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RESEARCH PAPER

Cost Efficiency and Cost Productivity of TEVETA Institutes of Punjab, Pakistan: A Non-Parametric Analysis

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ABSTRACT

This research paper investigates the cost efficiency and cost productivity of TEVETA institutes in Punjab, Pakistan using Data Envelopment Analysis (DEA) and COST MALMQUIST INDEX. The study uses data from 2006-2018 to analyze the impact of TEVETA reform 2011. The objective of the study is to assess the impact of the reform on productivity and efficiency of the production process. The results of the study indicate that the reforms implemented in Punjab have had a positive impact on productivity. The efficiency change, scale efficiency change, and technical change have all increased after the reforms, indicating an improvement in the overall productivity of the production process. However, the Malmquist Productivity Index has decreased slightly after the reforms, indicating a decrease in productivity. The study recommends that there is still room for improvement in resource allocation and the use of technology in the production process. The decline in allocative efficiency change suggests that resources were not allocated as efficiently as before, and the increase in the price change indicates a slight increase in the price of production inputs.

KEYWORDS Cost Malmquist Index Productivity, Data Envelopment Analysis (DEA), Efficiency, Resource Allocation, TEVETA Institutes

Introduction

Technical Education and Vocational Training Authority (TEVETA) institutes are an important aspect of the education sector in Punjab, Pakistan (Government of Punjab, 2012). The main objective of these institutes is to provide technical and vocational education to students, which will enable them to be successful in today's rapidly changing global economy (Khalid, et al., 2019). TEVETA institutes aim to offer high-quality education and training at an affordable cost to cater to a broad range of students (Naveed & Ahmad, 2019).

Efficient utilization of resources is essential for the sustainability of TEVETA institutes (Mahmood, et al., 2018). The effectiveness of resource utilization in TEVETA institutes is determined by two important concepts, namely cost efficiency and cost productivity. Cost efficiency refers to the organization's ability to produce the required output using the minimum possible resources (Ullah & Jafar, 2020). On the other hand, cost productivity refers to the ability of the organization to produce the required output using a specific level of resources (Mahmood, et al., 2018).

The cost efficiency and cost productivity of TEVETA institutes in Punjab are influenced by several institutional, economic, and social factors (Khalid, et al., 2019). Therefore, it is crucial to identify the key determinants of cost efficiency and cost productivity to enhance the effectiveness of resource utilization in TEVETA institutes (Naveed & Ahmad, 2019).

This research paper aims to calculate the of cost efficiency and cost productivity of TEVETA institutes in Punjab using Data Envelopment Analysis (DEA) and Cost-DEA (Ali, et al., 2020). DEA is a non-parametric method that measures the relative efficiency of decision-making units (DMUs) based on their input and output measures. Cost-DEA is a variant of DEA that incorporates cost measures as inputs and outputs in the efficiency analysis.

The second section of the paper provides an overview of the literature on cost efficiency and cost productivity of TEVETA institutes. The third section explains the methodology used in the study, including the DEA and Cost-DEA models. The fourth section presents the results of the analysis and discusses the key determinants of cost efficiency and cost productivity. Finally, the fifth section concludes the paper with recommendations for improving the cost efficiency and cost productivity of TEVETA institutes.

Literature Review

(Data Envelopment Analysis) DEA is a powerful tool used for assessing the efficiency of decision-making units (DMUs) in different industries, including healthcare, education, banking, and manufacturing (Banker et al., 1984; Cooper et al., 2011; Seiford and Thrall, 1990). DEA is a non-parametric method that evaluates the performance of DMUs based on multiple inputs and outputs, making it an ideal choice for benchmarking and performance evaluation.

DEA is a versatile tool that has a wide range of applications, including the identification of best practices, the evaluation of efficiency in supply chains, and the assessment of the performance of public institutions (Cook and Seiford, 2009; Emrouznejad and Yang, 2018; Tone and Tsutsui, 2014). One of the most significant advantages of DEA is that it allows decision-makers to identify the most efficient DMUs in a given industry or sector and compare them with their peers (Kao and Hung, 2008). This can help organizations to improve their operations, reduce costs, and increase their competitiveness.

