

Efficiency and Its Determinants in Community Health Service Centers in a Deeply Aging Peri-Urban District: A Three-Stage DEA-Tobit Analysis of Chongming District, Shanghai (2016-2025)

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Abstract: Community health service centers (CHSCs) anchor China's tiered healthcare system, yet efficiency in rural/peri-urban CHSCs facing depopulation and aging remains unclear once environment is accounted for. Using a ten-year panel of all 18 CHSCs in Chongming, Shanghai's largest, least dense, most aged district (2016-2025, 180 observations), we apply a three-stage DEA-Tobit framework: Stage 1 input-oriented BCC efficiency; Stage 2 stochastic frontier analysis (SFA) removing environmental effects and noise; Stage 3 re-estimation with adjusted inputs; then panel Tobit regression on determinants. Mean comprehensive technical efficiency was 0.874 (Stage 1) and 0.862 (Stage 3), but composition reversed: pure technical efficiency rose 0.917 to 0.939, scale efficiency fell 0.952 to 0.915, showing management is relatively strong and scale diseconomy binds. Bed redundancy was highest (15.8%). Bachelor's-degree staff share and operating years robustly raised efficiency; fiscal-subsidy dependence lowered it; family-doctor contract coverage showed no robust effect. Efficiency rose monotonically with township size (0.658, 0.897, 0.951 for remote, general, central townships). In environmentally homogeneous rural settings, efficiency gains hinge on management, human capital, and fiscal-incentive reform rather than capacity expansion.

Keywords: community health service center; three-stage DEA; Tobit regression; efficiency; aging; primary healthcare

1. Introduction

CHSCs are gatekeepers of China's primary-care network, but many rural and peri-urban centers show weak capacity utilization and limited downward referral despite rising investment. Chongming District—Shanghai's largest, least dense, most aged district, with over 40% of residents aged 60+ and continuing outmigration—typifies this challenge across its 18 townships. Prior DEA studies of Chinese CHSCs, including one covering Chongming through 2023 [1], rarely purge environmental influence from efficiency scores or model its determinants, and often under-represent elderly-care output. This study applies a three-stage DEA-Tobit design to all 18 Chongming CHSCs (2016-2025) to obtain “net” managerial efficiency, test environmental heterogeneity, and identify controllable determinants for policy design.

2. Materials and Methods

2.1 Setting and Data

DMUs are the 18 CHSCs matching Chongming's 18 townships, 2016-2025 (180 DMU-years)[2]. Input-output data come from centers' reports to the district health commission; environmental variables (population density, distance to nearest hospital, aging ratio) come from the Chongming Statistical Yearbook, with limited 2025 gaps trend-extrapolated. DEAP 2.1 (Stages 1, 3), Frontier 4.1c (Stage 2) and Stata 18 (Tobit) were used, with each year treated as an independent frontier[3].

2.2 Indicators

After screening nine candidate inputs/outputs against availability, salience and parsimony criteria [4], three inputs (health technicians, actual beds, annual expenditure) and three outputs (total visits, combined hypertension/diabetes management caseload, elderly check-ups) were retained; the latter two outputs capture the aging-driven service burden. All input-output pairs correlate positively ($p < .05$).

2.3 Three-Stage DEA

Stage 1 uses an input-oriented, variable-returns BCC model [4], giving $TE = PTE \times SE$ and input slacks. Stage 2 regresses each slack on environmental variables via SFA, $S = f(Z; \beta) + v + u$ [5], with $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ indicating the managerial-inefficiency share; inputs are adjusted to a common environment/noise level using the Jondrow estimator [6]. Stage 3 reruns BCC on adjusted inputs.

2.4 Panel Tobit

With 51/180 (28.3%) Stage-3 scores censored at 1, a right-censored Tobit model is used [7], mainly pooled with township-clustered SEs, with random-effects Tobit as a robustness check (fixed effects being infeasible [8]). Explanatory variables: bachelor's-degree-or-above share (x1), licensed-physician share (x2), fiscal-subsidy share (x3), family-doctor contract rate (x4), operating years (x5), plus pandemic and trend controls. VIFs (mean 2.08, max 4.11) rule out multicollinearity.

3. Results

3.1 Stage 1

Mean TE was 0.874 (PTE 0.917, SE 0.952); 30.6% of DMU-years were efficient. Hengsha and Miaozhen were efficient every year; Dongping (mean TE 0.547), Xinhai (0.707) and Changxing (0.742) lagged persistently.

3.2 Stage 2

Gamma values (0.967, 0.924, 0.973, all $p < .01$; Table 1) show over 90% of slack variance reflects managerial inefficiency, indicating strong environmental homogeneity across townships. The aging ratio most strongly reduces staffing/expenditure slack ($\beta = -23.11$, $p < .01$; $\beta = -19.48$, $p < .05$), consistent with denser real demand in older townships; distance to hospital reduces slack at 10%; density is never significant.

