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Using explicit knowledge of groups to enhance firm productivity: A data envelopment analysis application

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Background: The telecommunication industry is globally recognised to be a knowledge-intensive industry where high levels of technological sophistication are a key determinant of success and performance. Consequently, existing research has examined the role of labour hours and the firm's capital on productivity. Nonetheless, research is yet to relate, with empirical evidence, productivity gains that accrue to organisations as a direct function of knowledge work and knowledge workers, especially with respect to group-explicit knowledge usage in emerging economies such as Nigeria. The adoption of data envelopment analysis further provides originality in the area of benchmarking group-explicit knowledge in telecommunication firms to enhance productivity. As such, this research takes on a scientific investigation to fill this gap.

Aim: The purpose of this research work was to determine the influence of group-explicit knowledge on the productivity of telecommunication organisations.

Setting: The setting of this research is composed of the four leading telecommunication firms in Nigeria and their customer service centres.

Methods: Based on a sample size of 42 customer service centres of the four most active global system for mobile communications organisations in Lagos state and Federal Capital Territory (FCT), Nigeria, the research adopted the output-oriented data envelopment analysis model to show the influence of group-explicit knowledge on productivity.

Results: The results showed that 15 decision-making units (DMUs) (representing 36%) were found to be technically efficient using the constant return to scale approach, while only 12 DMUs (representing about 28.6%), based on variable return to scale approach, were found to productively engage their present input resources in outputs that achieve optimal productivity for the firm.

Conclusion: Group-explicit knowledge dimensions that were investigated in this study significantly influence productivity of firms in Nigeria's telecommunication industry. It was recommended that DMUs that were identified to be productivity deficient should hold resources input constant while their employees made efforts to scale up operations to enhance productivity.

Introduction

Organisations' objective to achieve and improve productivity has been a major managerial concern for almost a century. Organisational and behavioural theorists such as Fredrick Taylor (Scientific Management theorists), Abraham Maslow (hierarchy of needs), Victor Vroom, Elton Mayo, Fredrick Herzberg (Motivator-Hygiene theory) and Peter Drucker (management by objective) are typical examples of researchers who have attempted to enhance organisational and, indeed, workplace productivity through theoretical innovations. Productivity refers to the increase in value of an organisation over time (Phipps, Priento & Ndinguri 2013). Thus, measuring productivity involves identifying human and non-human factors that contribute to organisational success. Also, productivity according to Syverson (2011) can be described as the degree of efficiency with which a firm transfers input to output. One way of measuring productivity is by examining capital and labour inputs in relation to their gross output or value-adding capability (Schreyer & Pilat 2001). This approach measures productivity based on single factors. The limitation identified with such an approach is that it does not explain the collective strength of input measures. Thus, decision-makers stand at risk of misinterpreting the weighted average effect of productive factors (Syverson 2011). Therefore, most empirical literature takes a multifactor

analysis or approach to the measurement of productivity (e.g. Antonelli, Patrucco & Quatraro 2011; Del Gatto, Di Liberto, & Petraglia 2011). This implies, therefore, that the measurement of productivity in empirical literature follows a more objective approach.

More so, research on productivity of firms continues to gain the interest of practitioners and scholars (Kremp & Mairesse 2004). This is because productivity is an important part of firms' performance that measures the degree to which the firms can improve on the quantity of output given a specified level of input (Phusavat 2013). In Nigeria, examining productivity-based performance of the telecommunication industry is critical because the industry is recognised to be a multibillion-dollar industry, where huge financial, intellectual and structural capital is invested yearly (David 2013). Despite this, organisations' operations are still characterised by poor signals during calls, call jamming and dropping, delay in or non-delivery of text messages after charges have been deducted and echoing of speech when making calls (CPC 2010; Oghojafor et al. 2014). The telecommunication industry is globally recognised to be a knowledge-intensive industry where high levels of technological sophistication is a key determinant of success and performance. Consequently, existing research works, such as Igbaekemen (2014) and Madsen and Mikkelsen (2012), have examined the role of labour hours and firm's capital on productivity. Nonetheless, research is yet to relate, with empirical evidence, productivity gains that accrue to organisations as a direct function of knowledge work and the knowledge workers, especially with respect to group-explicit knowledge. It is also important to state that unlike existing productivity-based research, such relationship must be examined by objective rather than subjective means, in order to avoid chances of human bias. This research is therefore focused on investigating the influence of group-explicit knowledge on productivity of telecommunication firms in Nigeria.

