Journal of Education and Practice
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol.16, No.12, 2025

Transitioning to Technical Universities: A Productivity and Efficiency Analysis of Public Polytechnic Institutions in Ghana

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Abstract
Purpose: The paper investigates the production and efficiency of 10 public polytechnic institutions multi-production in their transition to public technical universities in the 2015-2016 academic year in Ghana.
Design/methodology/approach – Data Envelopment Analysis (DEA), a linear programming model, is applied to study the relative multi-production efficiency of the polytechnic institutions.
Findings – The paper established that 50% of the public polytechnic institutions must continue to expand the enrolment of students into their programmes once they have transitioned into technical universities, since they enjoy economies of scale in their multi-productions and there are potential gains through efficiency.
Research limitations – The research findings are stated with caution, given the small average size of public polytechnics in terms of Full-Time Equivalence student numbers.
Practical implication – Matching inputs and outputs data for polytechnic institutions as higher education institutions (HEIs) to evaluate their efficiency and to encourage benchmarking as a means of improving performance in the academic year transiting them into public technical universities and beyond in Ghana, is thus welcome and unique and responds appropriately to the AU Agenda 2063 calls for evaluating the efficiency of higher education institutions on the continent.
Social implication- The paper addressed a significant gap in the current public higher education literature in Ghana.
Originality – To the author's knowledge, this is the first study using original data allowing analysis of multi-product performance and efficiency in the 10 public polytechnic institutions in Ghana before their transition to public technical universities.
Keywords: Ghana, public polytechnics, DEA, productivity, performance, efficiency
DOI: 10.7176/JEP/16-12-04
Publication date: November 30th 2025

1. Introduction

There is growing pressure on higher education institutions (HEIs) worldwide to increase efficiency, productivity, and provide high-quality services (Addai, 2024; Alvarez-Sandez et al. 2023; Avenali, et, al., 2023). The Ghanaian government (GOG) is under pressure to reduce the amount of public resources allocated to HEIs while maintaining the quality of their services (Addai, 2024). HEIs must maintain the dynamics of the services they offer while optimizing their resources, (Alvarez-Sandez et al. 2023). This paradigm demonstrates the growing emphasis on HEIs efficiency management research worldwide, (Addai, 2024; Alvarez-Sandez et al. 2023; Martınez-Campillo, & Fernandez-Santos, 2020).). The effectiveness of public funds allotted to polytechnic institutions in Ghana, a subset of educational services, is crucial because of the polytechnic institutions' contribution to societal advancements in technology and the economy (Addai, 2024; Lee & Johnes, 2024).

Since the study of the economics of education, it has been recognized that education contributes to human capital development by branding it as an investment in people and its consequences as a form of capital. Studies in a broad theoretical and empirical literature (Addai, 2022; Becker, 1964; Mincer, 1974; Schultz, 1971) confirmed as factual education promoting socio-economic growth. (Addai, 2024, 2024b, 2022) argues that higher education is a key component of social and economic growth that increases individual productivity and lifetime earnings. Countries pride themselves on the quantity and quality of the higher education institutions (HEIs) they operate in pursuit of their economic development.

The Sustainable Development Goals 4 (SDG4) and AU Agenda 2063 (2013) recognize the role of HEIs in the growth and economic development of African economies. The GOG also regards the development of its higher education sector as a priority, as the Constitution of the Republic of Ghana, (1992) emphasizes improved citizen access to higher education to expand the country's human capital base. And Ghana had since its independence in 1957, promoted internally and externally many policies formulated by the GOG and the (World Bank, 1986, 1988, 1994) to encourage the growth of higher education. The last 14 years have been a time of rapid change in

Ghana's higher education sector. All of the 10 public polytechnics most recently ceased to be public polytechnics in the 2015-2016 academic year by the promulgation of the Technical Universities Law 922 which granted technical university status in the 2016-2017 academic year in response to an education policy by the GOG.

