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Abstract

Background: This study examines long-term patterns in the WHO/WDI modelled proportion of the Somali population primarily using clean fuels and technologies for cooking, with attention to urban–rural disparities. Methods: Annual published estimates for 2001–2023 (23 years) were summarized using endpoint differences, descriptive OLS trends with Newey–West (lag 2) standard errors, Kendall tau-b and Sen's slope. Exploratory one-break segmented models assessed sensitivity to time-varying rates. Results: In the supplied dataset, national access rose from 0.4% to 5.4%, urban access from 0.3% to 8.8%, and rural access from 0.3% to 0.5%. The urban–rural absolute gap rose from 0.0 to 8.3 percentage points. Rural improvement was negligible in practical terms. Linear models showed positive average long-run slopes, but strong dependence and curvature for some series limit interpretation of naive statistical significance. The 2001 national estimate exceeds both published subgroup values and requires source-vintage reconciliation. Conclusions: Modelled access rose predominantly in urban areas while the absolute urban–rural disparity widened. Results are descriptive, and cannot establish underlying causes or household-level outcomes.
Keywords: clean cooking; modelled estimates; Somalia; urban–rural disparity; SDG 7; longitudinal trends.

1. Introduction

Access to clean cooking fuels and technologies is a critical element of sustainable development, as it has implications for public health, gender equality, environmental sustainability and socio-economic well-being. Clean cooking broadly covers fuels and technologies such as liquefied petroleum gas (LPG), electricity, biogas, natural gas and other technologies meeting set emission-performance standards. Sustainable Development Goal (SDG) 7.1 explicitly recognizes universal access to affordable, reliable and modern energy services. Yet, despite this commitment, more than two billion people around the world still rely on polluting fuels, including firewood, charcoal, kerosene, coal and agricultural residues, with the greatest burden concentrated in low- and middle-income countries. Household air pollution from these fuels contributes substantially to premature mortality and is linked to respiratory and cardiovascular diseases, adverse pregnancy outcomes and impaired child development. Reliance on biomass also places a disproportionate time burden on women and girls, contributes to deforestation and land degradation, and generates emissions that undermine climate-change mitigation efforts (Belaïd & Hejazi, 2026; International Energy Agency, 2021, 2025; Khavari et al., 2023; Stoner et al., 2021; Uny et al., 2024; World Bank, 2025).

The challenge is most acute in Sub-Saharan Africa (SSA), where progress toward universal clean cooking is far outstripped by population growth and energy demand. An estimated 23% of the regional population had access to clean cooking solutions by 2024, leaving approximately 970–990 million people without

access. Current trajectories suggest that universal access is unlikely to be achieved in the region by 2030. Persistent energy poverty, insufficient infrastructure, lack of affordability of modern fuels, weak policy and regulatory environments, and large informal biomass markets continue to hinder the transition (Belaïd & Hejazi, 2026; Energy Transition Africa, 2024; International Energy Agency, 2025, 2026; Khavari et al., 2023; Malah-Kuete, 2025; World Bank, 2025; Yadav et al., 2025). The constraints are not spatially uniform. Rural households are still much less likely than urban households to use modern cooking fuels, and the continued growth in charcoal use suggests that energy transitions tend to involve fuel stacking rather than the complete substitution of traditional fuels by cleaner alternatives (Energy Transition Africa, 2024; OPEC Fund Clean Cooking Report 2024, n.d.; Uny et al., 2024).

In this regional challenge, Somalia is a particularly important case. The country has widespread energy poverty, fragile infrastructure, high dependence on biomass, large urban–rural inequalities, recurrent climatic shocks, and a highly decentralized energy system. In 2022, only 4.8% of the population had access to clean cooking fuels and cooking technologies, and charcoal and firewood accounted for 47.9% and 41.3% of household cooking energy respectively. There is a great deal of variation in the pattern by residence: charcoal is especially important in urban areas; firewood is prevalent in rural households; and around 94.3% of the nomadic and pastoralist population use firewood (Ali et al., 2025; National Bureau of Statistics, 2023; World Bank, 2026). These differences imply that national averages alone may mask significant differences in the speed and distribution of Somalia's clean cooking transition.

While existing household surveys and recent studies provide valuable evidence on fuel use and its socioeconomic determinants in Somalia, the available literature is mainly descriptive and cross-sectional. Existing analyzes predominantly offer point-in-time estimates of household energy choices and identify factors such as residence, electricity availability, wealth, and remittance income, but provide little evidence on how access to clean cooking has changed over longer periods (African Power Platform, 2025; Ali et al., 2025; National Bureau of Statistics, 2023; Puntland Ministry of Planning, Economic Development and International Cooperation, 2023; World Bank, 2026). Consequently, it is unclear whether Somalia's progress has sped up, stalled or reversed over time and, crucially, whether improvements have been shared equally between urban and rural populations. The absence of a systematic long-term assessment hinders the evaluation of progress on SDG 7 and limits the evidence for targeting scarce energy sector resources (International Trade Administration, 2024; National Bureau of Statistics, 2023; World Bank, 2026).