Group-explicit knowledge usage in organisations

Group-explicit knowledge represent codified forms of knowledge which are contained in firms' policies and procedures and most often passed through signs and symbols (Lam 2000). It also reflects the knowledge that organisations have in their database, process manuals and produce through intellectual property (Fei, Chen & Chen 2009). A common characteristic of the group-explicit knowledge is that behavioural outcomes of organisations, when dwelling on this knowledge, are highly predictable (Lam 2000). Training programmes can also facilitate group-explicit knowledge exchange (Ibidunni, Ogunnaike & Abiodun 2017; Olokundun et al. 2018). Group-explicit knowledge has been described in organisations as a form of internal organisational memory. According to Englis, Englis, Solomon, Valentine, Bieak and Turner (2006), organisational memory is the store of information and knowledge which the firm can retrieve and replicate among its members. The importance of such communised knowledge among organisational members is to foster unified understanding and a common pursuit of an organisation's strategic directions by every member of the firm. Enhancing teamwork and effectiveness among employee groups can be achieved through group-explicit knowledge.

Most of the discussions in existing literature about group-explicit knowledge reflect the capability of organisational members to share and utilise knowledge that is stored in the organisation's informational technological systems (Madhoushi, Sadati & Delavari 2011). López-Nicolás and Merono-Cerdán (2011) observed that explicit knowledge of groups in the organisation influences its financial, process and internal performance. Alegre, Sengupta and Lapiedra (2011) posited that knowledge storage and dissemination among groups can enhance innovative performance in the organisation.

Enhancing group-explicit knowledge through collective intelligence

Collective intelligence (CI) is the engagement of communal efforts (e.g. members of an organisation) as opposed to individual effort, to execute tasks or initiate solutions to problems, with the aim of achieving more effective and efficient outcomes (Leimeister 2010). By implication, collective intelligence explains how people and technology can be connected to act systematically. It shows a combination of human cognition and technological memory to enhance the performance of groups of organisational members towards achieving organisational objectives. Wooley, Chabris, Pentland, Hashmi and Malone (2010) observed that, with the help of collective intelligence, groups can use their combined cognition to solve single and a wide variety of tasks, which ordinarily individual knowledge might not be so competent at solving.

The need for timely and accurate decision-making about the fast-paced and hyper-competitive business environment makes it quite risky for firms to rely on practices that encourage individual decision-making (Bonabeau 2009). Supposedly, this is why firms harness the advantages associated with team structures in designing, evaluating and implementing decisions.

The CI theory of organisational knowledge propagates relational thinking, which means a way of human intellectual interactions within a social context, as an essential for enhancing organisational and workforce productivity, as well as goal achievement. It showcases organisational network systems (or practices) in which people interact among themselves and sometimes with computers and other information technology facilities, to generate and share knowledge for the use of the organisation. Thus, it is multi-systemic in nature, creating a network form of knowledge that shifts focus principally from individuals to groups (Liang-Chieh & Wen-Ching 2015; Svobodová & Koudelková 2011).

During the collective work process, it is vital that job tasks are organised in a way that suggest proper structuring in which individuals are aware of the roles they must perform to achieve the collective objective of the organisation. Consequently, Malone, Laubacher and Dellarocas (2009) opined that CI in organisations should involve defining two major factors, namely: (1) what and how job tasks must be executed and (2) who is performing the tasks and why. Identifying what job task is to be done and how, involves the pattern with which groups would combine knowledge efforts together to generate novel ideas that advance the organisational competitiveness (Shu-Chen & ChienHsing 2016). In this same light, they must decide how the tasks will be organised to achieve the set objectives of the organisation. Deciding who should perform each task in the organisation depends on deciding whether it would be an individual or a crowd. Crowd in this context is defined as a collection or group of individuals collaborating based on expertise and knowledge sharing.

