to 1999. The small stepwise increases illustrate the difficulties of scaling up and down capacity in these programs, which are resource intensive and subject to tight government regulation. The picture is different for the engineering programs, as there is an overall decreasing number of planned study places in the years 2000-2005, with varying changes within the group. A positive trend with some variation appears after 2005, and in 2015 total capacity is about five percent higher than in 1999. The programs in business administration have a strong positive trend, whereas the history programs in total are stable from 2011.[34]

[31] This relates to the BA program located in the town *Mo i Rana* in 2004 belonging to the program portfolio of Bodø University College which already had a similar BA program located in the town of *Bodø*. Because of mergers, one institution has four programs, three institutions have each three programs, and two have each two programs. The programs are located at different campuses. See Appendix A.
[32] The only exception is the history program at NTNU, where the first observation is 2004.
[33] Appendix B gives more descriptive statistics.
[34] The dip in 2001 for business administration is due to missing observations in some programs in that particular year. For the year 2003 these programs did not report planned study places, so the 2003 index is interpolated. The dips in 2004 and 2005 for the history programs is due three (out of seven) missing values in 2004 and one in 2005. We also have two missing observations for these programs in 2003, so the index in 2017 overstate the total program capacity at the end. In the regression analysis cases with missing observations are excluded.

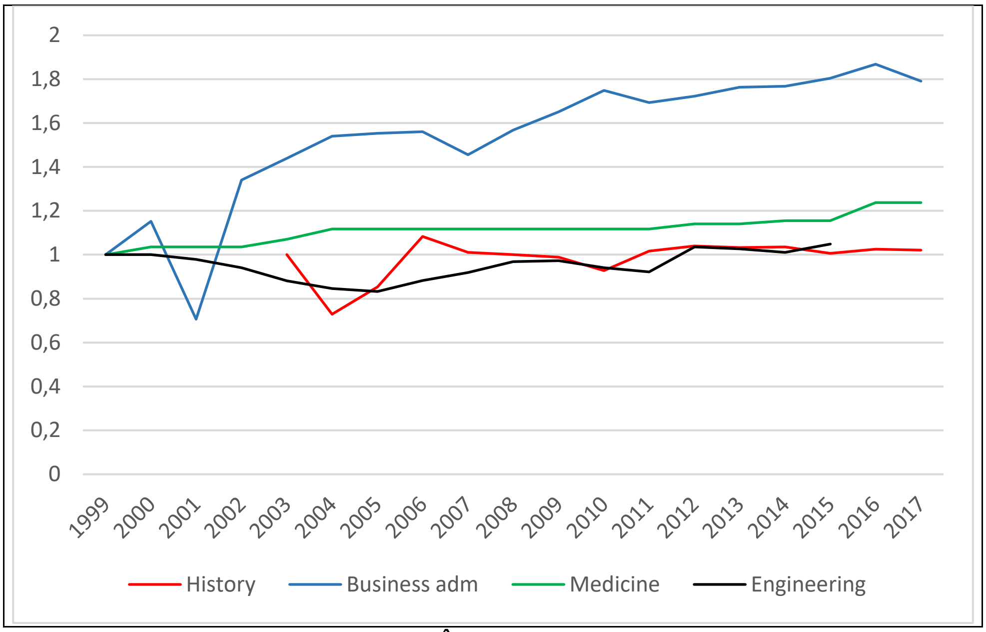

Figure 3. Planned study places ($\hat{S}_{p,t}$), index. Business adm. and Medicine 1999-2017 ($\hat{S}_{ba,1999}$ = 1100, $\hat{S}_{med,1999}$ = 425), Engineering 1999-2015 ($\hat{S}e_{neng,1999}$ = 1578) and History 2003-2017 ($\hat{S}_{hist,2003}$ = 480).

Figure 4 presents the number of enrolled students ($S_{p,t}$), admissions ($Adm_{p,t}$), and primary applicants ($A_{p,t}$), all as shares of planned study places.[35] Admissions are systematically higher than planned study places, as expected. For the engineering programs, on average over-admittance is 1.6 (1; 2.3), i.e., 60 percent. The corresponding numbers for business administration, history and medicine are on average respectively 2.3 (0.6; 8.3), 1.9 (0.3; 4.3) and 1.6 (1.1; 1.6). The (min; max) numbers illustrate the large variation within the respective groups. For instance, the lowest ratio is 0.6 in the business administration group, implying empty places, whereas the highest is 8.3, implying that more than eight students on average are offered the same study place. Also, for the history programs there are several years with empty places, and on average the number of admissions is higher than the number of primary applicants in these programs. Primary applicants have ranked the given program at the top of their prioritized list of study programs, whereas the total number of applicants to a program also

[35] Numerators and denominators in figure 4 are consistently estimated, c.f. the preceding footnote. Note that the panels in figure 4 use different scales.

