Technical Efficiency and Productivity at Higher Education Institutions – Some problems and some solutions

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Abstract

In this paper we address some problems that have been on the research agenda when accessing technical efficiency and productivity among higher educational intuitions. One of problem concerns adjusting efficiency scores for input quality. This is done by using the grades from the upper secondary schools. A second problem concerns how to adjust for heterogeneity with respect to subjects and institutions between HEI's. This has two implications; firstly that resources requests differ depending on what subjects is thought, secondly the publication tradition differs between subjects. With the use of the national resource allocation system we weight students according to subject. For research production we use a bibliometric index to allow for differences in publication traditions. A third problem when using the DEA approach, as done in most previous studies of technical efficiency, is the lack of inference around the efficiency and productivity scores. We use a bootstrapping approach to approach this problem. The results indicate an average inefficiency of 12 percent, which is comparable to international findings, and a productivity increase of around 1.7 percent per year. A second step analysis reveals that HEIs with a large proportion of programme students and HEIs with a low proportion of students enrolled in distance education in general have higher efficiency scores.

Keywords: Efficiency; Productivity; DEA; Bootstrap Estimation; Higher Education Institutions

JEL classifications: C15; D24; I23

1. Introduction

Efficiency and productivity are two topics that are receiving increasing attention in the higher education policy discussion. However, the higher education sector has some characteristics which make it difficult to measure efficiency and productivity. First of all, it is a non-profit sector which implies a lack of output and input prices. Furthermore, Higher Education Institutions (HEIs) produce multiple outputs from multiple inputs. However, since the mid-1980s both parametric and non-parametric efficiency estimation techniques capable of evaluating multi-input/output units have been developed. This has implied a growing literature of empirical research on the efficiency and productivity of higher education institutions (Johnes, 2004; Salerno, 2003).

Sweden's the government spends considerable resources on higher education and research at universities and university colleges. In 2008 the total funding for Swedish universities and university colleges was SEK 50.1 billion, or 1.6 percent of GDP.[1] This is considerable less than what USA spends on higher education (3.1 percent), but more than for example United Kingdom (1.3 percent). The figure for Sweden is comparable to the other Nordic countries.[2] About SEK 22 billion was allocated to education at the undergraduate and advanced levels and SEK 28 billion to graduate education and research. During the spring of 2008, the number of students registered at Swedish HEIs at the undergraduate and advanced level totalled around 297,000. The corresponding number of students at the graduate level was about 20,000. During the same period, about 24,000 full-time equivalents were employed as teachers and/or research staff.

[1] € 1 is approximately equal to SEK 9.0.
[2] OECD (2010).

The purpose of this paper is to measure technical efficiency and productivity in the context of Swedish higher education. We use a Data Envelopment Analysis (DEA) approach with bootstrapping to measure the relative efficiency of 30 universities and university colleges in Sweden between 2005 and 2008. Our results indicate an average inefficiency of 12 percent, which is comparable to international findings, and a productivity increase of around 1.7 percent per year.

The reminder of this paper is arranged as follows. Section 2 briefly discusses higher education in Sweden and section 3 gives the theoretical framework and previous studies. The data used is discussed in section 4. The results are presented in section 5 and section 6 concludes.

2. Higher Education in Sweden

The higher education system in Sweden comprises traditional academic education as well as study programmes aimed at specific professions. Both are provided by universities and university colleges. Another characteristic of the Swedish higher education system is that there are a wide range of freestanding, non-programme courses in addition to study programmes leading to a professional or general qualification.

Higher education is generally provided by state universities and university colleges, although there are some private institutions that are entitled to award degrees. There are 14 state universities and 21 state university colleges. Three categories of qualifications exist in Swedish higher education 1) general qualification, 2) qualification in the fine, applied and performing arts and 3) professional qualifications. Within these qualifications students can be awarded different degrees. A general qualification and a qualification in the fine, applied and performing arts can lead to a higher education diploma, bachelor of arts/science, master of arts/science, licentiate or doctor of philosophy. A professional qualification can lead to the same degrees except for licentiate and doctor of philosophy.

In the fall of 2008 about 348,000 students were enrolled in undergraduate education and about 17,000 students were enrolled in graduate education. A total number of 43,000 full-time equivalents were working at the Swedish HEIs, and about 22,000 of them were employed as teaching and/or research staff.

According to the Higher Education Act, the objective of Swedish HEIs is to provide education at the undergraduate, advanced and graduate levels. HEIs shall furthermore conduct and publish research. Both objectives will be carried out jointly. HEIs have, in general, no specific goals regarding the number of examined students or the amount of research that should be published. In most education fields and study programmes, HEIs are free to determine the supply of education within a certain economic framework.

Undergraduate and advanced education is funded mainly by the government funding. Graduate education and research activities receive about 50 percent of their funding from the government and the remaining 50 percent from public and private research funding bodies. Each HEI can receive a maximum amount, a so-called funding cap, which is set by the parliament. The funding cap for each HEI is divided in two parts. The first part is based on the number of full-time equivalent students (HST). The second part is based on the number of annual performance equivalents (HPR).[3] HEIs are free in deciding how to distribute funding among faculties and disciplinary research domains. Each disciplinary domain is associated with a certain amount of funding per HST and HPR. HEIs are free to allocate research

[3] All HEIs receive the same funding for a student enrolled within a certain disciplinary domain. On average the funding per HST and HPR are the same. The exact funding for each disciplinary domain and the funding cap for each HEI is presented in the government approval document for each year.

funding received from the government. The funding received from public and private funding bodies is earmarked for certain research projects.

3. Theoretical framework and previous studies

3.1. Theoretical framework

This study relies on a Data Envelopment Analysis (DEA) framework.[4] A starting point for the modern development of empirically measuring efficiency is Charnes, Cooper and Rhodes (1978), who introduced the DEA method.[5] Even though all empirical ideas presented in that article were formulated in Farrell (1957) and the theoretical foundations were laid down in Shephard (1953) and Shephard (1970), the Charnes, Cooper and Rhodes (1978) paper extended the efficiency measurement to the use of both multiple inputs and multiple outputs. This extension made DEA suitable to study efficiency in private and public service production, such as the production of higher education. The DEA method has since the early 1980s become widely used in assessing technical efficiency in the disciplines of management science and economics. In a survey by Emrouznejad et al. (2008) the authors traced more than 4,000 published scientific articles using the DEA method. Depending on the objective of the units studied there are two common directions in which efficiency can be evaluated, input based and output based. Since resources allocated to the HEIs are more or less fixed we apply an output based measure of efficiency. In this model inefficiency is interpreted as potential increase in outputs given resources.[6]

An output-oriented DEA model, such as the one used in this study, use existing data to construct the production possibility set (i.e. combinations of outputs given inputs). This means that efficiency is defined as 'efficient relative to other observations'. The first step in

[4] Other possible methodological approaches include deterministic parametric frontier (see e.g. Bjurek et al., 1990 and Månsson, 2006) and Stochastic Frontier Analysis (SFA) (see e.g. Thanassoulis et al., 2011).
[5] Limitations of the DEA method are discussed in e.g. Dyson et al. (2001) and Mettas et al. (2001).
[6] The input based efficiency measure express inefficiency as potential input savings given output.

the analysis is to identify those units that form the efficiency frontier. Common to these observations is that they produce more output at a given input level compared to inefficient units. This frontier is sometimes referred to as the ‘best practice frontier’.

To study productivity changes, we make use of the same framework, but the study changes over time. We apply a Malmquist productivity index developed by Färe et al. (1989) based on Malmquist (1953). The Malmquist productivity index makes it possible to distinguish productivity changes that are due to increased efficiency (catching-up) from technological changes, e.g. introduction of distance learning technology.

