Oxford Economic Papers, 2023, **00**, 1–23
https://doi.org/10.1093/oep/gpad009
Article

OXFORD

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

Jan Morten Dyrstad[1,*], Mia Marie Wallgren Sohlman[1], Tor Henrik Teigen[1]

[1]Department of Economics, Norwegian University of Science and Technology, Trondheim, N-7491, Norway

*Corresponding author: Email: jan.dyrstad@ntnu.no

Abstract

Objectives aimed at increasing higher education productivity, for instance, measured by credits per student, have stimulated the use of performance-based funding (PBF) by higher education institutions (HEIs). On theoretical grounds, PBF is expected to speed-up study program capacity adjustments through (re)allocations of study places. We conclude from analyses of Norwegian data that study places are adjusted efficiently if there are binding capacity restrictions at the institution level, or competition for students. Strengthened PBF does not affect long-run 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 impose tighter restrictions on the total number of study places allocated to HEIs, or to change the price structure of the PBF model.

JEL classifications: H52, I22, I28, L51

1. Introduction

During the last three to four decades, higher education institutions (HEIs) in several countries have met new forms of output or performance-based funding (PBF). For many European universities, this is closely connected to the 1999 Bologna Process and its European Higher Education Area,[1] which have stimulated use of PBF (Jongbloed, 2010; Jongbloed *et al.*, 2018). 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,[2] and to European universities, with the noticeable exception of Agasisti *et al.* (2021) using Russian data, who find some positive short-run effects of PBF on national entrance exam scores. Jongbloed and Vossensteyn (2016) provide a descriptive analysis using data from OECD countries 1995–2012 concluding 'that we still know relatively little about the impact of

1 See: http://www.wg.aegee.org/ewg/bolognadeclaration.htm. Last accessed 30 October 2022.
2 See, for example, Shin (2010), Dougherty *et al.* (2014, 2016a, 2016b), Tandberg and Hillman (2014), Hillman *et al.* (2014, 2015), Umbricht *et al.* (2017), and Ward and Ost (2021).

performance-based funding . . .' (Jongbloed and Vassensteyn, 2016, p. 593).[3] Given the strong focus and large amounts of resources spent on the reforms 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 analyse adjustments of study program capacities measured by number of study places, and particularly how adjustments are affected by PBF. Capacity decisions affect the number and quality of enrolled students for several years, thus long-run education productivity. For a funding-maximizing HEI with autonomy to make capacity adjustments within an overall and binding capacity restriction, the capacity elasticities in every program must equal one in the long run, meaning that a 1% increase in capacity increases the number of enrolled students by 1%. An elasticity below one implies that it is optimal to reallocate capacity from a 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 modeling.

Measured by number of students, 90% of Norwegian HEIs are public, and we use data from these in the empirical analysis. The advantage is 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 easy to communicate and understand, and Norwegian HEIs have the autonomy to change their study program capacities.

The main conclusion from the empirical analysis is that the HEIs adjust capacity efficiently if they face binding restrictions on the total number of study places, or if there is competition for students. Moreover, the 2006 PBF model has not affected long-run capacity adjustments. Instead of adjusting capacities, the HEIs adjust student admissions to meet targets of full enrollment. For one program the PBF model has affected student 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, 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 capacity utilization, or by imposing tighter governmental restrictions on the number of study places to the HEIs.

The article 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 time to adjust study program portfolios, and hence productivity. For example, the time-dependent enrollment contracts between the HEIs and the students limit the room for changing the program portfolios from which admitted students may choose courses. The actual composition of staff and infrastructure hindrances may impose delays, and dynamics may also capture the formation of expectations and organizational changes within the HEIs.

The article is organized as follows. The next section gives more detailed motivation for the article and institutional background. The theoretical and empirical models are presented in Sections 3 and 4, respectively. Section 5 describes data and Section 6 presents the results. Discussion and conclusions appear in Sections 7 and 8, respectively.

2. Background

In a comprehensive discussion of responses to reduced funding of public universities in the USA, Fethke and Policano (2012) underline the importance of a strategic attitude toward study program dimensioning, admissions, and enrollment of students. Universities must ask

[3] Research incentives may be more effective, see, for example, Aghion *et al.* (2010) and Bolli *et al.* (2016).

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,[4] but they should also ask these questions, particularly when facing more PBF. The implication is that more PBF should not only improve productivity within 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. Program portfolio decisions have important long-run consequences as they affect for several years the composition of enrolled students and consequently productivity development.

On this background, it is interesting to investigate capacity adjustments in higher education theoretically and empirically. The empirical analysis requires that we have an institutional setting, and reliable and valid data, that makes it interesting and relevant. A meaningful empirical analysis also requires institutional autonomy and organizational capacities for effective internal decisions. In the following, we address these requirements.

2.1 Institutional context

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 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)[5] 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 of the model. A comprehensive revision implemented in 2017 strengthened the performance and incentive part of the model,[6] and the government underlined that this policy would continue, with higher shares of PBF in the future.[7] To illustrate, for the year 2016 the government allocated 69%, 25%, and 6%, respectively, to base funding, and funding based on teaching and research achievements. Almost all the funding based on teaching achievements is measured by credit points, 99%. 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, giving correlation coefficients close to 1 (0.98–1.00).[8] 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 are funded according to these prices, different from research funding where the HEIs compete within a fixed government budget implying endogenous prices on the research performance variables. Credit points measure number of exams students pass, thus study progression and completion, so stronger and more accurate funding incentives are expected to increase credit points per student.[9]

[4] See OECD Education at a glance 2019, Table C5.1, p. 315, https://www.oecd-ilibrary.org/education/education-at-a-glance-2019_f8d7880d-en. Last accessed 30 October 2022.

[5] 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 30 October 2022.

[6] Prop. 1 S (2016–2017), p. 285 (Proposition to Parliament): https://www.regjeringen.no/no/dokumenter/prop.-1-s-jd-20162017/id2513950/. Last accessed 30 October 2022.

[7] Meld. St. 18 (2014–2015), p. 59 (White Paper): https://www.regjeringen.no/no/dokumenter/meld.-st.-18-2014-2015/id2402377/. Last accessed 30 October 2022.

[8] Own calculations. *Source*: DBH (n.d.).

[9] See, for example, the government's budget proposal for 2016 arguing for more incentives in the future (Prop. 1 S (2015–2016)), p. 286: https://www.regjeringen.no/contentassets/e9b528a9f0ce4adea0a4131b2131999b/nn-no/pdfs/prp201520160001_kddddpdfs.pdf. A recent report from a government appointed committee (17 March 2022), recommends more funding based on credit points: https://www.regjeringen.no/contentas

The HEIs decide and report formally their program capacities in terms of study places the coming year to the centralized, national intake authority, Norwegian Universities and Colleges Admission Service (NUCAS), no later than 1 December.[10] The capacities are binding so that all students fulfilling the requirements for a given program are admitted if the capacity limit allows. Hence, *planned study places* are the decision variable for study program dimensioning.

The students apply for higher education in Norway 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 released, 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) are admitted, and more study places in a program will normally reduce a program's APL.

Despite extensive reforms, we do not see evident changes in credit points (ECTS) per student over time. At the national level, the average number of credit points per student was 43.3 in 2006, and 45.3 in 2021[11] which is only 75% of a student following normal study progression, defined as passing exams equal to 60 ECTS per year. Almost constant average credit point rates over several years do not necessarily imply that PBF is ineffective. Several counteracting mechanisms are possible, for instance that more students now do not—as compared to the past—follow normal study progression but do part-time work besides studying. Teaching effort among academics may have declined, thus generating lower rates, because of heavier total workload (Leiytė *et al.*, 2009; Horta *et al.*, 2012; Leiytė, 2016), or because of stronger preferences and individual incentives for research than teaching (Cummings and Shin, 2014; Chen, 2015; Geschwind and Broström, 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 capacities, institutional resistance to PBF, and insufficient knowledge of performance.