In organisational knowledge research, the theory of CI is significant in that it emphasises group tacit and explicit knowledge as important organisational factors for achieving competitive performance (Leimeister 2010). The theory suggests that the capacity of groups to reason through their tacit knowledge is one aspect of organisational collective thinking that can achieve organisational objectives (Rajendran, Narendran & Ai 2017; Topchyan 2016). In the same way, it suggests that group knowledge encoded in explicit form by the organisation, can also be a part of the organisational knowledge asset (Preece & Shneiderman 2009). Some of the modern expressions of collective intelligence in organisations include: crowdsourcing, decision support, open innovation and social collaboration.

Crowdsourcing is the outsourcing of organisational activities to a crowd of independent operators (Howe 2009). It is an essential means through which organisations execute projects, with the aim of leveraging the efficiency and effectiveness capacity of experts. A group of communications experts building a new network communication system can enhance speed and quality in accomplishing the task. Open innovation is an organisational practice in which opinions and ideas from stakeholders of the organisation are incorporated into a new product or service building process. According to Chesbrough (2003), by incorporating the environment into their innovation process, organisations can enhance their innovation capabilities to achieve superior competitive performance. This is more likely to result from the fact that the collective knowledge gathered from customers and the organisation's customer relations unit, for example, would guide the organisation's new product design, promotion and pricing to satisfy customers' expectations. Organisations can also leverage on the use of social collaborations to generate CI. An example of one of the fastest growing social collaborations on the web is Wikipedia (Leimeister 2010). Many other social collaborations have since emerged such as Investopedia, Business Dictionary, Slide Share and so on.

Organisational knowledge utilisation in Nigeria's telecommunication industry

The service sector is increasingly occupying the front line of economic activities in most industrialised economies across the globe (Dejardin 2011; Liu 2012; Tick & Oaxaca 2010). The World Bank Report (1995) reveals that high-income countries operate economies that run on 66% services, while middle-income countries operate on 52% and low-income countries on only 35% services. This growth could be traceable to the increasing trends of technological advancements in these economies (OECD 2000; Osabuohien & Efobi 2012). However, Nigeria's service industry still lags behind as the least explored sector of the economy. Radwan and Pellegrini (2010) observed that, as in developed economies, Nigeria's service sector must be empowered to take the lead in the midst of the ongoing knowledge economy.

Of particular interest is the telecommunications industry in the service sector. The Nigerian telecommunications industry broadly consists of three major sub-sectors, namely: global system for mobile communication (GSM), code division multiple access (CDMA) and fixed or fixed wireless operations. Among these, the GSM sub-sector is the largest, consisting of four active operators: MTN, Etisalat, Globacom and Airtel. Statistics from Nigeria Communication Commission (2016) reveal that MTN has the largest subscriber base followed by Globacom, Airtel and Etisalat. This industry is knowledge based and driven by high levels of technology and innovation. Therefore, there is an increasing demand on telecommunications organisations to further invest in knowledge-based resources and capabilities as a means of improving performance (Dzunic, Boljanovic & Subotic 2012; Liao & Luo 2012; Murmann 2003; Sedziuviene & Vveinhardt 2010). There is some level of looseness (informality) in the competition that exists in the industry. An important question of research interest is: could there be something the market leader knows and knows how to do that other competitors are not conscious of? An investigation of organisational knowledge and behavioural patterns in competition is necessary in the telecommunications industry.