However, the conversion of public polytechnic institutions into public technical universities was undertaken without any productivity and efficiency analysis that would have served as point of reference for future comparative analysis of converting the public polytechnic institutions into public technical universities, (Addai, 2024). Although analysing the efficiencies of HEIs have been undertaken using mostly data from the developed economies and Asia by (Lee & Johnes, 2024; Johnes, 2020; Verry & Layard, 1975; Sheehan, 1977; Mamun, 2011; Cheng & Wu, 2008; Li, 2016; Johnes & Thanassoulis, 2008; Johnes, & Johnes, 2009, 2016; Jana & Maiti, 2018; Cohn et al. 1989; Thanassoulis, Johnes, & Johnes, 1995; Worthington & Higgs 2011) since the pioneering work of (Farell,1957), no such HEIs performance and efficiency analysis has ever been investigated in the higher education sector in Ghana, 68 years after attaining her independence in 1957, and 98 years of founding Ghana's first higher education insttution, The Prince of Wales College, in 1927, (Leney, 2003), as of 2025. Public HEIs efficiency analysis has not been investigated in Ghana largely because public HEIs are solely financed and controlled on behalf of the tax payer by the GOG from the consolidated fund, and public HEIs operate as non-profit entities, hence the market-motivation of efficiency may not be their primary operational objectives.

Thus far, investigating how Ghana public polytechnic institutions used multi-inputs (such as compensations/salaries, staff, capital expenditure) to generate multi-outputs like full-time equivalence (FTE) diploma, higher national diploma (HND), undergraduates and graduates students respectively, has not received the empirical attention in the higher education literature in Ghana. There is an efficiency and performance assessment gap because the Ghana Tertiary Education Commission's format for evaluating the functions of HEIs in Ghana does not analyze the performance and efficiency functions; instead, it focuses primarily on the accreditations of the various programs that the HEIs run.

In order to fill this major research gap, an attempt is made in this novel paper to examine the performance and efficiency of public polytechnic higher education institutions in the 2015-2016 academic year, which is the academic year of their transition to public technical universities, for which data is available. The structure of this paper is outlined as follows: A brief literature review of the Ghanaian higher education sector in Section 2 is next, followed by the methodology, empirical strategy, model specification, and data description and source in Section 3. Section 4 deals with the empirical results. The penultimate section deals with the discussion and policy implications, and the final section 6 provides the conclusion.

2. Literature Review

2.1 *The Ghana public polytechnic institutions education sector*

Ghana HEIs operate in a vibrant sector comprising over 270 institutions in 2021, which consist of 7 chartered private universities, 1 private polytechnic, 1 public agriculture college, 2 distance learning institutions, 2 private colleges of education, 9 private nurses training colleges, 80 private tertiary institutions offering higher national diploma (HND) and degree programmes, 46 public colleges of education, 7 public degree awarding and professional institutions, 49 public nurses training colleges, 10 public technical universities, 15 public universities, 1 regionally-owned tertiary institution,3 registered foreign institutions, 6 tutorial colleges, and 1 private college of education, 3 private nurses training colleges, 22 private tertiary institutions offering HND and degree programmes, 9 public nurses training colleges, 2 tutorial college, undergoing certification for reaccreditation, (https://gtec.edu.gh/statistical-report, 2021), the Ghana Tertiary Education Commission's (GTEC) most recent report on higher education for a population of 31 million.

The development and growth of HEIs in Ghana is replete with struggles and protest and agitation for higher education by the nationalist movements. The agitation was stirred up by the fewer Africans with higher education at the end of World War II. (Emudong, 1997) asserts that the colonial governor apprehension among other things was that the graduates of such institutions especially the universities will eventually undermine the expatriate monopoly on higher government administration, and would also make up a pool of nationalist agitators against the colonial administration clamouring for an independent state Even so, incessant agitation and struggles by the nationalist led to the inauguration of the Phelps-Stokes Commission whose recommendation led to establishing the first local higher education institution, called the Prince of Wales College of Achimota in 1927, which was in the course of time transformed to become the University of Ghana, awarding its own certificates and degrees (Leney, 2003).

Although, the Justice Asquith commission had earlier on recommended establishing the Prince of Wales College

of Achimota and the creation of local universities to award degrees from England in the areas of arts and science, engineering, and economics, the recommendation was never put into practice, (Daniel, 1996). Eventually, University College of Gold Coast was established in 1948 and on attaining independence, it was renamed the University of Ghana (UG). After attaining independence, the GOG rigorously promoted the establishment of more public HEIs to produce graduates and augment the human capital base of the newly independent state in the areas of social sciences, arts and humanities to manage its public service, which up until the late 1970s became over bloated.