One of the drawbacks of the DEA method is that it is deterministic. This means that all data is considered to be ‘correct’ and that the computations are free from uncertainty. As a consequence it is not possible to directly make statistical inference (i.e. to investigate if the efficiency and productivity scores are statistically significant). Kneip et al. (2008) have shown the asymptotical statistical properties of the efficiency scores using the DEA framework, however, since computing the efficiency and productivity scores relies on solving a mathematical linear programming problem the only way of getting statistical inference around the efficiency and productivity scores is by using some type of re-sampling (e.g., Bootstrap or Jackknife). Following Simar and Wilson (1998, 1999, 2000) we apply bootstrapping to our data and compute efficiency and productivity scores using 2,000 iterations.[7] The variation in these results gives us the possibility to create confidence intervals around our efficiency and productivity scores. Further, Simar and Wilson (2008) claim that DEA estimators are biased

[7] We have used the R-plug-in FEAR 1.15, created and generously provided to the research community by Paul Wilson 2010 (see e.g. Wilson, 2008)

by construction.[8] Another advantage of the bootstrapping technique is that it makes it possible to adjust the efficiency scores for this bias.

3.2. Previous research

There are a few surveys of efficiency in the production of Higher Education Institutions (HEI), e.g. Salerno (2003) and Johnes (2004). In summary these surveys point to the fact that in evaluating technical efficiency among HEIs, the Data Envelopment Analysis (DEA) method is the most common. The surveys show an average level of inefficiency of 5 to 15 percent. Further, most of the studies are limited to one country.

The only study that includes more than one country is Agasisti and Johnes (2009). In that study, a panel of 127 English and 57 Italian HEIs (2001–2005) is used. The DEA framework is used and the authors conduct both country specific and aggregated analysis. The separate analyses report an average inefficiency of around 11 percent for both countries. When pooling the data country-specific differences were found. The Italian HEIs had an average inefficiency of around 23 percent while the English had an average inefficiency of around 13 percent. It is, however, unclear if the frontier consisted of both Italian and English HEIs and how much of the inefficiency is due to managerial issues and how much is due to country-specific differences.

More recent country-specific studies of HEIs include the work of Johnes (2006) who uses data for 109 English HEIs for the academic year 2000/01. HEIs were grouped into two groups – new and old universities. The division is based on whether or not they acquired university status before or after 1992. This is the first study that quality adjusts inputs. In this case university students are quality adjusted by incorporating information about their grades from

[8] See also Färe et.al (1997).

upper secondary school. The author uses the DEA method and found an average inefficiency of around 5 percent. In a slightly different study by Agasisti and Salerno (2007) the Italian case is studied. The authors use a DEA approach and claim to be studying cost efficiency. However the results can only be interpreted as a measure of cost efficiency if equal input prices are assumed. Information from 52 HEIs is used for the years 2002 and 2003 and the inefficiency score reported is 2 percent for HEIs without a medical faculty and 6 percent for those with a medical faculty. Johnes and Yu (2008) use the DEA method to study efficiency for 100 selected Chinese HEIs for the years 2003 and 2004. The novelty of this study is that a 'prestige' index is used.[9] This index is assumed to capture quality dimensions of both inputs as well as outputs. The logic is that HEIs with high prestige are more likely to attract 'good' students and they have earned their reputation by producing high quality output. This is reflected in the results. If the prestige index is excluded from the analysis, the average inefficiency is around 36 percent, but if included the average inefficiency increases to 8 percent.

A different approach is presented in Tzeremes and Halkos (2010) who, with the use of DEA, study the relative efficiency among 16 departments of the same university. The average department inefficiency was 15 percent. A problem with the approach used in Tzeremes and Halkos (2010) is how to divide common resources, such as university administration.

As mentioned above, the most common method for studying efficiency is the DEA framework. An exception is Thanassoulis et al. (2011) who use the same data as Johnes (2006) but uses the Stochastic Frontier Approach (SFA) which is a statistical rather than a mathematical approach. In addition to measuring efficiency, the authors compare the

[9] This index builds on a questionnaire sent out to HEIs where they were asked to rank the influence of the research carried out by other institutions.

sensitivity with respect to other methods.[10] The study showed that the estimated inefficiency is to some extent dependent on the method. Using the SFA approach, an inefficiency of approximately 14 percent is reported, while the DEA method gives an average inefficiency of around 4 percent. This study also uses a Malmquist index approach to assess productivity change in higher education in the UK. The results show a productivity decrease for a majority of the HEIs during the period under examination. Another study that examines productivity change using the Malmquist index is Johnes (2008). This study uses DEA for 113 English HEIs from 1996/97 to 2002/03. The author found that in these years HEIs experienced an annual average increase in Malmquist productivity of 1.1 percent. When productivity is decomposed into technological and efficiency changes the former counts for a 6 percent increase while the latter counts for a 5 percent decrease.

To conclude, previous research has shown that DEA is the most common method for investigating efficiency. These efficiency studies report an inefficiency ranging from 5 to 15 percent. Only a few studies have studied productivity changes using the Malmquist approach. Further, no efficiency or productivity studies of HEIs have used the DEA framework with Swedish data.

4. Data

The data set includes 30 Swedish Higher Education Institutions (HEIs) for 2005 to 2008.[11] One of the assumptions of the DEA framework is that compared units use the same production technology. If a unit is unique in its input and/or output composition the unit will only be compared with itself. In Sweden there are seven specialised HEIs that fall into the category of having unique content with respect to both education and research. These are

[10] The Stochastic Frontier Analysis (SFA) is an econometric rather than a mathematical approach to estimate the reference technology (see e.g. Johnes, 2004).

[11] For 2005–2007 the number of HEIs is 31 because the Stockholm Institute of Education (SIE) is included. In 2008, the SIE merged with Stockholm University.

university colleges for fine, applied and performing arts and have therefore been excluded from the analysis. In addition, the Swedish National Defence College and the Stockholm School of Economics do not, for different reasons, produce comparable official data and was excluded for this reason.[12]

The majority of the data has been collected from the National Monitoring (NU) database provided by the Swedish National Agency for Higher Education (HSV). Other data sources are annual financial reports of the HEIs, the Statistics Sweden register for higher education, the Statistics Sweden register of upper secondary school leavers, and bibliometric data compiled by the Swedish Research Council.

4.1 Model specification

Numerous model specifications have been tested with different variables and variable definitions. The starting point when deciding our preferred model specification was to measure the output of HEIs based on the objectives established in the Higher Education Act. The act stipulates that HEIs shall conduct education at undergraduate and advanced levels in addition to research and graduate level education. Another starting point of the model specification work has been to cover as many of the available resources as possible. The number of included variables in the final model is limited by the fact that we only have 30 observations.[13]

4.2. Input variables

The input variables used in the preferred model specification are as follows:

- full-time equivalent graduate researchers and/or teaching staff
- full-time equivalent other staff
- other resources as an approximation for capital

[12] In addition, ten minor institutions have been excluded.
[13] See Dyson et al. (2001) for a discussion of model dimensions and number of observations.

- number of undergraduate students (HST) measured as full-time equivalents adjusted for differences in prerequisites measured as upper secondary grades
- number of graduate students measured as full-time equivalents

Data on staff per HEI are collected from the NU database and is measured as full-time equivalents. To take into account that there is a variation in staff composition among HEIs, total staff has been divided into two categories. The first category measures full-time equivalent *graduate researchers and/or teaching staff*.[14] The second staff category measures full-time equivalent *other staff* and consists of technical and administrative staff without research or teaching duties such as library staff, cleaners and hourly workers. These two staff variables measure different aspects of each HEI's labour input.