There is a substantial body of research on possible areas of relationship between organisational knowledge and performance (e.g. Garrido-Moreno & Padilla-Meléndez 2011; Inkinen, Kianto & Vanhala 2015; Kianto, Vanhala & Heilmann 2016; Moore 2012; Routley et al. 2013; Shamsie & Mannor 2013; Zheng, Yang & McLean 2010). Proponents of the resource- and knowledge-based views of the firm identify that intangible organisational resources, such as knowledge, offer unique competitive advantages when they are differentiated and are difficult to imitate (Barney 1991). However, within the existing body of literature on organisational knowledge, there is a gap in identifying how organisational knowledge should necessarily be linked to the business strategy as a means of improving performance (Davenport 1999). In channeling corporate strength, organisational leadership should provide

answers to the questions like: what are important factors or features of the environment (customers, competitors, and so on) to gain superior performance? Of interest is the source of strategic knowledge (internal or external sources?). These issues that aid the discretion of decisions-makers are of concern in this research.

Furthermore, evidence of growth in Nigeria's telecommunications industry by GDP (growing from 1.06% in 2003 to 7.76% in 2013, Nigeria Communications Commission 2015) indicates that the industry is highly competitive. Besides, the mobile market is expected to hit a growth rate of over 10 billion by 2020 with an increase in the number of users to about 182 million (Marketing Edge Mag 2015). Knowledge management researchers have, to a large extent, discussed the fundamental effects of knowledge processes to business performance. But there is a paucity of empirical evidence to show the link between knowledge and the growing success of the Nigerian telecommunications industry. Consequently, in practice this situation gives rise to information and knowledge resources in the organisation not being: (1) vital for the strategic pursuit of the firm and (2) properly processed by the firms' interconnected knowledge assets to achieve the desired competitive advantages. Thus, managers at the strategic level of the organisation are often misdirected about key knowledge areas to focus on in achieving their highest performance levels (Abdollahi, Rezaeian & Mohseni 2008).

Just as strategy is not designed in isolation of the business environment, neither is knowledge generated and reproduced into innovative products and services without the environment (Hipp & Grupp 2005; Koch & Strotmann 2008). Very little is known by means of empirical research about how the nature of a competitive and dynamic business environment influences the orientation and performance of the Nigeria telecommunications industry. Environmental competitiveness refers to the degree to which the external environment is characterised by intense competition while environmental dynamism explains the rate of change and instability of the environment (Dess, Lumpkin & Taylor 2005; Jansen, Van Den Bosch & Volberda 2006; Martínez-Martínez, Cegarra-Navarro & García-Pérez 2015). This research finds these two environmental contexts relevant in the major telecommunication industry, which largely demonstrates both traits. However, do these traits significantly influence competitive strategies adopted by telecommunication firms? In addition, which patterns of competitive orientation best represent the industry's interest to attain superior performance?

Another way of looking at the disparity in performance and competitive patterns among telecommunication firms is in the area of firm size and age. Gopalakrishnan and Bierly (2006) observed that firm size and firm age moderate the organisational knowledge and technological strength relationship. This research may not be automatically implied in Nigeria. Hence, there exists a gap in how differences in size and age of telecommunication firms explain their perspectives to competition and performance outcomes. The results arrived at in this study will likely reflect important implications for knowledge strategy literature and practitioners. They show how large and small firms, with varying years of existence, configure knowledge-based processes, assets and capabilities along four important strategic knowledge dimensions to enhance organisational worth.

Organisational knowledge and productivity

Chang and Gurbaxani (2012) empirically tested the impact of an IT provider's organisational knowledge on the productivity of client firms. Their study proposed that a vendor's IT-related knowledge could be a major determinant of productivity for client firms. The knowledge–productivity relationship has also been tested by Das (2003), using a context of technical support work. Productivity was tested through call resolution time and the extent of call escalation. Knowledge of technical support was measured through problem-solving tasks and moves dimensions. Their research indicated that along different activity lines of technical work, the relationship between knowledge of technical support and productivity was significant. Musolesi and Huiban (2010) examined the relationship between the sources of knowledge, innovation and productivity in knowledge-intensive business services and reported internal and external sources of knowledge like patents and R&D. In addition, they showed that knowledge and innovation have a strong and positive effect on productivity. They also compared their findings with existing literature based on investigations in the manufacturing industry and their reports showed consistency in findings with previous research studies.

