CESIS

Centre of Excellence
for Science and Innovation Studies

CESIS Electronic Working Paper Series

Paper No. 245

The Economic Efficiency of Swedish Higher Education Institutions

Zara Daghbashyan

December 2012

The Royal Institute of technology
Centre of Excellence for Science and Innovation Studies (CESIS)
http://www.cesis.se

The Economic Efficiency of Swedish Higher Education Institutions

Zara Daghbashyan[1]

Abstract

Using parametric frontier techniques, this paper investigates the economic efficiency of Swedish higher education institutions (HEIs) with an attempt to determine the factors causing efficiency differences. The analysis is conducted for 30 HEIs over the time period 2001-2005. A set of HEI organizational factors as well as faculty and student compositions are examined as potential determinants of economic efficiency.

According to the estimates, half of the Swedish HEIs have above average efficiency of 85 percent. The economic efficiency is positively affected by HEI size, the number of students per faculty and a high proportion of young professors in the faculty. Another interesting finding is that the source of financing matters for efficient use of resources; in particular, HEIs with a higher level of government support are found to be less efficient.

JEL classification: C21, C24, I21

Keywords**:** Cost efficiency, stochastic frontier analysis, universities

[1] Industrial Economics and Management, Royal Institute of Technology, Stockholm; email: zarad@kth.se

1. Introduction

Raising educational standards as a means of attaining competitiveness and growth has been in the agenda for more than fifteen years in Sweden and internationally. According to educational statistics for Sweden, the number of students in higher education rose by 52 percent between 1995 and 2005[2]. For a country with a publicly financed higher education system, the increase in student population means an increase in government expenditures.

Currently about 1.6 percent of the Swedish GDP is devoted to higher education and research, which provides employment for 64,300 people. Important though the higher education sector may be as a source of human capital production and development, rather little is known about its economic efficiency. The question addressed in this paper is how efficiently the Swedish higher education sector operates. Are the tax-payers' resources allocated to the higher education sector utilized efficiently? Do all HEIs operate at the same level of efficiency or do they exhibit different economic behaviour? What drives the economic efficiency of HEIs?

As mentioned in Kempkes and Pohl (2010) knowledge about university efficiency may enable university management to recognize their shortcomings and improve performance. In addition, efficiency indicators can be utilised by public authorities as a guideline for the distribution of funds and for enhancing a more efficient use of resources.

Before going further it is worth discussing the definition of the economic efficiency[3], which is the major concern of this paper. Modern efficiency measurement began with Farrel (1957), who defined economic efficiency as the ability to obtain maximum output from the resources available (technical efficiency), and to choose the best package of inputs given their prices and marginal productivities (allocative efficiency). Classical microeconomic theory assumes that firms and institutions operating in a free market will strive to maximize their profits/minimise their costs and hence operate close to or at 100 percent efficiency, i.e. produce maximum output from the given inputs and use the best combination of inputs. However, the evidence from practice does not always support this hypothesis. Some firms, especially those operating as non-profit organizations, tend to deviate from the predicted behavior and are hence regarded as inefficient (James, 1990).

There may be many reasons for such divergence from the optimal behaviour and differences in efficiency. Empirical studies of the determinants of efficiency date back to the early 1990s. For instance, Lovell (1993) states that identifying the factors which explain differences in efficiency is essential for improving the results, but that, unfortunately, economic theory does

[2] See Högsoleverkets årsrapport 2005 at http://hsv.se/statistik/hogskoleverketsarsrapport
[3] Also called cost efficiency

not supply a theoretical model of determinants of efficiency. However, Caves and Barton (1990) suggest that several studies, which have developed a strategy for identifying the determinants of efficiency, may be grouped into the following categories: (i) external factors, (ii) internal factors, (iii) ownership structure (public vs. private). For higher education institutions (HEI) the potential efficiency determinants might be related to organizational differences as well as to differences in faculty and student composition. It is hard to classify them into either external or internal, since they are influenced in the long-run by both external and internal factors.

Based on previous research on HEI efficiency, such as Robst (2001), Stevens (2005), McMillan and Chan (2006) and data availability, we distinguish the following efficiency determinants: organizational differences, such as size, the number of students per faculty, degree of specialization, the share of government support in HEI revenues, faculty composition in terms of the share and age of professors employed, student composition in terms of demographic characteristics and their pre-enrolment quality.

Thus, the focus of this paper is on estimation of the economic efficiency of higher education institutions in Sweden to see whether HEIs, operating in the same national market and regulated by the same legislation, exhibit different levels of efficiency and to what extent this difference can be explained by potential efficiency determinants. The paper contributes to the existing literature by making an efficiency analysis of a country with a publicly financed education sector, thus shedding light on efficiency differences in public education institutions and the influence of source of financing on their economic behaviour. Another contribution is the analysis of a wide set of possible efficiency determinants in an attempt to add to previous findings.

Using stochastic frontier methodology, this study is conducted on 30 HEIs in Sweden. We particularly apply the Battese and Coelli (1995) model, which allows us to estimate both economic efficiency and its determinants. According to our results, the average efficiency estimate is 85 percent, and half of the HEIs have above mean efficiency. Big universities, as well as those with a higher number of students per faculty, are found to be more efficient. Furthermore the results indicate that the source of funding matters for the economic behaviour of institutions, i.e. HEIs with a high share of government financing in total revenues seem to be less efficient. Another interesting finding is that HEIs employing a higher proportion of young professors are more efficient, ceteris paribus. Regarding the relationship between student characteristics and cost efficiency, our analysis suggests that efficiency is increased by enrolling more foreign students. Students’ pre-enrollment quality, measured by their median grade point average score from secondary school (GPA), is found to have no statistically significant effect on HEI efficiency.

The paper is organized as follows. The next section reviews methods and earlier empirical evidence and section 3 describes the methodology. The variable selection is discussed in section 4 and the data presented in section 5. The empirical model is described in section 6. The estimations and results are shown in section 7. Section 8 provides a brief summary of the main results.

2. Methods and empirical evidence

The previous literature that has focused on higher education efficiency can be divided into two main groups - those using Data Envelopment Analysis (DEA) and those choosing Stochastic Frontier Analysis (SFA). Both are frontier methodologies aimed at the estimation of production/cost frontier and efficiency, but they differ in the underlying assumptions. The advantages and disadvantages of both methods are now well recognized: in SFA the functional form of the efficient frontier is pre-defined or imposed a priori, whereas in DEA no functional form is pre-established but is estimated from the sample of observations in an empirical way. DEA is a deterministic method and assumes that all deviations from the efficient frontier are due to inefficiency, whereas in SFA the divergence from the efficient frontier occurs due to inefficiency and some random shocks out of agents' control. Because each method possesses its own strengths and limitations, neither method is strictly preferable to the other.

Several studies have applied DEA to investigate the relative efficiency of higher education institutions (see e.g. Johnes & Johnes, 1993, Johnes, 2006, Glass et al.,1995 Abbot & Doucouliagos, 2003). The results indicate that there are various degrees of technical and/or cost efficiency in higher education institutions, and that universities are not homogenous in their performance. One study has used DEA to analyze technical efficiency of Swedish HEIs and found that their average technical efficiency is 93 percent (Riksrevisionen, 2011:2)[4]. In an attempt to explain the variation in the efficiency of universities, some DEA studies also report scale efficiency scores (Abbot & Doucouliagos, 2003), while others compare efficiency scores for different ownership structures (Ahn et. al., 1988).

Studies that employ SFA as a method to estimate the economic efficiency of higher education institutions are more diverse. They differ not only in the choice of the functional form, but also in the distributional assumptions about the inefficiency term and the determinants of

[4] Our study differs by the method of estimation and broader analysis of efficiency determinants. Furthermore, we estimate the cost efficiency whereas the DEA study reports technical efficiency estimates only.

inefficiency. For instance, Izadi et al. (2002) use SFA techniques to estimate a CES cost function, and find that significant inefficiency remains in the British higher education system. Using stochastic frontier methodology, Robst (2001) investigates the impact of state appropriations on the cost efficiency of public universities, and suggests that universities with smaller state shares of public funding are not more efficient than universities with higher state shares. Stevens (2005) estimates the cost efficiency for a group of English and Welsh universities and finds that there is inefficiency in the higher education sector. His study is unique in the sense that it models the inefficiency as a function of staff and student characteristics as efficiency determinants, and finds that proportions of the professorial staff have a positive effect on efficiency, whereas the proportion of staff over fifty years of age affects the efficiency negatively. Arguing that efficiency estimates may be sensitive to the choice of methodology, McMillan & Chan (2006) compare results of the application of both DEA and SFA methods on a sample of 45 Canadian universities. They show consistency in the relative ranking of individual universities for high efficiency and low efficiency groups.