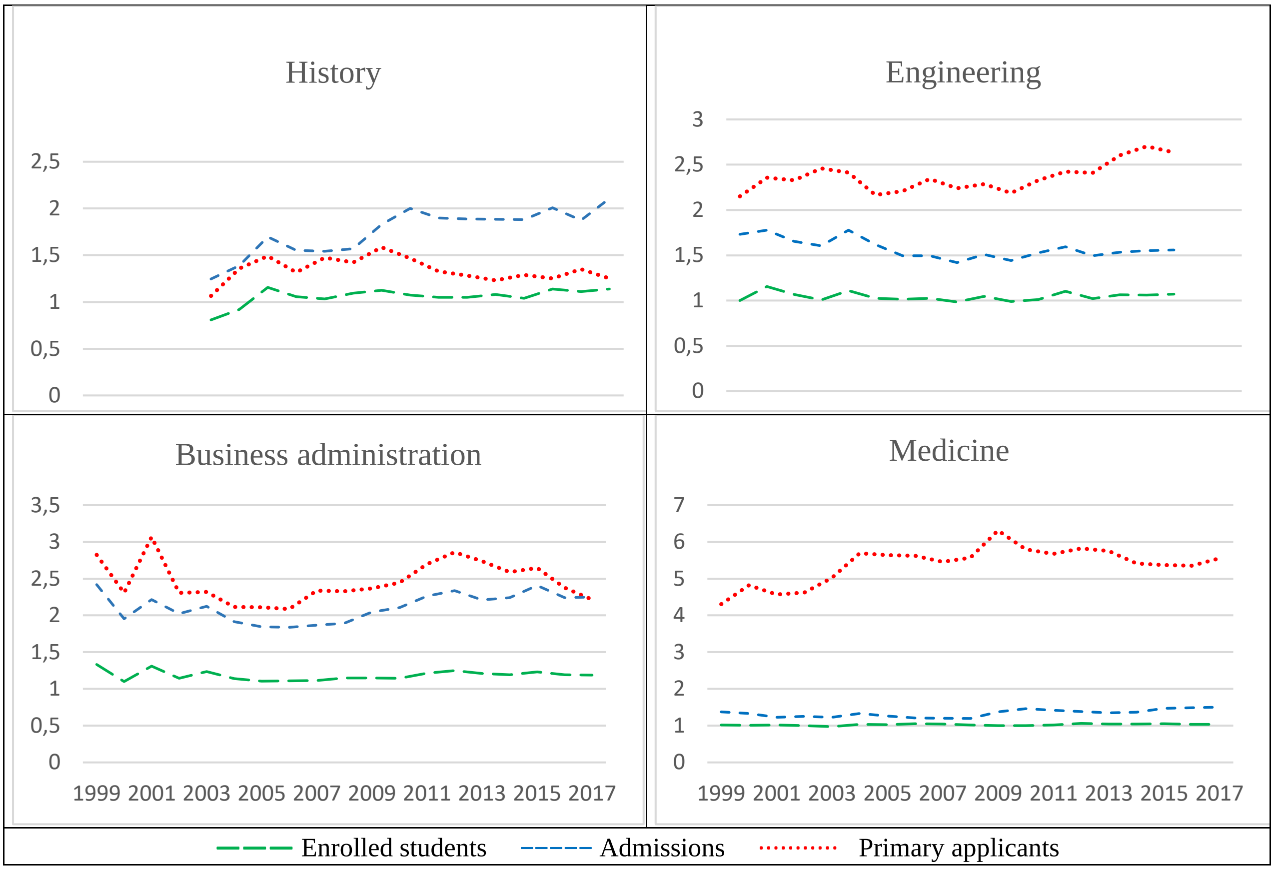

Figure 4. Enrolled students, admissions and primary applicants, as shares of planned study places, 1999-2017 (business admin. and medicine), 1999-2015 (engineering) and 2003-2017 (history).

include those who have the given program on the list, but not on the top. The total number of applicants is therefore higher than the number of primary applicants.

We use primary applicants in the empirical analysis because it is the best representation of demand for a study place in a specific program. There are large differences between the four groups of study programs regarding number of primary applicants per study place, as Figure 4 shows. Medicine has the highest ratio with a mean of 5.5. The corresponding numbers for the history, business administration and engineering programs are 1.15, 2.05 and 2.65, respectively. Thus, at the group level the programs may increase capacity and still fill the study places. For the history and business administration programs, the ratio is below one in 15 and 36 percent of the observations, respectively. For medicine we do not observe ratios below one, and only in three cases for the engineering programs. Combining the information in figures 3 and 4 we see a strong growth in applications for the business administration programs over the years.