Then, the GOG's attention was drawn to the need to promoting and providing vocational education by paying attention to polytechnic higher education. The GOG eventually in 1987 set up a University Rationalization Committee (URC), which was vested with the authority to develop proposals for reforming the HEIs sector in Ghana. Based on the URC recommendations, the GOG promulgated the (PNDCL 321, 1992), which for the first time, recognized and upgraded the public polytechnic institutions to fully-fledged HEIs status.
In line with the GOG's objective of making public polytechnic, higher education national in scope, a public polytechnic institution was established in each of the then ten regional capitals (Nsiah-Gyabaah, 2005; Manu et al. 2021).

The Polytechnic Law (PNDCL 321, 1992) tasked the polytechnic as HEIs to provide tertiary vocational education through full time courses in manufacturing, commerce, science, information communication technology, applied social science, applied arts and such other disciplines as may be approved of by the then National Council for Tertiary Education (NCTE) or the authority for that time being responsible for higher education and also encourage the study of advanced technical subjects at the higher education level, as well as promoting research and publishing research findings in technical subject to promote national development, (Nsiah-Gyabaah, 2005).

With virtually no demand for newly recruits into the civil and public sectors of the economy of Ghana, the situation has led to increased unemployment for mostly graduates in the humanities and social sciences and this spurred the GOG's strong desire to opening up access in post-secondary vocational education, and propelled the migration of the public polytechnic institutions into to fully fledged public technical universities in the 2016 – 2017 academic year. 10 out of the 16 regions of Ghana now currently, by 2025, do have public polytechnics in their various regional capitals, all of which have been transformed into technical universities.

3. Methodology

3.1 *Empirical strategy*

Public polytechnic institutions in Ghana, are identified as multi-product institutions (Cohn et al., 2009) that incur expenditure in the form of payment of compensations, salaries, and book and research allowance to their staff as inputs to generate multiple outputs consisting of full-time equivalence (FTE) Higher National Diploma (HND) Applied Science, Technology and Science (ASTSci) Student, FTE HND Business Administration and Social Sciences (BASOc) students, FTE HND Engineering (EngiNEs) students, FTE diploma Dispensary Technology and Certificate (DTCert) students, and graduated students. the DEA, the public polytechnic institutions' output variables are classified as exogenously fixed, and analysis is conducted to estimate the minimum cost at which the public polytechnic institutions could have produced the output levels in the 2015-2016 academic year, making the DEA efficiency investigation an input-oriented. DEA as a linear programming model for investigating relative efficiencies of decision-making Units (DMUs) such as polytechnics, universities, or banks, was by (Farrell, 1957) whose study was motivated by (Kantorovich, 1939; Debreu, 1951; Koopmans, 1951). DEA was popularised by (Charnes et al., 1978; Banker et al., 1984). As for efficiency gains, DEA is specified with a non-parametric weight from 0-1. Assignment of weight 1 indicates the highest efficiency weight attainable on a relative boundary, based on a specified input and output ratio.

The DEA estimates of efficient levels of costs or outputs are relative rather than absolute, and each time DEA model analysed the full set of programs run by the public polytechnic institution as (DMUs), it identifies benchmark public polytechnic institutions (DMUs), that offers the lowest total operating cost for their mix and absolute levels of output. All the public polytechnic institutions (DMUs), or any of the public polytechnic institution (DMU) that is not or is not on the frontier have scope for efficiency savings vis-a-vis the benchmarks. Benchmark public polytechnics (DMUs) may have a range of efficiency savings vis-a-vis some unknown absolute standard. The unknown absolute standards are a drawback of the DEA model as there are no suitable comparators for an efficient DMU mix of outputs and/or scale size, (Thanassoulis, Johnes, & Johnes, 2011; Johnes, 2020). However, the DEA as a non-parametric technique has the added advantage of identifying a public polytechnic institution (DMU) as inefficient and the benchmarks will clearly show why that unit is considered

inefficient ((Lee & Johnes, 2024; Thanassoulis, Johnes, & Johnes, 2011).

