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Measuring Efficiency in Illinois Public Universities: A DEA–SFA Analysis of State Funding and Student Retention

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ABSTRACT

The study of the efficiency of higher education institutions has been critical notably for university administrators to understand their institutions' challenges better and develop strategies to overcome them. This paper utilizes the Stochastic Frontier Analysis technique (SFA) and Data Envelopment Analysis (DEA) to investigate the cost efficiency of nine public universities (on twelve different campuses) in Illinois during the period 2011-2020. Maximum likelihood estimates are used to assess the impact of changing state appropriations, as well as retention and tuition rates, on the efficiency of Illinois public universities. While the key findings of this empirical study suggest that state appropriations have little impact on the efficiency of Illinois public universities, higher retention rates are the most significant factors in determining and enhancing efficiency. In short, Illinois public universities show different levels of efficiency, with some excelling despite limited resources, while others struggle. The results suggest certain reforms including enhancing retention, optimizing financial management, supporting underperforming universities, promoting innovative teaching, and conducting regular efficiency reviews.

INTRODUCTION

The constraints resulting from the massive reduction in state appropriations to public universities in Illinois were the reason given for some universities to find areas to cut their budgets. Specifically, overhead costs at higher education institutions in Illinois were targeted. Many feared that to achieve this cost efficiency, universities' ability to maintain substantial quality growth in performance would decline. This drew the attention of scholars and stakeholders to investigate the effect of alternative means of income (raising tuition costs) and public funding on technical efficiency and allocative efficiency. This might occur when the optimal mix of inputs is not utilized or the best combination of outputs is not achieved (Titus & Pusser, 2011). Taking from Efficiency Theory proposed by Farrell (1957) - with much importance given to both technical and allocative efficiency - has been widely reviewed in diverse empirical works, even though the theory has not been fully conceptualized by scholars, it has helped shape the evolution of the efficiency theory. Efficiency techniques are now widely applied and adopted in research, including Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). The former, being a parametric technique, has taken much interest of researchers in recent times for its power of efficiency explanation. The previous research in production, health service, agriculture, manufacturing, finance, transport service, and government institutions have accorded importance to this efficiency tool, providing the needed momentum for the current study to adopt SFA and DEA in investigating cost efficiency in Public Universities in Illinois. In the work of Aigner, D., Lovell, C., and Schmidt, P. (1977), they provided specifications for the parametric frontier model and stochastic frontier (making disturbance as the sum of symmetric normal and non-positive half-normal random variables). In contrast to implicit assumptions from past theoretical work of Aigner, D. and Chu, S. (1968) and Richmond (1974), in an attempt to solve the linear programming problem of the functional relations, Aigner et. al. (1977), argued that something magical happened in the process of moving from one equation to another in the estimation of their model. He further argued that their approach is sensitive to outlier and mathematical programming techniques do not lead to estimate with known statistical properties. On this basis, if one sided disturbance term has a known distribution as suggested by Aigner *et al.* (1976), the model can be estimated by maximum-likelihood techniques. However, in practical sense of it, maximum-likelihood techniques might not be a strong enough power tool. Aigner et. al (1977), believe that "unfortunately, the observation that maximum-likelihood techniques can estimate the model, and that under appropriate assumptions linear and quadratic programming are maximum-likelihood techniques, is of little practical value. This is because the usual 'regularity conditions' for the application of maximum likelihood are violated". In their work, error structure as suggested by Aigner, Amemiya, and Poirier (1976) was preferable to one-sided disturbance distribution. The primary contribution of this error structure to the literature is that it allows the placement of the fitted function to be estimated along with the usual parameters of interest through the parameter, Aigner *et al.* (1977). However,

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they advocated a more direct approach to model the error process, explicitly captured in the stochastic frontier with error structure that comprises of symmetric disturbance: independently and identically distributed and second error component derived from normal distribution truncate above zero. The use of SFA for estimating inefficiency has become a more handy tools thanks to the empirical works of Aigner, D., Amemiya, T. and Poirier, D (1976), Aigner, Lovell, and Schmidt (1977), Battese, G.E and Corra F. (1995). While several past research projects have used parametric Stochastic Frontier and Data Envelopment in the analysis of productive efficiency, there have been several critiques for their practicability as efficiency techniques. "Both methods have their individual strengths and shortcomings. One of the key strengths of DEA is that it allows the use of multiple inputs and outputs, while an important advantage of SFA is that there are a number of well-developed statistical tests to investigate the validity of the model and the significance of the variables", Bayrakta *et al.* (2013).

LITERATURE REVIEW

Literature concerning efficiency measurement covered a wide array of sectors such as health service, agriculture, manufacturing, finance, transport, museums, government institutions, and many more. Mojahedian, *et al.* (2020) explains that typically efficiency is understood to be "using minimum resources to produce the highest output and project" particularly, they explain that an efficient school, or government, or factory must be doing things right if they are performing at the most efficient level (Mojahedian, *et al.*, 2020).