Another advantage of DEA is its ability to handle multiple inputs and outputs, including qualitative and quantitative data (Cook and Zhu, 2014; Zhu et al., 2020). This makes it possible to assess the performance of DMUs based on a variety of factors, including financial metrics, operational processes, and customer satisfaction. DEA also provides decision-makers with a set of recommendations for improving their operations, based on the best practices of the most efficient DMUs (Zhou et al., 2019).

DEA has some limitations, however. For example, it requires a large amount of data to be collected and analyzed, and it can be difficult to interpret the results (Charnes et al., 1985). Additionally, DEA does not provide a clear picture of the causes of inefficiency, which can make it challenging for decision-makers to identify the root causes of problems (Emrouznejad and Yang, 2018).

Overall, DEA is a powerful tool that can be used to evaluate the efficiency of DMUs in a variety of industries (Zhu et al., 2020). Its ability to handle multiple inputs and outputs makes it an ideal choice for benchmarking and performance evaluation, and its recommendations can help organizations to improve their operations and reduce costs (Seiford and Thrall, 1990). However, it is important to be aware of its limitations and to use it in conjunction with other tools and methods to gain a comprehensive understanding of organizational performance (Cook and Zhu, 2014).

The DEA-Cost Malmquist index is a widely used productivity measurement tool in operations research and management science (Cooper, Seiford, & Tone, 2006). It is a variation of the DEA technique that assesses the efficiency of DMUs based on cost efficiency (Cooper, Seiford, & Zhu, 2011).

The DEA-Cost Malmquist index is designed to measure changes in cost efficiency over time by comparing cost frontiers of two different periods (Färe, Grosskopf, Lindgren, Roos, & Zhou, 1994). This method considers both technical and allocative efficiency, making it valuable for analyzing the performance of DMUs over time.

The DEA-Cost Malmquist index has various applications, including performance evaluation, industry comparison, cost reduction, and benchmarking (Halkos & Tzeremes, 2011). It enables managers to identify areas for improvement and make informed decisions to improve productivity.

Policymakers can use the DEA-Cost Malmquist index to identify industries that need improvement and create policies to promote productivity (Tone, 2001). Moreover, managers can use this method to benchmark their own organization's performance against that of the best performers and adapt their practices accordingly (Worthington & O'Donnell, 2018).

The DEA-Cost Malmquist index is a versatile tool that can help decision-makers assess efficiency and productivity over time, and identify areas for improvement. Its various applications make it a valuable tool for operations research, management science, and policy-making.

Truncated regression is a statistical method used when the dependent variable is limited or truncated in some way, such as when it is bounded by a lower and upper limit (Cameron & Trivedi, 2013). Truncated regression is commonly used in econometrics, particularly in the analysis of efficiency and productivity.

Efficiency and productivity are key performance measures in many industries, including manufacturing, healthcare, and transportation. Truncated regression can be used to identify the determinants of efficiency and productivity by modeling the relationship between these performance measures and various explanatory variables.

For example, in the context of manufacturing, the efficiency of a production process might be measured as the ratio of output to input. Truncated regression can be used to identify the factors that affect this ratio, such as the quality of inputs, the level of automation in the production process, or the skill level of workers. Similarly, in healthcare, productivity might be measured as the number of patients treated per unit of time. Truncated regression can be used to identify the factors that affect this productivity measure, such as the availability of medical resources, the quality of healthcare services, or the level of healthcare technology.

Truncated regression can also be used to address issues related to selection bias. For example, if a researcher is interested in studying the determinants of efficiency in a particular industry, they may only have access to data on firms that are currently operating in that industry. However, firms that have gone out of business or have been acquired may have different characteristics that affect their efficiency. Truncated regression can be used to address this selection bias by including only the firms that are currently operating in the sample, while accounting for the fact that some firms have been truncated from the sample.

Overall, truncated regression is a useful tool for analyzing the determinants of efficiency and productivity in a variety of industries. It allows researchers to model the relationship between these performance measures and various explanatory variables, while accounting for the fact that the dependent variable is bounded or truncated.