The relationship between productivity and transference of knowledge among organisations is also an important area of research in strategic management. Darr, Argote and Epple (1995) investigated the acquisition, transfer and depreciation of knowledge on productivity of 36 pizza stores in the USA. They reported that increased experience in production resulted in unit cost decline. Also, unless productivity continues, the knowledge of production is likely to depreciate significantly within a short period of less than a year. Whereas knowledge transfer was found to be possible between stores of the same franchise, it was inversely related across stores controlled by different franchisees. The insight revealed in literature shows the significant effect of various forms, sources and applications of knowledge to organisational productivity. Consequently, this study hypothesises that:

H_{1a}: Based on a constant return to scale, group-explicit knowledge enhances the productivity of firm.

H_{1b}: Based on variable returns to scale, group-explicit knowledge enhances the productivity of firms

Materials and methods

The research study is descriptive in nature. The use of descriptive research design is validated by the fact that

populations for the study are already established, theories are not newly explored or determined and the research study simply attempts to describe the relationships among the variables included in the research (Jong & Van der Voordt 2002). The sample size for this research includes the 124 customer service centres of the four biggest GSM firms in Lagos state and FCT, Nigeria. The GSM sub-sector is pivotal to the telecommunication industry in Nigeria because it has the highest number of subscribers (98.07%), thus serving as the major driver of growth in the industry. Questions about group-explicit knowledge were developed based on Chilton and Bloodgood (2007) and Fei et al. (2009). Measuring organisational productivity was based on input and output factors relating to the firms and their customer service centres.

The data envelopment analysis model

This study adopted three input and three output factors, against a total of 124 decision-making units to satisfy this condition. The input and output measures determined for this study were selected based on their ability to represent knowledge resources and knowledge outcomes. The following notations are defined to guide the analysis.

To achieve movement to the efficient frontier in a two-stage data envelopment analysis (DEA), there is the need to optimise the slack variables. This requires running the model below under the same assumption as in the basic DEA model above.

Max $S_1^- + S_2^- + S_3^- + S_1^+ + S_2^+ + S_3^+$

Subject to:

- Input constraints:
  - $\sum_{j=1}^{29} \lambda_j x_{1j} + S_1^- = \theta\, x_{10}$ – estimated number of employees (i.e. first input) available in CSC j
  - $\sum_{j=1}^{29} \lambda_j x_{2j} + S_2^- = \theta\, x_{20}$ – estimated expenditure on employee training (i.e. second input) in CSC j in a year
  - $\sum_{j=1}^{29} \lambda_j x_{3j} + S_3^- = \theta\, x_{30}$ – estimated expenditure on new technology (i.e. third input) in CSC j in a year
- Output constraints:
  - $\sum_{j=1}^{29} \lambda_j y_{1j} - S_1^- = y_{10}$ – average number of customers attended to daily (i.e. first output) in CSC j
  - $\sum_{j=1}^{29} \lambda_j y_{2j} - S_2^- = y_{20}$ – average number of customers with resolved cases (i.e. second output) in CSC j
  - $\sum_{j=1}^{29} \lambda_j y_{3j} - S_3^- = y_{30}$ – average number of innovations produced (i.e. third output) in CSC j in a year
  - $\sum_{j=1}^{29} \lambda_j = 1$

    $\lambda_j \geq 0 \forall_j, (j = 1,2 \ldots 29)$
- Scales constraint (VRS):
  - $\sum_{j=1}^{29} \lambda_j = 1$

Analysis and result

Table 1 shows that employees in the customer service centres range between 5 and a maximum of 124. Moreover, in some centres only 10 customers are attended to, while others have as many as 50 customers to attend to daily. Resolved cases of customer complaints range from 5 to 400. Firms in the telecommunication industry are also seen to incur huge expenditure in employee training and new technology, with average costs of 6 837 353 naira and 9 150 138 naira respectively.