2.2 Autonomy and organizational capacities

Norway implemented the central elements of the Bologna Declaration, and introduced important changes in governance and funding of the HEIs in 2003.[12] An important part of this reform was to give the HEIs much more freedom and flexibility vis-à-vis the government 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.[13] Consistently, the government highlights regularly and explicitly that the annual budget allocations give the HEIs scope to make their own strategic choices and priorities,[14] indicating high degree of autonomy.

sets/6c4c7be66d5c4a028d86686d701a3a96/f-4475-finansiering-av-universiteter-og-hoyskoler.pdf. Last accessed 30 October 2022.

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

[11] *Source*: DBH (n.d.).

[12] https://www.regjeringen.no/contentassets/eebf61fb4a204feb84e33355f30ad1a1/no/pdfa/stm200020010027000dddpdfa.pdf (White Paper). Last accessed 30 October 2022.

[13] Some professional studies, such as medicine, have target figures at the program level settled in the annual appropriation document. From the year 2014, 'credit points' are changed to 'graduates' for these studies but does not seem to make a real difference. Documents referring to several years: https://www.regjeringen.no/no/tema/utdanning/hoyere-utdanning/orientering-om-forslag-til-statsbudsjett-for-universiteter-og-hoyskoler/id619675/. Last accessed 30 October 2022.

[14] See, e.g. the budget proposal for 2017, Prop. 1 S (2016–2017), p. 281: https://www.regjeringen.no/no/dokumenter/prop.-1-s-jd-20162017/id2513950/. Last accessed 30 October 2022.

Autonomy has many dimensions (Verhoest *et al.*, 2004), and a first question is whether the enhanced autonomy on study program decisions in 2003 is real, or only formal. A second regards the HEIs organizational capacities, which affect decisional content and quality.

The study of 'autonomy-in-use' (real autonomy) versus formal autonomy by de Boer and Enders (2017) applies the autonomy dimensions in Verhoest *et al.* (2004) in an analysis on survey data from 26 universities in eight European countries, combined with information from research, policy documents, and experts. The dimension 'policy autonomy' is represented by five variables of which four are directly related to study programs and teaching, for example, 'Deciding on the number of study places' (de Boer and Enders, 2017, p. 67). Two of the Norwegian universities included in this study come out with 'high' on both formal and real autonomy, whereas the third is 'medium'. Only Norwegian and UK universities have high formal and real autonomy. These results are consistent with those from the University Autonomy Tool of the European University Association, where the Norwegian HE system in total is assessed to be among the upper 1/3 regarding organizational (77% score) and academic autonomy (87%), in the middle regarding handling of staff (62%), and at the bottom financially (29%).[15] The low degree on financial autonomy is first and foremost due to 100% public funding, no tuition fees and no ability to borrow money. The 100% score on handling of study programs, among them introduction and termination of programs, explains the high total score on academic autonomy.[16] Hence, high dependency on government funding and high real autonomy on study program adjustments should make Norway particularly relevant for testing consequences of PBF on study program capacity adjustments.

The decentralized academic model may not work in relation to incentives if the HEIs do not have the organizational capacities for accountable and legitimate decisions, for instance due to traditionally weak leadership and governing bodies, lack of relevant management data, limited abilities to address alternatives and consequences, and challenges regarding internal social and cultural history, etc. (see, e.g., Enders *et al.*, 2013). Seeber *et al.* (2015) conclude that European universities have moved toward the corporate-managerial model, which is another reason for taking dynamics into the empirical modeling. They also conclude from the same data as de Boer and Enders (2017) that the four Norwegian universities in the sample are all 'managerial universities', with high levels of 'hierarchy' and 'rationality'.

However, hierarchical structures indicating strong organizational control can be 'penetrated' in different ways, for instance by power struggles between leadership and academic staff rooted in legitimacy and power (Bleiklie *et al.*, 2015). Hence, one may question our assumption that it is the central leaderships and governing bodies of the HEIs that really make the decisions on study program capacities and admissions.

These decisions relate to the core work and function of every HEI, and it is extraordinary if they are not taken or controlled at the central level of the institutions. Norwegian legislation is very clear; it is the boards and rectors that are 'responsible for ensuring that the professional activities are of high quality and that the institutions are run efficiently and in accordance with the laws, regulations and rules that apply, and the framework and targets given by the higher authority'. Moreover, 'All decisions at the institution made by others than the board are made after delegation from the board and under the board's responsibility.'[17] This makes it clear that it is the institution that is responsible and must explain and

[15] See: https://www.university-autonomy.eu/countries/norway/. Last accessed 30 October 2022.

[16] However, there is a recent exception, indicating that autonomy has limitations. In the autumn of 2021 the government intervened against a decision of closing down a teacher education program at one of the campuses of Nord University, see: https://khrono.no/sikrer-utdanning-i-nesna-gjennom-kongelig-resolusjon/683479. Norwegian only. Last accessed 30 October 2022.

[17] Act on universities and colleges, §9-1, see https://lovdata.no/dokument/NLO/lov/1995-05-12-22. Last accessed 25 October 2022. Our translation to English.

defend the decisions in, for example, the annual management dialogue meetings with the ministry.

2.3 Empirical approach

We ask, what would be an HEI's answer to the question of how many study places to allocate to its different study programs, given that it seeks an equilibrium of full capacity utilization and is only interested in maximizing government funding? The answer 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 reallocate places from these programs to other programs.

Empirically we analyse short and long-run study program capacities and student admissions adjustments 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 toward long-run equilibrium by investigating effects of the 2006 PBF model.

We need reliable and valid data, from identically defined study programs across institutions, covering a sufficient long period so it becomes possible to test empirically 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 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 10 times higher in 2007. From this peak, the number has fallen to about 6,400 programs in 2017.[18] The increases are due to the national follow-up of the Bologna Process to establish more structured and labor market-directed study programs, resulting in more heterogeneous study program portfolios, and more frequent adjustments of program content.

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 5-years engineering programs and four 6-years medicine programs).[19] 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, degree of government regulation, study program size, not least competition for students and study places. They also differ very much regarding funding rewards. Medicine belongs to the highest funding category A, Engineering to category D, and the two bachelor's programs to the lowest category F (cf. Section 2.1). Hence, the groups can be seen as representatives for four different program traditions within higher education. An important reason for choosing the 16 engineering programs is that they all belong to one university, the Norwegian University of Science and Technology (NTNU). This means that they are likely to face sharper restrictions as allocation of more study places to one of the programs is likely to reduce study places in other engineering programs, for example, due to infrastructure constraints for this group of programs.

Reliable program level credit points per student over time are difficult to establish for the bachelor's and the engineering programs. The reason is that a program consists of courses from several departments, and the departments offering courses change over time because the students choose different courses when taking their degrees. Keeping this in mind, the most reliable data for the bachelor's programs are aggregates from the broader groups of bachelor's programs in business administration, social sciences, and the humanities. Credit points per student in 2006 from these programs were, respectively, 40.1, 39.4, and 34.0. In

[18] *Source:* DBH (n.d.).
[19] Two-years master's programs are not included because the intake processes for these programs are HEI internal and not nationally coordinated.