There are a number of ways to evaluate efficiency. For example, Theodoridis *et al.* (2011) advocated non-parametric Data Envelopment Analysis and Stochastic Frontier Analysis to compare estimates of technical efficiency and the determinants of inefficiency in a sample of 240 crop farms in Bangladesh. The study substantiated that there is production inefficiency among sample farms in the country. The study further stressed that age factor, level of education and involvement with extension of service are significant variable for improving technical efficiency in agricultural production in Bangladesh. In related study on technical, allocative and economic efficiency on rice farmers in Bangladesh carried out by Wadud (1999), argued that technical and economic inefficiency that are observed in sample rice farms in Bangladesh can be improved on by policy measures that reduce land fragmentation, irrigation infrastructural system, land degradation and environmental factors. Like the previous counterpart study, education and age of farmers also affect the efficiency in terms of utilization of factor resource. Wadud (1999) stated given a level of technology, farm production can be increased if farmers improve their technical, allocative, and economic efficiency, "the sample farmer, on average, could increase their rice by 8 to 39 per cent depending upon the frontier methodology and scale assumption if they could operate at full technical, allocative and economic efficiency. These two studies conducted independently but which are related emphasized technical inefficiency that might have resulted from basic fundamental factors peculiar to Agriculture subsectors in the countries however, suggested policy measures to mitigate the less-optimal performances in farm produce in future.

Fan *et al.* (1996), in Semi-parametric Estimation of Stochastic Production Frontier Models, on data collected from Quebec dairy farms, took a different form of the classic SFA, in which production frontier function is unknown but the composite error terms are of known form – "specifically, we extend the linear stochastic frontier model to semiparametric frontier model in which the functional form of the production frontier is unknown". Using the semi-parametric pseudo likelihood estimators put forward by the authors, they came up with findings that labor-capital ratio causes efficiency in the farm and participating membership of the farm management club, which provides information on technical innovations, tend also to increase efficiency.

Wang (2003) claimed that there are associated problems with model specification of past empirical works in financing constraints on investments. To evade this challenge, Wang (2003) stressed the identification of the constraints can be achieved by imposing a one-sided distributional assumption on the effect of financing constraints. He technically assumed that financing constraints have one-sided effects on investment and can be explained by a vector of observable variables. Wang (2003) vehemently argued for Stochastic Frontier Analysis as a better estimation technique. Bearing this in mind, believed by imposing this distribution assumption on the constraint, the effect of financing constraints can be identified and quantified. His empirical findings in the study revealed cash flow would both promote the rate of investment in an environment dominated by financing constraints and reduce the spread of financing constraints. It was also revealed that Taiwan's case in financial liberation was efficiency driven while smaller firms show more improvement that is noticeable.

Mandal and Madheswaran (2012), examine whether growth in Total Factor Productivity or increase in use of energy resource was the major cause of growth in Indian cement industry. In the same vein, if technical progress or technical efficiency were the main drivers of productivity growth in the cement industry, using a stochastic production frontier. Two streams of studies were already notable as source of change in Total Factor Productivity; Mandal and Madheswaran (2012), claimed that earlier studies attributed factor input growth as the main source of output growth in which technical progress would be seen as the main source of TFP. It was in recent studies on TFP that recognized technical efficiency as other important unique source of growth. However, the study confirmed both economies of scale and technical progress but not technical efficiency that contributed to TFP growth. Also, suggesting energy-using technical progress in the industry is not desirable and it is unsustainable; therefore, advocate for firms to adopt energy-saving technologies.

Chakraborty *et al.* (2001), stated that efficiency in public education system is a significant issue in United States, mainly because of inefficient utilization of resources. The study empirically shows there is substantial variation in efficiency among school districts. It was revealed that quality of instructional staff and student-teacher ratio (weak relationship) affect achievement test scores in Utah. On efficiency scale, the study stressed that most of the 40 sampled schools investigated were technically efficient. In addition, both Non-parametric DEA and parametric SFA indicate parental education, socioeconomic and environmental factors demonstrate a strong correlation to student performance. Their view on policy measures was to fix these inefficiencies through better management of controllable inputs and adoption of programs that link part of teacher compensation to student performance.

Bayrakta *et al.* (2013), noted the objective of their study was to use Stochastic Function Analysis and Data Envelopment Analysis to investigate the public-held belief on the relative efficiency of public and private controlled universities using quality management factors and performance in Turkish universities. Three models were developed (Stakeholder-focus, factor-efficiency and total efficiency) to assess quality management practices efficiency. At the end of the study, using DEA, it was confirmed public and private universities did not vary in the total-efficiency model but private universities with higher levels of quality management on stakeholder-focus metrics outweigh the public universities' performance while public outperform private in superior teaching and research performance. They however, found that structural difference was observed in total-efficiency and factor-efficiency but not in stakeholder-focus model. By their empirical evidence, the differences are counterbalanced, that is, public universities tend to concentrate on factor efficiency while private focus on stakeholders.

Robst (2001) examines the cost efficiency of public higher education institutions, identifying factors that influence cost variations. The study uses a cost function approach to assess how institutional characteristics impact efficiency.