3.2 *Model specification*

The DMU used the c input to produce the q output in the 2015-2016 school year, in which case programming techniques were used to identify piecewise linear boundaries connecting all valid DMUs. Under the DEA variable returns to scale (VRS) input-orientated model for this paper, the following linear programming problem is specified and solved for each of the n public polytechnic institutions as DMUs, (p=1,…,n) as:

Minimize θ_p subject to

$$y_{rp} - \sum_{j=1}^{n} \lambda_j y_{rj} \leq 0 \qquad r=1,\ldots,q$$

$$\theta_p x_{ip} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0 \qquad i=1,\ldots,c$$

$$\sum_{j=1}^{n} \lambda_j = 1, \lambda_j \geq 0 \quad \forall j=1,\ldots,q$$

Overall efficiency of DMU p is measured by $E_p = \theta_p$. Scale efficiency is further estimated as: $SCE_P = \frac{E_P, CRS}{E_P, VRS}$ where *CRS* is constant returns to scale.

3.3 *Data description and source*

The data for this study was obtained with permission from The Ghana Tertiary Education Commission (GTEC). The Ghana Tertiary Education Commission was created by merging the National Council for Tertiary Education (NCTE) and the National Accreditation Board (NAB) under the new Education Regulatory Bodies Act, 2020 (Act 1023). The Governing Board was appointed and sworn in on November 25, 2020, following the Act's Presidential Assent on August 21, 2020, (gtec.edu.gh). GTEC publishes the Higher Education Annual Statistics Report, which includes information on all Ghanaian higher education institutions, their FTE student numbers, financial expenditures and costs incurred in any given academic year. The published (National Council for Tertiary Education, Statistical Report on Tertiary Education for 2015/2016 Academic Year, and the financial expenditure and costs incurred by the public polytechnic institutions in the 2015-2016 academic year is used as data for this study.

3. 4 *Descriptions of variables used in the paper*

The descriptions of the variables used in this paper are presented in Table 1.

Table 1: Definitions of variables used in the paper

Variable type	Variable	Descriptions
Inputs:	TOTCost*	The total operating expenditure including compensations/salaries and book and research allowance incurred by the public polytechnics central administration less depreciation and capital expenditures in the 2015-2016 academic year in cedis.
Outputs:	Pstaff	The total number of FTE academic and non-academic staff numbers
	ASTSci	The full-time equivalence (FTE) HND applied Science ,Technology and science students numbers

	BASocs	The FTE HND Business Administration and Social Sciences students
	EngiNEs	FTE HND engineering students numbers
	DTCert	FTE diploma and certificate students numbers
	GradSTDs	Graduated students numbers
VRS	Rank	DMUs relative efficiency rank
	Theta	DMUs relative efficiency score Variable returns to scale

*The TOTCost variable is measured in Ghana cedis (where 3.5 Ghana cedis is equivalent to US$1 in the 2015-2016 academic year).

4. Empirical results

4.1 *Descriptive statistics of the inputs and outputs variables*

The descriptive statistics of the public polytechnic institutions inputs and outputs variables used in the paper are presented in Table 2.

Table 2: Descriptive statistics of the public polytechnic institutions inputs and outputs variables used

Variable	N	Mean	SD	Min	Max
TOTCost	10	1240000	4916369	5389139	2100000
Pstaff	10	222.5	79.5	90	318
ASTSci	10	1025.4	525	255	1651
BASocs	10	2970.5	1, 685	476	5610
EngiNEs	10	1090.1	637	113	2206
DTCert	10	190.5	360	0	1073
GradSTDs	10	1485.4	1186.343	0	4171

Source: Author's estimation from 2015-2016 NCTE data.

4.2 *Scatter plots of the TOTcost input against the outputs variables*

Figures 1-5 plot TOTcost against the various output variables. The various scatters show clear positive relationships, with the exception of the DCert output, which is non-linear.

