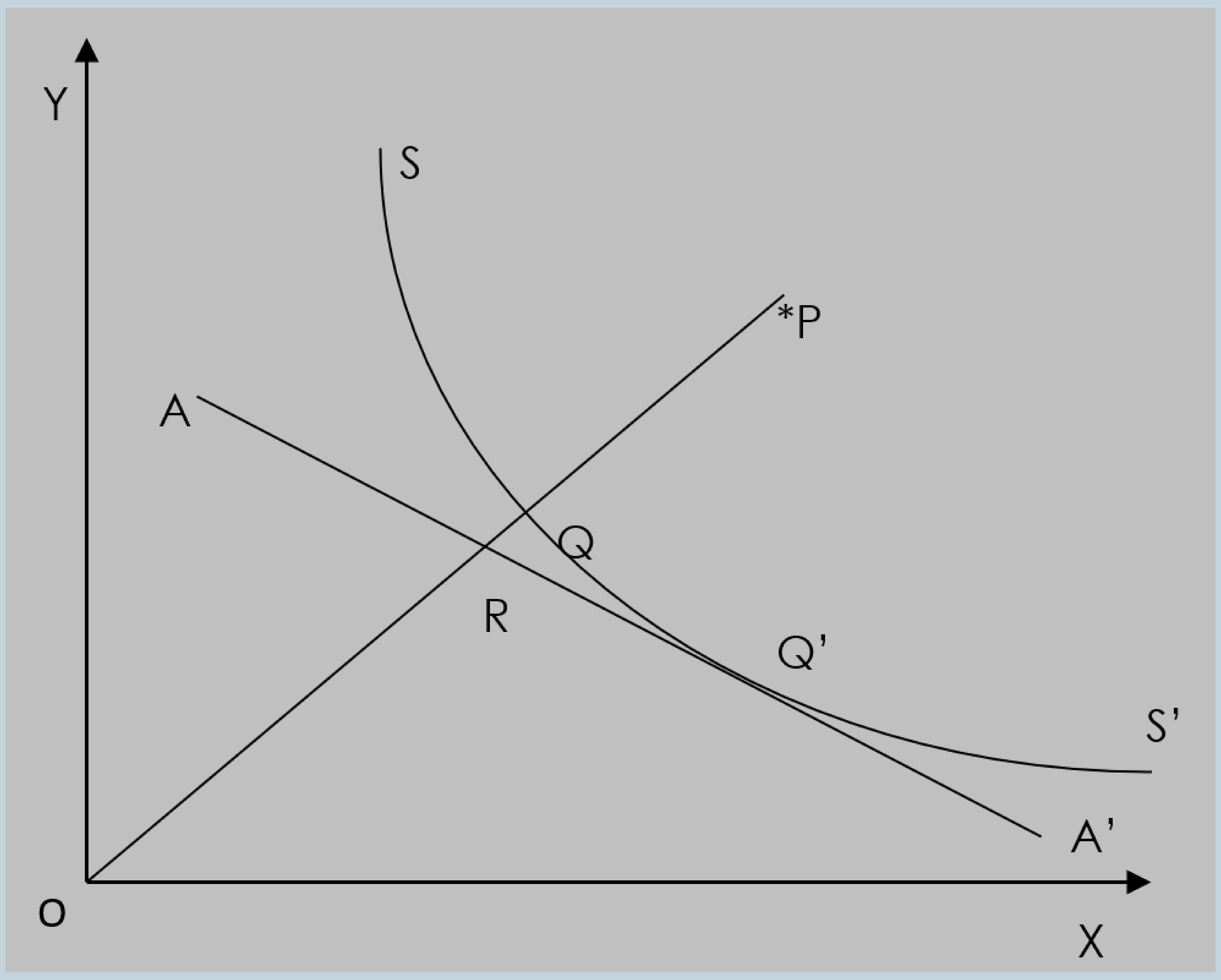
Sustainability, Inclusiveness and Governance of Mini-Grids in Africa (SIGMA) Project

Mini-Grid Performance Analysis using Data Envelopment Analysis (DEA)

INTRODUCTION AND PROBLEM STATEMENT

Performance benchmarking has become a common business practice, which is undertaken to understand the current performance of a given unit of production or service compared to its peers. The theoretical idea comes from the concept of economic efficiency which in simple terms means producing as large an output as possible from a given set of inputs. The seminal work of Farrel (1957) introduced the concept of using the 'best results observed in practice' peers to estimate an efficient production function. This is explained below using a two-input case. This research applies the concepts of performance benchmarking to the delivery of electricity services via mini-grids in Sub-Saharan Africa.