This paper addresses this gap by examining how access to clean cooking fuels and technologies has evolved in Somalia over the 23-year period from 2001 to 2023, with a specific focus on urban-rural disparities. Specifically, the study aims to (1) analyze long-term national trends in clean cooking fuels and technologies access; (2) compare urban and rural access trajectories, and estimate the size and orientation of the urban–rural gap; and (3) examine if the gap has closed, expanded, or stayed constant over time. Longitudinal analysis is even more beneficial in fragile contexts where household surveys with national coverage are conducted irregularly, as it enables the examination of trends, stagnation periods, and shifts in inequality using the scarce longitudinal data at hand (Yadav et al., 2025).

This paper is innovative in shifting the analytical emphasis from static levels of household energy access to the temporal development and distribution of clean cooking progress in Somalia. Rather than providing another cross-sectional estimate of who uses clean cooking fuels, the study evaluates the evolution of

national, urban and rural access over more than two decades and directly estimates the changing urban–rural gap. In doing so, it provides a longitudinal perspective that is largely absent in the existing Somalia-specific literature.

The study therefore makes three major contributions. First, it enhances the empirical evidence by constructing and analyzing a continuous long-term trajectory of clean cooking access, rather than isolated survey years. Second, it considers energy inequality as a dynamic outcome, measuring whether urban and rural populations are converging or diverging, instead of just reporting differences at a single point in time. Third, this study provides evidence for a fragile and conflict-affected country with extreme infrastructure constraints, relevant not only for Somalia's SDG 7 monitoring and national energy planning but also for other fragile contexts where data is limited and persistent spatial inequalities are hindering clean-energy transitions.

2. Review of the literature

Historically, the dominant theoretical framework for understanding household energy transitions has been the energy ladder hypothesis . The energy ladder hypothesis suggests that household energy choices evolve along a ladder from traditional biomass to transitional and finally modern fuels as income increases . Within this framework, economic improvement should lead to a transition from firewood and charcoal to LPG, electricity and other cleaner energy sources. But empirical evidence is increasingly challenging the assumption of a simple linear transition. Studies across Africa show that when households have access to modern fuels, they often continue to use traditional fuels, resulting in fuel stacking, where multiple fuels are used depending on cooking needs, affordability, availability and reliability. Therefore, household energy transitions are increasingly considered multidimensional processes shaped by economic, infrastructural, demographic, institutional and behavioral factors beyond income (Ngango & Hirwa, 2026; Ntegwa & Olan'g, 2023; Ochieng et al., 2020; Perros et al., 2023; Pye et al., 2020; Sani et al., 2026; Shankar et al., 2020; Uny et al., 2024; Yadav et al., 2025).

Empirical work in SSA supports this broader interpretation. Household economic status is consistently linked with the adoption of LPG, electricity and other cleaner fuels, while education can influence energy choice through greater awareness, earning capacity and engagement with the formal energy markets. Access to electricity is also important, both as a direct cooking option and as a proxy for broader infrastructure and market connectivity. Household size, age of the household head, housing characteristics, media exposure, proximity to markets and fuel-distribution networks have also been identified as important determinants. Larger, poorer, older, and geographically isolated households tend to be more persistent in biomass dependence (Adams et al., 2022; Haq et al., 2024; Ngango & Hirwa, 2026; Ntegwa & Olan'g, 2023; Sani et al., 2026).

Place of residence is particularly important since access to clean cooking infrastructure and markets is highly spatially differentiated. Rural households tend to have higher transportation costs, poorer distribution systems, lower electricity connectivity, and less purchasing power. For example, evidence from Tanzania suggests that access to electricity, education and household economic status explain a large share of the

urban–rural disparity in clean cooking, with access to electricity alone explaining an estimated 22–28% of the explained difference. Strong sub-national inequalities have also been noted elsewhere. In Nigeria, reported clean cooking utilization varies from around 70.9% in the South West to a mere 4.0% in the North East. These inequalities are further compounded by gender as female-headed households in some contexts face constraints related to access to finance, institutional support and control over household energy decisions (Ngango & Hirwa, 2026; Ntegwa & Olan'g, 2023; Ochieng et al., 2020; Perros et al., 2023; Pye et al., 2020; Sani et al., 2026; Shankar et al., 2020; Uny et al., 2024; Yadav et al., 2025).