Sav (2016), in a study carried out in South Carolina, USA, argues that state appropriations were linked to higher education efficiency using stochastic frontier analysis. In Sav's words, "government officials suggest that using performance measures and limiting state appropriations for higher education will control higher education costs and force institutions to provide an education more efficiently". The study was also to assess the relative reduction in efficiencies of the institutions with larger state share decline and smaller state share decline. With empirical evidence from South Carolina, it was successfully shown in the study that reduction of state appropriations to institutions affect their efficiency but more pronounced for the institutions that that have huge decline in the revenue from the state.

Titus and Pusser (2011), two objectives were significantly pursued in their study of state potential enrollment of adult students using stochastic frontier analysis: how tuition affects the level of undergraduate enrollment of adult learners within the states and to what extent are there gaps between the actual and potential maximum undergraduate enrollment of adult learners apparent in the state. With extensive empirical work on panel data on selected states in United States, they were able to correlate balance resource allocation through loan programs and other forms of subsidy with enrollments of adult students and long-term economic wellbeing of those who matriculate. In the study, some states are highly efficient than others with respect to the potential enrollment of adult students, financial aid, tuition, and other selected factors. It is in this light, they suggested that enrollment efficiency could be used as effective criterion in allocating funding in United States. An additional way to test the change of efficiency of universities over time is to use a Malmquist index (Asmild, et al, 2004). This technique works well with time series data, and it helps to see how the various types of efficiencies change over time. The next step is to determine the most appropriate inputs and outputs to be used in the model. Kuah and Wong (2011) discuss the variables of inputs and outputs that were used historically from past research. They explain that "generally, the agreed inputs for universities can be classified as human and physical capital, and the outputs should arise from teaching and research activities." Most research project look at either teaching or research efficiency and choose the outputs based on the results they are interested in finding (Kuah and Wong, 2011). Flegg, et al (2004), when investigating the efficiency of British universities argued that when deciding on the outputs for universities, they "should be defined primarily according to the services they provide". Because of this one of his outputs was the number of degrees a university awards per year (Flegg et al, 2004). This of course does not provide any details about the "quality" of the degree or teaching, but it is a good estimation of the number of students who successfully completed the programs (Flegg *et al.*, 2004). Bowrey, *et al.* (2020) discuss the level of attention that "retention rates and attrition rates" have gotten recently in colleges and universities. In their research to evaluate performance efficiency, they use the ratio of students to staff, the school retention rate for students, and attrition rates of faculty and staff (Bowrey, *et al.*, 2020).

Hasan (2025) examines how digital transformation influences performance and business model innovation, paralleling how universities might adopt digital tools or learning management systems to enhance efficiency. Moreover, Yan and Sviridova (2024) explore how enterprises integrate and apply big data in economic and business management decision-making, illustrating the broader role of data-driven approaches in organizational performance evaluation.

MATERIALS AND METHODS

Estimating Cost Inefficiency

To estimate the cost frontier functions, a transcendental logarithmic functional form is selected. This functional form is widely used because it is flexible. The study uses the translog stochastic frontier functions by Battese and Coelli (1995). Stochastic Frontier Analysis (SFA) is utilized to assess the effectiveness or ineffectiveness of production entities, such as universities, in our exercise, by calculating a frontier function that denotes the maximum achievable output given a specific set of inputs. A distinguishing aspect of SFA is the separation of deviations from this frontier into two elements: one that represents random variability (e.g., measurement errors or external shocks) and another that accounts for inefficiency. It is commonly assumed that the random variability component follows a symmetric distribution, while the inefficiency component conforms to an asymmetric distribution, often being half-normal or exponential. Through comparing actual outputs to the estimated frontier, SFA offers insights into the efficient utilization of resources and identifies the presence and extent of inefficiencies in the production process. This method is widely applied in diverse fields, including economics, healthcare, and agriculture, to appraise performance and pinpoint areas for enhancement.

According to this approach, the estimation of universities' relative efficiency using panel data is obtained by estimating a cost function of the general form:

Where Yit is total cost in logarithm form of university i in

$$Y_{it} = \beta\, X_{it} + e_{it} \qquad (1)$$

period t; Xit is a matrix of outputs and inputs, and the set of relevant independent variables in logarithm form; β is a vector of unknown parameters, and e is the error term. The stochastic frontier method allows the residual e to be decomposed into two parts: ei = Vi + Ui; where: Vi is a random variables assumed to be iid N(0,σV 2) and independent of the Ui, and Ui is a non-negative random variables assumed to account for the cost of inefficiency in production, which are often assumed to be iid N|(0,σU 2)|; such that:

According to Jacobs (2000), Ui now defines how far the

$$Yi = xi\beta + (Vi + Ui) \qquad i=1,\ldots,N, \qquad (2)$$

university operates above the cost frontier.

This analysis uses panel data to examine both differences across institutions and changes within institutions over time. Cross-sectional analysis allows us to determine whether institutions with a smaller share of revenues from state appropriations are more or less efficient than institutions with a larger state appropriation share. However, cross-sectional analysis has two important drawbacks. First, it is difficult to infer causation, and second, omitted variables can bias the estimated coefficients.