2021, the figures are, respectively, 44.7, 46.0, and 40.4, that is, close to the national figures presented in Section 2.1. For the engineering programs, credit points per student in 2006 vary between 40 and 50, and in 2021 correspondingly between 45 and 55. Credit points per student in the medicine programs were 53.6 (2006) and 55.9 (2021).[20]

This program variation makes the data set suitable for estimating our parameters of interest but is also helpful when it comes to model evaluation, as the adjustment processes are likely to differ between the 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, and they also vary according to age, size, location, and mergers during the estimation period.

3. Theoretical model

Capturing the essential features of the PBF model for Norwegian HEIs, we outline in this section a theoretical model for study program capacity decisions of a funding-maximizing HEI with credit points as the performance metric.

One may question an objective aimed at maximizing funding. Maximizing excellence in research and education, and academic reputation measured by, for instance, international rankings, are more in line with what we find in HEIs official documents. However, such goals are compatible with funding maximization because they are more easily realized by well-funded HEIs than the opposite, and study programs with high productivity students enhance academic reputation. From this perspective our theoretical model is valid as it captures central elements in HEIs' adjustments.

Based on academic reputation study programs may continue even though funding is lost due to few students by focusing on research, and not teaching and output from study programs. HEIs may also lack organizational capacity to handle study program decisions efficiently (cf. Section 2.2). Our model does not fit these kinds of HEIs, as we assume that they rationally allocate resources to maximize government funding. The model is meant to capture essential mechanisms which established government policy believes in, giving us sharp hypotheses to test.

More credit points can be achieved either by enrolling more students, which gives more credit points (extensive margin), or by increasing number of credit points per student (intensive margin). Hence, an HEI's problem is to find the optimal balance between enrolling students into its various programs and their ability to produce credit points. To arrive at the HEI's objective function, we start by analysing the relationship between student enrollment and program capacity. Next, we analyse 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, program capacities, and credit point production

In the following, let S_p be the number of enrolled students in study program p. Changing a program's number of study places, that is, the program capacity $\hat{S}_p$, will only influence the 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 to a program 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. The motivation is that the more study places a program offers, the more likely it is to get an offer and being enrolled in the program. The limits $\hat{S}_p = 0$ gives zero applicants and $\hat{S}_p \to \infty$ a constant number of applicants. The number of applicants also depends on many other factors, such as preferences for studying certain type of subjects, teaching quality, student accommodation, students'

[20] *Source:* DBH (n.d.).

working conditions, labor market conditions, for example, earnings and the possibility of finding a job after graduating (Becker, 1964; Black *et al.*, 2005; Haraldsvik and Strøm, 2021), and the attractiveness of the HEI's location. Some of these factors are controlled by the HEIs, others not. We simplify and denote these shift factors X. 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 $\partial^2 A_p / \partial \hat{S}_p^2 \leq 0$.[21]

Program capacity is binding if $A_p(\hat{S}_p, X) > \hat{S}_p$, implying that $S_p = \hat{S}_p$ and $\partial S_p / \partial \hat{S}_p = 1$, that is, an increase in study places increases the number of students by the same number. All qualified applicants are admitted ($S_p = A_p$) if $A_p(\hat{S}_p, X) \leq \hat{S}_p$. An increase in capacity 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 $A_p(\hat{S}_p, X) \geq \hat{S}_p$. On this background we formulate the enrollment function (1), with derivatives as indicated depending on the number of applicants relative to program capacity:

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

where (i) $\frac{\partial S_p}{\partial \hat{S}_p} = 1$ *if* $A_p \geq \hat{S}_p$ and (ii) $0 \leq \frac{\partial S_p}{\partial \hat{S}_p} = \frac{\partial A_p}{\partial \hat{S}_p} < 1$ *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 $\frac{\partial S_p}{\partial \hat{S}_p} \frac{\hat{S}_p}{S_p} = 1$. If $S_p = A_p < \hat{S}_p$, there is excess supply of study places, and the capacity elasticity is less than one. Figure 1 illustrates the relationships between program capacity, enrollment, and applicants.

A study program's total production of credit points, CP_p, is assumed to depend on the students' ability to acquire knowledge. The intake process ranks students according to their previous achievements, and we assume that the students' average ability is a positive but decreasing function of ranked applicants, giving a positive but decreasing relationship between credit points and enrolled students[22]:

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

Quality of teachers and learning environment may affect the production of credit points. External factors may also have a direct impact on the number of produced credit points. For instance, a tight labor market may reduce students' effort (Haraldsvik and Strøm, 2021), 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).

3.2 Program capacities with a pure monetary objective function

We assume that an 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

[21] Regressing applications against planned study places with and without fixed effects show positive and concave relations except for Medicine, where linear relationships are more likely.

[22] As mentioned in Section 2.3, we do not have ECTS data from the study programs covered by the empirical analysis. Subject to this, aggregate data from the bachelor's programs in the humanities and social sciences show clear positive and concave relationships between credit points and number of students. For the aggregate business administration and Medicine, the relationships seem to be linear.

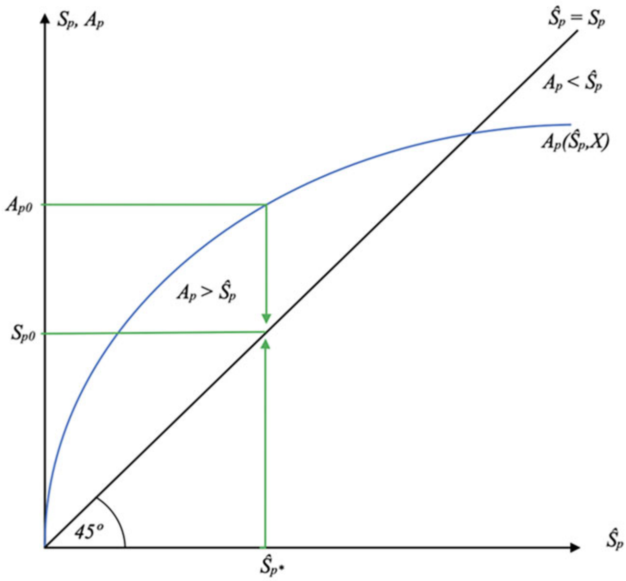

Figure 1. Qualified applicants (A_p), enrolled students (S_p), and program capacity ($\hat{S}_p$).

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

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

where q_p is the price per CP from study program p, like the Norwegian funding model. Marginal cost of one more student, c_p, is assumed to be constant. Maximizing F with respect to capacity, $\hat{S}_p$, the first-order conditions can be written as

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

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 1%, 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 $\hat{c}_p$.[23] Formally, $\partial S_p/\partial \hat{S}_p = 0$ satisfies Equation (4) but cannot be an equilibrium. Equilibrium requires that income from more credit points balance the effective cost of one more student ($\varepsilon_p = \hat{c}_p$).

[23] If the HEI aims at maximizing credit points instead of funding, for example, as a measure of education quality or effectiveness, $q_p = 1$ in Equations (3) and (4). The interpretation of Equation (4) is qualitatively the same.

If the government sets a cap on the HEI's total number of students, as is the case in Norway, it may affect capacity dimensioning.[24] Hence, we assume that there is an overall capacity limit $\hat{S}$ for the HEI, giving the restriction $\sum_{p=1}^{P} \hat{S}_p \leq \hat{S}$, where P is the total number of study programs.

Given that there is full study place substitutability between programs, which is the case except some professional programs (cf. Section 2.2), an interior solution requires that the funding rate of substitution between all pairs of program capacities i and j equals one, as the HEI's restriction implies $\Delta\hat{S}_i = -\Delta\hat{S}_j$:

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

In long-run equilibrium, all study places are filled, and $\partial S_p / \partial \hat{S}_p = 1$ $(\forall p)$, 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 Equation (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 transferred from program j (i) to program i (j).