Number of enrolled students ($S_{p,t}$) is the number of students that has registered for classes in the respective program by October. Overall, the average ratio of enrolled students relative to study places for the whole period is 1.1, i.e., 10 percent more students enrolled than planned for when the semester starts. Business administration drives this number with its ratio of 1.2. The corresponding ratios for medicine, engineering and history are 1.02, 1.04 and 1.01, respectively. So, despite some high admission ratios, c.f. Figure 4, the enrollment ratios are close to one except for business administration.

6. Results

The upper panel of Table 2 presents the estimated parameters from parsimonious versions of model (8). The results for the business administration and engineering programs show that they respond to deviations from long run equilibrium by adjusting planned study places, statistically significant and according to predictions. The estimated adjustment coefficients correct deviations from equilibrium within approximately two years. For both programs, the estimates of α_2 are statistically insignificant, i.e., no impact on adjustment speed of the funding change in 2006. Planned study places do not respond to deviations from long run equilibrium at all in the history and medicine programs, as the estimates of α_1 in eq. (8) are far from statistically significant, and this does not change after 2006. The result for medicine is consistent with the EqCM term having variation close to zero across years and programs. Explanatory power (R^2) is very low for the history programs. Similar for all the programs is that growth in student enrollment in previous years reduces growth in planned study places, though not statistically significant for the history programs. Adding up these short run adjustments of enrollment changes in previous years ($\Delta lnS_{p,t-s}$), we get respectively -0.88, and -0.55 for engineering and the medicine programs. Moreover, growth in primary applicants in previous years only affects the engineering programs positively and statistically significant ($\Delta lnA_{p,t-2}$). We also estimate an 11 percent higher average growth in planned study places for these programs after 2006, also

Table 2

FE estimates from equations (8) and (9). Robust SE in parentheses

Panel A

Model (8) *Dependent variable:* $\Delta ln\hat{S}_{p,t}$. $EqCM_{p,t-1} = ln\hat{S}_{p,t-1} - lnS_{p,t-1}$				
	Bachelor's programs		*Master's programs*	
	History	*Business administration*	*Engineering*	*Medicine*
$EqCM_{p,t-1}$	–0.02 (0.135)	–0.47** (0.202)	– 0.51*** (0.153)	–0.39 (0.335)
$EqCM_{p,t-1} \times F_{2006}$	–0.15 (0.116)	0.06 (0.248)	–0.06 (0.188)	–0.05 (0.283)
F_{2006}	0.03 (0.066)	–0.04 (0.072)	0.11*** (0.023)	–0.04 (0.032)
$\Delta lnS_{p,t-1}$	–0.11 (0.083)	–0.15** (0.072)	– 0.38*** (0.073)	–0.21 (0.136)
$\Delta lnS_{p,t-2}$	-	-	– 0.30*** (0.067)	–0.22*** (0.078)
$\Delta lnS_{p,t-3}$	-	-	– 0.20*** (0.048)	–0.12*** (0.022)
$\Delta lnA_{p,t-1}$	0.05 (0.092)	0.002 (0.047)	0.04 (0.046)	–0.01 (0.057)
$\Delta lnA_{p,t-2}$	-	-	0.09** (0.043)	–0.03 (0.037)
$\Delta lnA_{p,t-3}$	-	-	0.01 (0.074)	0.01 (0.074)
Within R^2	0.059	0.224	0.262	0.235

Panel B

Model (9) *Dependent variable:* $\Delta lnAdm_{p,t}$. $EqCM_{p,t-1} = lnS_{p,t-1} - ln\hat{S}_{p,t-1}$				
	Bachelor's programs		*Master's programs*	
	History	*Business administration*	*Engineering*	*Medicine*
$EqCM_{p,t-1}$	–0.09 (0.221)	–0.29*** (0.088)	–0.53*** (.123)	–0.64*** (0.066)
$EqCM_{p,t-1} \times F_{2006}$	–0.52** (0.214)	–0.06 (0.121)	0.17 (.125)	0.40 (0.250)
F_{2006}	–0.07 (0.133)	0.15*** (0.039)	0.04*** (.013)	0.01 (0.030)
$\Delta lnAdm_{p,t-1}$	–0.40*** (0.066)	–0.15** (0.078)	–0.16 (0.105)	–0.05 (0.114)
$\Delta ln\hat{S}_{p,t}$	1.07*** (0.266)	0.28** (0.126)	0.63*** (0.110)	0.66*** (0.203)
$\Delta lnA_{p,t}$	0.21 (0.143)	0.18* (0.095)	0.12*** (0.031)	0.04 (0.103)
$\Delta lnS_{p,t-1}$	0.37*** (0.077)	0.12* (0.071)	–0.05 (0.103)	–0.29 (0.259)
$\Delta lnS_{p,t-2}$	-	–0.101* (0.059)	–0.10** (0.047)	–0.29* (0.153)
Within R^2	0.451	0.243	0.574	0.316
N of obs.	87	294	217	64
N of programs	7	23	16	4
N of institutions	7	19	1	4