Without adequate controls for quality, which the data do not contain, a cross-sectional approach may attribute expenditures for higher quality to inefficiency. If we assume quality changes slowly, a time series analysis can implicitly account for expenditures above the minimum that create higher institutional quality. Thus, while levels of inefficiency may be partly due to quality, changes in inefficiency over a short period are unlikely to be severely affected by quality considerations. Although the relationship between a university's revenue structure and efficiency is not addressed in previous research, several studies provide intuitive reasons to expect a relationship between state appropriations and efficiency. For example, increasing state appropriations may lead to greater university expenditures and unless accompanied by an output or quality increase will likely lead to greater inefficiency. The findings of McPherson and Shapiro (1994), Volkwein (1987), and Gamkhar and Oates (1996) may suggest that state appropriation reductions might force public higher education institutions to become more efficient. Of course, an alternative interpretation is that schools may be forced to offer a lower quality education in order to reduce expenditure.

Data

The data used in this study are derived from 2011 through 2020 Illinois Board of Higher Education (IBHE) Data Book and university websites. The sample ends right at the COVID-19 lockdown in Illinois. The sample is limited to four-year public institutions within the State of Illinois. These institutions are Chicago State University, Eastern Illinois University, Governors State University, Illinois State University, Northeast Illinois University, Northern Illinois University, Western Illinois University, Southern Illinois University (Carbondale and Edwardsville), and University of Illinois (Chicago, Urbana Champaign, and Springfield). The study period ends in 2020 to avoid extending the analysis into the substantial structural disruptions to higher education associated with the COVID-19 pandemic.

This study will use total enrollment and number of degrees awarded for the public universities as outputs as shown in figure (1) and (2) respectively. The annual state appropriation as shown in figure (3) and tuition & fees as shown in figure (4), along with the Fall-to-Fall student retention rate as input factors shown in figure (5). Figure (1) through (5) summarizes the evolution of input and output factors over the period of study from 2011 to 2020. Figure (1) and (2) displays that University of Illinois Urbana Champaign and University of Illinois Chicago have the highest enrollment rates as well as the number of degrees awarded annually. At the same time, these two universities also receive the highest appropriation from the state government as shown in figure (3) and they also charge the highest tuition and fees in the state as shown in figure (4).

The input factors might not be the best representative of inputs, but the study's concern is the role and impact of funds (tuition or/and appropriation) on public universities efficiencies.