Though all these studies give considerable insight into the operation of higher education institutions, and suggest that HEIs differ in the efficiency of their operation, they report ambiguous findings on efficiency determinants. Furthermore, efficiency variation in a country with a publicly owned education sector has not been discussed. Hence, this study is an attempt to estimate the efficiency of publicly owned higher education institutions, and to explain the reasons for variation in HEIs performance.

3. Methodology

In choosing a methodology for the estimation of the economic efficiency of Swedish HEIs we give preference to SFA, due to the possibility of accounting for random shocks and making an absolute estimate of efficiency. In DEA the efficiency estimates are relative and there are no statistical tests to check for the presence of overall inefficiency.

The application of SFA for estimation of economic efficiency is based on the assumption that all units under consideration are cost minimisers. We argue that while the activity of higher education institutions is more often targeted at “the pursuit of excellence” and “prestige maximization” (Robst, 2001), this does not preclude them from minimizing their costs given the same aspirations for excellence and prestige. Moreover, due to budget restrictions, public authorities allocating funds to universities are interested not only in “prestige maximization” but also efficient utilization of their resources; hence cost minimization behavior seems to be plausible in the higher education sector context. Farsi & Filippini (2009) note that even if some institutions do not fully minimize their costs, the cost function approach is still meaningful, and may be used as a "behavioral" approach for comparing the performance of units and marginal effects of various factors.

3.1. Cost function

It is now well recognized that the activity of HEIs is targeted at teaching, research and community service and hence HEIs should be treated as multi-product organizations. The traditional multiple-output cost function given below relates costs to the multiple outputs, input prices and some exogenous variables having impact on the cost function.

$$C = c(y, w, z; \beta, \gamma, \theta)$$

where C is the total cost, y is a vector of output variables, w represents the vector of input prices and z is a vector of exogenous factors; β,γ,θ are the respective parameters to be estimated. To estimate the relationship between the cost and the dependent variables a functional form is to be assumed. Which functional form to choose for the empirical analysis is usually not a straightforward decision, since the true shape of the function is unknown. Within the context of the problem, the form should be as general as possible and impose the fewest possible a priori constraints. Some functional forms suggested in the literature are more restrictive, imposing several constraints upon parameters of the cost function (Cobb-Douglas, CES and Leontief), while others which are more flexible should be checked for meeting the properties of cost functions (Translog, Quadratic, Generalized Translog). Many authors prefer to use flexible functional forms because they are less restrictive and provide local second-order approximation to any well-behaved underlying cost function; however, the estimation of flexible functional forms requires a large sample size, which is not always possible. Moreover, multicolinearity among the regressors is likely to lead to imprecise estimates of model parameters. As noted in Kumbhakar and Lovell (2000), the benefit of flexibility is likely to be offset by the "cost" of statistically insignificant parameter estimates.

Different functional forms have been used to estimate the costs of HEIs. Thus, McMillan and Chan (2006) use a Cobb-Douglas functional form for Canadian HEIs, Izadi et al. (2002), estimate a CES function for British HEIs, Robst (2001) estimates a translog cost function for South Carolina HEI, and Koshal and Koshal (2000) use a flexible quadratic form. Their choices are mainly motivated by the character of their data and sample size.

We follow McMillan and Chan (2006) and use the Cobb-Douglas functional form to estimate the cost function of Swedish HEIs in view of the small number of observations. The great virtue of the Cobb-Douglas form is that its simplicity enables us to focus on the inefficiency problem, which is the major concern of this analysis, and that it is less data demanding.

3.2. Stochastic Frontier Analysis

The estimation of the cost function by traditional OLS would allow finding the average cost function under the assumption that all units exhibit the same efficiency of operation. This would be in compliance with traditional microeconomic theory, which assumes that firms and institutions are profit-maximizers/cost-minimisers, and hence they make maximum effort to produce maximum output with minimal costs. However, empirical studies suggest that in reality not all firms are always so successful in solving their optimization problems. While some firms operate on the frontier and earn high profits, others lag behind and barely survive (Badunenko et al., 2008). Such organizations tend to deviate from predicted optimal behaviour, and hence are treated as inefficient. Efficient firms operate on the frontier; they produce maximum output from the given input (technical efficiency) and use the optimal input proportions (allocative efficiency). Inefficient firms diverge from the optimal behaviour and operate beneath the frontier. Stochastic frontier analysis allows building cost models with consideration of unit specific inefficiency and exogenous shocks beyond the control of analysed units (see more in Kumbhakar & Lovell, 2000).

The classical cost function in SFA $C_i = c(y_i, w_i, z_i; \beta, \gamma, \theta)\exp(v_i + u_i)$ consists of three parts – a deterministic frontier $c(y_i, w_i, z_i; \beta, \gamma, \theta)$ common to all producers (in our case HEIs), a producer-specific random part v_i, which captures the effects of random shocks on each producer, and an inefficiency component u_i .The first error component v_i is intended to capture the effect of statistical noise, whereas u_i is the non-negative cost inefficiency component, which is the product of technical and allocative inefficiencies. The units operate at the frontier or beneath if their inefficiency component u_i is 0 or u_i >0 respectively. If all the units operate at the frontier then u_i =0 for all the units and there is no place for inefficiency (Coelli et al.,2005).

3.3. Incorporating exogenous influences on efficiency

The analysis of cost efficiency has two main components. The first is the estimation of the stochastic frontier that serves as a benchmark against which to estimate the efficiency under some behavioural assumptions. The second component concerns the incorporation of exogenous variables[5], which are neither inputs nor outputs, but which nonetheless exert an influence on the performance. As noted ín Kumbhakar and Lovell (2000, p.261), "the objective of the second component is to associate variation in producer performance with

[5] Also called environmental variables

variation in exogenous variables characterizing the environment in which production occurs". Examples include the quality of input and output indicators, various managerial characteristics, ownership structure etc. These factors may influence the cost function either directly or indirectly through affecting the efficiency with which inputs are converted into outputs. Kumbhakar, Gosh and McGulkin (1991) have developed a model for estimating both frontier and efficiency terms with exogenous variables serving as determinants of efficiency. The model has been further modified by Battese and Coelli (1992, 1995) for panel data with time varying efficiency.

4. Swedish higher education sector and variable selection

Before addressing the choice of university input and output variables as well as exogenous variables affecting efficiency, we will briefly discuss the Swedish higher education sector.

4.1. Swedish higher education sector

The first thing to note is that the majority of Swedish HEIs are public authorities. A small number of HEIs are private and operate on the basis of an agreement with the government. However, in Sweden the concept of public or private HEIs refers to whether they are financed by government or other public or private foundations. The tuition at all higher education institutions in Sweden is free of charge[6]; hence, students at public or private HEIs do not have to pay for their education.

The primary mission of HEIs, as stipulated by the Swedish Agency of Higher Education, is to provide higher education, conduct research and interact with the surrounding society, ensuring that benefit is derived from the research findings. For fulfilment of these missions, Swedish HEIs get public funding; about 86 percent of graduate and undergraduate education[7] and about 50 percent of research are publicly financed (Högskoleverket, 2009).

The funding for undergraduate and graduate education is based on the number of full-time equivalent students and their annual performance equivalent. The amount of funding varies depending on the disciplinary domain. It is the responsibility of each HEI to decide on the number of students and variety of courses and programs, but there is also a funding cap that limits the size of funding a HEI may receive. PhD programs and research are financed by the government as well as indirect government funding and external sources. Nonetheless, not all Swedish HEIs have the right to offer a PhD program and receive government funding for research. Those entitled to do so are called universities, whereas others are classified as

[6] Tuition fees were introduced for students from outside the EU/EEA in 2011.
[7] Private HEIs get funding from governmental foundations but not the government.

university colleges[8]. Thus, though all HEIs seek external funding for research, university colleges are more dependent on it.

The management of Swedish higher education institutions is carried out by a board, which is responsible for ensuring the effective management of the HEI and for planning its future development, and by the HEI president, who is responsible for overall operation and organization of the HEI.[9]

Though Swedish HEIs are mainly publicly financed, they are responsible for the organization and operation of their activities. They are free to allocate funds for acquisition of resources necessary for their operation, and to define courses and programs, admission and enrolment procedures, research focus etc.

Based on the above discussion we can use the following diagram to describe the operation of HEIs in Sweden.