The models are estimated by STATA 15. Statistical significance: 1%: ***, 5%: **, 10%: *
Program level clustered SE.

statistically significant. These results show that the process of capacity adjustments in the engineering programs differs from the other programs.

Panel B of Table 2 reports the estimated parameters from parsimonious versions of model (9), where the dependent variable is growth in admissions, $\Delta lnAdm_{p,t}$. For business administration, engineering and medicine, admissions are significantly responsive to deviations from long run equilibrium. For business administration, adjustment speed is between three and four years, and for medicine and engineering about one and a half, and two years, respectively. There is no similar long run response for the history programs but a strong and statistically significant short run effect ($\Delta lnAdm_{p,t-1}$). Although not so large, there is also for the engineering programs such a short run effect.

Turning to the estimates of θ_2, it is noticeable that the history programs after the funding change get a statistically significant estimate with adjustment back to long run equilibrium within two years. For the other programs none of the estimates are statistically significant. This means that after 2006 speed of adjustment is statistically almost the same for all four programs. Moreover, there is a significantly higher average growth in admissions after the funding change for the business administration and engineering programs, respectively 15 and four percent, cf. the F_{2006}-estimates. For history and medicine, there are no such effects.

As expected, an increase in planned study places ($\Delta ln\hat{S}_{p,t}$) has a positive and statistically significant effect on admissions. A priori, we expect these estimates to be close to one, which is the case for history with an estimate of 1.07. The point estimate for medicine (0.66) is statistically not different from one. The small estimate for the business administration programs (0.28) is consistent with very high average admission rates (see Figure 4), so an increase in planned study places will not take full effect. The estimate for engineering is in line with medicine, 0.63, but statistically different from one, and cannot be explained by high over-admittance. The likely explanation is that internal competition for study places and students among the engineering programs strengthens focus on student recruitment during the intake process. Hence, an increase in planned study places in a program is not automatically filled if the actual applicants are not regarded as qualified as wanted, so some of the program's study places possibly go to other engineering programs.

Demand for study places ($\Delta lnA_{p,t}$) is known when the admission decisions are taken. The results from model (9) show that demand is particularly important in the engineering programs, but also of importance for business administration and history, though the latter is not statistically different from zero. The number of applicants for the medicine programs is constantly very high, cf. Figure 4, and most of those getting admission enroll. Thus, there is no reason that changes in the number of applicants should matter.

The second lag of growth in enrollment in previous years ($\Delta lnS_{p,t-2}$) affects admissions statistically negative in the medicine, engineering, and business administration programs. The likely interpretation is that these estimates capture adjustments of over-enrollment in previous periods. History stands out with a positive and statistically significant estimate on the first lag. The history programs have problems with filling their study places, so when they succeed by increasing enrollment this year, this possibly stimulates and gives arguments to more admissions the next year.

7. Discussion

The empirical analysis of study program capacities presents two main findings. First, the results support that the outlined long run adjustment mechanism works for the bachelor's programs in business administration and the integrated master's programs in engineering, but not for the bachelor's programs in history and the six-year master's programs in medicine. The second main finding is that the funding change in 2006 did not affect speed of adjustment of planned study places, telling us that PBF does not affect the most important variable for long run productivity development. However, the change increases the average growth in planned study places in engineering by 10 percent, indicating more focus on production of credit points. In the following we discuss in more detail the results for the four program groups.

7.1 The medicine programs

The results for medicine are expected as marginal costs are high. The programs are instructor intensive, so more students require more instructors, but also necessary hospital capacity and general practitioners to house doctoral interns, and lab spaces for the students. This, in combination with tight government regulation and a queue of applicants (Figure 4), illustrate that there is not much to adjust. The results from model (9) show that admissions react to deviations between planned and enrolled students also for medicine. Though not statistically different from zero by conventional levels of significance, the 2006 funding change may have reduced speed of adjustment, which immediately may sound odd. However, keeping in mind that the HEIs are faced with credit point or graduate target figures for these study programs, and that the completion rates are not 100 percent, cf. Section IV, it is consistent that the universities become more retaining to adjust deviations from long run equilibrium after the funding change because dropouts cost more after the change.