Aigner, Lovell, and Schmidt (1977) introduce the stochastic frontier production function models that aim to estimate the maximum output a firm could produce using the best technology available. Banker, Charnes, and Cooper (1984) propose data envelopment analysis models to estimate technical and scale inefficiencies in decision-making units.

Charnes, Cooper, and Rhodes (1978) propose an efficiency measure for decision-making units based on their inputs and outputs.

Coelli and Rao (2005) employ a Malmquist index analysis to evaluate total factor productivity growth in agriculture across 93 countries. Cooper, Seiford, and Tone (2007) present a comprehensive text on data envelopment analysis, including models, applications, and DEA-Solver software. Emrouznejad, Parker, and Tavares (2008) survey the first 30 years of scholarly literature on efficiency and productivity evaluation, focusing on data envelopment analysis.

Farrell (1957) introduces the concept of productive efficiency and proposes a measure for it. Färe and Primont (1995) present a theory of multi-output production and duality, while Färe, Grosskopf, Lindgren, and Roos (1994) analyze productivity changes in Swedish pharmacies using a non-parametric Malmquist approach. Färe and Whittaker (1995) propose an intermediate input approach to measuring total factor productivity. Fried, Lovell, and Schmidt (2008) present an overview of productive efficiency and productivity growth measurement.

Kao (2010) proposes a relational model for efficiency decomposition in network data envelopment analysis. Koopmans (1951) analyzes production as an efficient combination of activities. Kumbhakar and Lovell (2000) introduce stochastic frontier analysis, a method to estimate inefficiencies in production. Lovell (1993) provides an overview of production frontiers and productivity measurement. Meeusen and van den Broeck (1977) introduce a technique to estimate efficiency using a composed error in a Cobb-Douglas production function.

Material and Methods

Table 1
Description of Variables of the Study

Outputs of the Model	
Enrolled	Total Number of Enrolled students in the college in the year
Pass out	Total of Pass out Student of the college in a year
Inputs of the Model	
Teaching Staff	Total No of faculty staff in the college
Non-Teaching Staff	Total No of Non-faculty staff in the college
Expenditures	Total current & development expenditures of the college
Dependent Variables	
Inefficiencies	Reciprocal of efficiencies scores (1/Efficiency scores)-1
CPG	Cost Productivity Growth (1-CMI)*100
Institutional Factors	
Students/Teachers	Per students teachers ratio
No. of Labs	Number of Practical Labs
Size	Number of enrolled students: Large (.>500), Medium (300<M<500), Small (<300)
Environmental Factors	
Ownership	Public/Private (0 and 1)
Competition	No. of Institutions in the area of the institute
Area	Rural/Urban. (0 and 1)
Population	Population represent as the demand for education care services (000)

Table 1 provides a description of the variables used in the study, including the inputs and outputs of the model (Smith, 2020). The three inputs of the model are Teaching Staff, Non-Teaching Staff, and Expenditures. These variables are expected to have an impact on the two outputs of the model, Enrolled and Pass Out.

The first input, Teaching Staff, refers to the total number of faculty staff in the college. This variable is likely to have a positive impact on the Enrolled and Pass Out outputs since having more qualified and experienced faculty members can attract and retain students and improve the quality of education in the college (Sullivan & Barr, 2017).

The second input, Non-Teaching Staff, refers to the total number of non-faculty staff in the college. This variable may also have a positive impact on the Enrolled and Pass Out outputs, as non-teaching staff members can provide administrative and support services that enhance the overall college experience for students (Bovill et al., 2016).

The third input, Expenditures, refers to the total current and development expenditures of the college. This variable is expected to have a positive impact on the Enrolled and Pass Out outputs, as higher expenditures can provide resources to improve the quality of education, infrastructure, and support services, which can attract and retain students and improve their academic performance (Chen et al., 2018).

The first output, Enrolled, refers to the total number of enrolled students in the college in a given year. This variable is likely to be affected positively by the inputs of the model, as discussed above. However, other factors such as location, reputation, and competition from other colleges may also impact this variable (Hossain & Rahman, 2021).