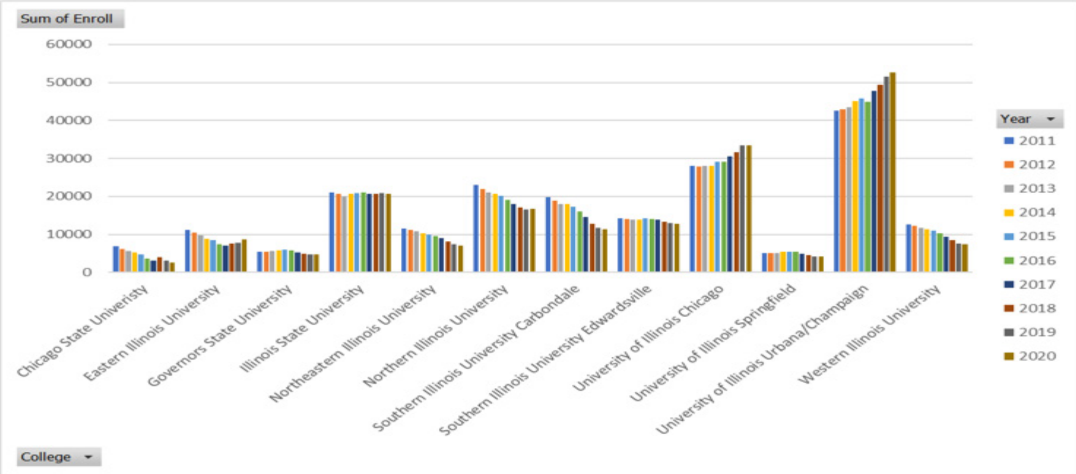

Figure 1: Total Enrollment

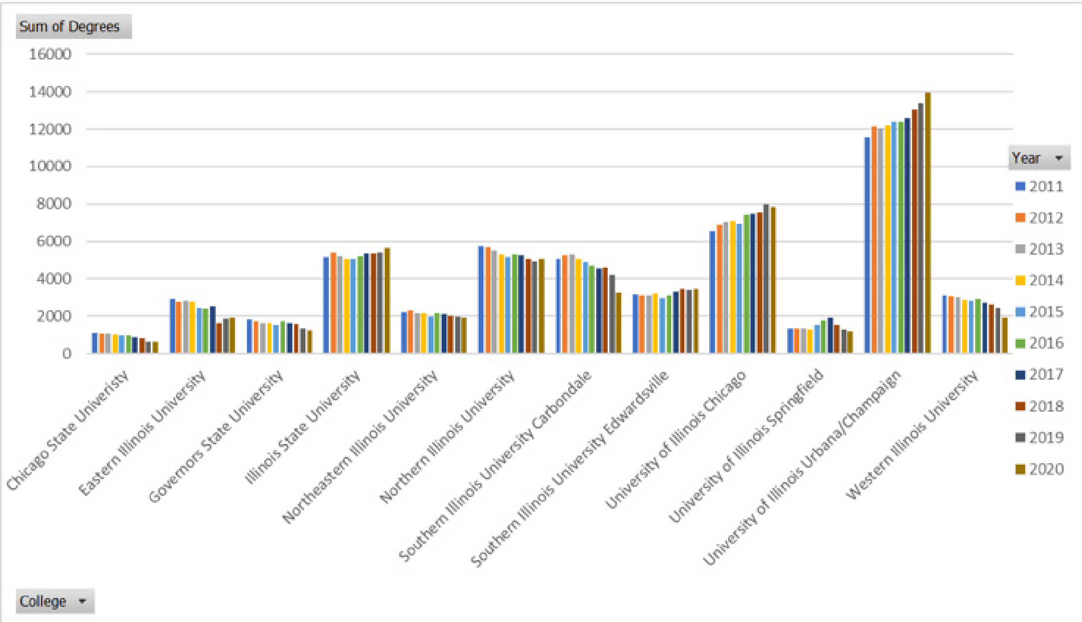

Figure 2: Degrees Awarded per Year

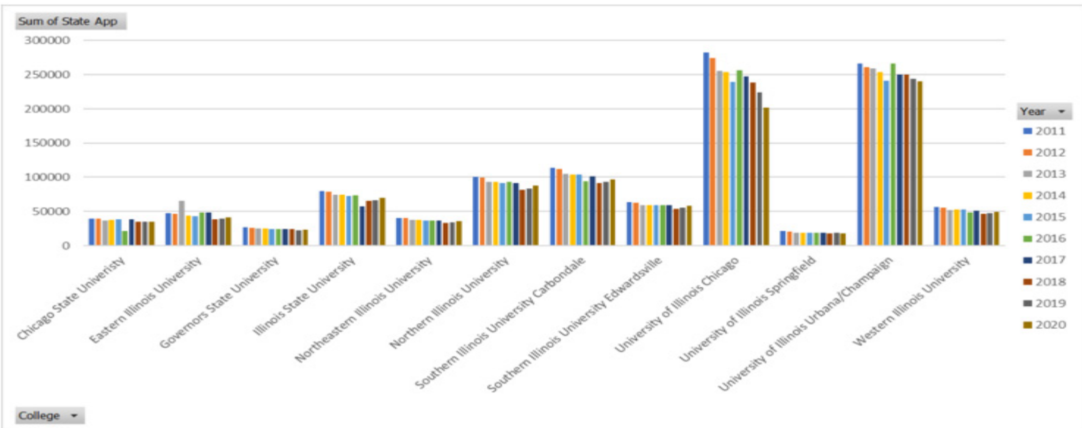

Figure 3: State Appropriation

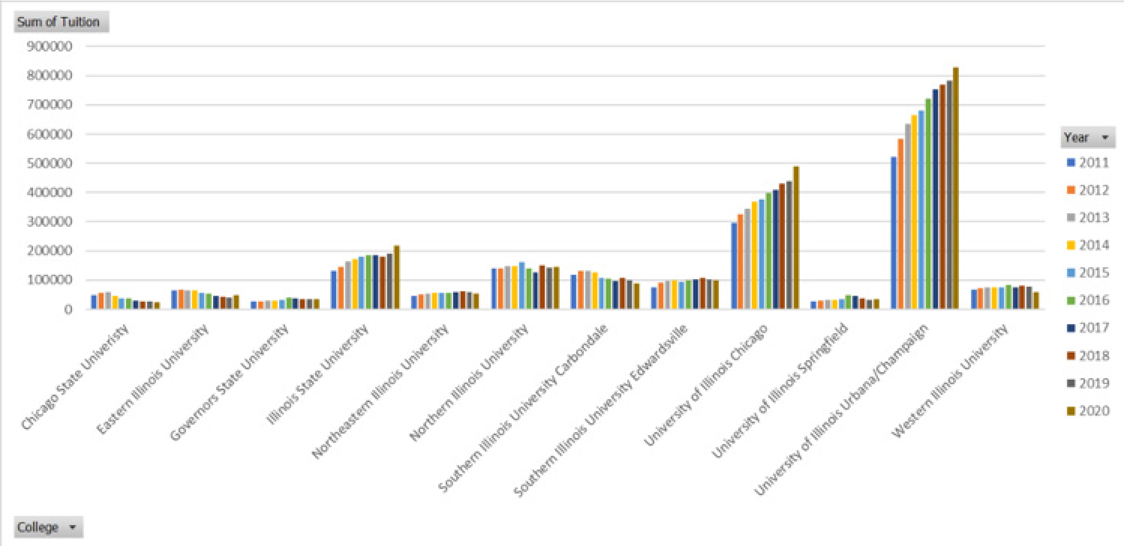

Figure 4: Tuition & Fees

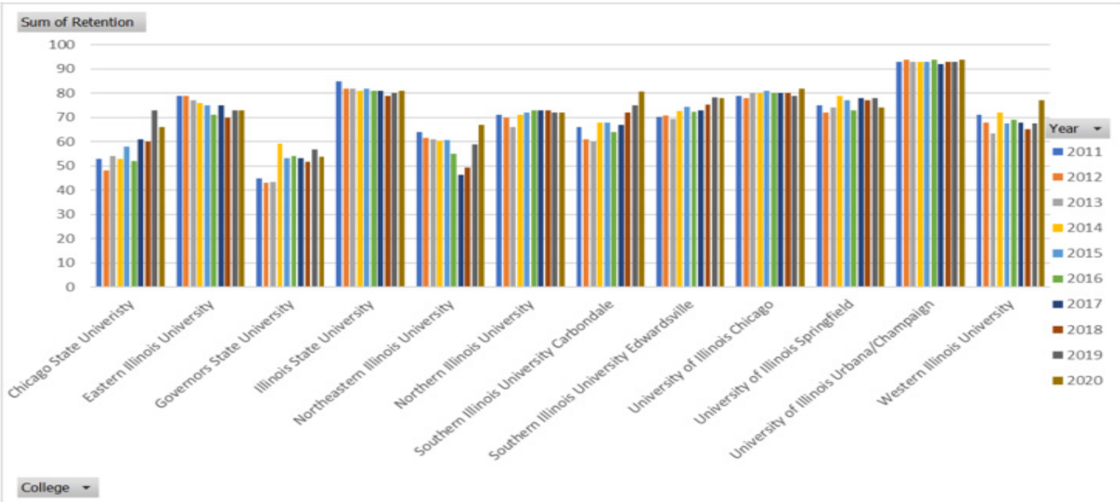

Figure 5: Fall to Fall Freshman Retention Rate

RESULTS AND DISCUSSION

The results of first model of the Stochastic Frontier Analysis, where the enrollment rate is used as output, indicate that all three inputs (the retention rate, tuition rate, and state appropriation) inputs are statistically significant, where the retention rate is particularly the strongest factor in determining the level of enrolment at these universities. That is, the larger the retention rate, the more students we will have enrolled in the next year, regardless of what steps the university takes. In other words, as the retention rate decreases, we will also see a decrease in the total enrolment numbers. For example, Illinois State University (ISU) has been consistently one of the most efficient universities in the state because it has one of the highest retention rate. The high retention rate at ISU is likely driven by the fact that the university offers more student support services, academic advising, and campus engagement initiatives than other universities in the state. In fact, ISU invested around $390 per full-time equivalent student in Pell grant recipients, which is far more than any other university in the state (the average is $50 for all universities). All these student support services from ISU play a pivotal role in increasing its retention rate and should therefore enhance its selectivity over time, too. SFA explores why a retention rate is important and how we can improve it. Chicago State University (CSU) started with a high retention rate, but the number has been going down, which corresponds to a reduction in the total enrolment. The reason might be due to the fact that the university struggles with low retention rates. And some of it may be rooted in the socioeconomic conditions of the student body, less effective student support services, or some other institutional barriers that prevent them from having better outcomes at that institution. Even though more it would be difficult to do given the university's strong commitment to social justice and community engagement.