7.2 The engineering and business administration programs

There are structural similarities between the medicine and the engineering programs, although marginal costs and credit point prices on average are lower for the latter. The total number of study places in these programs show a variation around an average of 1,500, with an indicated upper capacity of 1,600. Compared to medicine, an important difference is that the 16 engineering programs compete for study places within one institution, c.f. Section II, which may make those involved in the capacity decisions much aware of study place allocation.[36] The

[36] The engineering programs have the Executive Committee for Engineering Education with representation from the involved faculties, reporting directly to Rector of NTNU. The mandate of the committee 'is to manage inter-faculty coordination and develop common quality requirements for the Master of Science in Engineering programs'. See: https://innsida.ntnu.no/wiki/-/wiki/English/Executive+Committee+for+Engineering+Education

results that previous years' enrollment and application growth play a significant role for planned study place adjustments only in the engineering programs, support this argument.

The business administration programs have strong growth in applications. High demand for study places and low marginal costs may make the HEIs reluctant to reduce capacity after the funding change. The gap between planned and enrolled students can then be closed by increasing admissions relative to planned study places, cf. Figure 4, thus increasing credit point production and government funding.

A reasonable explanation to the similarly estimated equilibrating adjustments for the engineering and business administration programs is that they both compete for students to a much larger extent than the other two program groups: History is probably protected due to its long-lasting position and requisite as university discipline, whereas the capacities in the medicine programs are regulated directly by the government. This is different for the business administration programs, where the number of applicants – and planned study places – has increased a lot over the years. For engineering, there is likely to be distinct internal competition for students. The students may choose between 16 different programs that have a common content of generic subjects (mathematics, mechanics, physics, chemistry, etc.) the first 2-3 years. Program specific specialization takes place the last 2-3 years. So, competition is an important common element for the business administration and engineering programs. It is worth noting that although short run dynamics in the relations for planned study places differ between engineering and business administration, it is qualitatively similar in the admission model.

7.3 The history programs

For the history programs, marginal costs, funding rewards and admission requirements are low, and direct government regulation absent. The number of applicants is so low that the number of admissions is higher than number of *primary* applicants (Figure 4). Three of the seven history programs have been open the whole estimation period, i.e., all students fulfilling the formal requirements for university studies got admitted. From narrow economic reasoning, the implication of our results is to allocate (some of) the study places in history to other programs, which does not happen (Figure 3). There are at least two main explanations why re-allocation does not occur. First, it is more difficult to *reduce* than *increase* capacity of a study program, for several reasons. A minimum capacity in terms of staff is necessary to run a program, and in most cases a department is required, implying fixed costs primarily tied to employment of staff. Internal resistance against reduced capacity may also be challenging, for instance because key academics may quit if the research and teaching environment shrinks. Thus, the decision becomes binary, either closing down or continue with the same capacity. Second, the HEIs avoid closing down because the institutions have a paramount objective to uphold knowledge within a discipline, irrespective number of students. Hence, closing down is a tough decision, so continuation at the same capacity level keeps the programs on an apparently safe track.

The admission results for the history programs show that the estimated adjustment coefficient becomes statistically negative (–0.52) after 2006, and statistically not different from the other program groups. It is also interesting to note that short run dynamics play a role for admissions, and not for planned study places, and that explanatory power (R^2) is much higher for admissions than planned study places. Changes in planned study places are more fundamental decisions than admission changes, which are non-binding from one year to the next. So, in spite that we find short run admission dynamics in line with theory for the history programs, the dimensioning processes imply no capacity changes.

8. Conclusion

The main conclusion is that the higher education institutions adjust study program capacities efficiently only when there is competition for students. If not, adjustments are absent, which could be explained by sunk costs and/or a commitment to keep up a discipline despite few students (history), or by strong direct government regulation (medicine).

The change in the government's funding model in 2006 did not affect the processes of long run study program dimensioning. However, for engineering we find that the funding change increased short run average growth in planned study places and admissions. For business administration the funding change increased average growth in admissions. Stronger competition for students in these two programs seems a likely explanation. The results for the history programs demonstrate that deviations from long run equilibrium affect admissions after the funding reform. The estimated adjustment coefficient is identical to the estimated adjustment coefficients for capacity in the business administration and engineering programs and may indicate inertia before a reform take effect (Tandberg and Hillman, 2014).