Fig. 1. Scatterplot of TOTcost vrs FTE HND Business Administration and Social Sciences Students

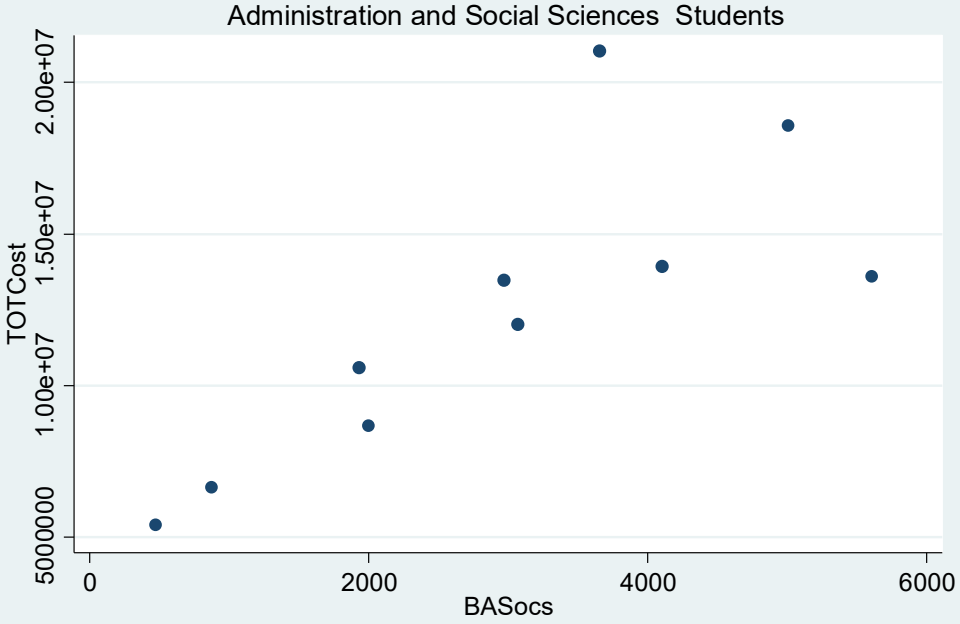


Fig. 2. Scatterplot of TOTcost vrs FTE HND Applied Science Technology And Science Students