Table 1: SFA with number of Students enrolled as output
Stochastic Frontier normal/half-normal model

Variable	Coef.	St.Err.	t-value	p-value	95% Conf. Interval	Sig.
Retention	90.281	30.241	2.99	.003	31.01 – 149.553	***
Tuition	.044	.003	13.04	0	.037 – .05	***
StateApp	.035	.008	4.51	0	.02 – .05	***
Constant	-586.384	90793.155	-0.01	.995	-178537.7 – 177364.93	
Constant	15.87	.129	122.93	0	15.617 – 16.123	***
Constant	-5.13	295864.4	-0.00	1	-5798845.5 – 5798835.3	
Mean dependent var	15795.450	SD dependent var	11969.126			
Model Statistics						

Statistic	Value	Statistic	Value
Mean dependent var	15795.450	SD dependent var	11969.126
Number of obs	120.000	Chi-square	2064.427
Prob > chi2	0.000	Akaike crit. (AIC)	2256.968

*** *p < .01*, ** *p < .05*, * *p < .1*

The second SFA model looked at the output "number of degrees awarded". Again, all three inputs are highly significant, but the retention rate had a smaller effect on the final outcome of the degrees awarded. That is expected since the retention rate is typically calculated for Freshman returning as Sophomores. Students still might drop out later, but the results do show that the retention rate does play a big role in students finally graduating. For instance, the University of Illinois Urbana-Champaign (UIUC) stands out for its high number of degrees awarded, which can be attributed to its substantial state appropriations and tuition income. UIUC's large resource base allows it to offer a wide range of programs and maintain high academic standards, leading to higher graduation rates. This efficiency in degree production is a testament to the university's ability to convert its inputs into successful outputs effectively. In contrast, Western Illinois University (WIU) has struggled with declining efficiency in recent years, as evidenced by the lower number of degrees awarded. Despite efforts to improve retention and academic support, WIU faces challenges in translating its inputs into a higher number of graduates. Factors such as regional economic conditions, competition from other institutions, and possibly less effective allocation of state appropriations could be contributing to this inefficiency.