Both the empirical analyses and the descriptive statistics do not support the finding by Dougherty et al. (2014) on US data of more restrictive admission practices to avoid reduced productivity after the introduction of performance funding in higher education. On the contrary, the results indicate that the institutions take unintended actions to inflate their funding metrics (credit points), which is likely to have the opposite effect on productivity. More students enrolled than planned for put pressure on resources, such as reading rooms and time with supervisors, thus reducing students' learning, and production of credit points. This negative result connects to social problems with performance metrics (Campbell, 1979).

Our results identify a channel to why so few, if any, positive effects of PBF in higher education are found in the literature. Moreover, the results indicate that the institutions have loose restrictions on the total number of study places to allocate to their different study programs. A policy aimed at increasing credit points per student can thus be undermined because it is tempting or easier to use resources to secure full enrollment in a study program structure that is possibly not optimal with respect to this productivity measure.

If governments continue to aim at increasing credit points per student by use of PBF, the likely policy implication of our analysis is to consider critically the total allocation of study places to the institutions, and/or to include mechanisms in the PBF models stimulating optimal capacity utilization. In the short run such policies may have negative impacts on the development of academic disciplines, but not necessarily in the long run.

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Appendix A: The study programs

This overview shows the different study programs included in the analysis. The identifying number of the study program is a six digits code, the three first identify higher education institution (HEI), and the last three program. As indicated in the tables, the chosen programs have either the same, or similar program identifier codes.

Programs in Business and administration (23 programs)

Program id	Campus	Period	Program id	Higher education institution
1	Tromsø	2003-2008	221369	
		2009-2017	186369	University of Tromsø
2	Alta	1999	206035	
		2000-2013	206369	
		2014-2017	186468	University of Tromsø
4	Harstad	1999-2015	208035	
		2016-2017	186035	University of Tromsø
5	Ås	2002-2017	192369	Norwegian University of Life Sciences
7	Trondheim	1999-2015	219035	
		2016-2017	194035	NTNU
10	Kristiansand	1999-2001	201035	
		2002-2017	201369	University of Agder
11	Grimstad	1999-2001	201337	
		2002-2017	201404	University of Agder
12	Bergen	1999-2002	203035	
		2002-2017	203369	Western Norway Univ. of Applied Science
13	Sogndal	2002-2016	216369	
		2017	203526	Western Norway Univ. of Applied Science
14	Haugesund	1999-2001	218035	
		2002-2016	218369	
		2017	203404	Western Norway Univ. of Applied Science
15	Molde	2002-2017	211369	Molde University College
16	Oslo	1999-2001	215035	
		2002-2017	215369	OsloMet
17	Stavanger	1999-2002	217035	
		2003-2017	217369	University of Stavanger
18	Østfold	1999-2017	224035	Østfold University College
19	Telemark	2002-2016	220369	South-Eastern Norway Univ. of Applied Science
20	Kongsberg	2002-2013	205404	
		2014-2017	222404	South-Eastern Norway Univ. of Applied Science
21	Ringerike	2002-2013	205414	
		2014-2017	222414	South-Eastern Norway Univ. of Applied Science
23	Horten	2002-2017	222369	South-Eastern Norway Univ. of Applied Science
24	Hedmark	1999-2001	209035	
		2003-2017	209369	Inland Norway University of Applied Science
25	Lillehammer	1999-2017	210035	Inland Norway University of Applied Science
26	Steinkjer	2002-2015	214369	Nord University
27	Mo i Rana	2004-2017	204470	Nord University
28	Bodø	2003-2017	204342	Nord University

Programs in History (Seven programs)

Program id	Institution (HEI)	Time period	Study program id
1	University of Bergen	2003-2017	184481
2	University of Oslo	2003-2017	185481
3	University of Tromsø	2003-2017	186481
4	NTNU	2004-2017	194481
5	University of Agder	2003-2017	201481
6	Nord University	2003-2017	204481
7	University of Stavanger	2003-2017	217481

Programs in Medicine (Four programs)

Program id	Institution (HEI)	Time period	Study program id
1	University of Bergen	1999-2017	184740
2	University of Oslo (fall)	1999-2017	185740
4	University of Tromsø	1999-2017	186740
5	NTNU	1999-2017	194740

Programs in Engineering, NTNU (16 programs)

Program id	Reference name	Time period	Study program id
1	Materials Science and Engineering	1999-2015	194755
2	Petroleum Geosciences and Engineering	1999-2015	194757
		2008-2015	194946 (Geotechnology)
3	Civil and Environmental Engineering	1999-2015	194759
4	Engineering and ICT	1999-2015	194760
		2003-2015	194905 (ICT)
5	Electronics Systems Design and Innovation	1999-2015	194761
6	Applied Physics and Mathematics	1999-2015	194763
7	Chemical Engineering and Biotechnology	1999-2015	194764
8	Marine Technology	1999-2015	194765
9	Mechanical Engineering	1999-2015	194766
10	Industrial Economics and Technology Management	1999-2015	194767
11	Industrial Design Engineering	1999-2015	194768
12	Energy and Environmental Engineering	1999-2015	194769
13	Communication Technology	1999-2015	194770
14	Cybernetics and Robotics	1999-2015	194798
16	Nanotechnology	2006-2015	194937
18	Architecture	1999-2015	194756