From Equation (3), a constant level of net funding gives iso-funding curves showing combinations of study place allocations to different pairs of study programs. The curves are convex with negative slopes because $CP_p(S_p, Z)$ is a concave function of S_p, cf. Equation (2). Outside equilibrium $A_p < \hat{S}_p$ implying $S_p = A_p$ and $\partial S_p / \partial \hat{S}_p < 1$, but the iso-funding curves are still convex because of $\partial^2 S_p / \partial \hat{S}_p^2 \leq 0$, cf. Equation (1) and Figure 1.[25]

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 than 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 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 reduction in credit points, and consequently funding. For a higher elasticity in program i we get the opposite.

The long-run equilibrium adjustment mechanism 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, for example, 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 maximize its government funding by moving to c giving $F = F^1 > F^0$. Outside equilibrium, an increase in $\partial S_j / \partial \hat{S}_j$ toward 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 $\partial S_i / \partial \hat{S}_i$ gives the opposite result.

24 We come back other types of restrictions in Section 4.2 and when we discuss the empirical results.

25 In long run equilibrium, $\frac{\partial S_p}{\partial \hat{S}_p} = 1$ and $\left(q_p \frac{\partial CP_p}{\partial S_p} - c_p\right) \equiv \Omega_p > 0$, the second-order derivative becomes

$$\frac{d^2 \hat{S}_i}{d\hat{S}_j^2} = -q_j \frac{\partial^2 CP_j}{\partial S_j^2} \frac{1}{\Omega_i} + q_i \frac{\partial^2 CP_i}{\partial S_i^2} \frac{d\hat{S}_i}{d\hat{S}_j} \frac{\Omega_j}{\Omega_i^2} > 0.$$

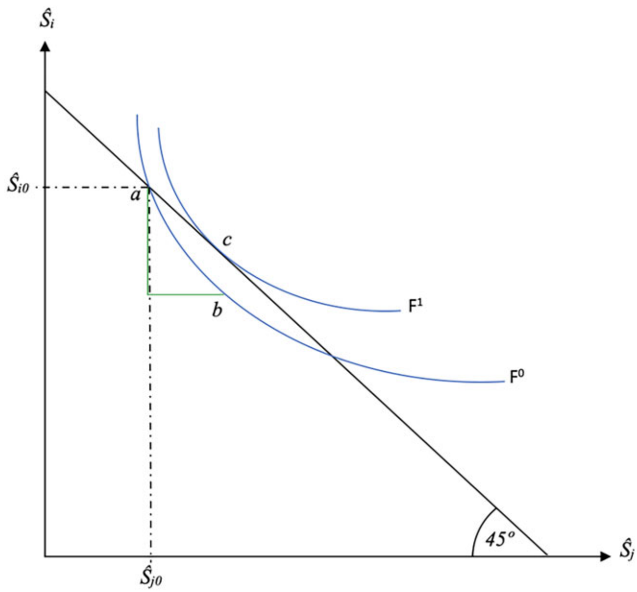

Figure 2. Allocation of study places between two programs, $\hat{S}_i$ and $\hat{S}_j$.

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 $\varepsilon_i = \varepsilon_j$), the iso-funding curves are linear with slope q_j/q_i, so program dimensioning will depend only on the relative prices in the 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 signs of the partial derivatives are indicated below each argument:

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

4. Empirical modeling

The theoretical model gives the empirically testable prediction that the capacity elasticities equal one in the long run. Irrespective of the introduction of PBF, the institutions should 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 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.

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:

$$\begin{aligned}\Delta ln\hat{S}_{p,t} &= const + \boldsymbol{\alpha}_1 EqCM_{p,t-1} + \boldsymbol{\alpha}_2 EqCM_{p,t-1} \times F_{2006} + \beta_1 F_{2006} + \ \beta_2 \Delta F_{2006} \\ &+ \textstyle\sum_{s=1}^{3} \gamma_{1s} \Delta ln\hat{S}\ _{p,t-s} + \sum_{s=1}^{3} \gamma_{2s} \Delta ln\mathrm{S}_{p,t-s} + \sum_{s=1}^{3} \gamma_{3s} \Delta lnA_{p,t-s} \\ &+ Merger\ dummy\ variables + \ Program\ FE + error\ term\end{aligned} \tag{8}$$

In Equation (8), ln denotes log-transformation, Δ denotes first difference, and the subscript p and t are indicators for program and year. The dependent variable $\Delta ln\hat{S}_{p,t}$ is growth in planned study places from year $t-1$ to t. The explanatory variable $\Delta ln\mathrm{S}_{p,t-s}$ is growth in enrolled students, $\Delta lnA_{p,t-s}$ is growth in number of primary applicants, and $\Delta ln\hat{S}_{p,t-s}$ planned study place growth in previous years. Three years lags are chosen to ensure rich short-run dynamics, also motivated by time-dependent contractual relations between students and the HEIs. Model (8) and model (9) below are general specifications simplified to parsimonious models during the modeling process.

The dummy variable F_{2006} represents the change in government funding in 2006, equal to one from 2006, otherwise zero. $EqCM_{p,t-1} = ln\hat{S}_{p,t-1}\_ln\mathrm{S}_{p,t-1}$ is the equilibrium correction term with the long-run unity elasticity imposed. *Merger dummy variables* capture possible effects at the program level of institutional mergers, and/or changes in status from university college to university. *Program FE* captures unobserved heterogeneity of the programs.

The parameters $\alpha_1$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, and program capacity moves toward equilibrium. The same arguments apply 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 Section 2.1, the intake process is centralized at the national level in Norway. 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. However, some students reject the offer of a study place, or accept but do not show up, imposing a random component between admissions and enrollment. 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. Hence, it is optimal to offer more admissions than planned study places. Particularly, study programs not facing tight capacity restrictions, or have problems utilizing the decided capacity, may admit a lot more students than allocated capacity. So, instead of allocating study places to other programs, they are likely 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 analyses of study places. This is the background for estimating the following general EqCM model for admissions:

$$\begin{aligned}\Delta lnAdm_{p,t} &= const - \boldsymbol{\theta}_1 EqCM_{p,t-1} - \boldsymbol{\theta}_2 EqCM_{p,t-1} \times F_{2006} + \lambda_1 F_{2006} + \ \lambda_2 \Delta F_{2006} \\ &+ \textstyle\sum_{s=1}^{3} \mu_{0s} \Delta lnAdm_{p,t-s} + \sum_{s=0}^{3} \mu_{1s} \Delta ln\hat{S}_{p,t-s} + \sum_{s=1}^{3} \mu_{2s} \Delta ln\mathrm{S}_{p,t-s} \\ &+ \textstyle\sum_{s=0}^{3} \mu_{3s} \Delta lnA_{p,t-s} + \ Merger\ dummy\ variables + \ Program\ FE + error\ term,\end{aligned} \tag{9}$$

where the dependent variable $\Delta lnAdm_{p,t}$ is growth in admissions. Multiplying the equilibrium correction term in Equation (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. Analogously 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 Equation (9) because the HEIs know the number of applicants in year t, when the admission decisions are taken.

The capacity and admission decisions are sequential. Hence, Equations (8) and (9) form a recursive system, so single equation OLS gives consistent estimates. However, both equations relate to similar underlying processes so the error terms can be correlated. We thus estimated the model by the SURE estimator (Zellner, 1962), giving parameter estimates almost identical to those presented in Table 2. Some of the estimates get smaller, and a few larger, standard errors, not qualitatively changing the conclusions of the empirical analysis.