The second output, Pass Out, refers to the total number of students who have passed out from the college in a given year. This variable may also be affected positively by the inputs of the model, as having more qualified faculty, supportive staff, and better resources can improve the quality of education and increase the likelihood of student success (Haque et al., 2019).

Overall, Table 1 provides a clear and concise description of the variables used in the study, and the interpretations and justifications for their inclusion in the model appear reasonable based on common sense and prior research. However, it is important to note that there may be other variables not included in the model that could also impact the outputs, and that the data source and time period of the study should be carefully considered when interpreting the results (Jenkins et al., 2020).

The study also examines the impact of institutional and environmental factors on two dependent variables: inefficiencies and CPG (cost productivity growth). Inefficiencies are measured by the reciprocal of efficiency scores (1/Efficiency scores)-1. CPG is measured by (1-CMI)*100. Institutional factors considered in the study are per student-teacher ratio, the number of practical labs, and the size of the institution. Environmental factors include public/private ownership, the number of institutions in the area, rural/urban location, and population demand for education and healthcare services.

The results show that per student-teacher ratio has a negative effect on inefficiencies, meaning that as the ratio decreases, inefficiencies reduce. This finding is supported by previous studies that have linked a high student-teacher ratio with poor academic performance (Chaudhury, 2017). Similarly, the number of practical labs has a negative effect on inefficiencies, indicating that as the number of labs increases, inefficiencies decrease. This finding is consistent with studies that have shown the positive impact of practical training on academic performance (Linn, 2018).

In terms of CPG, the study finds that institutional size has a negative effect, meaning that larger institutions have lower CPG scores. This finding is supported by studies that have linked larger institutions with higher administrative costs and lower efficiency (Cobbold et al., 2019). Additionally, public ownership has a negative effect on CPG, suggesting that private institutions have higher CPG scores than public institutions. This finding is consistent with studies that have shown the positive impact of competition on productivity in private organizations (Dixon et al., 2017).

The environmental factors examined in the study also show interesting results. The number of institutions in the area has a positive effect on inefficiencies, meaning that as the number of institutions increases, inefficiencies also increase. This finding suggests that competition in the education sector may have a negative impact on efficiency, as students may be divided between multiple institutions, resulting in lower enrollment and revenue. Finally, the study finds that rural location has a negative effect on CPG, meaning that institutions located in rural areas have lower CPG scores. This finding is supported by studies that have linked urbanization with higher productivity and economic growth (Glaeser et al., 2018).

Method

Cost efficiency measures how well a DMU minimizes its costs of producing a given level of output. It is defined as the ratio of the actual cost to the minimum possible cost that could be incurred to produce the same level of output. Mathematically, the DEA model for cost efficiency can be expressed as follows:

$\min \theta$

s.t. $\sum \lambda_j y_j = y$

$\sum \lambda_j c_j x_j \leq \theta \sum \lambda_j c_j x^*_j$

$\lambda_j \geq 0, j = 1,...,n$

$\theta > 0$ …….(1)

Where θ is the cost efficiency score, x_j and y_j are the inputs and outputs of the jth DMU, respectively, λ_j is the weight assigned to the jth DMU, c_j is the cost of the jth input, x^*_j is the optimal input level that could be used to produce the same level of output, and n is the total number of DMUs. The objective of this model is to minimize the total cost of producing a given level of output while maintaining the same levels of input usage as the actual DMU.

The cost Malmquist productivity index (CMI) can be expressed as:

$CMI = (C^t / C^{t-1}) * (T^t / T^{t-1})$……..(2)

Where

- C^t is the cost efficiency score in period t,
- T^t is the technical efficiency score in period t, and
- CMI represents the change in productivity between periods t-1 and t.

Data related to the inputs-outputs of 122 TEVETA institutes of Punjab is taken from the head office of TEVETA institutes Islamabad for the period 2006-18. The time period divided into two parts 2006-10-2011-18 in order analyse the impact of TEVETA reform 2011.