Online Appendix B: Descriptive statistics

History (Seven programs)

Variable		Mean	Std.dev.	Min	Max	observations
Admissions	Overall	124.6731	88.21569	9	321	N = 104
	Between		90.87364	27.6	291.6	n = 7
	Within		23.86461	62.20641	197.2064	T-bar = 14.8571
Enrolled students	Overall	74.75	60.84003	5	228	N = 104
	Between		63.84573	11.6	189.4667	n = 7
	Within		11.9732	40.28333	119.55	T-bar = 14.8571
Planned study places	Overall	69.5098	53.73159	0	200	N = 102
	Between		55.35824	23	171.4667	n = 7
	Within		12.86476	-12.79789	110.2431	T-bar = 14.5714
Primary applicants	Overall	94.51923	93.65501	6	340	N = 104
	Between		98.58885	11.6	291.3333	n = 7
	Within		16.72515	45.1859	156.8526	T-bar = 14.8571
Qualified applicants	Overall	504.4135	447.5793	42	1834	N = 104
	Between		469.4592	70.53333	1432.2	n = 7
	Within		88.85365	244.2135	906.2135	T-bar = 14.8571
Number of applicants	Overall	602.9327	533.8796	57	2252	N = 104
	Between		554.6794	90.73333	1709	n = 7
	Within		127.9613	193.9327	1145.933	T-bar = 14.8571
Admission/planned	Overall	1.862067	.675892	.3	4.285714	N = 99
	Between		.4081506	1.336667	2.428724	n = 7
	Within		.5566034	.5333427	3.719057	T-bar = 14.1429
Applicants/planned	Overall	8.075197	2.665742	1.74	17.8	N = 99
	Between		2.218435	4.373778	11.38963	n = 7
	Within		1.611732	4.585563	14.48556	T-bar = 14.1429
Primary applicants/planned	Overall	1.155449	.4487216	.18	2.4	N = 99
	Between		.3975327	.5464444	1.699077	n = 7
	Within		.2427573	.464278	2.082985	T-bar = 14.1429
Enrolled/planned	Overall	1.011951	.3584601	.12	2.3	N = 99
	Between		.2727851	.5491111	1.336854	n = 7
	Within		.2491177	.4409305	1.975097	T-bar = 14.1429

Medicine (Four programs)

Variable		Mean	Std.dev.	Min	Max	observations
Admissions	Overall	159	42.04823	99	257	N = 76
	Between		41.91525	127.8947	219.4211	n = 4
	Within		20.80428	121.1053	209.1053	T = 19
Enrolled students	Overall	121.7368	26.96238	84	181	N = 76
	Between		28.67106	100.5789	163.3158	n = 4
	Within		10.11076	101.5789	149.1579	T = 19
Planned study places	Overall	118.4737	22.75872	85	165	N = 76
	Between		24.53731	99.15789	153.6842	n = 4
	Within		7.770389	102.1579	137.1579	T = 19
Primary applicants	Overall	640.3553	231.5233	166	1097	N = 76
	Between		239.6516	335.0526	905.7895	n = 4
	Within		99.77014	448.6711	856.4605	T = 19
Qualified applicants	Overall	1803.013	318.8055	960	2469	N = 76
	Between		129.316	1634.053	1939.421	n = 4
	Within		298.2075	1055.592	2332.592	T = 19
Number of applicants	Overall	2384.763	326.9331	1495	2925	N = 76
	Between		202.2309	2090.895	2552.421	n = 4
	Within		275.3239	1720.342	2854.289	T = 19
Admission/planned	Overall	1.328865	.1396494	1.06	1.64	N = 76
	Between		.085054	1.219458	1.426479	n = 4
	Within		.1183383	1.045902	1.55194	T = 19
Applicants/planned	Overall	20.51287	3.088612	12.58667	27.17143	N = 76
	Between		2.856306	16.59643	23.45621	n = 4
	Within		1.827314	16.05666	24.22809	T = 19
Primary applicants/planned	Overall	5.519957	2.243648	1.952941	10.44762	N = 76
	Between		2.427813	3.339949	8.644406	n = 4
	Within		.7445184	3.751742	7.32317	T = 19
Enrolled/planned	Overall	1.023208	.0509841	.84	1.126667	N = 76
	Between		.0265647	1.003456	1.062414	n = 4
	Within		.0454209	.849198	1.13184	T = 19