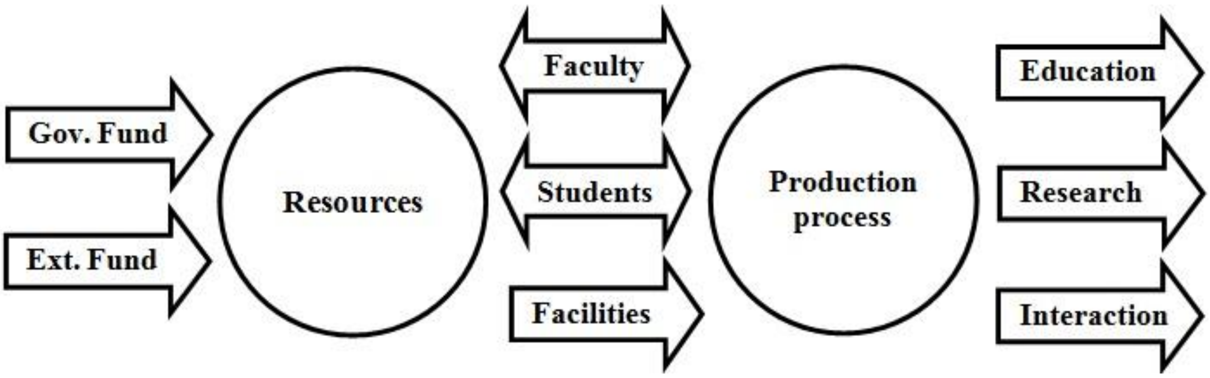

Diagram 1. The operation of HEI

The two-sided arrows for students and faculty indicate that government financing for education is based on the number of students, whereas the ability to attract external resources is closely related to faculty quality. To the extent that any production process is defined as transformation of inputs into outputs, we may refer to faculty, facilities and students as inputs, whereas education, research and interaction with society will be outputs. The output is produced due to transformation and dissemination of initial knowledge and skills supplied by students and faculty in a certain organizational environment. Both the quality and quantity of output are affected by the original supply of knowledge and skills as well as by organizational differences.

The difference in resource utilization may happen either in the process of resource allocation, i.e. mix of faculty, students and facilities or during the production process, which transforms inputs into outputs. The former can happen because of differences in faculty size and

---

[8] University colleges may apply to the Swedish National Agency for Higher Education for the right to have PhD programs and get government funding in specific domains.

[9] For more details see Högskoleverket annual reports from 2008, 2009, 2010.

composition; for instance some HEIs may prefer hiring professors, while others may prefer other types of personnel, such as associate professors, assistant professors etc. Additionally, there may also be differences in the admission criteria of students, causing student pre-enrolment quality differences. As a result the original supply of knowledge and skills will be different. Differences caused by the production process may occur due to organizational forms, in particular differences in content, size and design of courses and study programmes. Besides, the relative size of education and research activities may also matter. This is because production of research is more uncertain and results are less predictable compared to education output. Hence more research-oriented HEIs face more uncertainty about the quality and quantity of research outcomes, which may affect their short-run efficiency.

4.2. Input and output variables

To be able to conduct an empirical analysis we should find a way to measure the inputs and outputs of HEI production. The choice of the university output variables is especially troublesome, because, as noted in McMillan and Chan (2006), none of the HEI outputs are easily measureable and community service is not measurable at all. There is considerable disagreement among economists as to what is the best way to quantify the output of education (Cohn et al., 1989). So far, the most common measure of education or teaching output used in the literature is the number of students in undergraduate and graduate education either in headcounts or full year equivalents. Though such an indicator allows controlling for the number of students, it disregards the level of their performance. An alternative is to use the number of graduates; however, this indicator reflects the outcome of HEI operation in preceding years and is less precise. Furthermore, it does not account for students who do not complete degrees but still take single courses. To cope with these shortcomings we use the so-called full-year equivalent performance indicator. The latter is defined as the sum of credits gained during one academic year by all students[10], divided by the full-time equivalent credits for one academic year, i.e. 60. To control for the heterogeneity of institutions in specializations, we distinguish among students in humanities, medicine and technical sciences, thereby accounting for differences in education costs and the size of government allocations for educating students in different fields. Such distinctions have been used by Izadi et al, (2002), Johnes (1997) and Stevens (2005).

HEIs are not homogeneous in the “quality” of students that are admitted and graduate. The initial stock of students’ knowledge and skills may be seen as an input to the HEI production process. The higher the starting level of students the less effort is required to further educate

[10] This is a common indicator for undergraduate, graduate and doctoral education.

them. On the other hand more knowledgeable students might demand more advanced and costly education. Previous studies have rarely taken into account the quality of students enrolled in HEIs. An exception to this is Koshal and Koshal (1999), where a Student Aptitude Test is used to control for the quality of admitted students and Stevens (2005), where "A level" scores are used as an indicator of student quality. We use median GPA scores from upper secondary school to control for pre-enrolment quality of HEI entrants.

Furthermore, the quality of teaching output is another aspect that requires special care. For instance, consider two institutions with the same number of students; one provides "excellent education" while the other provides only a "standard" education. The failure to incorporate this quality factor may result in a misleading evaluation and comparison. Yet, to our knowledge the only study that models the quality of graduates is Stevens (2005), in which the proportion of first and upper second class degrees[11] is suggested as a consistent measure of degree quality. Other potential indicators of graduates' quality might be the initial salary of graduates normalized by the field or the employment possibilities after graduation. The latter is used in this study to control for the quality of HEI graduates. It is assumed that a high likelihood of employment is a sign of high quality of education, ceteris paribus. Of course, one can argue that success on the labour market is also linked to other factors such as personal characteristics and labor market demand. Still, given the same labor market conditions and personal characteristics, success in finding employment after graduation is more likely to be due to higher productivity[12], and further promotion due to personal characteristics.

The difficulties in measuring the research output of HEIs have been discussed in many studies. The research produced in HEIs is an intangible asset and its valuation is not an easy task. Empirical studies mostly use either publication counts or research expenditures (Tauer et al., 2007, Johnes and Johnes, 2008); however, both of them have shortcomings. For instance, using a field normalized number of journal publications, as suggested by some authors, allows controlling for the quality and field of research, but, as argued in many studies, the research output of HEIs is not limited to journal publications. Conference papers, book reviews, and patents are all viable outputs and simply choosing one biases the results. Research funding, used in Robst (2001) and Abbot & Doucouliagos (2003) as an indicator of research output, fails to account for the quality and field differences. The advantage of a research funding indicator is that, being an annual indicator, it can be directly related to the annual costs. It is more difficult to relate publications and other similar indicators to annual costs, since the

[11] It is not clear what he means by "the proportion of first and upper second class degrees".

[12] Better employment opportunities may also arise due to signaling effects, according to which employers make judgments about the quality of education based on the reputation of the HEI (see Hermansson (2011) for discussion of signalling effects).

research conducted in a particular year is usually published in the form of journal papers with some time lag. The researchers using research funding as a measure of research output also argue that the ability of HEI to generate such funds is closely correlated with its research output (Cohn, et al, 1989). The ideal output measure would involve a weighted measure for different types of research output and quality. However specifying the weights a priori based on value judgements could be erroneous. In this paper the research output of HEIs is proxied by a bibliometric index provided by the Swedish Research Council. It represents the number of publications in the Web of Science database weighted by the field and average citation index for the respective field. The latter means that the index accounts for different publication traditions specific to different fields of science, as well as for citation frequency and hence quality of publications[13]. Thus, the bibliometric index allows accounting for quantity, quality and research area, but disregards unpublished research efforts. It is also worth mentioning that the correlation coefficient between research funding and the bibliometric index applied in this study is about 90 percent, pointing to equivalence of both measures for this analysis. Additionally both research output indicators are highly correlated with the number of PhD students[14].

The prices of inputs to the production process are the next category of variables to be included in the model. The average salary of HEI personnel is taken as the price paid for labour input. It could be desirable to distinguish between prices paid to different labor categories, but this information is difficult to obtain. In addition, we do not have direct data for the price paid for capital inputs, i.e. facilities and equipment. This is a common problem, and as a result it is unusual for capital input measures to appear in higher education cost studies (McMillan & Chan, 2006). Swedish HEIs rent their facilities from the so-called "Akademiska Hus"[15] at different rates. We assume that the price paid for facilities is close to the average real estate price in the corresponding municipality (Andersson & Lundström, 2003). Though this allows controlling for the price paid for facilities, we still lack data on other capital inputs. Furthermore, though students can be considered as another input category, it is hard to find a price indicator for them. Hence, we will assume that the quality of students measured by the grade point average score from upper secondary school serves as a rough proxy for students' value.

[13] Swedish Research Council further normalizes the number of field and citation normalized publications by dividing by the average number of publications per researcher in the respective field.