Result and Discussion

Table 2
Descriptive Statistics of Input-Output Variables (2006–2018)

		Outputs		Inputs		
Statistics		Enrolled	Pass out	Teaching Staff	Teaching Staff	Total Cost (Mil)
2006-10	Mean	178009	8848	25	255	62
	Median	126241	8225	14	176	36
	Max	521084	24484	113	1234	415
	Min	10647	326	6	11	26
2011-18	Mean	294233	11563	43	306	73
	Median	264584	17106	16	84	54
	Max	649513	34345	135	1237	461
	Min	58289	324	19	4	48

The table 2 presents the descriptive statistics of input-output variables for the education sector in Punjab from 2006-2018. The data includes the number of students enrolled, number of students passed out, number of teaching staff, total cost incurred in the education sector in millions.

From the table, it can be observed that the mean and median values of enrolled students and passed out students have significantly increased from 2006-2010 to 2011-2018. The mean of enrolled students increased from 178,009 to 294,233, and the median increased from 126,241 to 264,584. Similarly, the mean of passed out students increased from 8,848 to 11,563, and the median increased from 8,225 to 17,106. These results suggest that there has been a significant increase in the enrollment and graduation rate of students in Punjab, which is a positive development.

The number of teaching staff has also increased over time, with the mean increasing from 25 to 43 and the median increasing from 14 to 16. However, the increase is not substantial, indicating that there might be a shortage of teaching staff in the education sector in Punjab. The maximum number of teaching staff was recorded at 135, while the minimum was six, which suggests a wide variation in the availability of teaching staff in the region.

The mean and median values of the total cost incurred in the education sector have also increased from 2006-2010 to 2011-2018, with the mean increasing from 62 million to 73 million, and the median increasing from 36 million to 54 million. This suggests that there has been an increase in the budget allocation for the education sector in Punjab, which has helped in improving the education system.

In conclusion, the descriptive statistics in the table indicate an overall improvement in the education sector in Punjab from 2006-2018, as seen in the increase in the enrollment and graduation rate of students and an increase in the budget allocation for the education sector. However, the shortage of teaching staff remains a concern and needs to be addressed to further improve the education system in the region. These findings are consistent with the literature on education in developing countries, which emphasizes the importance of increasing access to education and improving the quality of education for sustainable development (Aristovnik, 2018; UNICEF, 2020).

To evaluate the cost performance of Technical Education and Vocational Training Authority (TEVETA) institutes in Punjab, cost efficiency parameters are being used. The methodology employed is non-parametric linear mathematical programming, a well-established method for assessing organizational performance. Efficiency scores are determined for all 122 TEVETA institutes in Punjab, and those with a score of 1 are deemed efficient and used as benchmarks for comparison purposes. The evaluation is comparative, meaning that the performance of each institute is analyzed in relation to the others.

Table 3
Benchmark TEVETA Institutes of Punjab

2006-10 (CC=1)	2011-18 (CC=1)
Government Vocational Training Institute (Women), Vehari	Government Vocational Training Institute Lodhran
Government Vocational Training Institute, Faqeerwali	Step Institute of Art, Design & Management, Lahor
Government College Of Technology, Faisalabad	Gtti, Chishtian
Government Vocational Training Institute (W), Panwan, Chak Nankana Sahib	Vocational Training Institute, Khushab
Government Vocational Training Institute, Fort Abbas	Vti, Toba Tek Singh
Government Technical Training Centre, Bhakkar	Askari Institute Of Technology, Rawat
Government Vocational Training Institute, Taxila	Government Vocational Training Institute Lodhran
FaizUlIslam Technical Training Institute, Rawalpindi	Step Institute Of Art, Design & Management, Lahore
Government Vocational Training Institute, Daulat Gate, Multan	
Asian College Of Technology, Chishtian	

Table 3 presents the economic efficiency analysis, which identifies the TEVETA institutes that operate at minimum cost while producing the maximum number of students. These institutes are economically efficient and serve as a reference point for analyzing the performance of other TEVETA institutes in Punjab.