Table 2: SFA with numbers of degree awarded as output
Stochastic Frontier normal/half-normal model

Variable	Coef.	St.Err.	t-value	p-value	95% Conf. Interval	Sig.
Retention	29.723	8.668	3.43	.001	12.735 – 46.711	***
Tuition	.012	.001	12.46	0	.01 – .014	***
StateApp	.007	.002	3.31	.001	.003 – .012	***
Constant	-523.511	5018.605	-0.10	.917	-10359.795 – 9312.773	
Constant	13.371	.129	103.57	0	13.118 – 13.624	***
Constant	-5.17	165771.13	-0.00	1	-324910.62 – 324900.28	
Model Statistics						

Statistic	Value	Statistic	Value
Mean dependent var	4126.783	SD dependent var	3171.915
Number of obs	120.000	Chi-square	1747.473
Prob > chi2	0.000	Akaike crit. (AIC)	1957.061

*** *p < .01*, ** *p < .05*, * *p < .1*

Finally, we estimate a time-invariant inefficiency model, which assumes that institution-specific inefficiency remains constant over the study period while allowing other model components to vary over time (Belotti et al., 2013). In this case, the retention rate is negative and only marginally significant at the 10% level, while tuition and state appropriations remain statistically significant, although their estimated coefficients are relatively small. The relatively small coefficients may reflect the limited year-to-year variation in state appropriations and tuition income.

Table 3: Time Invariant Model
Time-invariant inefficiency model

Variable	Coef.	St.Err.	t-value	p-value	95% Conf. Interval	Sig.
Retention	-9.713	5.561	-1.75	.081	-20.612 – 1.186	*
Tuition	.01	.001	16.60	0	.009 – .011	***
StateApp	.014	.002	7.04	0	.01 – .018	***
Constant	3496.297	486.887	7.18	0	2542.017 – 4450.577	***
Constant	952.883	845.308	1.13	.26	-703.891 – 2609.657	
Constant	14.233	.803	17.72	0	12.659 – 15.807	***
Constant	3.118	.854	3.65	0	1.444 – 4.792	***

Model Statistics

Statistic	Value	Statistic	Value
Mean dependent var	4126.783	SD dependent var	3171.915
Number of obs	120.000	Chi-square	349.442
Prob > chi2	0.000	Akaike crit. (AIC)	1739.626

*** $p < .01$, ** $p < .05$, * $p < .1$

Data Envelopment Analysis

Using the Data Envelopment Analysis Program (DEAP) (Coelli, 1996) and in particular the Malmquist Index (MI), Figure 6 shows the efficiency results for the twelve universities over time.

Table 4: Efficiency Frontier

University	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Chicago State University	0.641	0.594	0.555	0.618	0.687	0.636	0.667	0.794	0.576	0.631
Eastern Illinois University	0.951	0.914	0.852	0.988	0.972	1	1	1	1	1
Governors State University	1	1	1	1	1	1	0.992	1	0.985	1
Illinois State University	1	1	1	1	1	1	1	1	1	1
Northeastern Illinois University	1	1	1	1	1	1	1	0.98	0.938	0.992
Northern Illinois University	1	1	1	1	1	1	1	1	1	1
Southern Illinois University Carbondale	1	1	1	1	1	1	1	1	1	0.977
Southern Illinois University Edwardsville	0.93	0.882	0.905	0.921	0.988	0.971	0.927	0.976	0.975	1
University of Illinois Chicago	0.915	0.923	0.908	0.902	0.941	0.968	0.979	0.99	1	0.963
University of Illinois Springfield	0.987	1	1	1	1	1	1	1	1	1
University of Illinois Urbana/Champaign	1	1	1	1	1	1	1	1	1	1
Western Illinois University	0.93	0.924	0.946	0.932	0.949	0.923	0.883	0.874	0.872	0.836

The results indicate that Illinois State, Northern Illinois, and the University of Illinois Urbana/Champaign are efficient throughout the entire time series. The three universities are very efficient mainly because they have high demand and a good number of student population. The three universities have a masters and Ph.D. programs in various disciplines, which gives a signal to many parents about the quality of instruction in these schools.

Figure 7 shows the information above in graph form (with the three most efficient universities removed).

Most universities are moving more towards efficiency except Western Illinois University and Chicago State University which have been struggling recently. Eastern Illinois University has moved to a technical efficient level since 2016.