However, the methodological structure of this evidence base is an important limitation. Much of the clean cooking research relies on cross-sectional household surveys, which are good for identifying the socioeconomic correlates of fuel choice, but provide relatively limited information on how access and inequalities evolve over time. One synthesis reported that approximately 73.6% of studies employed cross-sectional designs, whereas only 26.4% utilized longitudinal approaches. This imbalance is important as cross-sectional associations do not determine if population-level clean cooking transitions are speeding up, slowing down, or increasing in inequality over time (Ngango & Hirwa, 2026; Ntegwa & Olan'g, 2023; Ochieng et al., 2020; Perros et al., 2023; Pye et al., 2020; Sani et al., 2026; Shankar et al., 2020; Uny et al., 2024; Yadav et al., 2025).

These regional dynamics are especially pertinent for Somalia where unique structural factors limit the clean cooking transition. Access to electricity remains highly unequal, with about 80.1% of urban residents reported to have access, compared to 39.4% of rural residents and less than 9% of nomadic households. Electricity prices have also been historically very high due to reliance on imported diesel, fragmented private mini-grids and no integrated national network. LPG is a potentially important clean cooking alternative, but its uptake is limited by import costs, lack of distribution infrastructure, and affordability and safety issues, particularly outside of major urban centers. Such barriers exist in addition to the widespread multidimensional poverty, with the most acute disadvantages concentrated among rural and nomadic populations (Abdi et al., 2025; National Bureau of Statistics, 2023; World Bank, 2021, 2026).

Institutional and environmental conditions add another layer of complexity. Prolonged conflict, fragmented governance, climatic shocks and historically weak energy-sector regulation have constrained infrastructure development and investment. There is increasing institutional attention to the energy sector, with recent reforms such as the National Electricity Law (2023), establishment of the National Electricity Authority, the Somalia Electricity Recovery Project, and the long-term Optimized Cost Electricity Generation and Transmission Development Plan. Nevertheless, implementation is relatively recent, and clean cooking has received less policy attention than electricity generation. Moreover, persistent use of charcoal and fuelwood results in forest degradation, loss of vegetation, soil erosion, and pressure on biodiversity. The political economy of charcoal production and trade has also hampered efforts to reduce dependence on biomass (Ministry of Energy and Water Resources, 2025; Okash, 2025; Puntland Ministry of Planning, Economic Development and International Cooperation, 2023; World Bank, 2021).

Somalia-specific empirical evidence is beginning to document these conditions, mainly through household surveys such as the Somalia Integrated Household Budget Survey (SIHBS) and related regional household assessments. Prior studies have shown that there are large differences in fuel use by residence. Factors associated with household energy choices include electricity access, household wealth, place of residence

and remittance flows. However, such studies largely reflect the situation at specific survey moments and therefore provide limited insights into temporal changes (African Power Platform, 2025; Ali et al., 2025; National Bureau of Statistics, 2023; Puntland Ministry of Planning, Economic Development and International Cooperation, 2023; World Bank, 2026).

The literature, taken together, shows significant progress in understanding who adopts clean cooking and why, but much less is known about how access itself changes over time in fragile settings. This is the distinction on which the present study turns. The empirical question that remains is not whether urban and rural households in Somalia differ in terms of access to clean cooking (the evidence already clearly shows they do), but whether that inequality has narrowed, remained constant, or widened over the longer term. Therefore, the analysis of the 2001–2023 national, urban, and rural trajectories complements the existing literature on determinants by adding a temporal and distributional perspective to the Somali clean cooking transition.

2. Methodology

2.1 Study Area

Somalia is located in the Horn of Africa and covers approximately 637,657 km², with a coastline of about 3,333 km along the Gulf of Aden and the Indian Ocean. The country is bordered by Djibouti, Ethiopia, and Kenya and is characterized predominantly by arid and semi-arid plains, plateaus, and lowlands, with mountainous terrain in the north. Its population is distributed across rapidly growing urban centres, sedentary agricultural communities concentrated mainly along the Juba and Shabelle river basins, and mobile pastoral populations occupying much of the central and northern regions.

The climate is predominantly arid to semi-arid, with high temperatures, marked rainfall variability, and recurrent droughts and floods. Rainfall follows four main seasons: Gu (April–June), the principal rainy season; Xagaa (July–September), a dry and windy period; Deyr (October–December), the secondary rainy season; and Jilaal (January–March), the main dry season. Annual precipitation varies from less than 100 mm in the driest northern areas to approximately 500–700 mm in the wetter southern regions. These climatic and environmental conditions strongly influence agriculture, livestock production, water availability, population mobility, and overall livelihood vulnerability.