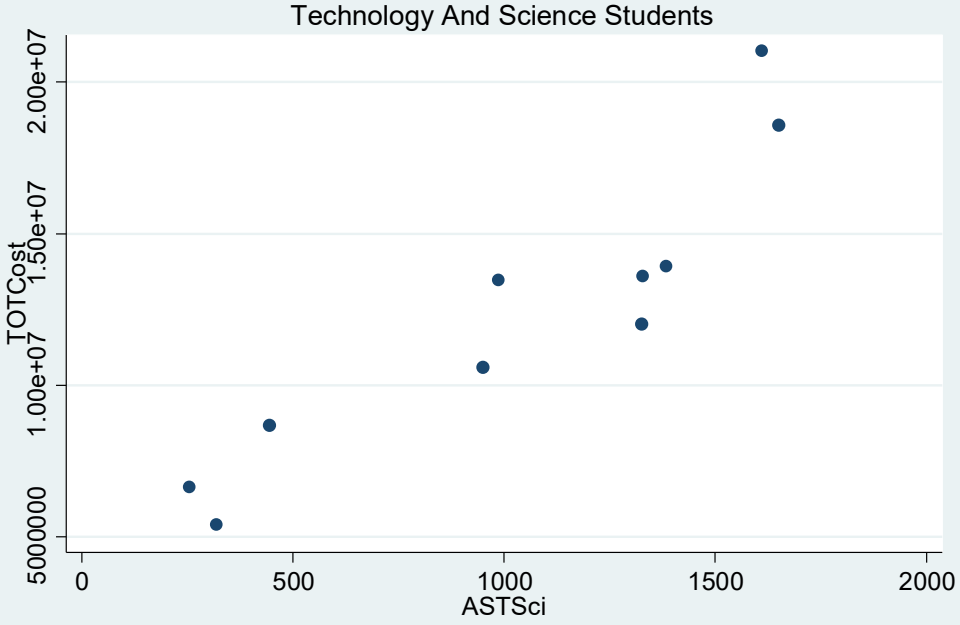


Fig. 3. Scatterplot of TOTcost vrs FTE HND Engineering Students

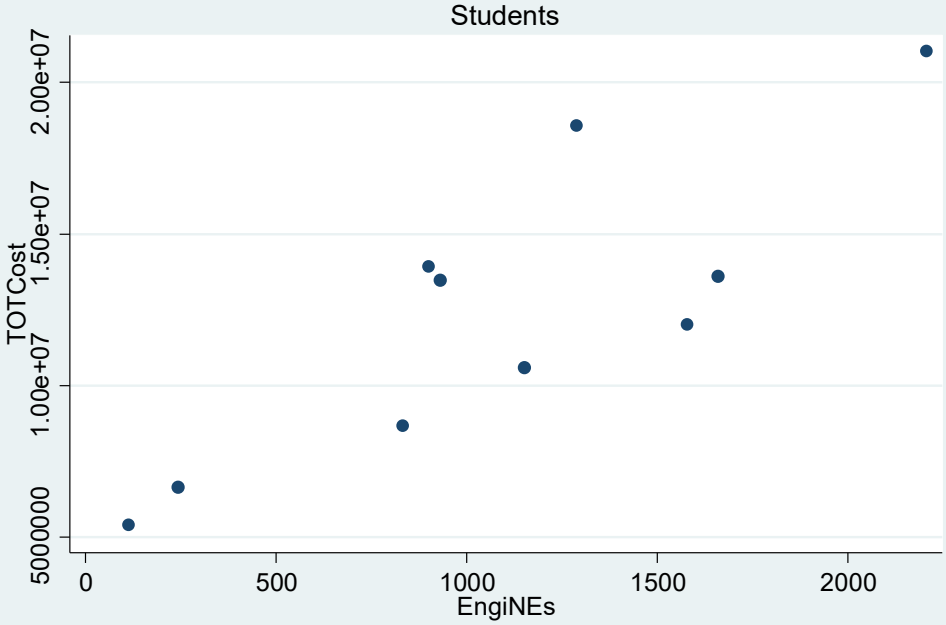
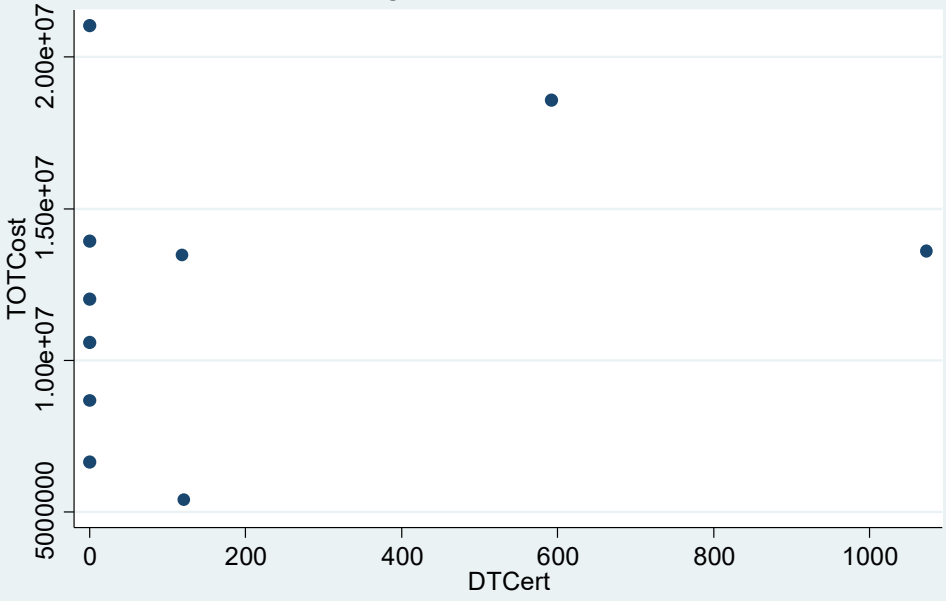
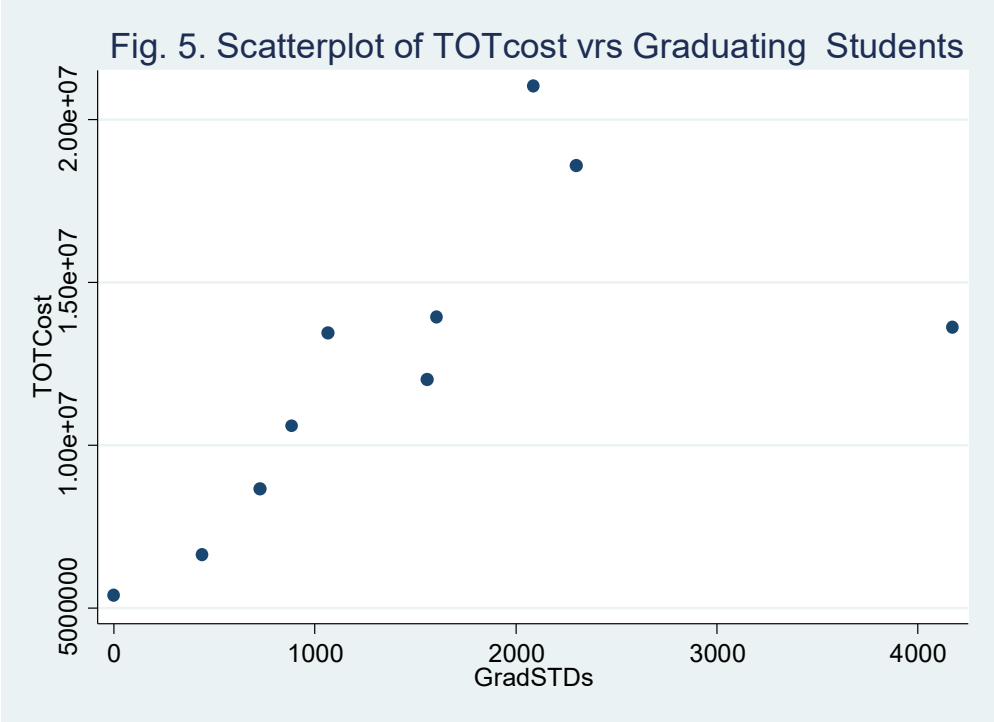