4.2 Program differences

Except from credit point prices, quantitative data on the theoretical variables are not available. The price series are highly correlated and therefore useless for the estimation of price effects (cf. Section 2.1). Hence, we are left with qualitative information.

Information on completion rates and admission requirements is relevant for assessing the importance of average and marginal credit point production (r_p, ε_p) in the four program groups. Of the students starting in 2010, 82% finished 2 years after regulated study time in the medicine programs, and 63.4%, 51.6%, and 34.0%, respectively, in the engineering programs, and the business administration and the humanities programs.[26] This is consistent with the credit points per student figures in Section 2.3.

Admission requirements vary a lot. The applicants are ranged according to their grade point average, multiplied by 10. A program's APL, reported by NUCAS, is the minimum admission point a student needs to be admitted to a program. For Medicine and Engineering, the average APLs (min, max) in our data set are 60 (57, 65) and 55 (44, 68), respectively.[27] Of the 104 History and 364 Business Administration admission processes from which we use data, respectively, 64% and 72% admitted all qualified applicants. Opposite, calculating APLs from intakes where planned study places are binding restrictions, we get 44 (max = 49) and 45 (max = 54) points, respectively.

Medicine has the highest credit point price in the government's funding model (cf. Section 2.3), reflecting high marginal cost, and is likely to have the highest average and marginal credit point production based on completion rates and admission requirements. Engineering is characterized as 'medium' in this respect. The bachelor's programs in business administration, and the humanities to which History belongs, have lower completion rates and lower admission requirements, thus reasonably lower average credit points per student and credit point elasticities. Credit point prices and marginal costs are low in these programs. The above-discussed characteristics of the programs are listed in Table 1. Data on admissions, applicants, and enrollment are given in the next section.

The theoretical variables and parameters are important not only when interpreting the empirical results, but also how they relate to the optimality conditions (4) and (6), which

26 *Source:* DBH (n.d.). Again, we are using aggregate data, cf. Section 2.3.

27 Students completing courses in mathematics and natural science in high school get additional admission points, so more than 60 points are possible.

Table 1 Theoretical variables/conditions and empirical counterparts

	Bachelor's programs		Master's programs	
Theoretical variables and conditions	History	Business Adm.	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	Medium	High
Credit point elasticity (ε_p)	Low	Low	Medium	High
Admission requirements	Low	Low	High	High
Admissions per study place	High	High	Low	Low
Applicants per study place	Low	Medium	Medium	High
Enrollment responsiveness to more study places ($\partial S_p/\partial \hat{S}_p$)	Low	Medium	High	High
Restrictions on number of study places	Low	Low	Medium	High
Substitutability of study places	High	High	Medium	Low
Implications for the optimality conditions (4) and (6)	$\varepsilon_p - \hat{c}_p \geq 0$	$\varepsilon_p - \hat{c}_p \geq 0$	$q_j r_j(\varepsilon_j - \hat{c_j}) = q_i r_i(\varepsilon_i - \hat{c_i})$	Equation (6) does not apply

depend on study place restrictions and substitutability, see lower part of Table 1. We may group the study place restrictions into three:

A. Government regulations at the institutional level, and for some professional studies, for example, medicine, at the program level (cf. Section 2.2).
B. Physical infrastructure, which is expensive and time consuming to change, for example, labs and hospital capacities.
C. Softer restrictions such as ordinary teaching room, teachers, and administrative staff.

Medicine faces government target figures for graduates and is the only programs facing restrictions of type A at the program level. Therefore, substituting study places in medicine with other programs is very limited so the optimality condition (6) should not apply.

Engineering does not face type A restrictions at the program level, but as a group these programs are likely to have a lower limit on study places because the university (NTNU) graduates about 80% of all MSc in Engineering in Norway. So, large reductions in the number of graduates are likely to be followed up by the government. On the other hand, type B restrictions may impose upper limits of study places at least in the medium run for (some of) these programs. Hence, substitution of study places between Engineering and other programs is possible and takes place, but more restricted than the bachelor's programs History and Business Administration. History and Business Administration are not facing type A and B restrictions, and type C restrictions are easily solved in the short run. Consequently, there is high degree of substitutability between these and other programs.

5. Data

Indices of aggregate planned study places ($\hat{S}_{p,t}$) are given in Figure 3, illustrating some striking differences between the program groups. Data inspection at the program level reveals large variation within the groups. Medicine is stable, with constant number of planned study places for long stretches of time, and a capacity 24% higher in 2017 compared to 1999. The small stepwise increases illustrate the difficulties of scaling up and down capacity in these programs. The picture is different for Engineering, as there is an overall decreasing number of planned study places in the years 2000–5, with varying changes within the group. A positive trend with some variation appears after 2005, and in 2015 total capacity

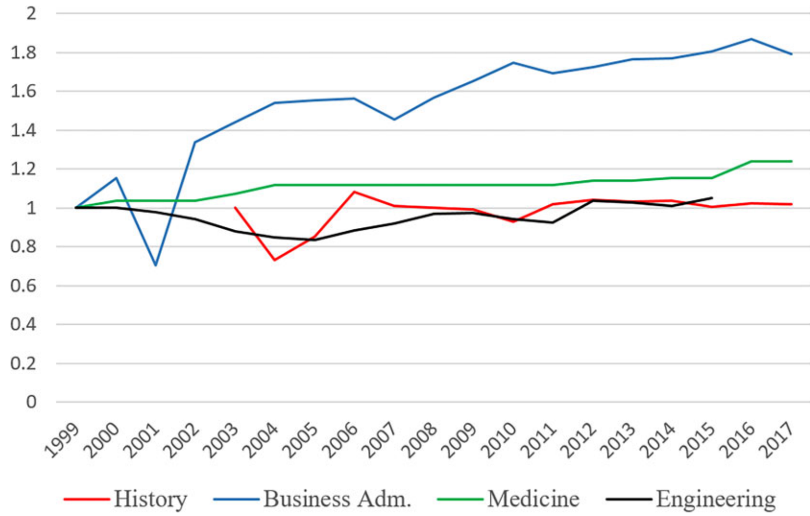

Figure 3. Planned study places ($\hat{S}_{p,t}$), indices. Business Administration and Medicine 1999–2017 ($\hat{S}_{ba,1999} =$ 1100, $\hat{S}_{med,1999} = 425$), Engineering 1999–2015 ($\hat{S}_{eng,1999} = 1578$), and History 2003–17 ($\hat{S}_{hist,2003} = 480$).

is about 5% higher than in 1999. Business Administration has a strong positive trend, whereas History in total is rather stable.[28]

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. Admissions are systematically higher than planned study places, as expected. For Engineering, on average over-admittance is 1.6 (1; 2.3), that is, 60%. 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 large variations within the respective groups. For instance, the lowest ratio is 0.6 within Business Administration, implying empty places, whereas the highest is 8.3, implying that more than eight students on average are offered the same study place. It does not seem to be systematic variation between institutions and programs in over- or under-admittance. Also, for History 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 includes 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.

Primary applicants are used in the empirical analysis as this variable best represents demand for a study place in a specific program. Figure 4 shows that there are large differences between the study programs regarding number of primary applicants per study place. Medicine has the highest ratio with a mean of 5.5, and History, Business Administration, and Engineering 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 History and Business Administration, the ratios are below one in 15% and 36% of the observations, respectively. For Medicine, we do not observe ratios below one, and only in three cases for Engineering. Combining the information in Figures 3 and 4, we see a strong growth in applications for the business administration programs over the years.