Somalia's energy sector is characterized by fragmented electricity networks, limited grid infrastructure, dependence on private electricity providers, and substantial urban–rural disparities in energy access. Traditional biomass, particularly charcoal and fuelwood, remains widely used for household cooking, contributing to deforestation, land degradation, and household air pollution. Although solar photovoltaic systems, hybrid mini-grids, LPG, and other modern energy technologies are increasingly expanding, access remains concentrated mainly in urban areas, while many rural and nomadic communities continue to experience limited access to electricity and clean cooking services.

2.2 Study design and analytical period

This retrospective descriptive longitudinal assessment covers 2001–2023 (23 annual published modelled estimates). The calendar year is the unit of analysis, rather than an independently sampled household survey. The temporal window was defined as the study period and does not imply that WDI lacks observations outside these years. No causal relationships are estimated.

2.3 Data source and processing

We examined published annual estimates of the proportion of the population primarily using clean fuels and technologies for cooking, for Somalia (World Development Indicators, WDI), over the prespecified analytic period 2001–2023. Indicators were national EG.CFT.ACCS.ZS, urban EG.CFT.ACCS.UR.ZS, and rural EG.CFT.ACCS.RU.ZS. These are model-based WHO Global Household Energy Model estimates informed by national household surveys, not 23 independent annual household surveys. The Bayesian hierarchical estimation framework smooths time trends and jointly models fuel categories and urban–rural populations (Stoner et al., 2020; Stoner et al., 2021). The analysis uses the supplied WDI-derived workbook; its download date and archived series vintage were not recorded and cannot currently be verified. The study years define the target window, although WDI publishes data outside that interval.

The dataset was sorted by calendar year, assessed for duplicate years, missing values and out-of-range percentages, and the urban–rural gap was defined as urban access minus rural access (percentage points). National access was retained as its separately published series; it was not calculated by averaging the urban and rural series. In 2001 the national value (0.4%) is higher than both subgroup values (0.3% each), violating the weighted-average consistency check at reported precision. This discrepancy is unresolved; cross-vintage mixing, published rounding or other upstream processing cannot be asserted as the cause without the original source-level values. The authors should acquire same-vintage, higher-precision WDI/WHO values before interpreting that baseline. Changes based on the uncorrected national series are provisional. No missing values were imputed.

2.4 Definitions and descriptive analysis

National, urban and rural percentages are each reported against their relevant population denominators. The urban–rural absolute gap (percentage points) is urban minus rural, not a population-weighted national access value. Descriptive summaries include reported endpoints, the endpoint difference and the endpoint average change (2023 minus 2001 divided by 22), which is distinct from the regression slope.

2.5 Statistical methods and diagnostic checks

Each outcome was summarized using its 2001 and 2023 estimates, absolute change, and endpoint average annual change defined as (value in 2023 − value in 2001)/22. Descriptive OLS fits used $y_t = \beta_0 + \beta_1$ (year − 2001) + ε_t, with β_1 reported in percentage points/year. To limit false precision from heteroskedastic and serially dependent residuals, 95% confidence intervals and two-sided p-values for β_1 were estimated using Newey–West HAC covariance with lag length 2. This covariance adjustment neither removes residual autocorrelation nor validates a linear data-generating model, especially for modelled yearly estimates. Durbin–Watson and Ljung–Box (lag 4, null: no autocorrelation through four lags) were applied to OLS residuals. Kendall tau-b and Theil–Sen median pairwise slopes provided supplementary descriptive trend estimates. Because WHO model smoothing and ties at the reported precision violate the interpretation of 23 independent measurements, unadjusted Kendall p-values are exploratory only.

As a parsimonious model-specification sensitivity, we fitted a continuous one-knot piecewise linear model $y_t = \alpha + b_1 t + b_2 \max(0, \text{year} - k) + e_t$, choosing the lowest-AIC fit across candidate k = 2006,...,2018 (at least five years before/after). The pre-break slope was b_1 and post-break slope was b_1+b_2. Breakpoints and associated nominal p-values were data-selected and must not be interpreted as confirmatory evidence of a

discrete policy or causal shift. Independent reanalysis was implemented in Python (NumPy, SciPy and statsmodels); original-analysis software should be reconciled with author records.

2.6 Interpretation of urban–rural inequalities

The absolute urban–rural gap is expressed in percentage points and measures neither relative inequality nor any nomadic-specific or district-level differences. Estimates of national and subgroup access are not interchangeable. The comparisons are descriptive; technology uptake, specific fuels and household determinants were not independently measured.

