

Understanding efficiency and the effect of payment for performance across health facilities in Tanzania

List of appendices

Appendix Table 1: Constant returns to scale (CRS) - Overall technical efficiency

Health facility type	Baseline -round 1			Endline-round 2		
	Intervention	Comparison	All facilities	Intervention	Comparison	All facilities
Panel A: Model 1						
Hospitals	0.38 (16.7% eff.)	0.51 (16.7% eff.)	0.45 (16.7% eff.)	0.38 (16.7% eff.)	0.57 (16.7% eff.)	0.47 (16.7% eff.)
Health Centres	0.38 (0% eff.)	0.46 (12.5% eff.)	0.42 (6.3% eff.)	0.38 (0% eff.)	0.39 (0% eff.)	0.38 (0% eff.)
Dispensaries	0.18 (0% eff.)	0.23 (1.9% eff.)	0.21 (0.9% eff.)	0.16 (0% eff.)	0.22 (0% eff.)	0.19 (0% eff.)
Panel B: Model 2						
Hospitals	0.63 (16.7% eff.)	0.65 (33.3% eff.)	0.64 (25.0% eff.)	0.60 (16.7% eff.)	0.71 (50% eff.)	0.65 (33.3% eff.)
Health Centres	0.60 (18.8% eff.)	0.59 (8.3% eff.)	0.60 (14.3% eff.)	0.65 (31.3% eff.)	0.55 (8.3% eff.)	0.61 (21.1% eff.)

Model 1: Inputs (*total staff, drugs and vaccines, medical supplies, equipment*); Outputs (*outpatient visits*)

Model 2: Inputs (*total staff, drugs and vaccines, medical supplies, equipment, beds*); Outputs (*outpatient visits and normal deliveries*)

Appendix Table 2: Variable returns to scale (VRS) - Pure technical efficiency (PTE) and Scale efficiency (SE) score

	Year 2012 -round 1		Year 2013-round 2	
	Pure TE	Scale Efficiency	Pure TE	Scale Efficiency
Panel A: Model 1				
Hospitals	0.46 (25.0% eff.)	0.99 (66.7% eff.)	0.48 (16.7% eff.)	0.99 (91.7% eff.)
Health Centres	0.49 (12.5% eff.)	0.95 (21.9% eff.)	0.39 (0% eff.)	0.97 (18.8% eff.)
Dispensaries	0.22 (0.9% eff.)	0.95 (68.3% eff.)	0.21 (0.9% eff.)	0.94 (65.7% eff.)
Panel B: Model 2				
Hospitals	0.64 (33.3% eff.)	1.0 (58.3% eff.)	0.66 (41.7% eff.)	0.99 (50.0% eff.)
Health Centres	0.66 (25.0% eff.)	0.95 (42.9% eff.)	0.64 (32.1% eff.)	0.97 (32.1% eff.)

OTE=PTE x SE

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APPENDIX FOR METHODS

Measuring efficiency using DEA approach

DEA is a non-parametric linear programming method that has been commonly used to estimate technical efficiency, particularly in low- and middle-income settings, where given the nature of the data it presents some practical advantage over the stochastic frontiers. The technical efficiency score of each facility are estimated by solving the following output-oriented optimization.

$$\text{Max } \theta = \sum O_r Y_{rj0} + \theta_0$$

Subject to constraints:

$$\sum_{i=1}^m V_i + X_{ij0} = 1$$

$$\sum_{r=1}^s O_r + Y_{rj} - \sum V_r X_{ij} + \theta_0 \leq 0, j=1, \dots, n$$

$$O_r, V_i \geq 0$$

$$\theta_0 > 0, \text{ or } \theta_0 = 0 \text{ or } \theta_0 < 0$$

Where,

Y_{rj} = amount of output r from facility j.

X_{ij} = amount of input i to facility j.

O_r = weight given to output r.

V_i = weight given to input i.

n = number of facilities.

s = number of outputs.

m = number of inputs.

$O_0 > 0$ defines increasing returns to scale (IRS), $O_0 = 0$ defines constant returns to scale (CRS), and $O_0 < 0$ defines decreasing returns to scale (DRS). Thus, the technical efficiency score is defined by θ and, it ranges between 0 and 1. If the score equals 1 then the facility or decision-making unit is efficient, while scores less than 1 the facility is inefficient.

Through VRS assumption, we were able to decompose the overall technical efficiency scores into *scale efficiency* and *pure technical efficiency*. Scale efficiency is related to the size of the health facility, e.g. a health facility can be too large or small for its level of operation/ volume of activities, which leads to inefficiencies of scale (i.e. decreasing or increasing returns to scale). Scale efficiency is calculated as a ratio between the health facility's technical efficiency score under the assumption of CRS and the technical efficiency score under VRS.

Efficiency scores were computed in Stata by applying the `dea` user-written command, with alternatively constant or variable returns to scale, as required by each model, and with output orientation¹. The analysis was performed using Stata 15.

Determinants of efficiency: Regression analyses

To identify the determinants of technical efficiency, we regressed the efficiency scores over observed contextual factors. The efficiency scores are censored (0 to 1) and the correlation pattern among DEA efficiency scores is typically complex and unknown. We therefore used the approach developed by Simar and Wilson² and recently applied by Moreno Serra et al.³, as it accounts for bounded dependant variable, corrects the standard errors by simulating the unknown error correlation among efficiency scores and calculates bootstrapped standard errors⁴.