One of the most important inputs regarding HEI production is the number of students, where we distinguish undergraduate from graduate students. Some university colleges do not have any graduate students. Both the *number of undergraduate students* (HST) and the *number of graduate students* are measured as full-time equivalents. Information on undergraduate students is collected from the NU database and information on graduate students from Statistics Sweden.

An important variable for describing differences in student prerequisites at HEIs is given by the mean grade point average (GPA) from upper secondary school. Information about mean GPA is taken from Statistic Sweden's register of upper secondary school leavers. This variable measures the mean GPA for all registered students at each HEI and year. To adjust for differences in student prerequisites at different HEIs the full-time equivalent HST variable has been transformed into a quality-adjusted measure of undergraduate students. The GPA for

[14] The staff categories included in this measure are professors, research assistants, senior lecturers, lecturers, other research or teaching staff, visiting staff, part-time fixed-term lecturers and technical and administrative staff with teaching and/or research duties.

each HEI is first divided by the national overall mean GPA and then multiplied by the HST variable. This implies that HEIs with high-quality students are expected to produce more output than HEIs with low-quality students.

To capture capital, which is an important input factor for HEIs, we use tangible assets as a proxy.[15] This variable is taken from each HEI's annual financial report. To the tangible assets we have added the ALF- and TUA-compensations[16] that some universities receive because of their involvement in the education of physicians and dentists.[17] The sum of tangible assets and ALF- and TUA-compensations constitute the variable *other resources*. This variable reflects the physical capital in which the HEIs have invested.[18]

4.3 Output variables

The output variables used in our preferred model specification are listed below:

- annual performance equivalents (HPR) from undergraduate and advanced education adjusted for cost differences due to variation in the education mix among HEIs
- number of Doctor of Philosophy and Licentiate qualifications
- research output in terms of a bibliometric indicator that measures each HEI's research as a weighted number of scientific publications

The output variables used represent outputs from both research and teaching. The sum of *annual performance equivalents* (HPR) per HEI is calculated as the number of completed credits on courses during one calendar year. This implies that a student who studies full time at a HEI and completes all courses is counted as one HPR. Since there is a difference in which courses HEIs give and the fact that some courses are more resource-intensive, HEIs are

[15] Included in tangible assets are for example buildings, land, machines, inventory and installations. For more details see ESV (2004).
[16] ALF is an agreement for funding of medical training and research. TUA is an agreement for funding of dental training and research.
[17] Seven HEIs receives these extra resources and they are University of Gothenburg, Karolinska Institute, Linköping University, Lund University, Malmö University College, Umeå University and Uppsala University.
[18] The variable other resources is denominated in 2008 prices. The consumer price index (CPI) has been used as deflator.

compensated for this by the government rules of compensation. We have corrected for this by adjusting the HPR variable for the differences in educational mix among HEIs. This has been done by weighting the HPR variable by the financial compensation scheme, set every year by the government.[19] The HPR variable is included to measure HEI output from undergraduate and advanced level studies.

To create a variable for graduate studies, the *number of Licentiate and Doctor of Philosophy (PhD) qualifications* has been calculated for each HEI. One Licentiate represents the effort of half a PhD, so two Licentiates are coded as one PhD. In order to take into account that whether a qualification is issued by the end of one year or early the next is, to some degree, random, a moving average for two years is used when calculating the graduate qualification variable.

A bibliometric indicator is used to measure *research output* from each HEI. Bibliometrics is a statistical method of calculating publications for a specific unit. The bibliometric publication indicator has been provided by The Swedish Research Council[20] and it has been constructed to measure the number of publications in scientific journals included in the Web of Science database. The number of publications is calculated for each HEI and differences in publication tradition in different fields are compensated for by field standardization for each research field.[21] To handle differences in publication production among research fields, an estimated cost per normal cited Web of Science publication is used for each research field. In

[19] The weighting is done by calculating the shares of students at each HEI with different compensation levels. Thereafter the shares are multiplied by the respective compensation level for different educational fields and summed for each HEI. This sum is the weight that is used to adjust the HPR variable.
[20] For a more detailed description on how the bibliometric publication indicator is calculated see Swedish Research Council (2009).
[21] The indicator contains nine research fields.

order to take into account the delay between resources used and published articles in research journals, a three-year present and future moving average is used.[22]

5. Results

In this section we first present the efficiency scores from our preferred DEA specification using bootstrapping to bias adjust the efficiency scores and to create confidence intervals. We also discuss the results from extensive sensitivity analyses as well as the second step correlation analysis. Thereafter we present and discuss the productivity results using the Malmquist index.

Table 1 presents yearly cross-sectional bias adjusted bootstrapped efficiency scores. It should, however, be noted that changes in repeated cross-sectional efficiency analysis are somewhat problematic in their interpretation. If a HEI has become more efficient between two years, two factors might have influenced this outcome. The first explanation is that the HEI has become more efficient. However, the same result is obtained if those units that form the reference technology to this specific observation have become less efficient (i.e., the efficiency frontier has moved towards the origin). Therefore, rather than comparing the development over years it is advisable to look at the efficiency scores among HEIs within a year. Confidence intervals as well as unadjusted and bias adjusted efficiency scores for each HEI and year are presented in Appendix.

[22] Data for the bibliometric publication indicator is available up until 2009, which implies that one year is missing from the data needed to construct a moving average for 2008. The average trend for the years 2004 to 2008 is therefore used to impute a bibliometric indicator for 2010, which is then used in the moving average calculation for 2008.

Table 1. Bias adjusted bootstrapped efficiency scores, 2005–2008.

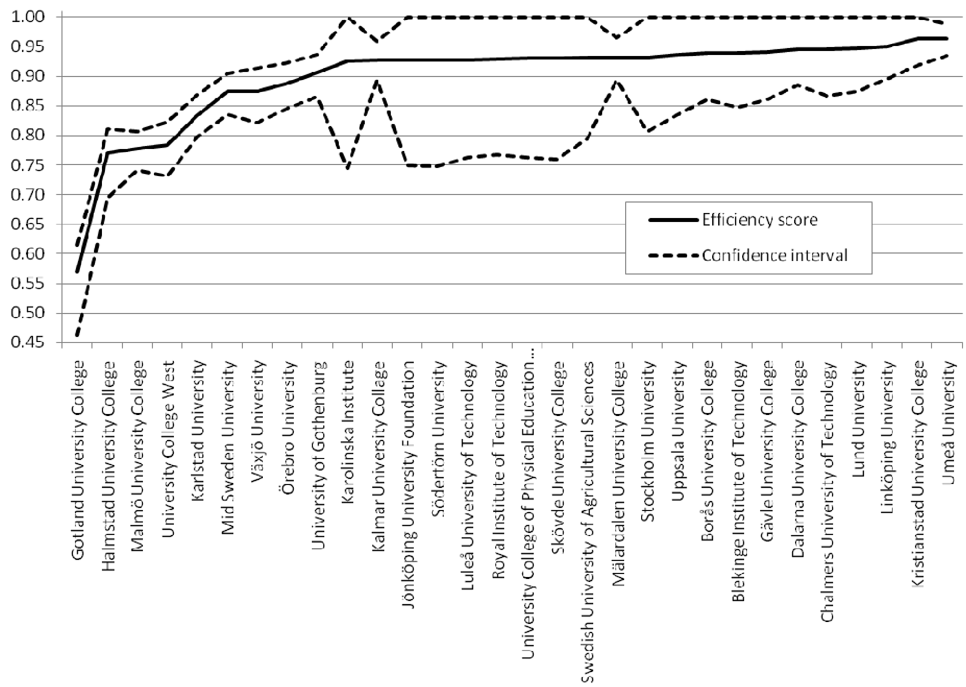
HEI	2005	2006	2007	2008	Arithmetic mean
Blekinge Institute of Technology	0.86*	0.94	0.91	0.94	0.91
Borås University College	0.96	0.96*	0.94	0.94	0.95
Chalmers University of Technology	0.91	0.92	0.91	0.95	0.92
Dalarna University College	0.94	0.94	0.92	0.95	0.94
Gävle University College	0.69*	0.79*	0.90*	0.94	0.83
Gotland University College	0.75*	0.70*	0.85*	0.57*	0.72
Halmstad University College	0.85*	0.95	0.92*	0.77*	0.87
Jönköping University Foundation	0.91	0.92	0.91	0.93	0.92
Kalmar University Collage	0.85*	0.84*	0.85*	0.93*	0.87
Karlstad University	0.70*	0.77*	0.72*	0.83*	0.76
Karolinska Institute	0.91	0.92	0.91	0.93	0.92
Kristianstad University College	0.87*	0.91*	0.88*	0.96	0.91
Linköping University	0.86*	0.92*	0.95*	0.95	0.92
Luleå University of Technology	0.91	0.92	0.91	0.93	0.92
Lund University	0.93	0.95	0.92	0.95	0.93
Mälardalen University College	0.96	0.89*	0.85*	0.93*	0.91
Malmö University College	0.88*	0.82*	0.67*	0.78*	0.79
Mid Sweden University	0.81*	0.92*	0.81*	0.87*	0.85
Royal Institute of Technology	0.91	0.92	0.91	0.93	0.92
Skövde University College	0.91	0.93	0.91	0.93	0.92
Södertörn University	0.88*	0.92	0.91	0.93	0.91
Stockholm Institute of Education	0.93*	0.97	0.82*	–	0.91
Stockholm University	0.91	0.93	0.91	0.93	0.92
Swedish University of Agricultural Sciences	0.93	0.92	0.91	0.93	0.92
Umeå University	0.70*	0.81*	0.78*	0.96*	0.81
University College of Physical Education and Sports	0.91	0.92	0.91	0.93	0.92
University College West	0.80*	0.81*	0.74*	0.78*	0.78
University of Gothenburg	0.83*	0.83*	0.84*	0.91*	0.85
Uppsala University	0.95	0.95	0.92	0.94	0.94
Växjö University	0.83*	0.71*	0.67*	0.88*	0.77
Örebro University	0.94	0.94	0.95	0.89*	0.93
Arithmetic mean	0.87	0.89	0.87	0.90	0.88