[14] Since the number of PhD students is highly correlated with research output, and because the courses taken by PhD students are included in our measure of teaching output, we don't treat it as a separate output.

[15] Akademiska Hus is a large real estate company in Sweden offering its services to higher education and research institutions.

4.3. Exogenous variables

Among exogenous or environmental variables that affect total costs either directly by influencing the cost frontier, or indirectly via affecting the inefficiency component, we identify three major sources of possible influence, namely organisational differences, differences in faculty composition and student composition. We now turn to a discussion of the definition of variables as well as previous findings concerning their impact and our expectations.

Among HEI organizational differences we distinguish size, the level of specialization, the number of students per faculty and source of financing.

- **HEI size** is proxied by the number of full-year equivalent students[16]. If HEIs operate under increasing returns to scale, which is the prediction of some studies (Koshal et al, 2000, Cohn et al., 1989) then big universities will be more cost efficient. However, other authors (Felderer and Obersteiner, 1999) suggest that diseconomies of scale may also occur due to bureaucracy and inefficient use of resources, which will in turn result in a negative effect on efficiency. Previous literature has found no consensus regarding economies of scale in the higher education sector.
- **The level of specialization** is constructed in the fashion of the Herfindahl-Hirschman Index, which is widely applied as a measure of market concentration. The index is defined as the sum of squares of each type of education (in shares) provided by a HEI. For example the index is equal to $(1/3)^2+(1/3)^2+(1/3)^2=1/3$ for a HEI with 1/3 of its students in medical sciences, 1/3 in technical sciences and 1/3 in social sciences. The higher the index the more specialized the HEI. We use the index to capture the degree of interdisciplinarity and to empirically test if it is more economically efficient to specialize in one education field, or whether there might be potential for economies of scope. An intensive review of previous empirical studies on the existence of economies of scope in the education sector is summarized in Bonaccorsi et al. (2006) and the overall picture is rather mixed. One can expect that HEIs with a higher variety of outputs will be less efficient unless they can use the same inputs for different purposes. Riksrevisionen (2011:2) has found a negative rank correlation between technical efficiency estimates and the spread in specialization of Swedish HEIs, suggesting that a high level of specialization is more efficient in terms of resource

[16] This indicator does not account for the research volumes, but since the correlation between the research activities expressed by research funding and the number of students is about 80%, we assume that it can capture size aspects.

utilization. This might signal the impossibility of using the same inputs for the production of different outputs in this sector.

- **The number of students per faculty**, defined as the ratio of full-time students to the teaching and research personnel. We assume that HEIs with a high number of students per faculty will decrease total costs and hence increase the efficiency of resource utilization, provided the quality of teaching is not affected.

- **The share of direct government funding in the total amount of HEI expenditures.** Robst (2001) and Kuo & Ho (2008) suggest that the proportion of government funding is a potential efficiency determinant. However, the finding in Robst (2001) for the South Carolina HEIs, that universities with smaller state shares are not more efficient, contradicts the results of Kuo & Ho (2008) for Taiwan public universities. Though the Swedish higher education sector is mainly publicly financed, the share of government support in the total revenues varies across HEIs depending on the relationship between teaching and research activities, and the ability of the HEI to attract external sources of financing. We hypothesize that HEIs with a higher share of government support make less effort to attract other financing, and hence have more reasons to be inefficient in their resource utilization. As an alternative, we also control for the share of external research financing. Though it mirrors the financial source for research purposes only, it has a high negative correlation with the share of government funding.

The next group of potential efficiency determinants is related to faculty composition, namely

- **the share of professors in the faculty**
- **the share of faculty aged over 50**

Following Stevens (2005) we use the above-mentioned indicators to control for differences in faculty composition and their effect on overall efficiency. Although a high share of professors would increase HEI costs, we expect that it might contribute to more efficient operation, and have an impact on education and research output in terms of quantity and quality. We also hypothesise that there might be some variation in economic efficiency of HEIs due to the different age composition of faculty. If young and senior professors have the same productivity, high salaries paid for the latter may result in higher costs and lower efficiency.

The third group includes student-related characteristics such as

- **students' pre-enrolment and graduation quality,** measured by the GPA score from upper secondary school and employment possibilities after graduation, as discussed in section 4.2
- **the share of students with a foreign background**
- **the share of students aged 25 and under**

We assume that there might be some variation in the economic efficiency of HEIs due to differences in pre-enrolment quality, based on the fact that the education of smarter students may be less costly. However, the opposite hypothesis, i.e. students with higher level of knowledge are more demanding and hence their education is more costly, is also possible and hence should be tested empirically. Besides, the ethnical background of enrolled students might be another potential source of inefficiency variation. While the enrolment of foreign students might be linked with extra costs, it may positively affect the efficiency provided that foreign students have higher quality and take more advanced courses. The higher the quality of students with a foreign background, the higher the likelihood that the extra costs will be compensated for and will not affect the efficiency. We also control for the average age of students to empirically investigate the possible link between HEI performance and the age composition of students.

5. Data

The Swedish higher education sector consists of 14 government controlled universities and 15 university colleges[17]. In addition there are 3 private universities with the right to examine PhD students. Using data from 2001-2005 the analysis is carried out for 30 HEIs[18].

The data used for the analysis is to a large extent drawn from the database of the Swedish National Agency for Higher Education, which contains detailed information on students, personnel and economy. The research output data, i.e. bibliometric index, is originally based on Swedish Research Council reports and adjusted annually. As mentioned earlier, the bibliometric index is based on the number of field normalized annual publications multiplied by the average citation index for each field[19]. The descriptive statistics of all the data used for the analysis, divided into six categories, are presented in the following table.

[17] Excluding those university colleges devoted to arts, sports, pedagogy and the like.
[18] 2 universities are withdrawn from the analysis in view of the small number of students.
[19] For more detailed definition of the bibliometric index see Swedish Research Council reports.

Table 1.
Descriptive statistics of main variables (Average for 2001-2005)

Variable description	Abbr.	Mean	St.Dev.	Min	Max
Output Indicators					
Full-year equiv. perform. of undergr. stud. in medicine	MedSt	921	1019	0	4402
Full-year equiv. perform. of undergr. stud. in humanity	HumSt	4158	3962	123	14869
Full-year equiv. perform. of undergr. stud. in techn. sc.	TechSt	2460	2152	0	9427
Publications (Bibmiometric index)	Public	293	408	6	1482
Input Price					
Average annual salary (ths. SEK)	AvSalary	479	61	370	871
Average rent per sq meter	Rent	1265	343	850	1900
Organizational differences					
Size (full-year equiv. number of undergraduate students)	Size	9301	6 823	832	27971
Number of students per faculty member	St_Per_Fac	13	5	2	24
% of government allocations in total revenues	GovAlloc (%)	69	14	23	89
% of research funding from external sources	ResFundExt(%)	53	14	24	92
Degree of Specialization	Specialization	0.53	0.16	0.36	1
Student composition					
Median GPA score	IntakeQuality	14	1.16	13	19
% of graduates employed after 1-2 years of graduation	GradQuaility	75	8	52	90
% of students aged below 25	STB25	48	8	33	70
% of students with foreign background	ForBack	14	6	4	35
Faculty composition					
% of professors in teaching and research personnel	Prof	12	8	1	44
% of teaching and research personnel aged over 50	TA50	46	6	31	61
Costs*					
Total HEI expenditures (mln. SEK)	TotalCost	1 296	1 247	99	4 960

*All the monetary variables have been deflated using producer and import price index with 2005 as a base year.

The first panel, which describes HEI outputs, points to heterogeneity of HEIs in terms of outputs and their size. As shown by the data, some universities do not educate students in medicine, while others do not have technical science students. The average HEI included in the analysis has about 9300 students, with the smallest having 832 and the biggest 27 971 students, which points to the necessity of normalization by size. Furthermore, Swedish HEIs are nor similar in their research orientation, which is represented by the bibliometric index. The latter varies from 6 to 1482 with a mean of 293. Given that the publication of papers in academic journals takes time, we assume that papers published in 2005-2008 reflect the research done in 2002-2005, i.e. on average, it takes 3 years to have papers published. Moreover, since the data provided by the Swedish Research Council are aggregated for the whole period of 2005-2008, we used data on research funding to disaggregate them and get annual equivalents. To get corresponding data for the year 2001, we assume that the growth/decline in the number of publications was equivalent to the growth/decline in the amount of research funding. Hence, our indicator of research output has been divided into years based on annual growth/decline in research funding.