2.7 Inference, software and ethics

All nominal tests are two-sided; statistical significance does not imply practically important improvement. Newey–West covariance corrects standard errors under assumptions and does not remove residual correlation or the modelled nature of the values. Reanalysis was performed using Python (NumPy, SciPy, statsmodels). The original statistical software and exact package versions require confirmation from study records. Only openly available aggregated published values were used, so no participant recruitment or identifiable data were involved.

3 Results

3.1 Data completeness and descriptive characteristics

The supplied workbook contains 23 rows for 2001–2023 and no missing annual values or duplicate years. These are annual WHO/WDI modelled estimates, not 23 independent observed survey measurements. The reported national 2001 percentage (0.4%) exceeds both reported urban and rural values (0.3% each), and fails the published-precision weighted-average coherence check; therefore this national baseline and related comparisons are provisional until a single source vintage can be verified. National access changes from 0.4% to 5.4%, urban from 0.3% to 8.8%, and rural from 0.3% to 0.5% in the supplied file. The rural gain is only 0.2 percentage points over 22 years, indicating practical stagnation.

The published estimates display pronounced urban growth and persistently very low rural access. Because these annual values were modelled and smoothed, graphic appearance cannot alone identify a real-world acceleration or its causes.

Table 1: Descriptive statistics (recalculated from supplied workbook; provisional pending WDI source verification)

Indicator	N	2001	2023	Change (pp)	Endpoint pp/year	Mean	SD	Min	Max
National	23	0.40	5.40	5.00	0.2273	—	—	—	—

Urban	23	0.30	8.80	8.50	0.3864	—	—	—	—
Rural	23	0.30	0.50	0.20	0.0091	—	—	—	—
Urban–rural gap	23	0.00	8.30	8.30	0.3773	—	—	—	—

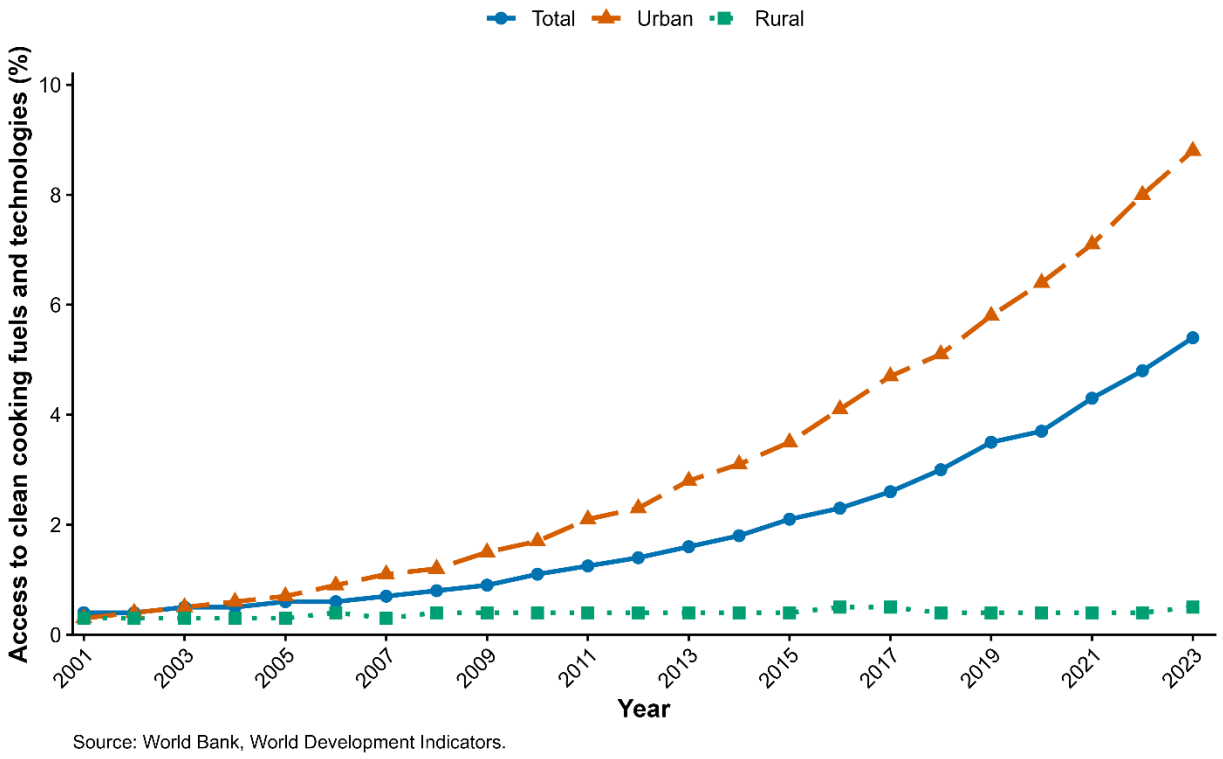


Figure 1: Trends in total, urban, and rural access, 2001–2023

3.2 Evolution of the urban–rural gap

The absolute urban–rural difference increased from 0.0 percentage points in 2001 (urban and rural both reported at 0.3%) to 8.3 percentage points in 2023 (8.8% versus 0.5%). This is a reported endpoint comparison, not an estimate of relative or household-level inequality.