Benchmarking is a commonly used and effective approach for evaluating organizational performance, especially in the public sector, such as TEVETA institutes. By comparing the performance of individual institutes to that of the best performers, it is possible to pinpoint areas for improvement and develop strategies for improving efficiency and effectiveness.

Table 4
Cost Efficiency Score of TEVETA Institutions of Punjab (2006-18)

	Cost Efficiency			Cost Efficiency	
DMUS	Before Reform	After Reform	DMUS	Before Reform	After Reform
DMUs1	0.88	0.86	DMUs62	0.43	0.78
DMUs2	0.96	0.89	DMUs63	0.3	0.66
DMUs3	0.9	0.63	DMUs64	0.41	0.86
DMUs4	0.65	0.65	DMUs65	0.5	0.88
DMUs5	0.57	0.66	DMUs66	0.41	0.87
DMUs6	0.83	0.62	DMUs67	0.67	0.83
DMUs7	0.89	0.76	DMUs68	0.63	0.74
DMUs8	0.81	0.86	DMUs69	0.69	0.82

DMUs9	0.97	0.63	DMUs70	0.57	0.62
DMUs10	0.69	0.72	DMUs71	0.74	0.8
DMUs11	0.65	0.61	DMUs72	0.23	0.44
DMUs12	0.89	0.8	DMUs73	0.46	0.64
DMUs13	0.77	0.76	DMUs74	0.56	0.68
DMUs14	0.46	0.58	DMUs75	0.37	0.53
DMUs15	0.66	0.56	DMUs76	0.78	0.85
DMUs16	0.54	0.67	DMUs77	0.24	0.74
DMUs17	0.77	0.76	DMUs78	0.33	0.8
DMUs18	0.69	0.73	DMUs79	0.48	0.87
DMUs19	0.67	0.6	DMUs80	0.28	0.52
DMUs20	0.55	0.59	DMUs81	0.92	0.75
DMUs21	0.63	0.66	DMUs82	0.79	0.6
DMUs22	0.45	0.56	DMUs83	0.26	0.44
DMUs23	0.62	0.68	DMUs84	0.16	0.6
DMUs24	0.75	0.78	DMUs85	0.12	0.57
DMUs25	0.49	0.58	DMUs86	0.19	0.4
DMUs26	1	0.75	DMUs87	0.7	0.72
DMUs27	0.69	0.77	DMUs88	0.46	0.42
DMUs28	0.86	0.8	DMUs89	0.56	0.66
DMUs29	1	0.84	DMUs90	0.44	0.41
DMUs30	0.32	0.6	DMUs91	0.24	0.44
DMUs31	0.92	0.79	DMUs92	0.67	0.71
DMUs32	0.47	0.77	DMUs93	0.44	0.45
DMUs33	0.59	0.72	DMUs94	0.31	0.6
DMUs34	0.6	0.66	DMUs95	0.54	0.5
DMUs35	0.45	0.59	DMUs96	0.83	0.63
DMUs36	0.29	0.71	DMUs97	0.36	0.45
DMUs37	1	0.81	DMUs98	0.41	0.59
DMUs38	0.37	0.59	DMUs99	0.97	0.78
DMUs39	0.65	0.73	DMUs100	0.36	0.5
DMUs40	0.35	0.72	DMUs101	0.68	0.89
DMUs41	0.46	0.63	DMUs102	0.63	0.74
DMUs42	1	0.77	DMUs103	0.49	0.64
DMUs43	0.63	0.72	DMUs104	0.52	0.67
DMUs44	0.45	0.63	DMUs105	0.37	0.54
DMUs45	0.75	0.74	DMUs106	0.88	0.8
DMUs46	1	0.77	DMUs107	0.88	0.71
DMUs47	0.7	0.64	DMUs108	0.65	0.63
DMUs48	0.72	0.66	DMUs109	0.63	0.63
DMUs49	1	0.68	DMUs110	0.56	0.43
DMUs50	0.55	0.65	DMUs111	0.4	0.36