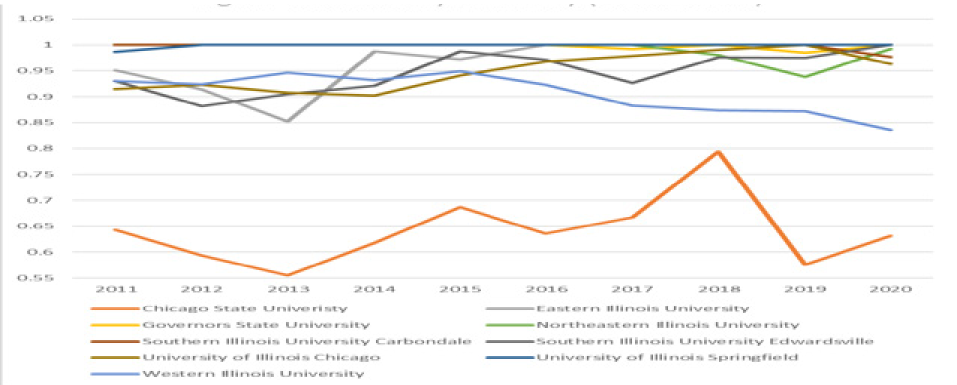

Figure 6: University Efficiency (2011–2020)

In summary, the effects of state appropriations and tuition on efficiency are relatively stable, with minor fluctuations. For example, Northern Illinois University (NIU) has shown consistent efficiency over time, with only slight variations. The university's ability to maintain efficiency despite fluctuations in state funding or tuition adjustments indicates a stable operational model. NIU's approach to managing its resources efficiently, including investments in infrastructure and student services, helps to mitigate the impact of external financial changes on its overall performance. Moreover, Eastern Illinois University (EIU) presents an interesting case where efficiency has increased significantly since 2016. The improvement in EIU's efficiency could be linked to strategic initiatives aimed at improving retention and graduation rates, coupled with careful management of tuition and state appropriations. This positive trend showcases how targeted efforts to address inefficiencies can lead to meaningful improvements over time.

Chicago State University exhibits persistently lower efficiency scores relative to the other institutions in the sample, warranting further investigation. Given the institution's distinctive mission and strong commitment to social justice and community engagement, these efficiency estimates should also be interpreted in light of institutional objectives that may not be fully captured by the inputs and outputs included in the DEA model.

Figure 8 shows an index summary of firm means. As Chang *et al.* (2019) explains in their paper about the efficiency of Taiwanese bakeries, these results show the average change in efficiency over the years. For example, Eastern Illinois University saw and increase in efficiency by 6% and Chicago State's average efficiency decreased by 2%. The final column shows the change in Total Factor Productivity Change. This seems to show that productivity and technical efficiency don't change much for universities over time.

CONCLUSION

University	effch	techch	pech	sech	tfpch
Chicago State Univeristy	0.998	0.985	1.014	0.984	0.983
Eastern Illinois University	1.006	0.995	1.006	1	1
Governors State University	1	0.948	1	1	0.948
Illinois State University	1	1.002	1	1	1.002
Northeastern Illinois University	0.999	0.956	0.999	1	0.955
Northern Illinois University	1	0.975	1	1	0.975
Southern Illinois University Carbondale	0.997	0.969	0.999	0.999	0.966
Southern Illinois University Edwardsville	1.008	0.974	1.007	1.001	0.982
University of Illinois Chicago	1.006	0.985	1.003	1.002	0.99
University of Illinois Springfield	1.002	0.99	1	1.002	0.992
University of Illinois Urbana/Champaign	1	1.014	1	1	1.014
Western Illinois University	0.988	0.967	0.985	1.003	0.955
mean	1	0.98	1.001	0.999	0.98
effch=efficiency change (pech x sech)					
techch=technical efficiency change					
pech=pure technical efficiency change					
sech=scale efficiency change					
tfpch=total factor productivity change					

Figure 7: Malmquist Index Summary of Firm Means

Illinois Public Universities' performance reveals significant variation in their efficiency levels due to multiple factors. During the study period, some universities experienced fluctuations in efficiency, while others managed to sustain quality education relative to the resources available to them. The analysis highlights that retention rates play a particularly important role, as efforts that help students continue beyond their freshman year raise both enrollment and graduation outcomes. Although tuition and state appropriations also matter, their influence on efficiency is comparatively stable and less pronounced, suggesting that retention initiatives are the most critical driver of performance. Institutions facing persistent challenges, such as Western Illinois University and Chicago State University, may therefore require strategic adjustments and targeted support.

These findings carry important implications for policy. First, strengthening student retention initiatives through enhanced advising, mentorship, mental health support, and early warning systems is vital for maintaining enrollment and improving degree completion. Second, financial management and resource allocation should be improved by adopting performance-based funding models, expanding financial aid, diversifying revenue sources, and fostering partnerships. Third, underperforming institutions need tailored assistance, whether through direct financial and infrastructure support or through collaboration with stronger universities to share data, experiences, and best practices. Fourth, promoting innovation in teaching and learning—such as expanding online and blended learning formats and investing in instructional technology—can enhance flexibility and student outcomes. Finally, continuous evaluation of efficiency through statewide audits and data-driven decision-making would help ensure accountability and long-term effectiveness.

In sum, improving retention, enhancing financial strategies, supporting weaker institutions, fostering innovation, and instituting ongoing evaluation together provide a comprehensive framework for strengthening the efficiency and sustainability of Illinois public universities.

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