The endpoint-based gap change is 8.3 percentage points, equivalent to 0.3773 percentage points per year averaged across 22 intervals. This is separate from the OLS slope of 0.3639 percentage points per year. The widening gap largely reflects the stronger numerical increase in urban estimates than rural estimates; the aggregate time series cannot determine the reasons.

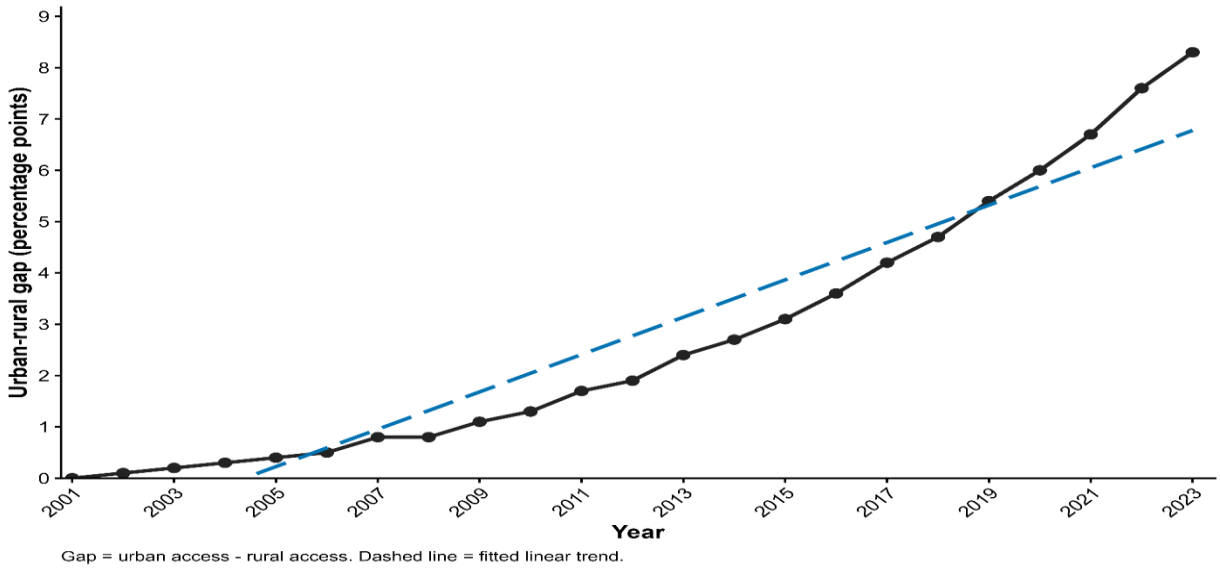


Figure 2: Urban–rural gap over time

3.3 Linear time trends and Newey–West HAC-adjusted estimates

Table 2 gives recalculated descriptive OLS trend slopes for each published series and two-sided lag-2 Newey–West confidence intervals. National: 0.2118 (95% CI 0.1542–0.2694); urban: 0.3708 (0.2878–0.4539); rural: 0.0069 (0.0039–0.0099); and urban–rural gap: 0.3639 (0.2790–0.4489) percentage points/year. The positive rural estimate is negligible practically; these slopes are full-period linear summaries, not necessarily constant actual rates of adoption.

HAC adjustment changes inferential uncertainty rather than the fitted OLS coefficients. The reported intervals do not include underlying WHO Bayesian model uncertainty. Positive slopes should not be interpreted as causal impacts or proof of acceleration.

Table 2: HAC-adjusted linear trend models (recalculated from supplied workbook; provisional pending WDI source verification)

Indicator	OLS beta (pp/y)	HAC SE	95% CI lower	95% CI upper	HAC p	R-squared	NW lag	Interpretation
National	0.2118	—	0.1542	0.2694	1.67e-07	—	2	Descriptive positive trend
Urban	0.3708	—	0.2878	0.4539	7.03e-09	—	2	Descriptive positive trend
Rural	0.0069	—	0.0039	0.0099	0.00011	—	2	Descriptive positive trend