Data envelopment analysis was initially proposed as a performance assessment methodology of a set of homogeneous decision-making units (DMUs) in the mid-1970s, through the work of Charnes, Cooper & Rhodes (1978). The authors presented a linear programming formulation of efficiency measurement that facilitated the development of a data-driven approach of performance measurement.



SS' - Combinations of two inputs, X and Y, representing efficient production of unit output, or the efficiency frontier

P - Combination of X and Y for an inefficient decision-making unit

Q - Efficiency point for decision-making unit with output P

OP/OQ - Output increase if decision-making unit were on the efficiency frontier

AA' - Input cost efficiency slope

Q' - Tangent point for cost efficiency for decision-making unit producing at point P

OR/OQ - Cost efficiency for decision-making unit

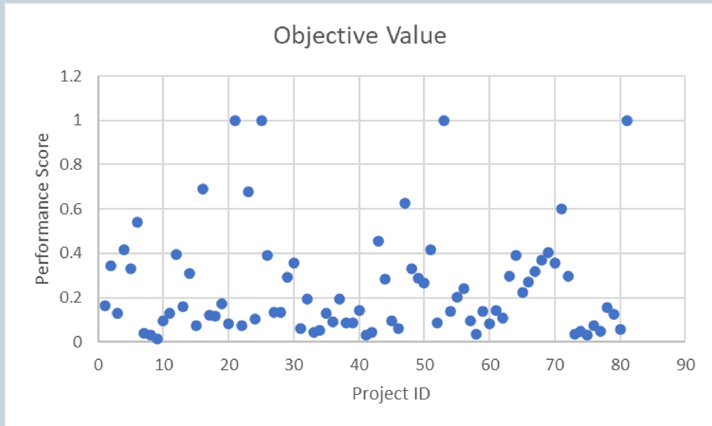
Overall Efficiency - (OQ/OP) * (OR/OQ) = OR/OP

DATA AND METHODOLOGY

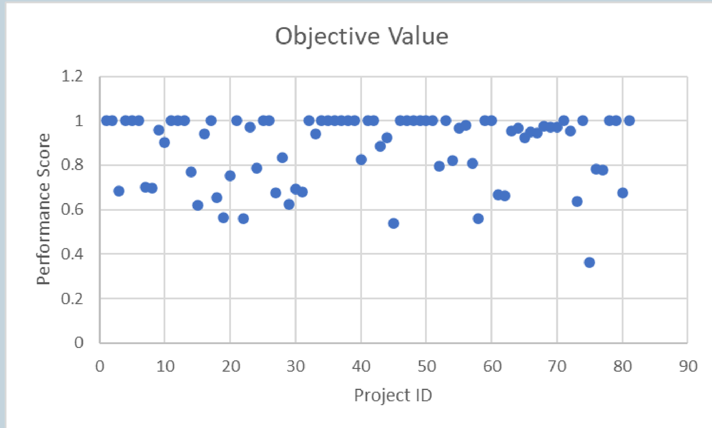
Duran and Sahinyazan (2021a) reported a global dataset of mini-grid projects covering both developed and developing countries. The data contains information about project location, year of construction, technology type, capacity, population served, and project cost estimates, among others. The data was used to conduct an econometric analysis of mini-grid projects which was reported in Duran and Sahinyazan (2021b).

RESULTS

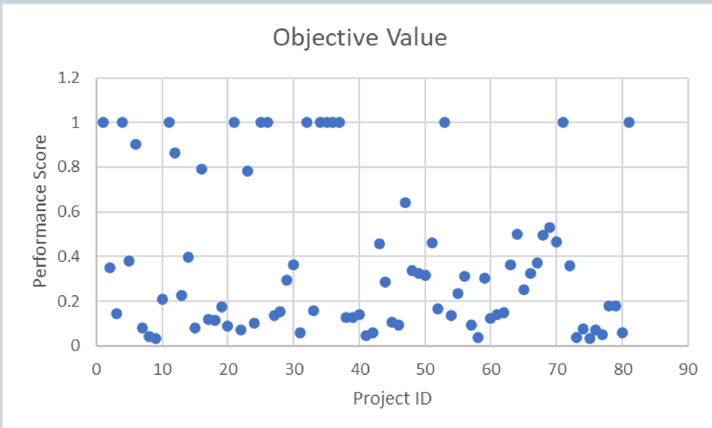
The graphs below show the results of this analysis: numbers closer to 1 represent more efficient mini-grids.