Results of output-oriented constant returns to scale model: Pure technical efficiency

This study hypothesised that based on a constant return to scale, group-explicit knowledge enhances the productivity of firms. Appendix 1 show the result of output-oriented constant returns to scale (CRS) of pure technical efficiency of the four telecommunication firms' customer service centres in Lagos state and FCT. The result from the analysis suggests that out of the 42 DMUs analysed and represented in Appendix 1, 15 (representing 36%) were found to be technically efficient, thus achieving productivity with the firms' group-explicit knowledge. In other words, their productive capacity is fully optimised. These customer service centres serve as models

TABLE 1: Input and output measures for productivity of telecommunication firms.

Measures	Mean	Standard deviation	Maximum	Minimum
Inputs				
Number of employees	20.72093023	24.01781424	120	5
Estimated expenditure on employee training	6 837 353	22285624.43	125 000 000	30 000
Estimated expenditure on new technology	9 150 138	32395067.28	175 000 000	1000
Outputs				
Number of customers attended to daily	269.5	766.9927	5000	10
Number of customers with resolved cases	92.02381	87.96105	400	5
Number of innovations produced	9.705882	9.564864	50	1

Please see the full reference list of the article, Ibidunni, A.S., Abiodun, J.A., Ibidunni, O.M. & Olokundun, M.A., 2019, 'Using explicit knowledge of groups to enhance firm productivity: A data envelopment analysis application', *South African Journal of Economic and Management Sciences* 22(1), a2159. https://doi.org/10.4102/sajems.v22i1.2159, for more information.

Note: A total of 42 customer service centres in Lagos state and the Federal Capital Territory were included in this study. Therefore, the study consisted of 42 decision-making units upon whom the data envelopment analysis was performed.

which centres that are not technically efficient can follow. However, 27 other DMUs were measured to be inefficient. Inefficiency in the DEA occurs when the efficiency scores are either greater than or less than 1. From the table the 27, DMUs representing 64%, will be required to keep inputs constant while they attempt to utilise their existing output level to achieve productivity.

Results of output-oriented variable return to scale model: Pure technical efficiency

This study also hypothesised that based on a variable return to scale, group-explicit knowledge enhances the productivity of firms. Appendix 2 shows the output-oriented VRS technical efficiency of customer service centres of the telecommunication firms. The results reveal that 12, representing about 28.6% of DMUs, were found to productively apply the group-explicit knowledge to achieve optimal productivity for the firm. This implies that those 12 DMUs fully utilise all input resources invested into them by the firms' headquarters. Every other DMU has a figure above 1, indicating that it is inefficient in the use of the firm's resources to achieve its productivity objective.

The ideal solution is for inefficient customer services centres to maintain their present input level and enhance utilisation of output targets such as achieving increased numbers of customers with resolved cases and producing more innovations that can help achieve the firms' productivity objective.

Ethical consideration

Respondents participated in the survey willingly and their identities were not disclosed in accordance with their request.

Discussion

The output-oriented constant returns to scale and variable returns to scale, obtained from using data envelopment analysis, justified the acceptance of the alternate hypothesis. Viewed from the constant returns to scale model, 15 customer service centres across the four GSM telecommunication firms were found to be productive. This implies that they were yielding outputs that corresponded with the resources invested in them. However, the result of variable returns to scale showed some slight downward slope, as only 12 of the 42 customer service centres were reported to be productive. The assumption of constant returns to scale is that decision-making units, in this case customer service centres, would produce outputs that are directly proportionate to the resources invested in them. While on the other hand, variable returns to scale assume that, given the effect of environmental conditions on the production or transformation process, resources invested might not always yield proportionate outputs. The implication is that outputs will vary depending on the extent to which the transformation process is impeded (Emerald Group Publishing 2010). Hence, in reality the assumption of variability holds.

Productivity is a measure of firms' input to output. The results obtained imply that the telecommunication firms' management, especially for customer service centres that are productivity deficient, should retain resource investment in the customer service centres, while the supervisors and other employees at those centres are charged to upgrade their levels of output (Abiodun et al. 2018; Tyagi et al. 2015). In this sense, they will need to pay more attention to attending to all customers that complain about the firms' products and services (Ibidunni et al. 2018). They will also need to ensure that a larger number of customer complaints are resolved.