Urban–rural gap	0.3639	—	0.2790	0.4489	1.41e-08	—	2	Descriptive positive trend

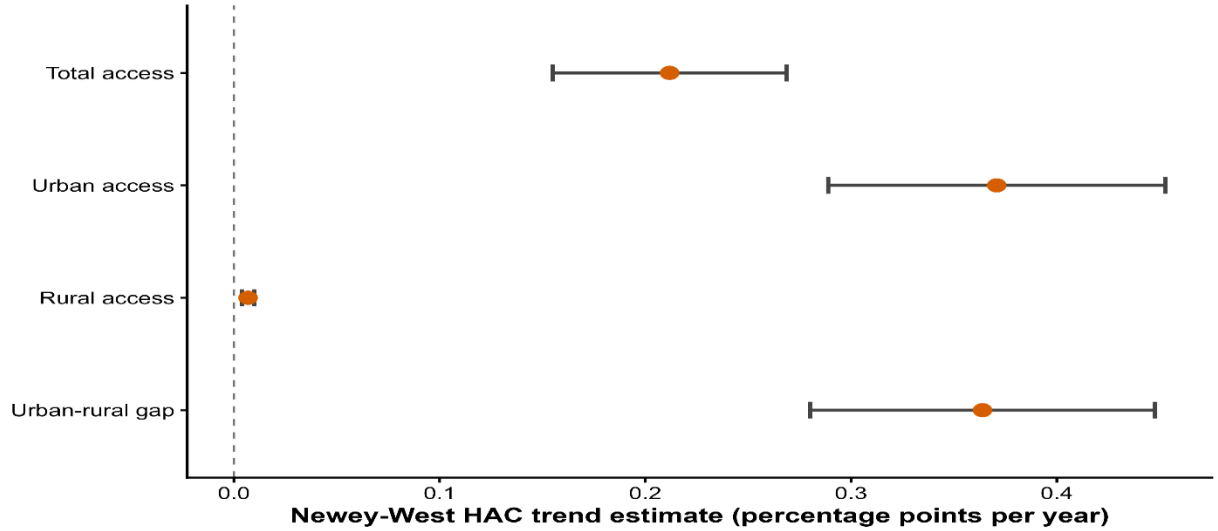


Figure 3: Newey–West HAC trend estimates with confidence intervals

3.4 Residual autocorrelation and regression diagnostics

OLS residuals exhibit strong positive serial dependence for national, urban and urban–rural gap estimates (Durbin–Watson 0.130, 0.115 and 0.109, respectively; Ljung–Box lag-4 Q = 27.60, 28.86 and 30.09). Rural residual diagnostics are weaker (Durbin–Watson 1.547; Ljung–Box lag-4 Q ≈ 2.14, p ≈ 0.71 in the independent reanalysis). The Ljung–Box test concerns residual autocorrelation through the specified lags. Curvature suggests linear trend misspecification; it does not by itself establish acceleration or a dated structural break.

An exploratory one-knot continuous segmented model (candidate knots 2006–2018; AIC selection) selected 2014 for the national, urban and gap series and 2016 for rural. The urban fitted slope was approximately 0.2099 pp/year before and 0.6443 after the selected knot; the gap slopes were 0.1991 and 0.6439. These are data-selected descriptive sensitivity results, not independently validated change points, causal transitions or evidence of a specific policy effect. WHO model smoothing and a short time series constrain their interpretation.