28 Regarding the dips in 2001 for business administration, and 2004 and 2005 for the history programs, see Supplementary Material.

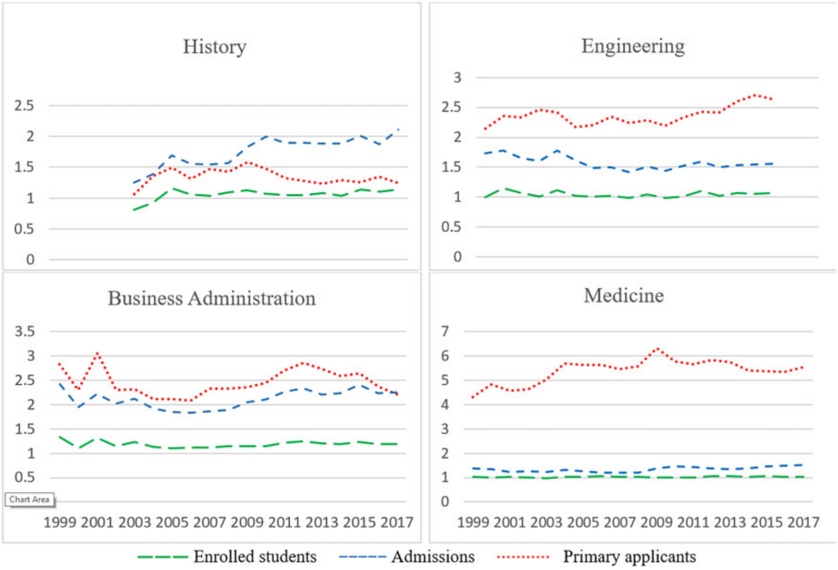

Figure 4. Enrolled students, admissions, and primary applicants, as shares of planned study places.

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, that is, 10% 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, the enrollment ratios are close to one except for Business Administration.[29]

6. Results

The upper panel of Table 2 presents the estimated parameters from model (8). The results for Business Administration and Engineering 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, that is, 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 Medicine and History, as the estimates of α_1 in model (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 History. Similar for all the programs is that student enrollment growth in previous years reduces growth in planned study places, though not statistically significant for History. Adding up these short-run adjustments of enrollment growth in previous years ($\Delta lnS_{p,t-s}$), we get, respectively, −0.88 and −0.55 for Engineering and Medicine. Moreover, growth in primary applicants in previous years only affects Engineering

29 See Supplementary Material for more details on data.

Table 2 Estimates of parsimonious models for planned study places, Equation (8) and admissions, Equation (9)

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
Equilibrium Correction Mechanism ($EqCM_{p,t-1}$)	−0.02	-0.47^{**}	-0.51^{***}	−0.39
	(0.135)	(0.199)	(0.153)	(0.335)
Interaction term ($EqCM_{p,t-1} \times F_{2006}$)	−0.14	0.06	−0.06	−0.05
	(0.116)	(0.248)	(0.188)	(0.283)
PBF dummy (F_{2006})	0.03	−0.04	0.11^{***}	−0.04
	(0.066)	(0.072)	(0.023)	(0.032)
Student enrollment growth lagged 1 year ($\Delta lnS_{p,t-1}$)	−0.11	-0.15^{**}	-0.38^{***}	−0.21
	(0.083)	(0.072)	(0.073)	(0.136)
Student enrollment growth lagged 2 years ($\Delta lnS_{p,t-2}$)	–	–	-0.30^{***}	-0.22^{***}
			(0.067)	(0.078)
Student enrollment growth lagged 3 years ($\Delta lnS_{p,t-3}$)	–	–	-0.20^{***}	-0.12^{***}
			(0.048)	(0.022)
Application growth lagged 1 year ($\Delta lnA_{p,t-1}$)	0.05	0.002	0.04	−0.01
	(0.092)	(0.047)	(0.046)	(0.057)
Application growth lagged 2 years ($\Delta lnA_{p,t-2}$)	–	–	0.09^{**}	−0.03
			(0.043)	(0.037)
Application growth lagged 3 years ($\Delta lnA_{p,t-3}$)	–	–	0.01	0.01
			(0.074)	(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
Equilibrium Correction Mechanism ($EqCM_{p,t-1}$)	−0.09	-0.29^{***}	-0.53^{***}	-0.64^{***}
	(0.221)	(0.088)	(0.123)	(0.066)
Interaction term ($EqCM_{p,t-1} \times F_{2006}$)	-0.52^{**}	−0.06	0.17	0.40
	(0.214)	(0.121)	(0.125)	(0.250)
PBF dummy (F_{2006})	−0.07	0.15^{***}	0.04^{***}	0.01
	(0.133)	(0.039)	(0.013)	(0.030)
Admission growth, lagged 1 year ($\Delta lnAdm_{p,t-1}$)	-0.40^{***}	-0.15^{**}	−0.16	−0.05
	(0.066)	(0.078)	(0.105)	(0.114)
Study place growth, year t ($\Delta ln\hat{S}_{p,t}$)	1.07^{***}	0.28^{**}	0.63^{***}	0.66^{***}
	(0.266)	(0.126)	(0.110)	(0.203)
Application growth, year t ($\Delta lnA_{p,t}$)	0.21	0.18^{*}	0.12^{***}	0.04
	(0.143)	(0.095)	(0.031)	(0.103)
Student enrolment growth lagged 1 year ($\Delta lnS_{p,t-1}$)	0.37^{***}	0.12^{*}	−0.05	−0.29
	(0.077)	(0.071)	(0.103)	(0.259)
Student enrollment growth lagged 2 years ($\Delta lnS_{p,t-2}$)	–	-0.101^{*}	-0.10^{**}	-0.29^{*}
	–	(0.059)	(0.047)	(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 version 15.
***,**, and * refer to statistical significance at 1%, 5%, and 10%, respectively.
Program level clustered SE.

positively and statistically significant ($\Delta lnA_{p,t-2}$). We also estimate an 11% higher average study place growth for Engineering after 2006, also 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). For Business Administration, adjustment speed is between three and four years, and for Medicine and Engineering about one and a half, and 2 years, respectively. There is no similar long-run response for History but a strong and statistically significant short-run effect ($\Delta lnAdm_{p,t-1}$). Although smaller, there is also for Business Administration a similar effect.

Turning to the estimates of θ_2, it is noticeable that the history programs after the funding change gain a statistically significant estimate with adjustment back to long-run equilibrium within 2 years. For the other programs none of the corresponding estimates are statistically significant. This means that after 2006 speed of adjustment is statistically almost the same for all the four programs. Moreover, there is a significantly higher average admission growth after the funding change for Business Administration and Engineering, respectively, 15% and 4%, cf. the F_{2006} estimates. For History and Medicine, there are no such effects.

As expected, an increase in planned study places ($\Delta ln\hat{S}_{p,t}$), decided the year before as explained in Section 2.1, 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 estimate for Medicine (0.66) is statistically not different from one. The small estimate for Business Administration (0.28) is consistent with very high average admission rates (cf. 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 internal adjustments of study places within the university's total engineering program. Hence, an increase in planned study places in a program is not automatically filled, probably because actual applicants are not regarded as qualified.

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 Engineering, but also of importance for Business Administration and History, though the latter is not statistically different from zero. The number of applicants for Medicine is constantly very high, so there is no reason that changes in applications should matter.