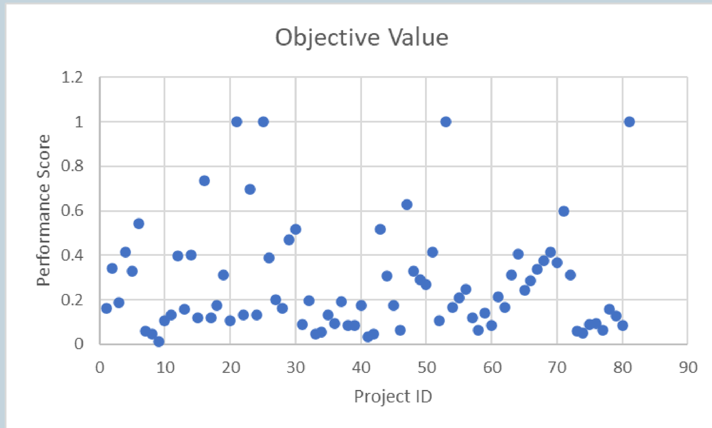
Output-Oriented Charnes, Cooper & Rhodes (CCR) Model Efficiency



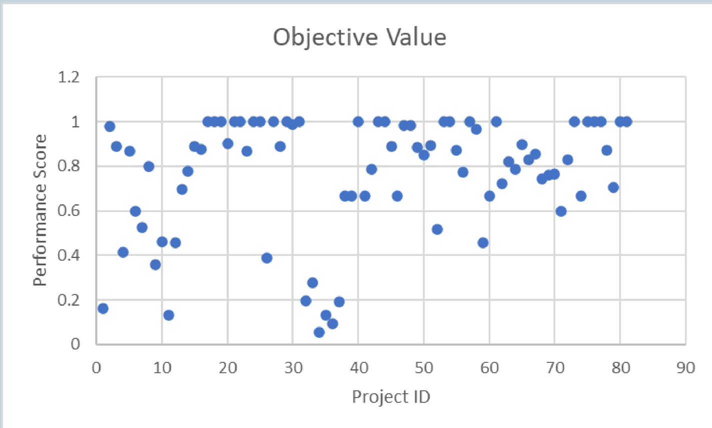
Input-Oriented Banker, Charnes & Cooper (BCC) Model Efficiency



Output-Oriented BCC Model Efficiency



Input-Oriented Scale Efficiency (CCR/BCC)



Output-Oriented Scale Efficiency

CONCLUSION

This analysis has shown that there are significant issues present with the productive efficiency of mini-grids in developing countries. Compared to their peers in the dataset, the majority of mini-grids are inefficient, with a large number of mini-grids being very inefficient compared to their peers. The input-oriented models in particular highlight this inefficiency: input-oriented scale efficiency is low across the corpus, indicating that the majority of mini-grids are operating far away from their most productive scale size. Moving forward, the mini-grid sector in developing countries needs to assess the scale of their operations, and determine whether increasing or decreasing returns to scale are present to expand or diversify their operations as appropriate. DEA as a methodology shows promise in the analysis of productive efficiency in the mini-grids sector.

Banker, R., Charnes, A. and Cooper, W. (1984) Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science, 30, pp. 1078-1092

Bhattacharyya, S.C. & Kerr, D. (2024) Mini-Grid Performance Analysis using Data Envelopment Analysis. Sustainability, Inclusiveness and Governance of Mini-Grids in Africa (SIGMA) Project, Working Paper 4

Charnes, A., Cooper, W.W. & Rhodes, E. (1978) Measuring the efficiency of decision making units. European Journal of Operational Research, 2(6), pp. 429-444

Duran, A.S. and Sahinyazan, F.G. (2021a) Meta-analysis data of 104 renewable mini-grid projects for rural electrification. Data in Brief, 34, 106739, https://doi.org/10.1016/j.dib.2021.106739

Duran, A.S. and Sahinyazan, F.G. (2021b) An analysis of renewable mini-grid projects for rural electrification. Socio-economic Planning Sciences, 77, 100999, https://doi.org/10.1016/j.seps.2020.100999

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