*Note: * = Significant at the 5 percent level. Stockholm Institute of Education merged with Stockholm University in 2008.*

A first observation from Table 1 is that almost 50 percent of all HEIs have efficiency scores that are not statistically significant different from 1.00, which should be interpreted as a non-significant inefficiency. For example, in 2005 Chalmers University of Technology had a bias adjusted efficiency score of 0.91 which is interpreted as 9 percent inefficiency. This efficiency score is, however, not statistically significant different from 1.00. Almost half of the HEIs, however, have efficiency scores that are statistically significant different from 1. For example, in 2008 Umeå University had an efficiency score of 0.96 (i.e. an inefficiency of 4 percent). This deviation from the efficiency frontier is significantly different from 1 at the 5 percent level.

The yearly efficiency scores are relatively stable between years. There is only a three percentage point difference between the year with the highest observed average efficiency scores (2008) and the two years with the lowest observed average efficiency score (2005 and 2007). The yearly average inefficiency scores ranges from 10 to 13 percent and are well in line with international findings. In addition, those HEIs that have the largest inefficiencies are all significant. The lowest efficiency score for the complete period is found for Gotland University College who in 2008 had an inefficiency corresponding to 43 percent. Figure 1 illustrates bias adjusted efficiency scores and 95 percent confidence intervals for 2008.

Figure 1. Bootstrapped efficiency scores for 2008.



In Figure 1 the dashed lines are the calculated confidence intervals from the bootstrapping procedure. As seen in Figure 1, those HEIs with the lowest efficiency scores are all significantly different from 1, meaning that the inefficiency is statistically significant at the 5 percent level. Further the confidence intervals for these units are generally small. The figure also reveals that there are quite large uncertainties for some HEIs. For example, the width of the confidence interval for Karolinska Institute is 25 percentage points. A total of 12 HEIs have bias adjusted efficiency scores that are statistically significant different from 1 in 2008.

5.1 Sensitivity analysis[23]

To study the robustness of the calculated efficiency scores, a wide range of sensitivity analyses have been carried out. Firstly, we have performed calculations of the efficiency scores using averages of inputs and outputs for each HEI for 2005–2008. Secondly, we have tested a variety of model specifications with alternative input and output variables. Thirdly, we have tested the robustness of the results by excluding those HEIs from the analysis that most frequently form the reference point to other HEIs.

Even though official statistics are used in the analysis the possibility of measurement errors in the data cannot be disregarded. We therefore use averages for our input and output variables for all the studied years and then re-calculate the preferred specification. The result neither show any large differences in the efficiency scores nor in the ranking if HEIs when compared to the results presented in Table 1. Our conclusion from this sensitivity check is that measurement errors does not seem to bias our results.

A variety of model specifications with alternative measures and definitions of the included input and output variables was also carried out. Using *office space* instead of *other recourses* as an alternative approximation for capital only gives minor changes in the calculated efficiency scores. We have also calculated the model without adjusting the *HST* variable for

[23] All sensitivity analyses are available from the authors on request.

differences in student prerequisites (measured as upper secondary grades). Surprisingly, the results are hardly affected by this adjustment.

As reported in section 4, we have adjusted the *HPR* variable in our preferred specification to the fact that different types of education are associated with different costs. As a sensitivity check we have also carried out calculations without this adjustment. The results show that the efficiency scores are sensitive to this adjustment. The average efficiency scores are around 3 percentage points higher when we do not take into account the differences in cost between levels and types of education. However, since HEIs have a different mix of educational fields and the fact that some educations are more costly and therefore acquire more of the HEIs resources, we believe that this is a most reasonable adjustment to make.

A variety of variable definitions for *HST*, *HPR* and *number of graduate students* has also been tested. For the variable *graduate students* we have made different considerations when it comes to moving averages. These checks result only in marginal changes in the efficiency scores and no changes in efficiency ranking between HEIs.

When the *number of PhD and Lic qualifications* is reported in the NU database, the qualification is registered at the HEI where the graduate student is registered. However, some graduate students are financed by other HEIs that are not eligible to grant a PhD qualification. These HEIs put resources into the education of graduate students at other HEIs and this fact is not reflected in our model. We have tried to account for this situation by specifying a model where the HEIs that are not eligible to examine graduate students are attributed the output of these PhD and Lic qualifications. This analysis results in somewhat lower efficiency scores. However, the same HEIs display inefficiencies and the efficiency ranking of HEIs is not affected.

We have also performed sensitivity checks with different measures of each HEI's research output. Instead of using the number of publications, we have tried to measure the research output both as the number of citations as well as the number of publication without standardizing by research field. When citations are used instead of publications the efficiency scores are about 0.5 percentage point lower; when using non-standardized publications the efficiency scores are about 1 percentage point lower. The conclusion is that our results are not very sensitive to the use of different bibliometric measures.

Finally we have checked the robustness of the results by systematically excluding efficient HEIs that are the reference point to many inefficient HEIs. When repeating this procedure for each year, the efficiency scores increase only marginally and the efficiency ranking of HEIs is not altered. The conclusion is that neither the calculated efficiency scores nor the efficiency ranking are heavily influenced by extreme observations.

5.2 Correlation analysis

To investigate if factors outside of our specified model can explain the observed efficiency scores, a correlation analysis is performed. The factors that we have included in this analysis are 1) share of distance students, 2) share of university beginners, 3) share of non-programme students, 4) share of teachers/researchers that hold a PhD and 5) number of education fields.