The second lag of enrollment growth ($\Delta lnS_{p,t-2}$) affects admissions statistically negative for Medicine, Engineering, and Business Administration. 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. As these programs have problems filling the study places, increased enrollment may give arguments to more admissions the next year.

7. Discussion

The empirical analysis presents two main findings. First, the results support that the outlined long-run adjustment mechanism works for Business Administration and Engineering, but not for History and Medicine. Second, the funding change in 2006 did not influence the speed of adjustment of planned study places, indicating that PBF does not affect an important variable for long-run productivity development. However, the change increases the average growth in planned study places in Engineering by 10%, implying more focus on production of credit points. In the following, we discuss in more detail the results for the four program groups.

7.1 Medicine and engineering

Both programs are integrated master's programs but face different study place restrictions. Medicine is restricted at the program level and cannot make capacity changes and only marginal admission adjustments. The results in panel A of Table 2 are therefore consistent with the expectation that the optimality condition (6) from the theoretical model does not apply. The results from model (9) show that admissions react to deviations between planned and enrolled students. Though not statistically different from zero by conventional levels of significance, the 2006 funding change may have reduced speed of adjustment, which may sound odd. However, keeping in mind that the HEIs face targets on graduates (credit points) from the medicine programs, and that the completion rates are not 100% (cf. Section 4.2), it is consistent to become more retaining to adjust deviations from long-run equilibrium after the funding change because dropouts cost more after the change.

As a group, the engineering programs are restricted upwards due to physical infrastructure limitations, and downwards because of likely government reactions if the number of study places become too low (cf. the discussion in connection to Table 1). The total number of study places varies around an average of 1,500, with an indicated upper restriction of 1,600, cf. Figure 3. Hence, substitution of study places within Engineering, and with other programs, is possible. The engineering programs have a common content of generic subjects (mathematics, mechanics, physics, chemistry, etc.) the first 2–3 years and program-specific specialization the last 2–3 years. Average marginal costs and credit point prices are in the middle, which also makes substitution easier. Moreover, Engineering has a formal coordinating body reporting directly to Rector with mandate 'to manage inter-faculty coordination and develop common quality requirements for the Master of Science in Engineering programs'.[30] This setting makes those involved considerate to study place allocations. The results that previous years' enrollment and application growth play a significant role for planned study place adjustments, support this argument. The results are thus consistent with the theoretical predictions.

7.2 Business administration and history

Related to the theoretical model, Business Administration and History are similar in that study places are substitutable with other programs, and that all types of study place restrictions are much looser. This makes it likely that the optimality condition given by Equation (4) from the theoretical model applies, saying that the number of study places will increase if the credit point elasticities are larger than effective marginal costs, and vice versa. However, this requires that the demand for study places is sufficiently high, and in this respect the two programs differ.

Business Administration has strong application growth. High demand for study places and low marginal costs, make the HEIs reluctant to reduce capacity after the funding change. Gaps between planned and enrolled students can then be closed by increasing admissions (cf. Figure 4), thus increasing credit point production and government funding. From Panel B of Table 2, we see that the average admission growth increases by 15% after 2006, and that application growth affects admissions positively.

Competition for students and study places is a likely common element for Business Administration and Engineering. However, short-run dynamics in the relation for planned study places differ a lot between the two programs, reflecting different mechanisms, but are qualitatively similar in the admission model.

For History, marginal costs, funding rewards, and admission requirements are low, and direct government regulation absent. Applications are so low that the number of admissions is higher than number of primary applicants (cf. Figure 4). Three of the seven history

[30] See: https://innsida.ntnu.no/wiki/-/wiki/English/Executive+Committee+for+Engineering+Education. Last accessed 30 October 2022.

programs have been open the whole estimation period, that is, all students fulfilling the formal requirements for university studies got admitted. Thus, it seems not possible to increase the number of students, and credit points, to reach $\varepsilon_p = \hat{c}_p$.

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 (cf. 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. Thus, the decision becomes binary, either closing or continue with the same capacity. Second, the HEIs avoid closing because the institutions have a paramount objective to uphold knowledge within the discipline, irrespective number of students. History is requisite as university discipline and required for good academic reputation. Hence, closing is a tough decision, so continuation at the same capacity level keeps the programs on an apparently safe track.

The admission results for History show that the estimated adjustment coefficient becomes statistically negative (-0.52) after 2006, and statistically not different from the other programs. 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 a given year to the next. So, in spite that we find short-run admission dynamics in line with theory for History, the dimensioning process implies no capacity changes.

8. Conclusion

The main conclusion is that HEIs adjust study program capacities efficiently when capacity restrictions are binding and substitution possible. If not, long-run optimal capacity adjustments are absent, which could be explained by sunk costs and/or academic reputation implying commitments to keep up disciplines despite few students (History). Tight government regulation (Medicine) gives no room for adjustments.

The change in the government's funding model in 2006 did not affect adjustments of long-run study program dimensioning. However, for Engineering we find that the funding change increased short-run average growth in planned study places a lot and to a lesser extent admissions, whereas this change increased average admission for Business Administration considerably. This, and other differences in short-run dynamics, indicate that the student competitive elements in the adjustment processes of the two programs are different. The results for History demonstrate that deviations from long-run equilibrium affect admissions after the funding reform. The estimated adjustment coefficient is almost identical to the estimated adjustment coefficients for study places in Business Administration and Engineering and may indicate inertia before a reform take effect (Tandberg and Hillman, 2014).

The results are explained consistently within the theoretical model. However, we cannot rule out the possibility that the 2006 PBF model was anticipated by the HEIs. Hence, the long-run impacts on capacity adjustments were completed when the model was implemented, so we are left with short-run effects. This means that it is difficult to explain our results by for instance obstacles to PBF, inappropriate metrics, incomplete organizations, or insufficient knowledge of performance.

The empirical analysis and the descriptive statistics do not support the findings from US higher education data of more restrictive admission practices due to performance funding (Dougherty *et al.*, 2014; Umbricht *et al.*, 2017). On the contrary, our results indicate that the institutions take unintended actions to inflate their funding metrics, which is likely to have the opposite effect on education productivity. More students enrolled than planned for put pressure on resources, with negative consequences for the educational setting, which also connects to social problems with performance metrics (Campbell, 1979).

Our results identify possible channels 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 may have loose restrictions on the total number of study places. 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 want to use PBF to stimulate education productivity, the likely policy implication is to consider critically the allocation and follow-up of study places to each institution. An alternative would be to impose measures that incentivize the HEIs to keep to their target figures, for instance by negative sanctions, or to change the price structure by, for example, rewarding credit points *per student*. In the short run, such policies may have negative impacts on the development of academic disciplines, but not necessarily in the long run because more efficient use of resources should make higher quality more attainable.

Supplementary material

Supplementary material is available on the OUP website, comprising the Supplementary Appendix, data files, and replication files.

Funding

This work has not been supported by any particular funding.

Acknowledgements

Valuable comments from three anonymous referees are gratefully acknowledged. We are also grateful to Gunnar Bårdsen, Olav Fagerlid, Torberg Falch, Colin Green, Thomas de Haan, and Bjarne Strøm for discussions and comments to a previous version of the article. The usual disclaimer applies.

References

Aghion, P., Dewatripont, M., Hoxby, C., Mas-Colell, A., and Sapir, A. (2010) The governance and performance of universities: evidence from Europe and the US, *Economic Policy*, **25**, 7–59.

Agasisti, T., Abalmasova, E., Shibanova, E., and Egorov, A. (2021) The causal impact of performance-based funding on university performance: quasi-experimental evidence from a policy in Russian higher Education, *Oxford Economic Papers*, **74**, 1021–44.