Fig. 4. Scatterplot of TOTcost vrs FTE Diploma And Certificate Students





4.3 ***VRS input-oriented efficiency scores and scale results***

The VRS input-oriented efficiency scores and scale results are presented in Table 3.

Table 3: VRS-input oriented efficiency scores and scale results

DMUs	Rank	Theta	Returns to Scale	VRS Frontier
Accra Polytechnic	1	1	0.000000	CRS established
Kumasi Polytechnic	1	1	-1.000000	DRS established
Takoradi Polytechnic	1	1	0.000000	CRS established
Ho Polytechnic	8	0.98218	1.000000	IRS established
Cape Coast Polytechnic	1	1	1.000000	IRS established
Tamale Polytechnic	1	1	0.000000	CRS established
Sunyani Polytechnic	10	0.806923	1.000000	IRS established
Koforidua Polytechnic	7	0.988527	-1.000000	DRS established
Wa Polytechnic	1	1	1.000000	IRS established
Bolgatanga Polytechnic	9	0.942874	1.000000	IRS established
DMUs	**Inputs**	**Slack**	**Outputs**	**Slack**
Koforidua Polytechnic	TOTcost	148672	EngiNEs	647.544
	Pstaff	7.2	DTCert	397.387
			GradSTDs	794.896
Ho Polytechnic	TOTcost	402836	BASocs	431.389
			DTCert	20.145
			GradSTDs	212.38
Bolgatanga Polytechnic	TOTcost	0.075696	ASTSci	170.787
	Pstaff	5.59366	BASocs	144.818
			EngiNEs	34.4586
			DTCert	221.655
Sunyani Polytechnic	TOTcost	591867	EngiNEs	178.722
			DTCert	249.213
			GradSTDs	763.684

Source: Author's estimation from STATA using 2015-2016 NCTE data.

5. Discussion

Ho polytechnic efficiency could be improved by reducing its TOTcost input by 402, 836 cedis, reduce its FTE BASocs students by 432, FTE DTCert students by 21 and graduated students (GradSTDs) by 213. By having an efficiency score of 0.98218%, Ho polytechnic could have reduced its inputs by 1.782 % to maintain the same output levels during the 2015-2016 academic year. Koforidua polytechnic efficiency, likewise could be improved by reducing its TOTcost input by 148,672 cedis, Pstaff by 7, reduce its FTE EngiNEs students by 648, FTE DTCert students by 398, and graduated students (GradSTDs) by 795, and by having an efficiency score of 98.8527%, Koforidua polytechnic as an institution could have reduced its inputs by 1.1473% to maintain the same output levels during the 2015-2016 academic year. The efficiency of Bolgatanga Polytechnic can be reduced by reducing its TOTcost input by 7cedis, 60 pesewas, reduce its FTE ASTSci students by 171, FTE BASocs students by 145, FTE DTCert students by 222 and FTE EngiNEs students by 35, and having an efficiency score of 94.2874%, Bolgatanga polytechnic could have reduced all its inputs by 5.7126% to maintain the same outputs level during the 2015-2016 academic year.