These factors have been chosen since there are indications that they can affect the efficiency scores. When it comes to distance students the Swedish National Agency for Higher Education has recently published a report indicating that distance students perform worse than campus students.[24] A high share of distance students can therefore be expected to have a positive correlation with inefficiency. Also a high share of university beginners can be

[24] Swedish National Agency for Higher Education (2010).

expected to correlate positively with inefficiency, since the transition from upper secondary education to university studies might be difficult. Another hypothesis is that non-programme students perform worse than programme students and this might affect the efficiency scores. Furthermore, a high share of staff with a PhD can be expected to affect both the quality of the teaching as well as the quality of the research and is included for this reason. Finally, the measure of specialisation is included in the analysis since it is sometimes claimed that specialisation can have a positive effect on efficiency.[25] The results are presented in Table 2.

Table 2. Spearman's rank correlations between the bias adjusted efficiency scores and different explanatory variables and t-tests between statistically significant and insignificant HEIs, 2005–2008.

Variable	Correlation coefficient	Sign. inefficient HEIs	Efficient HEIs	Efficient HEIs vs. sign. inefficient HEIs
Share of distance students	–0.30*** (<0.01)	19.5%	10.0%	9.5%***
Share of university beginners	–0.00 (0.99)	32.5%	32.5%	0.0%
Share of non-programme students	–0.22** (0.01)	47.3%	37.7%	9.6%***
Share of teachers/researchers that hold a PhD degree	0.05 (0.56)	44.6%	45.8%	1.2%
Number of education fields	–0.07 (0.42)	11.2	9.0	2.2***

*Note: *** significant at 1% ** significant at 5% * significant at 10%.*

The rank correlation analysis shows that some of the exogenous factors are correlated with the observed efficiency scores. The factors that show a statistically significant correlation with the efficiency scores are the share of distance students and the share of students on self-contained courses. It is also worth noting that there is no statistically significant correlation between the share of researchers that hold a PhD degree and the efficiency scores.

[25] Bonaccorsi and Daraio (2007)

The t-tests between significant inefficient and efficient HEIs show a similar picture. The share of distance students, the share of non-programme students, and the number of education fields all have a statistically significant co-variation with the two groups.

5.3. Productivity development

To calculate the productivity development, we use the Malmquist index. In Table 3 we present the average productivity changes from 2005/2006 to 2007/2008.

Table 3. Productivity development using the Malmquist index.

HEI	2005/2006	2006/2007	2007/2008	Geometric Mean
Blekinge Institute of Technology	1.118*	1.139*	0.826*	1.017
Borås University College	0.950*	1.039*	1.041*	1.009
Chalmers University of Technology	1.005*	1.015*	0.904*	0.973
Dalarna University College	0.988	1.026*	0.948*	0.987
Gävle University College	1.051*	1.174*	1.240*	1.152
Gotland University College	0.894*	1.063*	0.828*	0.923
Halmstad University College	1.057*	0.963*	0.894*	0.969
Jönköping University Foundation	1.055*	1.105*	0.980	1.045
Kalmar University Collage	0.962*	1.027*	1.094*	1.026
Karlstad University	1.061*	1.007*	1.007	1.025
Karolinska Institute	0.964*	0.980*	1.014*	0.986
Kristianstad University College	1.016	0.991	1.014*	1.007
Linköping University	1.033*	1.024*	1.034*	1.030
Luleå University of Technology	1.074*	1.002	0.966	1.013
Lund University	1.004	1.053*	0.969*	1.008
Mälardalen University College	0.906*	0.945*	1.086*	0.976
Malmö University College	0.907*	0.917*	1.045*	0.954
Mid Sweden University	1.031*	0.933*	1.020*	0.994
Royal Institute of Technology	1.018	0.977*	1.042*	1.012
Skövde University College	1.022*	1.062*	1.145*	1.075
Södertörn University	1.237*	1.124*	1.145*	1.168
Stockholm Institute of Education	0.988*	0.904*	–	0.945
Stockholm University	1.074*	1.014*	0.971*	1.019
Swedish University of Agricultural Sciences	1.126*	0.948*	0.936*	1.000
Umeå University	1.130*	0.997	1.106*	1.076
University College of Physical Education and Sports	1.010	1.044*	1.009	1.021
University College West	0.972*	0.974	1.013*	0.986
University of Gothenburg	1.013*	1.036*	1.058*	1.036
Uppsala University	1.044*	1.060*	1.018	1.041
Växjö University	0.898*	0.970*	1.185*	1.011
Örebro University	1.008	0.914*	0.981	0.967
Arithmetic mean	1.020	1.014	1.017	1.017

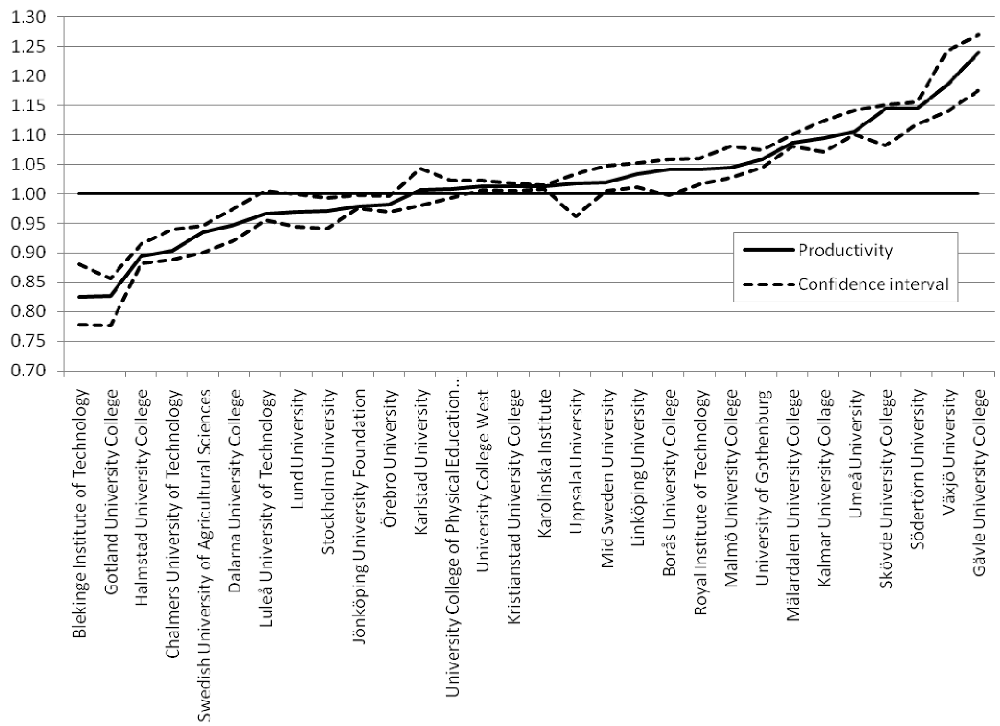
** = Significant at 5 percent level. Stockholm Institute of Education merged with Stockholm University in 2008.*

In Table 3 a value equal to 1 indicates neither an increase nor a decrease in productivity. A Malmquist index greater than 1 indicates a productivity increase while a value less than 1 indicates a productivity decline. The results show a modest average productivity increase of 1.7 percent over the studied period, but also statistically significant changes for almost all HEIs. On average, productivity increased by 2.0 percent between 2005 and 2006, with 1.4

percent between 2006 and 2007 and 1.7 percent between 2007 and 2008. Five HEIs had a statistically significant increase in productivity each studied year. Productivity decline can be observed at some HEIs for two out of three periods. However, none of the HEIs has a decline for all three periods. In total, 11 HEIs had a negative productivity decline on average over the studied period.