Becker, G.S. (1964). *Human Capital. A Theoretical and Empirical Analysis with Special Reference to Education*, The University of Chicago Press, Chicago, IL.

Black, D.A., McKinnish, T.G., and Sanders, S.G. (2005) Tight labor markets and the demand for education: evidence from the coal boom and bust, *Industrial and Labor Relations Review*, **59**, 3–16.

Bleiklie, I., Enders, J., and Lepori, B. (2015) Organizations as penetrated hierarchies: environmental pressures and control in professional organizations, *Organization Studies*, **36**, 873–96.

Bolli, T., Olivares, M., Bonaccorsi, A., Daraio, C., Garcia Aracil, A., and Lepori, B. (2016) The differential effects of competitive funding on the production frontier and the efficiency of universities, *Economics of Education Review*, **52**, 91–104.

Campbell, D.T. (1979) Assessing the impact of planned social change, *Evaluation and Program Planning*, **2**, 67–90.

Cantillon, B., De Ridder, A., Vanhaecht, E., and Verbist, G. (2011) (Un)desireable effects of output funding for Flemish universities, *Economics of Education Review*, **30**, 1059–72.

Chen, C.Y. (2015) A study showing research has been valued over teaching in higher education, *Journal of the Scholarship of Teaching and Learning*, **15**, 15–32.

Christensen, M., Dyrstad, J.M., and Innstrand, S.T. (2020) Academic work engagement, resources and productivity: empirical evidence with policy implications, *Studies in Higher Education*, **45**, 86–99.

Cummings, W.K. and Shin, J.C. (2014). Teaching and research in contemporary higher education: an overview, in J.C. Shin, A. Arimoto, W.K. Cummings, and U. Teichler (eds) *Teaching and Research in Contemporary Higher Education Systems, Activities and Rewards*, Springer, Dordrecht, 1–12.

DBH. (n.d.). Database for statistikk om høyere utdanning. https://dbh.hkdir.no/tall-og-statistikk/statistikk-meny/indeks. Last accessed 30 October 2022.

de Boer, H. and Enders, J. (2017). Working in the shadow of hierarchy: organisational autonomy and venues of external influence in European universities, in I. Bleiklie, J. Enders, and B. Lepori (eds) *Managing Universities. Policy and Organizational Change from a Western European Comparative Perspective*, Palgrave Studies in Global Higher Education, Cham. 57–83.

Dougherty, K.J., Jones, S.M., Lahr, H., Natow, R.S., and Reddy, V. (2014) Performance funding for higher education: forms, origins, impacts, and futures, *The Annals of the American Academy*, **655**, 163–84.

Dougherty, K.J., Jones, S.M., Lahr, H., Natow, R.S., Pheatt, L., and Reddy, V. (2016a) *Performance Funding for Higher Education*, Johns Hopkins University Press, Baltimore, MD.

Dougherty, K.J., Jones, S.M., Lahr, H., Natow, R.S., Pheatt, L., and Reddy, V. (2016b) Looking inside the black box of performance funding for higher education: policy instruments, organizational obstacles, and intended and unintended impacts, *The Russell Sage Foundation Journal of Social Sciences*, **2**, 147–73.

Dyrstad, J.M. and Pettersen, I. (2017) Finansieringsinsentiver og universitetsstrategier. En sammenligning av fagmiljøers tilpasning ved universitetene i bergen, *Oslo Og Trondheim. Samfunnsøkonomen*, **131**, 53–66.

Enders, J., de Boer, H., and Weyer, E. (2013) Regulatory autonomy and performance: the reform of higher education re-visited, *Higher Education*, **65**, 5–23.

Fethke, G.C. and Policano, A.J. (2012). *Public No More. A New Path to Excellence for America's Public Universities*, Stanford University Press, Stanford, CA.

Geschwind, L. and Broström, A. (2015) Managing the teaching-research nexus: ideals and practice in research-oriented universities, *Higher Education Research & Development*, **34**, 60–73.

Haraldsvik, M. and Strøm, B. (2021) Adult skills and labor market conditions during teenage years: cross-country evidence from international surveys, *Oxford Economic Papers*, **73**, 894–919.

Hillman, N.W., Tandberg, D.A., and Gross, J.P.K. (2014) Performance funding in higher education: Do financial incentives impact college completions, *The Journal of Higher Education*, **85**, 826–57.

Hillman, N.W., Tandberg, D.A., and Fryar, A.H. (2015) Evaluating the impacts of "new" performance funding in higher education, *Educational Evaluation and Policy Analysis*, **37**, 501–19.

Horta, H., Dautel, V., and Veloso, F.M. (2012) An output perspective on the teaching-research nexus: an analysis focusing on the United States higher education system, *Studies in Higher Education*, **37**, 171–87.

Jongbloed, B. (2010). *Funding Higher Education: A View across Europe*. European Centre for Strategic Management of Universities (ESMU), Brussel.

Jongbloed, B. and Vossensteyn, H. (2016) University funding and student funding: international Comparisons, *Oxford Review of Economic Policy*, **32**, 576–95.

Jongbloed, B., Kaiser, F., van Vught, F., and Westerheijden, D.F. (2018). Performance agreements in higher education: a new approach to higher education funding, in A. Curaj, L. Deca, and R. Pricopie (eds) *European Higher Education Area: The Impact of past and Future Policies*, Springer Open, Berlin, Germany, 671–687.

Leiytė, L., Enders, J., and de Boer, H. (2009) The balance between teaching and research in Dutch and English universities in the context of university governance reforms, *Higher Education*, **58**, 619–35.

Leiytė, L. (2016) New public management and research productivity – a precarious state of affairs of academic work in the Netherlands, *Studies in Higher Education*, **41**, 828–46.

Ministry of Education and Research. (2015). Finansiering for kvalitet, mangfold og samspill, Oslo. https://www.regjeringen.no/contentassets/0d3aa576467f4eeeb7f7af25a26d607a/finansieringuh_rapport.pdf. Last accessed 30 October 2022.

Seeber, M., Benedetto, L., Montauti, M., Enders, J., de Boer, H., Weyer, E., Bleiklie, I., Hope, K., Michelsen, S., Nyhagen Mathisen, G., Frølich, N., Scordato, L., Stensaker, B., Waagene, E., Zarko, D., Kretek, P., Krücken, G., Magalhães, A., Ribeiro, F.M., Sousa, S., Veiga, A., Santiago, R., Marini, G.,

and Reale, E. (2015) European universities as complete organizations? Understanding identity, hierarchy and rationality in public organizations, *Public Management Review*, **17**, 1444–74.

Shin, J.C. (2010) Impacts of performance-based accountability on institutional performance in the US, *Higher Education*, **60**, 47–68.

Tandberg, D.A. and Hillman, N.W. (2014) State higher education performance funding: data, outcomes, and policy implications, *Journal of Education Finance*, **39**, 222–43.

Umbricht, M.R., Fernandez, F., and Ortagus, J.C. (2017) An examination of the (un)intended consequences of performance funding in higher education, *Educational Policy*, **31**, 643–73.

Verhoest, K., Guy Peters, B., Bouckaert, G., and Verschuere, B. (2004) The study of organizational autonomy: a conceptual review, *Public Administration and Development*, **24**, 101–18.

Ward, J. and Ost, B. (2021) The effect of large-scale performance-based funding in higher education, *Education Finance and Policy*, **16**, 92–124.

Zellner, A. (1962) An efficient method of estimating seemingly unrelated regression equations and tests for aggregation Bias, *Journal of the American Statistical Association*, **57**, 348–68.