We also observe considerable differences in input prices, shown by the second panel of table 1. The average annual salary ranges from 370000 SEK to 871000 SEK with a mean of 479000 SEK. The differences should be attributed to faculty composition, to differences in wage setting policies as well as to regional labor market conditions. In addition, the difference in rent per square meter is also remarkable, and ranges from 850 to 1900 SEK, which reflects real estate price difference in different parts of Sweden. The price per sq meter of real estate is provided by Datscha, which is Sweden's leading provider of services for information and analysis of commercial properties.

The mean share of government allocations in total revenues is about 70 percent, but there are HEIs with a much lower share of government support of only 14 percent. The share of external research funding in total research funding ranges from 24 to 92 percent with a mean of 53 percent. The correlation analysis shown in table 1 in Appendix 1 indicates a rather high negative correlation between the share of government allocations and share of external research funding, suggesting that HEIs with less support from the government need to seek external financing for research. The data further indicate a negative correlation between the number of students per faculty and share of professors in teaching and research personnel, implying that HEIs employing more professors have a lower number of students per faculty. Interestingly, the correlation between the share of professors and government funding is positive, indicating that universities with more support can afford to hire more professors.

The average share of professors in teaching and research personnel is 12 percent, the lowest being 1 percent and the highest 44 percent. Generally, less than half of the professors are over 50.

When it comes to student characteristics, the data shows that the median GPA score, which is our proxy for students' pre-enrollment quality, varies from 13 to 19 with an average of 14. Thus, the data show considerable differences in the pre-enrolment quality of students across HEIs, suggesting that it might also affect economic performance. We observe variation in graduates' employment possibilities, the lowest being 52 percent and the highest 90 percent having a job 2 years after graduation. The data also suggest heterogeneity in the age and ethnic backgrounds of students in different HEIs.

6. Empirical model

Guided by the discussion above, the following empirical model is used for the estimation of the multi-dimensional cost function of HEIs.

$$
\begin{aligned}
lnTotCosts_{it} = \beta_0 &+ \beta_1 lnHumStud_{it} + \beta_2 lnTechStud_{it} + \beta_3 lnMedStud_{it} \\
&+ \beta_4 lnPublic_{it} + \beta_5 lnAvSal_{it} + \beta_6 lnRent_{it} \\
&+ \beta_7 GraduationQuality_{it} + \beta_8 IntakeQuality_{it} + \beta_9 GovAlloc_{it} \\
&+ v_{it} + u_{it} \qquad t=1,2\ldots5
\end{aligned} \tag{1.1}
$$

where *i* stands for HEI and *t* for the corresponding time period. $\beta_{0\ldots9}$ are the coefficients to be estimated, v_{it} is the random error component, which is assumed to be normally distributed with zero mean and variance σ_v^2. u_{it} is the non-negative inefficiency term which increases costs. Except for output and price variables traditionally included in the cost model, we also add controls for students' pre-enrolment and graduation quality as well as share of government support, with the later aimed to capture the level of state dependence[20].

Since the cost function must be linearly homogeneous in input prices, we re-formulate the above equation by dividing both total costs and average salary by the price of facilities, i.e. $Rent_{it}$ to ensure the homogeneity condition.

$$
\begin{aligned}
ln\frac{TotCosts_{it}}{Rent_{it}} = \beta_0 &+ \beta_1 lnHumStud_{it} + \beta_2 lnTechStud_{it} + \beta_3 lnMedStud_{it} \\
&+ \beta_4 lnPublic_{it} + \beta_5 ln\frac{AvSal_{it}}{Rent_{it}} + \beta_6 GradQuality_{it} \\
&+ \beta_7 IntakeQuality_{it} + \beta_8 GovAlloc_{it} + v_{it} + u_{it}
\end{aligned} \tag{1.2}
$$

Following Kempkes and Pohl (2010) we further normalize for differences in HEIs' sizes and divide total costs and outputs by the total number of students. Utilizing the Battese and Coelli (1995) model, we further assume that the u_{it}, which captures the effect of time-varying economic inefficiency, is a function of a set of ariables ($\boldsymbol{z_{it}}$) that affect the inefficiency. Thus,

$$u_{it} = \boldsymbol{\gamma' z_{it}} + \varepsilon_{it} \tag{1.3}$$

where $\boldsymbol{\gamma}'$ is the vector of corresponding coefficients to be estimated and ε_{it} is the normally distributed random component with 0 mean and variance σ_u^2 truncated at $-\boldsymbol{\gamma' z_{it}}$. As noted in Battese and Coelli (1995), these assumptions are consistent with u_{it} having truncated normal distribution with mean $\boldsymbol{\gamma' z_{it}}$ and variance of σ_u^2.

If it further assume that ε_{it}' and v_{it} are distributed independently of each other and the regressors, the parameters of the model can be estimated by one-stage maximum likelihood estimation (for more details see Battese and Coelli, 1995). An estimate of economic

[20] The Cobb-Douglas structure of the cost function assumes that all output indicators as well as price and total cost indicators should be in the logarithmic form. To make logarithmic transformation possible 0s are replaced with 1s wherever the number of students is 0.

inefficiency is then provided using the JLMS (Jondrow et al., 1982) conditional mean approach. Once point estimates of u_i are obtained, the estimates of cost efficiency (CE) of each HEI are calculated as

$$CE_{it} = \exp(-u_{it}) = \exp(-\boldsymbol{\gamma'z_{it}} - \varepsilon_{it}) \quad (1.4)$$

A similar model for cross-sectional data has been developed by Kumbhakar, Ghost and McGukin, (1991). The main advantage of panel data is that it allows unbiased and consistent estimates, whereas the cross-section analysis does not guarantee the consistency of results. The main disadvantage of this model is the impossibility of distinguishing between HEI-specific and inefficiency effects. As a solution Green (2005) suggests a true random or true fixed effects model, the application of which is not appropriate for our data due to small sample size and convergence difficulties. It is worth mentioning that the application of the true random effects model assumes independence of the HEI-specific effects and inefficiency components, which seems to be implausible in our setup.

7. Results

The Battese and Coelli (1995) estimates corresponding to different variations of the empirical model described above are presented in tables 2-4. The estimated model specifications have the same cost frontier, but differ in variables included in the cost inefficiency model. Table 2 reports coefficient estimates for the models with cost inefficiency explained by organizational differences. Faculty and student-specific characteristics are added in the specifications reported in table 3 and table 4.

Table 2. Maximum likelihood estimates of the frontier cost function (Battese and Coelli, 1995 model). Inefficiency is a function of organizational differences.

Cost frontier	**Coeff.**	**St.E.**	**Coeff.**	**St.E.**	**Coeff.**	**St.E.**
Constant	-1.01***	0.365	-1.07***	0.372	1.22*	0.726
LnPublic	0.14***	0.018	0.14***	0.018	0.33***	0.025
LnMedSt	0.02**	0.007	0.02**	0.007	0.06***	0.010
LnTechSt	0.03	0.021	0.04*	0.023	0.12***	0.022
LnHumSt	-0.04	0.032	-0.04	0.034	-0.12***	0.028
LnAvSalary	0.83***	0.046	0.83***	0.048	0.83***	0.093
GPA_Median	0.01	0.019	0.02	0.019	0.037	0.033
Employability	-0.002***	0.001	-0.003**	0.001	-0.01**	0.002
Gov_Support	-0.002*	0.001	-0.003**	0.002	-0.03***	0.005
Inefficiency model						
Constant	3.49***	0.242	3.65***	0.285	0.46	0.342
St_per_Fac	-0.10***	0.006	-0.09***	0.007		
Size	-0.19***	0.019	-0.20***	0.021	-0.15***	0.029
Specialization	-0.56***	0.181	-0.48***	0.182		

Table 2. (cont.)

	Coeff.	St.E.	Coeff.	St.E.	Coeff.	St.E.
ResFundExt			-0.002	0.002		
Gov_Support					0.02***	0.005
Variance parameters for compound error						
Gamma	0.69***	0.144	0.67***	0.163	0.98***	0.013
SigmaSqd	0.014***	0.003	.013***	0.003	0.021***	0.004
Log-likelihood	139		141		76	

1. The dependent variable is total costs normalized by the number of students
2. SigmaSqd is the variance of the composite error term $\sigma^2 = \sigma_u^2 + \sigma_v^2$.
3. ***, **, * ==> Significance at 1 percent, 5 percent, 10 percent level

Table3.