A feature of a small sample is that the confidence intervals tend to be large. In our case the confidence intervals are large, but not exceptionally so. To illustrate this we present the separate analysis for 2007/2008 in Figure 2. The productivity development is illustrated from the lowest to the highest and a 95 percent confidence interval is used. The solid line in the figure represents the productivity change, and the dashed lines are the lower and upper bounds of the confidence intervals.

Figure 2. Productivity development in Swedish HEIs between 2007 and 2008.



To interpret the results in Figure 2 recall that a Malmquist productivity index of 1 means neither an increase nor a decrease in productivity. HEIs that either have an upper or lower bound of the confidence interval containing 1 has not had a statistically significant productivity change. Those HEIs to the left in Figure 2 had a productivity decline, while those located to the right had a productivity increase. Sixteen HEIs had a statistically significant productivity increase between 2007 and 2008 while eleven HEIs had a significant productivity decline. For six HEIs, the productivity change was not significantly different from 1 (i.e. no productivity change). The average width of the confidence intervals is roughly 5 percent, but there are clearly some outliers with a confidence interval width of almost 10 percent. The smallest width is around 1 percent.

To investigate the productivity development for Swedish HEIs, the productivity change has been decomposed, with the use of the Malmquist index, into two components. One component represents efficiency change and the other component represents technological change. Efficiency change means that the HEI have moved closer to the existing frontier while technological changes can be transferred to as changes in the production possibility set, i.e. the frontier has moved. This has been done for each year and the results are presented in Table 4.

Table 4. Productivity change decomposed into technological and efficiency change, arithmetic means within years and geometric means between years.

Year	**2005/2006**	**2006/2007**	**2007/2008**	**Geometric average**
Efficiency change	1.015	0.993	1.016	1.008
Technological change	1.005	1.021	1.002	1.009
Productivity change	1.020	1.014	1.017	1.017

From this decomposition we can conclude that there are large differences both between the efficiency and technological change and between years. The overall productivity increase over the studied period is 1.7 percent and divides equally into efficiency change (0.8 percent) and technological change (0.9 percent). These results are of similar magnitude as those in Johnes (2008).

6. Conclusions

The aims of our study have been to investigate the efficiency and productivity development of HEIs in Sweden and to conduct a second stage analysis of the efficiency scores, using data for 2005–2008. A DEA framework is used motivated by the fact that the DEA framework can handle multiple inputs and outputs which certainly is the case for HEIs. This is the first study of efficiency and productivity for Swedish HEIs where multidimensional input and output relations are used. A limitation of the DEA approach that is frequently put forward is its deterministic nature. We have therefore used bootstrapping to produce confidence intervals around both efficiency and productivity scores. Furthermore, we have access to good and consistent data and have been able to conduct data adjustments that are lacking in many other studies. This study is one of a few to adjust the input variable undergraduate students for differences in student quality expressed as upper secondary grades. We also have access to a high quality bibliometric publication index for research outcome which is a more precise output measure of research than using resources spent on research as an output variable as many other studies do. In addition a vast range of sensitivity analyses has been carried out. Thus, we are confident that the study has good internal validity.

Despite the good quality of the data there are some limitations. Because there are so few Swedish HEIs, dimensionality is a problem that made it necessary to aggregate some variables (e.g., teachers and researchers). This type of aggregation is of course always necessary, but some of our aggregation is based on data limitations rather than economic arguments. Different aggregations have been tested in our sensitivity analysis and the present aggregations have limited influence on the results.

Our findings are very similar to those of international studies, with a yearly average inefficiency between 10 and 13 percent. Using the bootstrap approach reveals that those HEIs that show large inefficiencies also are statistically significant However, the bootstrap approach also reveals large confidence intervals for many HEIs. Further, using a Malmquist productivity index shows a moderate productivity growth of around 1.7 percent per year over the studied period.

The general policy recommendation from the study is that there is some inefficiency among Swedish HEIs although the potential for improvement is limited. However, the second stage analysis provides some additional information. There is a negative correlation between the number of distance students and efficiency, and there is also a significant difference between efficient and non efficient HEIs in relation to the number of distance students. The same pattern is found for non-programme students. These results call for a discussion of the resource efficiency of providing these kinds of courses. A second urgent question is the number of educational fields. Our results demonstrate that HEIs with a large number of educational fields are more likely to be inefficient. This result indicates that a certain degree of specialisation within HEIs makes it possible to use resources more efficiently.

References

Agasisti, T., and Salerno, C. (2007), Assessing the cost efficiency of Italian universities, *Education Economics 15*, 455–471.

Agasisti, T., and Johnes, G. (2009), Beyond frontiers: comparing the efficiency of higher education decision-making units across more than one country, *Education Economics 18*, 59–79.

Bjurek, H., Hjalmarsson, L., and Førsund, F. (1990), Deterministic parametric and nonparametric estimation of efficiency in service production: a comparison, *Journal of Econometrics 46*, 213–227.

Bonaccorsi, A., and Daraio, C. (2007), *Universities and strategic knowledge creation: Specialization and performance in Europe*, Edward Elgar, Cheltenham.

Charnes, A., Cooper, W., and Rhodes, E. (1978), Measuring the efficiency of decision making units, *European Journal of Operational Research 2*, 429–444.

Dyson, R., Allen, R., Camanho, A., Podinovski, V., Sarrico, C., and Shale, E. (2001), Pitfalls and protocols in DEA, *European Journal of Operational Research 132*, 245–259.

Emrouznejad, A., Parker, B., and Tavares, G. (2008), Evaluation of research in efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA, *Journal of Socio-Economics Planning Science 42*, 151–157.

ESV (2004), *Materiella anläggningstillgångar – En handledning om redovisning av materiella anläggningstillgångar vid statliga myndigheter*, ESV 2004:10.

Farrell, M. (1957), The Measurement of Productive Efficiency, *Journal of the Royal Statistical Society Series A. General 125*, 253–281.

Färe, R., Grosskopf, S., Lindgren, B., and Roos, P. (1989), *Productivity developments in Swedish hospitals: A Malmquist output index approach*, Discussion paper No. 89:3, Southern Illinois University.

Färe, E. Grifell-Tatjé, S. Grosskopf, C.A.K. Lovell (1997), Biased Technical Change and the Malmquist Productivity Index, *Scandinavian Journal of Economics 99*, 119-127

Johnes, J. (2004), *Efficiency measurement*, in Johnes G. and J. Johnes (eds.), International Handbook on the Economics of Education, Edward Elgar, Cheltenham.

Johnes, J. (2006), Data envelopment analysis and its application to the measurement of efficiency in higher education, *Economics of Education Review 25*, 273–288.

Johnes, J. (2008), Efficiency and productivity change in the English higher education sector from 1996/97 to 2002/03, *The Manchester School 76*, 653–674.

Johnes, J., and Yu, L. (2008), Measuring the research performance of Chinese higher education institutions using data envelopment analysis, *China Economic Review 19*, 679–696.

Kneip, A., Simar, L., and Wilson, P. (2008), Asymptotic and consistent bootstraps for DEA estimators in non-parametric frontier models, *Econometric Theory 24*, 1663-1697.

Månsson, J. (2006), Does quality matter? Analysing the effect of omitted variables on optimal scale: an application on Swedish employment offices in de Koning, J. (ed.) *The Evaluation of active labour market policies: Measures, Public Private Partnership and Benchmarking*, Edward Elgar Publishing, 357–379.

Malmquist, S. (1953), Index numbers and indifference surfaces, *Trabajos de Estatística 4*, 209–242.

Mettas, R., Vargas, V., and Whybark, D. (2001), An investigation of the sensitivity of DEA to data errors, *Computers & Industrial Engineering 41*, 163–171.

OECD (2010), *Education at a Glance – OECD Indicators*, OECD, Paris.