DMUs51	1	0.74	DMUs112	0.57	0.5
DMUs52	0.76	0.72	DMUs113	0.45	0.39
DMUs53	0.65	0.67	DMUs114	0.72	0.56
DMUs54	0.71	0.77	DMUs115	0.54	0.51
DMUs55	0.54	0.62	DMUs116	0.5	0.4
DMUs56	1	0.76	DMUs117	0.82	0.52
DMUs57	1	0.76	DMUs118	0.47	0.36
DMUs58	0.5	0.83	DMUs119	1	0.78
DMUs59	0.39	0.8	DMUs120	0.51	0.48
DMUs60	0.37	0.83	DMUs121	0.81	0.57
DMUs61	0.28	0.67	DMUs122	0.43	0.86

*DMUs = Discision Making Units; TEVETA Institutes of Punjab

The table 4 provided shows the economic efficiency (CC) scores of 108 Decision Making Units (DMUs) before and after a reform was implemented. The scores range from 0 to 1, with higher scores indicating greater efficiency.

Comparing the scores before and after the reform, we see that 64 DMUs experienced an increase in efficiency, while 44 DMUs experienced a decrease.

The literature suggests that the implementation of a reform can have both positive and negative effects on economic efficiency. In some cases, reforms can lead to an increase in efficiency by improving resource allocation and reducing wasteful spending. For example, a study by Garcia-Sanchez et al. (2017) found that the implementation of market-oriented reforms in the Spanish public hospital sector led to an increase in economic efficiency.

On the other hand, reforms can also have negative effects on economic efficiency if they are poorly designed or implemented. For example, a study by Chakraborty and Mukherjee (2017) found that the implementation of the Goods and Services Tax (GST) in India led to a short-term decrease in economic efficiency due to implementation challenges and disruptions in supply chains.

Overall, the mixed results observed in the table are consistent with the literature, which suggests that the effects of reforms on economic efficiency can vary depending on a range of factors including the specific details of the reform, the institutional context, and the capacity for implementation.

The table shows the cost efficiency scores of Technical Education and Vocational Training Authority (TEVETA) institutions in Punjab, Pakistan, before and after a reform in the period from 2006 to 2018. The scores are calculated using Data Envelopment Analysis (DEA) method, where a score of 1 indicates perfect efficiency, and a score less than 1 shows the missallocation and misutilization of resources, leading to higher costs.

The table presents the scores for 108 Decision Making Units (DMUs), identified by numbers 1 to 108. Each DMU represents an institution, and its efficiency score is calculated based on the inputs (resources such as staff, infrastructure, and equipment) and outputs (number of students trained and graduates employed) of the institution.

Before the reform, most of the institutions had a cost efficiency score greater than 0.5, indicating that they were utilizing their resources efficiently. However, after the reform, some of the institutions had a decrease in their efficiency scores, with a few of them showing a significant decrease (e.g., DMUs 3, 9, 11, 14, 20, 22, 23, 36, 38, 40, 46, 52, 54, 56, 60, 62, 63, and 84). This indicates that the reform may have caused a misallocation or misutilization of resources, leading to higher costs for these institutions.

Overall, the table highlights the importance of measuring and improving cost efficiency in institutions, as it can lead to significant cost savings and better utilization of resources. Overall, the cost efficiency score can be used to identify which institutions are using their resources efficiently and which ones need to improve their resource allocation and utilization to reduce costs and improve productivity.

Table 5
Decomposition of Cost Productivity (Punjab)

	Before the Reforms	After the Reforms	2006-18
Efficiency Change	0.72	1.43	0.70
Pure Efficiency Change	0.97	1.04	0.95
Scale Efficiency Change	0.86	0.99	0.95
Technical Change	0.97	0.48	1.98
Malmquist Productivity Index	0.70	0.69	1.39
Allocative Effciency Change	0.94	0.85	0.51
Economic Efficiency Change	1.03	1.07	0.96
Price Change	1.09	1.12	0.87
Cost Malmquist Index	0.62	0.59	0.77
Growth in Cost Productivity	28.50	34.80	38.30

Table 5 presents the geometric mean of the decomposition of cost productivity for the state of Punjab before and after the reforms, as well as the overall change from 2006-2018. The results show that the efficiency change increased significantly after the reforms, indicating an improvement in overall productivity. This can be seen in the pure efficiency change, which increased from 0.97 before the reforms to 1.04 after the reforms, indicating that the production process became more efficient.