Maximum likelihood estimates of the frontier cost function (Battese and Coelli 1995, model). Inefficiency is a function of organizational differences and faculty composition**.**

Cost frontier	Coeff.	St. E.	Coeff.	St. E.	Coeff.	St. E.
Constant	0.15	0.537	0.10	0.631	0.08	0.609
LnPublic	0.40***	0.026	0.35***	0.031	0.35***	0.031
LnMedSt	0.06***	0.008	0.06***	0.012	0.06***	0.011
LnTechSt	0.08***	0.016	0.09***	0.025	0.10***	0.024
LnHumSt	-0.12***	0.026	-0.13***	0.029	-0.11***	0.028
LnAvSalary	1.06***	0.077	0.97***	0.089	0.96***	0.078
GPA_Median	0.07***	0.022	0.08**	0.036	0.09***	0.032
Employability	-0.01	0.002	-.01***	0.002	-0.01**	0.002
Gov_Support	-0.012***	0.002	-0.01***	0.003	-0.01***	0.003
Inefficiency model						
Constant	1.51***	0.323	1.40***	0.322	1.6***	0.326
Size	-0.16***	0.042	-0.15***	0.035	-0.16***	0.037
Specialization			-0.06	0.200	-0.03	0.213
ResFundExt					-0.001	0.002
Profess	-0.025***	0.005	-0.02***	0.006	-.019***	0.005
TA50	.012***	0.003	.013***	0.003	.013***	0.003
Variance parameters for compound error						
Gamma	0.98***	0.009	0.97***	0.011	0.98***	0.031
SigmaSqd	0.03***	0.005	0.03***	0.004	0.03***	0.004
Log likelihood	78		80		80	

1. The dependent variable is total costs normalized by the number of students.
2. SigmaSqd is the variance of the composite error term $\sigma^2 = \sigma_u^2 + \sigma_v^2$.
3. ***, **, * ==> Significance at 1 percent, 5 percent, 10 percent level

Table4.

Maximum likelihood estimates of the frontier cost function (Battese and Coelli, 1995 model). Inefficiency is a function of organizational differences, faculty and student composition.

Cost frontier	**Coeff.**	**St. E.**	**Coeff.**	**St. E.**	**Coeff.**	**St. E.**
Constant	-0.64	1.363	-0.24	0.648	0.38	0.631
LnPublic	0.27***	0.031	0.33***	0.030	0.33***	0.026
LnMedSt	0.05***	0.010	0.05**	0.009	0.05***	0.008

Table4. (cont.)

	Coeff.	St. E.	Coeff.	St. E.	Coeff.	St. E.
LnTechSt	0.07**	0.027	0.11***	0.024	0.13***	0.022
LnHumSt	-0.18***	0.028	-0.11***	0.024	-0.09***	0.023
LnAvSalary	0.93***	0.091	0.94***	0.080	0.84***	0.086
GPA_Median	0.09	0.077	0.09***	0.037	0.07*	0.031
Employability	-0.01**	0.002	-0.01**	0.002	-0.00*	0.002
Gov_Support	-.001***	0.003	-0.01***	0.003	-0.02***	0.004
Inefficiency model						
Constant	2.04	1.297	2.08***	0.298	1.62***	0.425
STB25	-0.01***	0.003	-0.01***	0.003	-0.01***	0.003
ForBack	-0.01***	0.003	-0.01*	0.004	-0.01**	0.003
GPA_Median	-0.06	0.089				
Size			-0.15***	0.034	-0.16***	0.027
Specialization			0.04	0.239	0.12	0.224
Profess			-0.01**	0.005		
TA50			0.01***	0.003		
Gov_Support					0.01***	0.005
Variance parameters for compound error						
Gamma	0.99***	0.032	0.98***	0.118	0.97***	0.015
SigmaSqd	0.03***	0.003	0.02***	0.004	0.02***	0.003
Log likelihood	75		90		89	

1. The dependent variable is total costs normalized by the number of students.
2. SigmaSqd is the variance of the composite error term $\sigma^2 = \sigma_u^2 + \sigma_v^2$.
3. ***, **, * ==> Significance at 1 percent, 5 percent, 10 percent level

Before discussing the results, it is worth noting that the multicollinearty problem associated with a high correlation between the environmental variables has prohibited the estimation of a full model with all variables included. We have experimented with various specifications and used a likelihood ratio test to distinguish between them. Furthermore, we have tried to control for time effects by adding time dummies into both cost and inefficiency models, but the estimates are not significant and do not affect the overall picture.

The first thing to note in tables 2-4 is that all model specifications support the presence of cost inefficiency among Swedish HEIs. The gamma parameter at the bottom of the tables provides an indication of the relative contribution of inefficiency and random error terms to the whole error component $(v_{it} + u_{it})$. Gamma is defined as

$$\text{gamma}=\frac{\sigma_u^2}{\sigma_u^2+\sigma_v^2},$$

where $\sigma_u^2$and σ_v^2 are the varaiances of u and v respectively. If gamma is close to 0, then all the deviations from the frontier are due to random noise, whereas gamma close to 1 implies that the divergence from the frontier is due to inefficiency effects. Our estimates of gamma are significantly different from 0 in all model specifications, suggesting that the divergence from the frontier cost function is largely explained by inefficiency effects. It should also be mentioned that, though the estimate of σ_u is much bigger than σ_v , which is evidenced by gamma estimates close to 1, the absolute value of σ_u is ranging from 0.09 to 0.16, indicating a relatively low spread in cost efficiency among Swedish HEIs.

The estimates of coefficients for the deterministic part of the cost frontier function from the three groups of models are quite similar. Not surprisingly, the results suggest that costs increase with the number of students and publications. The increase in the number of publications by about 10 percent will increase costs by 1.4-3.5 per cent. At the same time, the increase in the number of students will affect costs less dramatically; for instance, a 10 percent increase in the number of medical students will increase costs by less than 1 percent. Besides, we find that the education of students in technical sciences is more costly as compared to medical students, whereas the education of humanists is less expensive.

The coefficient for the average salary is positive and significant in all models, suggesting that the increase in average salary by about 10 per cent will result in almost an identical increase in costs, i.e. 8-10 percent.

The proxy for the quality of education, i.e. the fraction of graduates employed after two years of graduation, is mostly negative and significant, implying that it costs less to graduate students with higher employment possibilities, everything else equal. Ideally, one would expect graduation of high quality students to be be more costly. One explanation is that the quality of graduates, proxied by the likelihood of employment, captures not only education quality but also students' personal characteristics, and it might be that teaching of smart students is less expensive. At the same time, this variable might also capture market demand for graduates from different disciplines and hence reflect not only the quality but also market demand differences. It ought to be mentioned that we have also tried to control for graduation quality using the median salary of graduates one year after graduation, and the results are the same, i.e. the higher the quality indicator the lower the costs. However, despite the statistical significance of this variable, the marginal effect is small.

The coefficient of the median GPA score, which is our proxy for student pre-enrolment quality, turns out to be non-significant in the model specifications of the first group, which either means that costs are not associated with students' pre-enrolment quality or that our proxy is not good enough to capture it. The coefficient estimates for the second and third groups are positive and significant, suggesting that the education of smart students is more costly everything else equal. This might be due to the more demanding character of students with higher potential. A similar finding is reported by Koshal and Koshal (1999). The general conclusion is that the costs of HEIs do not decrease with enrolment of students with higher admission credentials.

When it comes to the relationship between government support and total costs per student, we find that a high level of government support will decrease costs per student, and hence more autonomous HEIs will have higher costs per student. This supports findings in Laband and Lentz (2004), according to which public HEIs produce more cheaply that private ones.

Turning our attention to the inefficiency part of the table, which is the main concern of this study, one can see the potential determinants of inefficiency differences among HEIs. Recalling our model setup, a positive sign of the estimated parameters indicates that an increase in the variable is associated with an increase in inefficiency (decrease in efficiency) and vice versa. Thus, the coefficients for the number of students per faculty are negative and significant in all models with this variable included. It suggests that a high number of students per faculty will decrease economic inefficiency given the same quality of education and research, which seems to be logical.

The coefficient for HEI size is negative and significant in all model specifications, which means that big HEI are less inefficient. This signals the presence of scale effects and supports findings in Glass, McKillop and Hyndman (1995) and others.

The findings concerning the level of specialization are ambiguous. The first group of models suggests that high specialization will produce lower inefficiency, and hence more specialized universities make better use of their resources, which is in line with the findings of DEA analysis aimed at measuring the technical efficiency of Swedish HEIs (Riksrevisionen, 2011:2). This is evidence against economies of scope in the higher education sector, implying that economic performance will not improve due to a higher variety of outputs. However, the variable is found to be insignificant in models of the second and third group. One conclusion is that more specialized universities are not less efficient, ceteris paribus.

The coefficient for the proportion of government allocations in HEI revenues is positive and significant, meaning that the source of funding matters for economic performance. Thus, HEIs with a higher share of public support, ceteris paribus, are less efficient. So far, our findings suggest that more publicly supported HEI have lower costs per student and a higher inefficiency level, implying irrational use of resources.