Salerno, C. (2003), *What we know about the efficiency of higher education institutions: The best evidence*, CHEPS, University of Twente.

Shephard, R. (1953), *Cost and Production functions*, Princeton University Press, Princeton USA.

Shephard, R. (1970), *The Theory of Cost and Production functions*, Princeton University Press, Princeton USA.

Simar, L., and Wilson, P. (1998), Sensitivity analysis of efficiency scores: How to bootstrap in nonparametric frontier models, *Management Science 44*, 49–61.

Simar, L., and Wilson, P. (1999), Estimating and bootstrapping Malmquist indices, *European Journal of Operational Research 115*, 459–471.

Simar, L., and Wilson, P. (2000), A general methodology for bootstrapping in non-parametric frontier models, *Journal of Applied Statistics 27*, 779–802.

Simar, L., and Wilson, P. (2008), Statistical interference in nonparametric frontier models: recent developments and perspectives in Fried H., Lovell K. and S. Schmidt (eds.) *The measurement of productive efficiency and productivity change*, Oxford University Press, New York.

Swedish National Agency of Higher Education (2010), *Sjunkande prestationsgrader i högskolan*, Statistisk analys 2010/10.

Swedish Research Council (2009), *Bibliometrisk indikator som underlag för medelsfördelning, svar på uppdrag enligt regeringsbeslut U2009/322/F (2009-01-29) till Vetenskapsrådet*.

Thanassoulis, E., Kortelainen, M., Johnes, G., and Johnes, J. (2011), Cost and efficiency of higher education institutions in England: A DEA analysis, *Journal of the Operational Research Society 62*, 1282–1297.

Tzeremes, N., and Halkos, G. (2010), *A DEA approach for measuring university departments' efficiency*, MPRA paper no. 24029.

Wilson, P. (2008), FEAR: A software package for frontier efficiency analysis with R, *Socio-Economic Planning Sciences 42*, 247–254.

Appendix

Figure A1. Bias adjusted bootstrapped efficiency scores 2005.

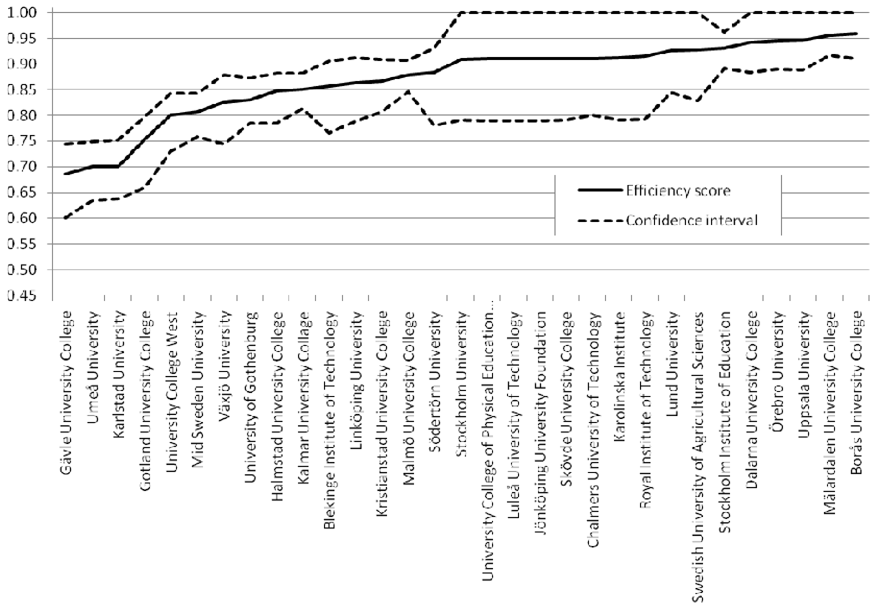


Figure A2. Bias adjusted bootstrapped efficiency scores 2006.

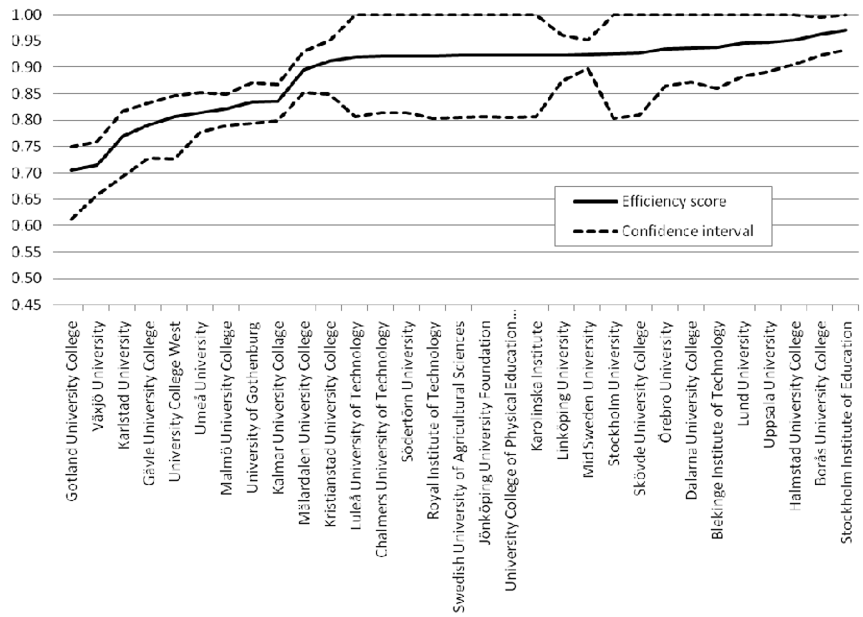


Figure A3. Bias adjusted bootstrapped efficiency scores 2007.

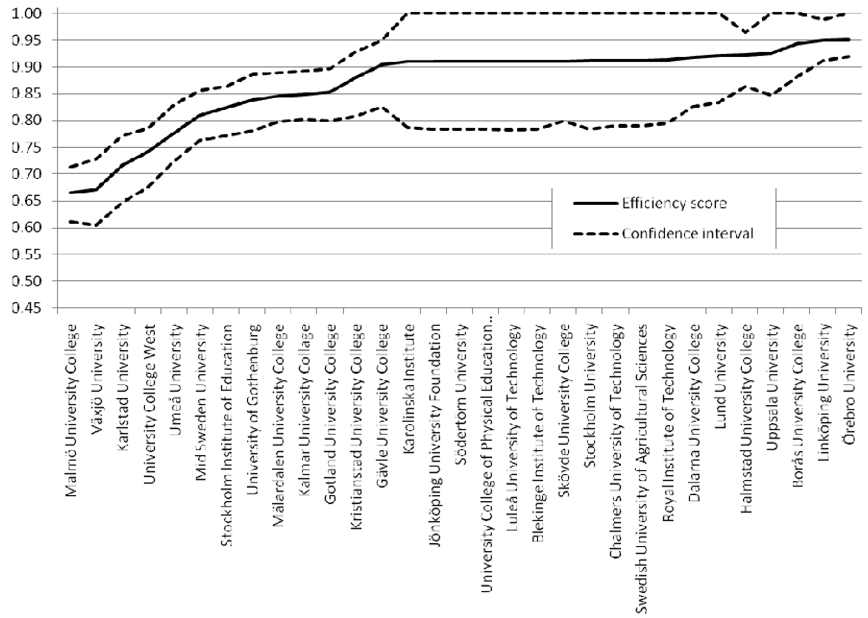


Figure A4. Bias adjusted bootstrapped productivity scores 2005/2006.