Conclusion and recommendation

This study adopted the DEA application to determine the influence of group-explicit knowledge on the productivity of telecommunication organisations in Nigeria. Data were gathered from the customer service centres of the telecommunication firms in the GSM sub-market and this gave very insightful details to the research work with respect to the use of explicit knowledge such as training and formal education, as a means of enhancing firm-level productivity. Based on the findings of this research work, it is concluded that group-explicit knowledge influences the productivity of telecommunication organisations. However, bearing in mind the context of the study, telecommunication managers in Nigeria, and similar developing economies, should pay attention to increasing the level of output of their firms' customer service centres. Consequently, strategic measures that will increase service demand should be implemented. It is further recommended that the firms' management, especially for customer service centres that are productivity deficient, should maintain present resource investment in the customer service centres, while supervisors and other employees at those centres make efforts to increase their levels of output.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contribution

A.S.I. coordinated the writing of the article and wrote sections of the article, carried out technical validation and quality control of the database and gathered data from the survey. J.A.A. and M.A.O. contributed to the design of the study. O.M.I. was involved in conceptualisation of the study and data cleaning.

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Appendix 1

TABLE 1-A1: Results of output-oriented constant returns to scale model: Pure technical efficiency – CSC in Lagos state and FCT.

Number	Name of DMU	Efficiency score	Type of scale
1	MTLCSC 1	0.919	Increasing
2	MTLLCSC 2	1.000	Constant
3	MTLCSC 3	1.159	Decreasing
4	MTLCSC 4	1.500	Decreasing
5	MTLCSC 5	1.000	Constant
6	MTLCSC 6	1.000	Constant
7	MTLCSC 7	0.750	Increasing
8	MTFCSC 1	1.000	Constant
9	MTFCSC 2	1.000	Constant
10	GLCSC 1	1.000	Constant
11	GLCSC 2	1.000	Constant
12	GLCSC 3	1.250	Decreasing
13	GLCSC 4	3.467	Decreasing
14	GLCSC 5	5.000	Decreasing
15	GLCSC 6	1.548	Decreasing
16	GLCSC 7	2.500	Decreasing
17	GFCSC 1	1.000	Constant
18	GFCSC 2	15.790	Decreasing
19	ALCSC 1	1.000	Constant
20	ALCSC 1	0.509	Increasing
21	ALCSC 3	4.453	Decreasing
22	ALCSC 4	2.161	Decreasing
23	ALCSC 5	1.600	Decreasing
24	ALCSC 6	7.119	Decreasing
25	ALCSC 7	1.125	Decreasing
26	ALCSC 8	1.131	Decreasing
27	ALCSC 9	1.500	Decreasing
28	AFCSC 1	1.000	Constant
29	GFCSC 2	1.000	Constant
30	ELCSC 1	2.258	Decreasing
31	ELCSC 2	1.875	Decreasing
32	ELCSC 3	0.619	Increasing
33	ELCSC 4	0.819	Increasing
34	ELCSC 5	1.863	Decreasing
35	ELCSC 6	1.000	Constant
36	ELCSC 7	1.000	Constant
37	ELCSC 8	1.000	Constant
38	ELCSC 9	1.523	Decreasing
39	ELCSC 10	0.714	Increasing
40	EFCSC 1	0.875	Increasing
41	EFCSC 2	1.000	Constant
42	EFCSC 3	0.627	Increasing

DMU, decision-making units; FCT, Federal Capital Territory; MTFCSC, MTN Customer Service Centre in Federal Capital Territory; GLCSC, Globacom Customer Service Centre in Lagos; ALCSC, Airtel Customer Service Centre in Lagos; GFCSC, Globacom Customer Service Centre in Federal Capital Territory; ELCSC, Etisalat Customer Service Centre in Lagos.