Business administration (23 programs)

Variable		Mean	Std.dev.	Min	Max	observations
Admissions	Overall	173.3561	113.2095	17	584	N = 396
	Between		102.6545	46.42857	466.9474	n = 23
	Within		45.31243	27.72448	347.5561	T-bar = 17.2174
Enrolled students	Overall	96.65404	70.0159	9	369	N = 396
	Between		65.64312	26.07143	304.3158	n = 23
	Within		22.28191	14.23299	164.7593	T-bar = 17.2174
Planned study places	Overall	83.89532	59.50435	10	314	N = 363
	Between		54.89152	18.66667	272.9444	n = 23
	Within		19.99348	20.32389	149.5203	T-bar = 17.7826
Primary applicants	Overall	199.3687	236.4208	4	1053	N = 396
	Between		227.1828	29.72222	835.0526	n = 23
	Within		52.94657	-9.841839	417.3161	T-bar = 17.2174
Qualified applicants	Overall	747.5934	727.767	61	3224	N = 396
	Between		676.084	98.07143	2282.368	n = 23
	Within		248.0065	108.225	1689.225	T-bar = 17.2174
Number of applicants	Overall	896.5682	834.3934	86	3428	N = 396
	Between		790.9161	127.0714	2716.737	n = 23
	Within		235.9944	271.1998	1709.2	T-bar = 17.2174
Admission/planned	Overall	2.263275	1.006922	.62	8.3	N = 363
	Between		.6348692	1.61265	4.294667	n = 23
	Within		.8036483	-.6113915	6.702797	T-bar = 17.7826
Applicants/planned	Overall	10.66273	6.916699	2.3	50.375	N = 363
	Between		5.840003	4.748491	32.67463	n = 23
	Within		3.469023	-5.988821	28.3631	T-bar = 17.7826
Primary applicants/planned	Overall	2.049092	1.402538	.4	9.025	N = 363
	Between		1.211539	.9937836	5.835378	n = 23
	Within		.661482	-1.00167	5.702367	T-bar = 17.7826
Enrolled/planned	Overall	1.189959	.409786	.3625	4.411765	N = 363
	Between		.2045632	.8873779	1.664909	n = 23
	Within		.3566384	.1375496	4.666518	T-bar = 17.7826

Engineering (16 programs)

Variable		Mean	Std.dev.	Min	Max	observations
Admissions	Overall	147.234	66.30535	27	373	N = 265
	Between		61.57111	39.47059	258.8235	n = 16
	Within		31.48137	71.35161	311.3516	T-bar = 16.5625
Enrolled students	Overall	97.45283	44.85995	20	272	N = 265
	Between		41.9914	26	173.5294	n = 16
	Within		20.54991	34.92342	226.3352	T-bar = 16.5625
Planned study places	Overall	93.30566	41.91723	20	230	N = 265
	Between		39.71458	25	170.3529	n = 16
	Within		18.31597	37.95272	153.6586	T-bar = 16.5625
Primary applicants	Overall	223.483	153.4436	25	852	N = 265
	Between		136.8973	42.05882	623.5294	n = 16
	Within		74.07851	22.95361	566.5418	T-bar = 16.5625
Qualified applicants	Overall	928.5434	322.2815	351	1843	N = 265
	Between		229.5606	585.6471	1331.294	n = 16
	Within		231.6661	320.014	1759.779	T-bar = 16.5625
Number of applicants	Overall	1166.423	396.9448	414	2278	N = 265
	Between		291.941	703.6471	1643.706	n = 16
	Within		276.7837	406.7168	2232.834	T-bar = 16.5625
Admission/planned	Overall	1.587693	.204212	.96	2.34	N = 265
	Between		.0572894	1.483529	1.685771	n = 16
	Within		.1963528	.9765808	2.328845	T-bar = 16.5625
Applicants/planned	Overall	15.01783	8.037547	5.092857	47.63334	N = 265
	Between		7.571299	8.105688	33.36605	n = 16
	Within		3.965411	2.899158	40.44029	T-bar = 16.5625
Primary applicants/planned	Overall	2.652522	1.880396	.65	10.85	N = 265
	Between		1.733724	1.316454	6.022129	n = 16
	Within		.9618579	-.02675	7.480393	T-bar = 16.5625
Enrolled/planned	Overall	1.045023	.1343561	.52	1.513044	N = 265
	Between		.0297241	.986936	1.087586	n = 16
	Within		.1311889	.5615995	1.520239	T-bar = 16.5625