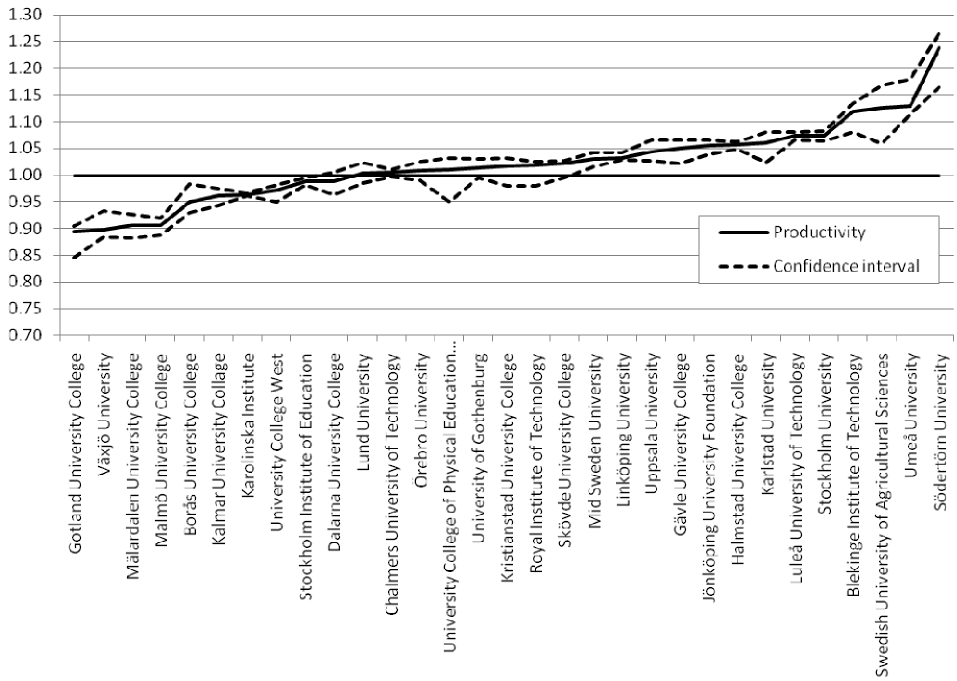


Figure A5. Bias adjusted bootstrapped productivity scores 2006/2007.

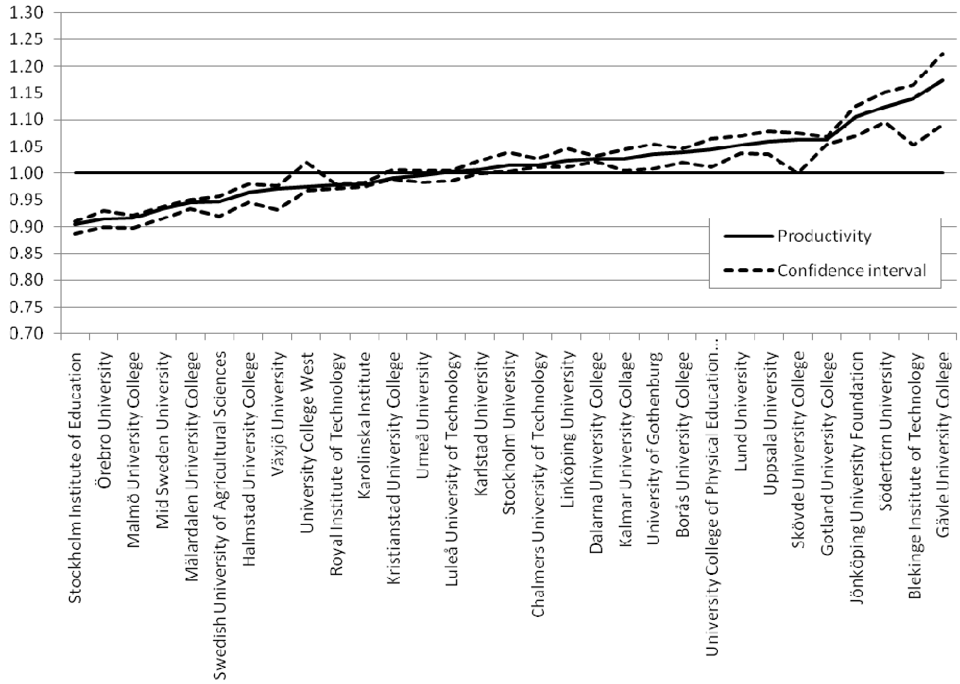


Table A1. Bias adjusted and unadjusted efficiency scores (EC) 2005–2008.

Year	**2005**		**2006**		**2007**		**2008**	
HEI	**EC**	**Adjusted EC**	**EC**	**Adjusted EC**	**EC**	**Adjusted EC**	**EC**	**Adjusted EC**
Blekinge Institute of Technology	0.91	0.86	1.00	0.94	1.00	0.91	1.00	0.94
Borås University College	1.00	0.96	0.99	0.96	1.00	0.94	1.00	0.94
Chalmers University of Technology	1.00	0.91	1.00	0.92	1.00	0.91	1.00	0.95
Dalarna University College	1.00	0.94	1.00	0.94	1.00	0.92	1.00	0.95
Gävle University College	0.74	0.69	0.83	0.79	0.95	0.90	1.00	0.94
Gotland University College	0.80	0.75	0.75	0.70	0.90	0.85	0.61	0.57
Halmstad University College	0.88	0.85	1.00	0.95	0.96	0.92	0.81	0.77
Jönköping University Foundation	1.00	0.91	1.00	0.92	1.00	0.91	1.00	0.93
Kalmar University Collage	0.88	0.85	0.87	0.84	0.89	0.85	0.96	0.93
Karlstad University	0.75	0.70	0.82	0.77	0.77	0.72	0.87	0.83
Karolinska Institute	1.00	0.91	1.00	0.92	1.00	0.91	1.00	0.93
Kristianstad University College	0.91	0.87	0.95	0.91	0.93	0.88	1.00	0.96
Linköping University	0.91	0.86	0.96	0.92	0.99	0.95	1.00	0.95
Luleå University of Technology	1.00	0.91	1.00	0.92	1.00	0.91	1.00	0.93
Lund University	1.00	0.93	1.00	0.95	1.00	0.92	1.00	0.95
Mälardalen University College	1.00	0.96	0.93	0.89	0.89	0.85	0.97	0.93
Malmö University College	0.91	0.88	0.85	0.82	0.71	0.67	0.81	0.78
Mid Sweden University	0.84	0.81	0.95	0.92	0.86	0.81	0.90	0.87
Royal Institute of Technology	1.00	0.91	1.00	0.92	1.00	0.91	1.00	0.93
Skövde University College	1.00	0.91	1.00	0.93	1.00	0.91	1.00	0.93
Södertörn University	0.93	0.88	1.00	0.92	1.00	0.91	1.00	0.93
Stockholm Institute of Education	0.96	0.93	1.00	0.97	0.86	0.82		
Stockholm University	1.00	0.91	1.00	0.93	1.00	0.91	1.00	0.93
Swedish University of Agricultural Sciences	1.00	0.93	1.00	0.92	1.00	0.91	1.00	0.93
Umeå University	0.75	0.70	0.85	0.81	0.83	0.78	0.99	0.96
University College of Physical Education and Sports	1.00	0.91	1.00	0.92	1.00	0.91	1.00	0.93
University College West	0.84	0.80	0.85	0.81	0.78	0.74	0.82	0.78
University of Gothenburg	0.87	0.83	0.87	0.83	0.89	0.84	0.94	0.91
Uppsala University	1.00	0.95	1.00	0.95	1.00	0.92	1.00	0.94
Växjö University	0.88	0.83	0.76	0.71	0.73	0.67	0.91	0.88
Örebro University	1.00	0.94	1.00	0.94	1.00	0.95	0.92	0.89
Geometric average	**0.92**	**0.87**	**0.94**	**0.89**	**0.93**	**0.86**	**0.95**	**0.89**