We pooled the efficiency scores estimated separately for dispensaries, health centres and hospitals in 2012 and in 2013 and we regressed them on a set of contextual and environmental factors (listed in Table 1). We also included binary indicators to control for

¹ Ji, Y. and C. Lee (2010), Data envelopment analysis, *The Stata Journal* 10, Number 2, pp. 267–280

² Simar L, Wilson PW. Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of econometrics* 2007;136(1):31-64.

³ Moreno-Serra R, Anaya-Montes M, Smith PC. Potential determinants of health system efficiency: Evidence from Latin America and the Caribbean. *PLoS One* 2019;14(5):e0216620. doi: 10.1371/journal.pone.0216620

⁴ Badunenko O, Tauchmann H. Simar and Wilson two-stage efficiency analysis for Stata. *The Stata Journal* 2019;19(4):950-88.

type of health facility, year and district. In model 1 we include dispensaries, health centres and hospitals, and in model 2 only health centre and hospitals.

The following regression was estimated:

$$Y_{it} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2it} + \gamma F_i + \tau T_t + \varphi D_i + \varepsilon_i \quad (1)$$

where Y_{it} is the efficiency score for the i^{th} health facility (in model 1 we include dispensaries, health centres and hospitals, and in model 2 only health centre and hospitals) in year t . X_{1i} is a set of contextual and environmental factors fixed over time including ownership status, facility size, catchment population characteristics, distance from district headquarter, location (rural/urban). X_{2i} is a set of contextual and environmental factors varying over time including number of outreach services, availability of community health fund (CHF) insurance and frequency of external supervision. F_i is a set of dummy variables for facility types, including Hospital and Health Centre in Model 1 and Hospital only in Model 2. T_t is a dummy variable for Year 2013 and D_i is a set of district dummies. We selected the potential determinants based on data availability as well as from previous studies assessing efficiency and associated determinants in LMICs⁵. β 's are the coefficients of determinants and ε_i is an error term. We estimated the regression using the Stata user-written command *simarwilson* with externally estimated efficiency scores and 2,000 replications⁶. In model 1 we included dispensaries, health centres and hospitals, and in model 2 only health centre and hospitals. The analysis was performed using Stata 15.

Effect of P4P on efficiency: Difference-in Difference analysis

To test whether P4P affects efficiency scores, we first compared descriptively the changes in efficiency scores over time for P4P and non-P4P facilities. We then applied a linear difference-in-differences regression analysis based on a controlled before and after design.

⁵ Hafidz F, Ensor T, Tubeuf S. Efficiency Measurement in Health Facilities: A Systematic Review in Low- and Middle-Income Countries. *Applied health economics and health policy* 2018;16(4):465-80. doi: 10.1007/s40258-018-0385-7 [published Online First: 2018/04/22]

⁶ Badunenko O, Tauchmann H. Simar and Wilson two-stage efficiency analysis for Stata. *The Stata Journal* 2019;19(4):950-88.

We regressed efficiency scores pooled across health facilities and years over a dummy variable, taking the value 1 if a facility is exposed to P4P in 2013 and 0 if not. We controlled for time invariant determinants, including facility fixed effects; and time specific effects including year fixed effects. The following regression was estimated:

$$Y_{it} = \beta_0 + \beta_1(P4P_i \times \delta_t) + \beta_2\delta_t + \gamma_i + \varepsilon_{it} \quad (2)$$

where Y_{it} is the efficiency score of facility i at time t . $P4P_i$ is a dummy variable, taking the value 1 if a facility is exposed to P4P and 0 if not. We included facility fixed effects γ_i and year fixed effects δ_t . The error term is ε_{it} . The effect of P4P on the efficiency scores is given by β_1 .

As average programme effect may mask important heterogeneous effects, we further attempted to assess the heterogeneous effect of P4P by facility type. We included in the regression the interaction term between P4P in 2013 and the category considered for heterogeneity, along with the category itself. The following regression was estimated:

$$Y_{it} = \beta_0 + \beta_1(P4P_i \times \delta_t \times H_i) + \beta_2(P4P_i \times \delta_t) + \beta_3H_i + \beta_4\delta_t + \gamma_i + \varepsilon_{it} \quad (3)$$

where Y_{it} is the efficiency score of facility i (in model 1 we include dispensaries, health centres and hospitals, and in model 2 only health centre and hospitals) in year t . $P4P_i$ is a dummy variable, taking the value 1 if a facility is exposed to P4P and 0 if not. H_i is a dummy variable indicating the group for which we tested heterogeneity in four separate regressions: 1) Urban versus Rural facilities; 2) Public versus Private facilities; 3) Dispensaries versus other facilities; and 4) Facilities with average socio-economic status in the catchment population lower than median. We included facility fixed effects γ_i and year fixed effects δ_t . The error term is ε_{it} . The effect of P4P on the efficiency scores for a specific category of health facilities is given by β_1 .

We estimated the regression using the Stata user-written command *simarwilson* with externally estimated efficiency scores and 2,000 replications⁷. In model 1 we included dispensaries, health centres and hospitals, and in model 2 only health centre and hospitals. The analysis was performed using Stata 15.

⁷ Badunenko O, Tauchmann H. Simar and Wilson two-stage efficiency analysis for Stata. *The Stata Journal* 2019;19(4):950-88.