The Sunyani polytechnic efficiency could be improved by reducing its TOTcost input by 591,867cedis, reduce its FTE EngiNEs students by 179, FTE DTCert students by 249, and reduce graduated students GradSTDs) by 764. And by having an efficiency score of 80.6923%, the Sunyani polytechnic could have reduced all its inputs by 19.3077% to maintain the same output levels during the 2015-2016 academic year. Accra, Kumasi, Cape Coast, Tamale Takoradi and Wa public polytechnic institutions were efficient in their multi-productions during the 2015-2016 academic year.

Kumasi and Koforidua, polytechnic institutions respectively, multi-productions were undertaken in decreasing returns to scale environment, and these two public polytechnic institutions have the potential of experiencing diseconomies of scale. Accra, Takoradi, and Tamale polytechnic institutions multi-productions were undertaken in constant returns to scale environment, and these public polytechnic institutions have the potential of experiencing constant returns to scale. 50% of the public polytechnic institutions namely, Ho, Cape Coast, Sunyani, Wa, Bolgatanga public polytechnic institutions multi- productions were undertaken in an increasing returns to scale environment, and they do have the potentials for enjoying economies of scale after the 2015-2016 academic year.

6. Conclusion

Numerous studies aim to increase the accuracy of the measures and the technique by adding new variables and broadening the tests in the robust field of evaluating HEIs performance and efficiency using data envelopment analysis. Matching inputs and outputs data for HEIs to evaluate their efficiency and to encourage benchmarking as a means of improving efficiency abounds in the developed economies. However, using data on HEIs on the African continent to evaluate efficiency is lacking, although the (AU Agenda 2063, 2013) calls for the evaluation of HEIs efficiency to encourage benchmarking as a means of improving HEIs multi-production on the African continent. Having a paper written using original data that allow analysis of efficiency in the 10 public polytechnic institutions in Ghana, to serve as a benchmark at the academic year of their departure in transiting them into public technical universities in Ghana, a developing economy with a growing private and public higher education sector of over 270 HEIs (https://gtec.edu.gh/statistical-report, 2021) for its 31 million populace is unique. 50% of the public polytechnic institutions must continue to expand the enrolment of students into their programmes, since they enjoy economies of scale in their multi-productions and there are potential gains through efficiency by increasing enrolment for all their programmes in their subsequent academic years. This serves as a managerial incentive for the 50% of the public polytechnic institutions respectively to revolutionise their traditional programmes inherited from the polytechnic status by offering and adding to their portfolio of programmes a wide range of academic degree and master-level and doctoral programmes as well as vocational programmes as public technical universities. The apparent exhaustion of economies of scale in the other 50% of the public polytechnic institutions has managerial and policy concerns as far as transiting into public technical universities is concerned. However, given the small average size of the public polytechnic institutions in terms of the FTE student numbers, this recommendation is cautiously stated.

The study addressed a significant gap in the current higher education literature in Ghana's quest to attaining economic development, and has set the pace for performance efficiency measurement in the HEIs in Ghana. There exists now a departure 2015-2016 academic year point of empirical performance and efficiency reference, for all the public technical universities, which until the 2015-2016 academic year, were all public polytechnic institutions. Policy-wise, this paper strengthens the GOG's (Educational Strategic Plan 2018-2030) intervention, which hinges on the strategic goal of efficient education service delivery. It also aids the (AU Agenda 2063 Strategy first 10 Year, Flagship Programmes spanning 2014 – 2023) aim at researching into performance and

efficiencies in higher education management and production on the African continent, as well as Ghana's economic development quest to achieving the SDG 4 targets in relation to higher education by 2030. Analyzing the performance and efficiency of the ten technical universities in the upcoming years continues to be a top research priority.

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Conflicting interests

The author declared no potential conflicts of interest with respect to the research data, authorship and/or publication of this article.

Funding

The author received no financial support.

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