We have found no significant relationship between the share of external research funding and inefficiency level, which means that HEIs’ ability to attract more external funds does not lead to more efficient use of resources.

The estimates of coefficients for staff characteristics, represented by the share of professors in the total research/teaching personnel and the share of teaching/research personnel aged over 50, suggest that HEI hiring more professors spend their resources more efficiently, whereas the age of faculty works in the opposite direction. This could be due to salary differences between young and senior professors, with the latter earning more but with the same level of productivity. These results support the findings in Stevens (2005) for the sample of English and Welsh universities.

Concerning the relationship between student characteristics and cost inefficiency presented in table 4, the results indicate that student composition matters for the cost efficiency of HEIs. Thus, a high share of students with a foreign background will decrease inefficiency, which means that HEIs enrolling more foreign students will be more efficient, ceteris paribus. One possible explanation is that students with a foreign background are more prepared and less effort is required for educating them. Interestingly, the results also imply that the higher the share of students under the age of 25, the less inefficient universities are, which might mean that younger students achieve higher results. The coefficient for the pre-enrolment quality is not significant, implying no relationship between the inefficiency and quality of students.

Efficiency estimates

As noted earlier, all our models suggest the existence of inefficiency effects among Swedish HEIs. The percentile distribution of efficiency estimates is presented in table 5[21].

Table 5. Descriptive statistics for cost efficiency estimates

Percentile	Estimate
25	0 .72
40	0.72
50	0.89
75	0 .96
90	0.98
99	0.99
Mean	0.85
Std. Dev.	0.11

The average efficiency is estimated to be 0.85 with more than half of HEIs operating with efficiency above the mean. Furthermore, about 10 percent of HEIs operate with efficiency above 0.98, and about 40 percent operate with efficiency close to minimum value.

[21] These are efficiency estimates corresponding to the first group of models with the highest log-likelihood value.

Figure 1 allows a comparison of mean efficiency scores for different HEIs over the period of 2001-2005.

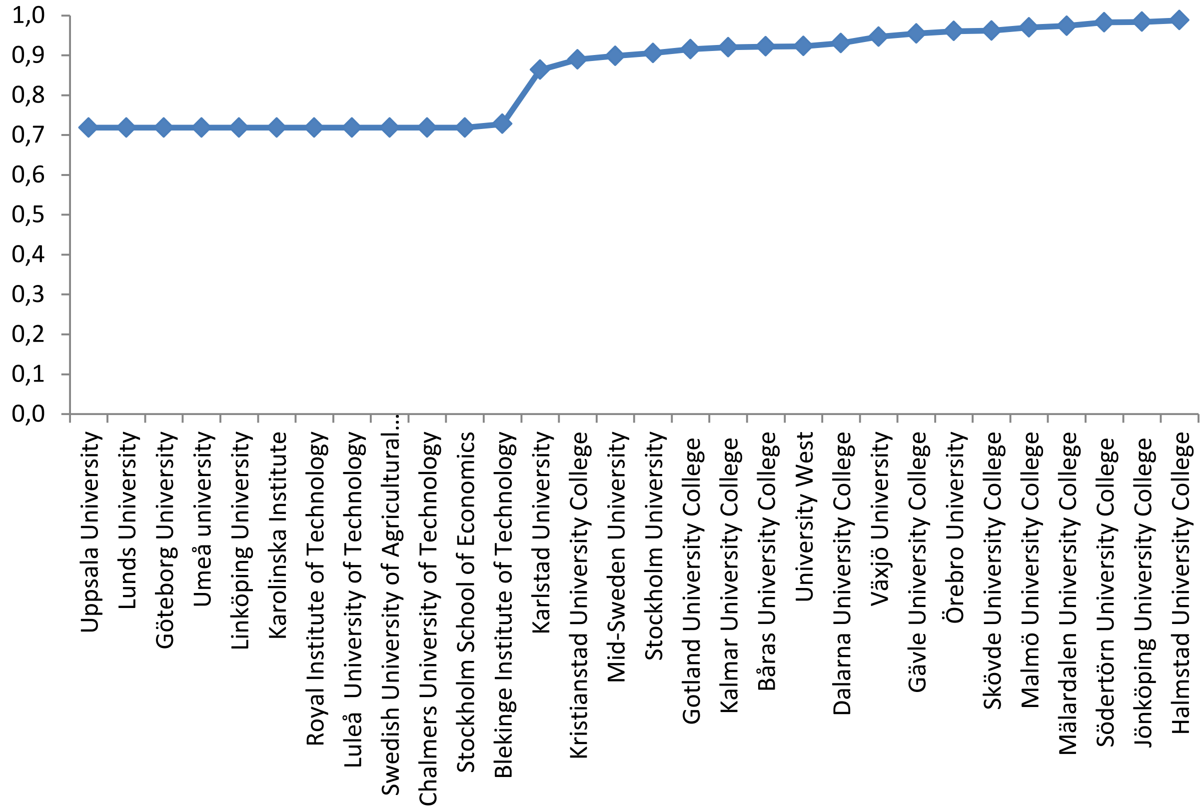

Figure 1. Cost efficiency estimates for Swedish HEIs (mean of 2001-2005)

The figure suggests that, in general, old research-oriented universities with longer traditions and bigger networks are less efficient, whereas relatively new university colleges have higher estimates of cost efficiency. Another observation is that almost all old universities seem to perform quite similarly with relatively low efficiency. The difference in efficiency estimates is more visible for new and less research-oriented HEIs, which are in the upper tail of efficiency distribution. One explanation is that research-oriented HEIs are less restricted in their resources and hence make more inefficient use of them, whereas others need to use their scarce resources more efficiently to survive.

It should be mentioned, though, that the ranking of HEIs by economic efficiency should not be compared to academic ranking. According to our results, HEIs with a high ranking by academic criteria are estimated to have low economic efficiency, whereas others ranked relatively low have higher economic efficiency estimates. This is because academic criteria traditionally used in creating HEI rankings do not account for cost aspects and hence can be quite different. Moreover, the cost efficiency analysis, which is the subject of this study, is based on the assumption that the units under investigation are cost minimisers. However, if HEIs are more interested in prestige or excellence maximization, which is not necessarily the same as cost minimization, they will get a high prestige ranking but low cost efficiency ranking.

8. Conclusion

The purpose of this study has been to examine the cost efficiency of Swedish HEIs and shed light upon factors causing efficiency variation. SFA is utilized for 30 HEIs for the academic years 2001-2005. The results suggest that Swedish HEIs differ in their cost efficiency. More than half of Swedish HEIs have an above-mean efficiency of 0.85, whereas little more than 10 percent reach a high efficiency of 0.98. According to our estimates, older and more research-oriented HEIs exhibit similar performance and are in the bottom tail of efficiency distribution. Newer HEIs operate more cost efficiently and exhibit more variation in their performance.

To analyse the inefficiency determinants, three groups of variables are included in the inefficiency model: HEI organizational indicators, faculty and student characteristics. The findings suggest that big HEIs, as well as those with a higher number of students per faculty, are more economically efficient. Besides, government support negatively affects the cost efficiency of HEIs, implying that HEIs seeking external financing make better use of their resources. When it comes to the relationship between interdisciplinarity and economic efficiency, we conclude that the more specialized HEIs are no less efficient than others. The results concerning the relationship between faculty composition and economic efficiency indicate a positive significant relationship in terms of the share of professors and their age.

We also find that cost efficiency is affected by such student characteristics as ethnicity and age. HEIs with a high share of students with a foreign background, as well as those enrolling younger students, seem to be more economically efficient.

The main implication from this analysis is that HEIs subject to the same legislation and regulations relevant to the higher education sector of Sweden exhibit different economic efficiency. Among other things the inefficiency is explained by differences in size, source of financing, level of specialization, as well as by faculty and student composition.

Summing up, we would like to mention that our efficiency estimates are based on the assumption that we have properly controlled for the quantity and quality of inputs and outputs of HEIs. However, our quality indicators are far from being ideal and future work is necessary to shed more light on HEIs performance with a more careful control for quality differences.