Table 1. Stage 2 SFA results

Parameter	Staff slack	Bed slack	Expenditure slack
Aging ratio (β_3)	-23.11 (-2.97)***	17.54 (0.86)	-19.48 (-2.41)**
Distance to hospital (β_2)	-0.134 (-1.66)*	-0.256 (-1.58)	-0.084 (-1.66)*
Gamma	0.967 (69.0)***	0.924 (115)***	0.973 (74.3)***

Note: t-values in parentheses; *, **, *** = 10%, 5%, 1%.

3.3 Stage 3

Mean TE fell slightly to 0.862; PTE rose to 0.939, SE fell to 0.915 (Table 2), reversing the Stage-1 diagnosis: scale diseconomy, not management, is now the binding constraint. Stage-1/Stage-3 rank correlations remain high (TE $r = 0.911$; PTE $r = 0.984$). Small townships (Luhua, Xincun) lost the most efficiency after adjustment, exposing under-scaling; Changxing gained, indicating prior unfavorable environment. Mean TE rises monotonically from remote small towns (0.658, $n = 4$) to general townships (0.897, $n = 8$) to central towns (0.951, $n = 6$).

Table 2. Efficiency by stage (N=180)

Measure	Stage 1	Stage 3	Change
TE	0.874	0.862	-0.012
PTE	0.917	0.939	+0.022
SE	0.952	0.915	-0.037

3.4 Input Redundancy

Bed redundancy (15.8%) far exceeds staff (9.3%) and expenditure (9.1%) redundancy, reflecting weak, pandemic-disrupted inpatient demand against tighter staffing/expenditure control.

3.5 Tobit Results

Bachelor's-degree share is the most robust positive determinant (pooled $\beta = 0.406$, $p < .01$; RE $\beta = 0.225$, $p < .01$); operating years is likewise robust (pooled $\beta = 0.005$, $p < .01$; RE $\beta = 0.007$, $p < .01$). Licensed-physician share is significant only in pooled estimates ($\beta = 0.518$, $p < .01$), suggesting cross-township rather than within-township effects. Fiscal-subsidy share is negative in the pooled model ($\beta = -0.584$, $p < .01$) but loses significance with clustering. Family-doctor coverage is never significant; health-record registration rate is significantly negative in extended models ($\beta = -0.328$, $p < .01$).

Table 3. Panel Tobit results (DV: Stage-3 TE)

Variable	Pooled	Clustered SE	Random effects
x1 Bachelor's share	0.406***	0.406***	0.225***
x2 Physician share	0.518***	0.518*	0.021

Variable	Pooled	Clustered SE	Random effects
x3 Fiscal-subsidy share	-0.584***	-0.584	-0.065
x5 Operating years	0.005***	0.005***	0.007***
Observations	180	180	180

4. Discussion

Once environment is purged, management is comparatively strong (PTE 0.939); residual inefficiency is chiefly a scale problem, with small remote centers under-scaled and some central townships mildly over-capacitated, particularly in beds—calling for differentiated rather than uniform intervention. High gamma values indicate townships are environmentally near-homogeneous, so post-adjustment gaps mainly reflect internal management, making peer benchmarking fair and actionable. The negative fiscal-dependence coefficient fits a soft-budget-constraint reading of the district's revenue-remittance/expenditure-appropriation system, where cost control is weakly linked to institutional reward [9]. Human-capital quality and clinical structure, both more directly manageable, are the strongest positive levers. Null results for contract coverage and negative results for record registration point to a “quantity over quality” pattern in public-health delivery.

5. Policy Implications

(1) Prioritize recruitment/retention that raises bachelor's-degree and licensed-physician shares. (2) Preserve managerial continuity and formalize peer-learning from persistently efficient townships (Hengsha, Miaozhen) to lagging ones (Dongping, Xinhai), given environmental homogeneity. (3) Shift family-doctor and health-record work from coverage targets to fulfillment/quality metrics, drawing on the UK Quality and Outcomes Framework [10] and Xiamen's team-based contracting model [11]. (4) Reform fiscal incentives toward performance-linked subsidies and retained-savings arrangements, as piloted in Sanming/Dongtai consortia [12], to reduce bed redundancy via consolidation. (5) Favor networked cooperation over unilateral expansion for remote townships, contain further capacity growth in larger townships, and reorient services toward chronic-disease and geriatric care, informed by Japan's community-based integrated-care model [13].

6. Conclusion

Net of environment, Chongming's CHSCs show relatively strong management but binding scale diseconomy; environmental conditions are highly homogeneous; and human-capital quality and institutional maturity are the most robust controllable efficiency determinants, while fiscal dependence and quantity-oriented public-health targets are associated with lower efficiency. These patterns likely generalize to comparable aging rural/peri-urban districts, though absolute efficiency levels are context-bound. Limitations include trend-extrapolated 2025 environmental data, omitted “soft” outputs (satisfaction, morale), potential reverse causality in the Tobit specification, and single-district scope; future work could add quasi-experimental identification and cross-district comparison.

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