Note: (1) MTLCSC = Firm 1, Lagos state, Customer service centre; (2) MTFCSC = Firm 1, FCT, Customer service centre; (3) GLCSC = Firm 2, Lagos state, Customer service centre; (4) GFCSC = Firm 2, FCT, Customer service centre; (5) ALCSC = Firm 3, Lagos state, Customer service centre; (6) AFCSC = Firm 3, FCT, Customer service centre; (7) ELCSC = Firm 4, Lagos state, Customer service centre; (8) EFCSC = Firm 4, FCT, Customer service centre. Please see the full reference list of the article, Ibidunni, A.S., Abiodun, J.A., Ibidunni, O.M. & Olokundun, M.A., 2019, 'Using explicit knowledge of groups to enhance firm productivity: A data envelopment analysis application', *South African Journal of Economic and Management Sciences* 22(1), a2159. https://doi.org/10.4102/sajems.v22i1.2159, for more information.

Appendix 2

TABLE 1-A2: Results of output-oriented VRS model: Pure technical efficiency – CSC in Lagos state and FCT.

Number	Name of DMU	Efficiency score
1	MTLCSC 1	1.31816
2	MTLLCSC 2	1.77004
3	MTLCSC 3	6.85950
4	MTLCSC 4	2.23684
5	MTLCSC 5	1.03088
6	MTLCSC 6	6.61841
7	MTLCSC 7	1.00000
8	MTFCSC 1	1.00000
9	MTFCSC 2	1.00000
10	GLCSC 1	2.41006
11	GLCSC 2	1.00000
12	GLCSC 3	5.00000
13	GLCSC 4	1.35645
14	GLCSC 5	1.00000
15	GLCSC 6	3.06832
16	GLCSC 7	1.25000
17	GFCSC 1	1.00000
18	GFCSC 2	1.12572
19	ALCSC 1	1.00000
20	ALCSC 1	1.42514
21	ALCSC 3	1.04384
22	ALCSC 4	1.45181
23	ALCSC 5	2.01338
24	ALCSC 6	2.50000
25	ALCSC 7	1.01563
26	ALCSC 8	1.77857
27	ALCSC 9	2.36111
28	AFCSC 1	1.46341
29	GFCSC 2	1.00000
30	ELCSC 1	2.72928
31	ELCSC 2	4.43624
32	ELCSC 3	1.00000
33	ELCSC 4	7.89973
34	ELCSC 5	7.54541
35	ELCSC 6	1.00000
36	ELCSC 7	1.00000
37	ELCSC 8	1.00000
38	ELCSC 9	1.00000
39	ELCSC 10	3.03833
40	EFCSC 1	2.27835
41	EFCSC 2	5.90625
42	EFCSC 3	1.00000

DMU, decision-making units; FCT, Federal Capital Territory; MTFCSC, MTN Customer Service Centre in Federal Capital Territory; GLCSC, Globacom Customer Service Centre in Lagos; ALCSC, Airtel Customer Service Centre in Lagos; GFCSC, Globacom Customer Service Centre in Federal Capital Territory; ELCSC, Etisalat Customer Service Centre in Lagos.

Note: (1) MTLCSC = Firm 1, Lagos state, Customer service centre; (2) MTFCSC = Firm 1, FCT, Customer service centre; (3) GLCSC = Firm 2, Lagos state, Customer service centre; (4) GFCSC = Firm 2, FCT, Customer service centre; (5) ALCSC = Firm 3, Lagos state, Customer service centre; (6) AFCSC = Firm 3, FCT, Customer service centre; (7) ELCSC = Firm 4, Lagos state, Customer service centre; (8) EFCSC = Firm 4, FCT, Customer service centre. Please see the full reference list of the article, Ibidunni, A.S., Abiodun, J.A., Ibidunni, O.M. & Olokundun, M.A., 2019, 'Using explicit knowledge of groups to enhance firm productivity: A data envelopment analysis application', *South African Journal of Economic and Management Sciences* 22(1), a2159. https://doi.org/10.4102/sajems.v22i1.2159, for more information.