References

Abbot, M., Doucouliagos, C. (2003). The efficiency of Australian universities: a data envelopment analysis. *Economics of Education Review* 22 (1) 89–97

Ahn, T., Charnes, A., Cooper, W. (1988). Some statistical and DEA evaluations of relative efficiencies of public and private institutions of higher learning. *Socio-economic Planning Sciences* 22(6):259-269

Andersson, Å., Beckmann, M. (2009). Economics of Knowledge: Theory, Models and Measurements. *Edward Elgar Publishing*

Andersson, Å, Lundström, S. (2003) Universitetens och högskolornas lokaler - Organisationsformer och prissättning, KTH

Badunenko, O., Fritsch, M., Stephan, A. (2008). What drives the productive efficiency of a firm? The importance of industry, location, RD and size. CESIS WP 126

Battese, G., Coelli, T. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics* 20: 325-332

Battese, G., Coelli, T. (1992). Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis* 3, 153-169

Battese, G. (1997). A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values. *Journal of Agriculture Economics.* 48 (2) 250-252

Bonaccorsi, A., Daraio, C., Cimar, L. (2006). Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data. *Scientometrics,* 66(2), 389-410

Caves, R., Barton, D. (1990). Efficiency in US manufacturing industries. MIT Press

Chakraborty, K., Biswas, B., Lewis, C. (20019. Measurement of technical efficiency in public education: A stochastic and non-stochastic production function approach, *Southern Economic Journal* 67(4): 889-905

Chambers, R. (1988). Applied production analysis: A dual approach. Cambridge University Press

Charnes, A., Cooper, W., Lewin A., Seiford, L. (1994). Data Envelopment Analysis, Theory, Methodology and Applications. *Boston, MA: Kluwer Academic Publishers*

Coelli, J., O'Donneli, J., Battese, G. (2005). An Introduction to efficiency and productivity Analysis. *Springer*

Cohn, E., Sherrie, L., Rhine, L., Santos, M. (1989). Institutions of higher education as multi-product firms: economies of scale and scope. *The Review of Economics and Statistics* 71 (284-290)

Daghbashyan, Z. (2006). University's Impact on Regional Economies: Case study for the Royal Institute of Technology (KTH). KTH Master Thesis

Glass, J., McKillop, D., Hyndman, N. (1995). Efficiency in the provision of university teaching and research: an empirical analysis of UK universities. *Journal of Applied Econometrics* 10, 61-72

Farrel, M. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*, A (General), 120, 253-281

Farsi, M., Filippini, M. (2009). An analysis of cost efficiency in Swiss multi-utilities. *Energy Economics, Elsevier,* vol. 31(2), 306-315

Felderer, B., Obersteiner, M. (1999). Efficiency and Economies of Scale in Academic Knowledge Production, *Economics Series*, 63, Institute for Advanced Studies, Vienna

Greene, W. (2005). Fixed and random effects in stochastic frontier models. *Journal of Productivity Analysis*, 23(1), 7-32.

Harold, O., Lovell, C., Schmidt, S. (2008). The measurement of productive efficiency and productivity growth. Oxford University Press, USA.

Hermansson, K. 2011. The overall economic impact of higher education institutions (HEI) on their host sub-regions: Multi-sectorial analysis for the city of Glasgow, *Dissertation*, Department of Economics, University of Strathclyde

Högskoleverket (2009). Universitet & högskolor, Högskoleverkets årsrapport 2009, Rapport 2009:12R

Izadi, H., Johnes, G., Oskrochi, R., Crouchley, R. (2002). Stochastic frontier estimation of a CES cost function: the case of higher education in Britain. *Economic of Education Review* 21, 61-71

James, E. (1990). Decision processes and priorities in higher education. In the economics of American universities, ed. S.A. Hoenack and E.I. Collins. Buffalo, NY: State University of New York Press

Johnes, G. (1997). Costs and industrial structure in contemporary British higher education. *The Economic Journal*, *107*(442), 727-737.

Johnes, G., Johnes, J. (1993). Measuring the research performance of UK economics departments: An application of data envelopment analysis. *Oxford Economic Papers* 45

Johnes, G., Johnes, J. (2008). Higher education institutions' costs and efficiency: Taking the decomposition a further step. *Economics of Education Review* 28(1), 107–113

Johnes, J. (2006a). Data Envelopment Analysis and its applications to the measurement of efficiency in higher education. *Economics of Education Review* 25(3) 273-288

Johnes, J. (2006b). Measuring teaching efficiency in higher education: An application to data envelopment analysis to economics graduates from UK Universities, 1993. *European Journal of Operations Research* 174(1), 443-456

Jondrow, J., Knox Lovell, C. A., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of econometrics*, 19(2), 233-238.

Koshal, R. K., & Koshal, M. (2000). State Appropriation and Higher Education Tuition: what is the relationship? *Education Economics*, 8(1), 81-89.

Koshal, R. K., & Koshal, M. (2000). Do liberal arts colleges exhibit economies of scale and scope? *Education Economics*, *8*(3), 209-220.

Kempkes, G., Pohl, C. (2010). The efficiency of German universities- some evidence from nonparamateric and parametric methods. *Applied Economics*, vol 42, pp 2063-2079

Kumbhakar, C., Ghosh, S., MCGukin, J. (1991). A generalized frontier approach for estimating determinants of inefficiency in US dairy firms. *Journal of Business and Economics Statistics* 9, 279-286

Kumbhakar, S., Lovell, K. (2000). Stochastic Frontier Analysis, Cambridge University Press

Kuo, J., Ho, Y. (2008). The cost efficiency impact of the university operation fund on public universities in Taiwan. *Economic of Education Review 27*

Laband, D., Lentz, B. (2004). Do costs differ between for-profit and not-for-profit producers of higher education? *Research in Higher Education, Vol. 45, No. 4,*

Lovell, K. (1993). Production frontier and productive efficiency. In *The Measurement of Productive Efficiency. Techniques and Applications*, ed. Harold O. Fried, C.A. Knox

Madden G., Savage S. & Kemp S. 1997. Measuring public sector efficiency: A study of the Economics Department at Australian universities. *Education Economics* 5(2), 153–168

McMillan, M., Chan, W. (2006). University efficiency: A comparison and consolidation of results from stochastic and non-stochastic methods. *Education Economics* 14(1) 1-30

Murillo-Zamorano, L. (2004). Economic efficiency and frontier techniques, *Journal of Economic Surveys 18(1)*

Pitt, M., Lee, M. (1981). The measurement and sources of technical inefficiency in the Indonesian weaving industry, *Journal of Development Economics* 9, 43-54

Riksrevisionen, (2011:2) Använder lärosätena resurserna effektivt? Effektivitet och produktivitet för universitet och högskolor, ISBN 978 91 7086 239 7, Stockholm

Robst, J. (2001). Cost efficiency in public higher education institutions, *Journal of Higher Education* 72(6)

Salerno, C. (2003). What we know about the efficiency of higher education institutions: the best evidence. The Centre for Higher Education Policy Studies, University of Twente

Stevens, P. (2005). A stochastic frontier analysis of English and Welsh universities. *Education Economics, 13, 355-74*

Tauer, L., Fried, H., Fry, W. (2007). Measuring Efficiencies of Academic Departments within a College. *Education Economics* 15(4), 473-489

Appendix 1

Table 1. Correlation between the variables in the cost frontier

	LnPublic	LnMedSt	LnTechSt	LnHumSt	LnAvSalary	Grad.Quality	IntakeQuality
LnPublic	1.00						
LnMedSt	-0.13	1.00					
LnTechSt	-0.08	0.12	1.00				
LnHumSt	-0.42	0.32	-0.36	1.00			
LnAvSalary	-0.43	0.06	0.05	0.17	1.00		
GradQuality	0.07	0.14	-0.01	-0.25	-0.28	1.00	
IntakeQuality	0.69	-0.37	-0.52	-0.16	-0.32	0.15	1.00
GovAlloc	0.73	0.45	0.40	0.29	0.38	-0.12	-0.79

Table2. Correlation between variables in the inefficiency model

	St_per_Fac	Size	GovAlloc	Index	Profess	TA50	stb25	IntakeQ	GradQ	ForBack
St_per_Fac	1.00									
Size	-0.30	1.00								
GovAlloc	0.61	0.10	1.00							
Specialization	-0.35	0.19	-0.75	1.00						
Profess	-0.64	0.18	-0.81	0.60	1.00					
TA50	0.20	0.36	0.46	-0.36	-0.14	1.00				
stb25	-0.19	-0.06	-0.56	0.51	0.54	-0.29	1.00			
IntakeQuality	-0.56	0.01	-0.79	0.65	0.89	-0.20	0.01	1.00		
GradQuality	-0.18	0.10	-0.12	0.08	0.08	0.16	0.00	0.15	1.00	
ForBack	-0.12	0.17	-0.23	0.40	0.24	0.02	-0.15	0.11	0.19	1.00
ResFundEx	-0.12	-0.20	-0.65	0.53	0.39	-0.38	0.47	0.41	0.09	0.29