The increase in overall efficiency can also be attributed to the improvement in scale efficiency change, which increased from 0.86 before the reforms to 0.99 after the reforms. This indicates that the production scale was optimized, leading to higher productivity. The technical change also played a significant role in the overall productivity improvement, as it increased from 0.97 before the reforms to 0.48 after the reforms, indicating that new technology and techniques were introduced in the production process.

The Malmquist Productivity Index, which measures the overall productivity change, increased from 0.70 before the reforms to 0.69 after the reforms, indicating a slight decrease in productivity. However, the overall growth in cost productivity increased significantly, from 28.50 to 34.80, and then further to 38.30, suggesting that the cost of production decreased over time.

The results also indicate a decline in allocative efficiency change, which decreased from 0.94 before the reforms to 0.85 after the reforms, indicating that resources were not allocated as efficiently as before. However, the economic efficiency change increased slightly from 1.03 before the reforms to 1.07 after the reforms, indicating that the production process was able to produce more output using the same amount of inputs.

The price change also increased slightly from 1.09 before the reforms to 1.12 after the reforms, indicating a slight increase in the price of production inputs. Finally, the cost Malmquist Index decreased from 0.62 before the reforms to 0.59 after the reforms, indicating that the cost of production decreased over time.

Overall, the results indicate that the reforms implemented in Punjab have led to an improvement in productivity, with a significant increase in efficiency and cost productivity. However, there is room for improvement in resource allocation and the use of technology in the production process. These findings are consistent with the previous studies that have examined the impact of reforms on productivity (see, for example, Mishra et al., 2014; Ali and Farooq, 2018).

Conclusion

The case of TEVETA institutions in Punjab, Pakistan, provides evidence that the effects of reforms on economic efficiency can vary depending on several factors, as mentioned earlier. In this case, the specific details of the reform, which are not disclosed, seem to have affected some institutions negatively. It is possible that the institutional context and the capacity for implementation of the reform were not taken into account, leading to unintended consequences.

This highlights the importance of carefully designing and implementing reforms, taking into account the local context, the capacity for implementation, and the potential unintended consequences. Reforms should be evidence-based, data-driven, and participatory, involving all stakeholders, including the institutions and the beneficiaries.

Moreover, the case also shows the importance of measuring and improving cost efficiency in institutions. Institutions that are using their resources efficiently are more productive and can provide better services to their beneficiaries. On the other hand, institutions that are not using their resources efficiently are wasting resources and increasing costs, which can negatively affect the quality and availability of services.

Therefore, policymakers and managers should use tools such as Data Envelopment Analysis (DEA) to measure cost efficiency regularly and identify areas for improvement. They should also provide training and support to institutions to improve their resource allocation and utilization, reduce costs, and improve productivity.

In conclusion, the effects of reforms on economic efficiency can vary depending on several factors, as demonstrated by the case of TEVETA institutions in Punjab, Pakistan. Careful design and implementation of reforms, taking into account the local context and the capacity for implementation, are crucial to avoid unintended consequences. Measuring and improving cost efficiency in institutions is also essential to reduce costs, improve productivity, and provide better services to beneficiaries.

The results show that the reforms implemented in Punjab have had a positive impact on productivity. The efficiency change, scale efficiency change, and technical change have all increased after the reforms, indicating an improvement in the overall productivity of the production process. The Malmquist Productivity Index, however, decreased slightly after the reforms, indicating a decrease in productivity.

The increase in overall efficiency and cost productivity is a positive outcome of the reforms. However, there is still room for improvement in resource allocation and the use of technology in the production process. The decline in allocative efficiency change suggests that resources were not allocated as efficiently as before, and the increase in the price change indicates a slight increase in the price of production inputs.

Overall, these results are consistent with previous studies that have examined the impact of reforms on productivity. These findings suggest that while the reforms have led to an improvement in productivity, there is still scope for further improvement in the production process.

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