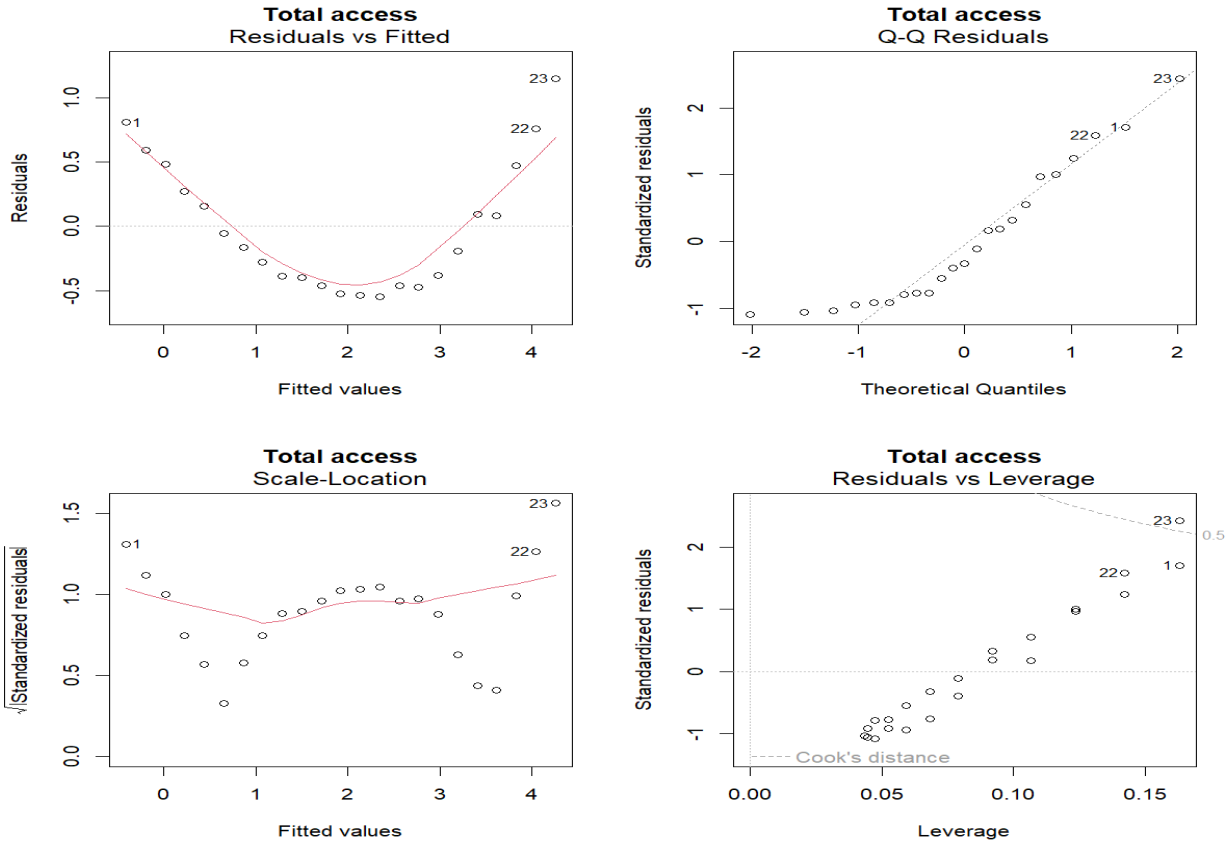


Figure 4:Diagnostic A: Total access

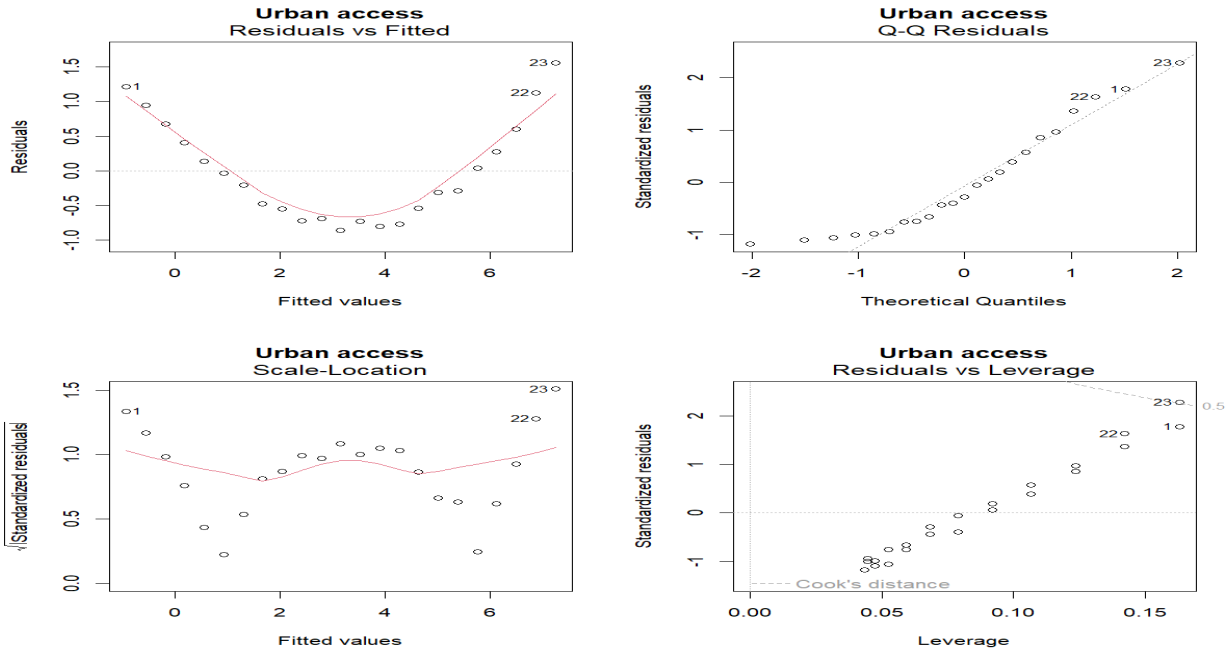


*Figure 4:***Diagnostic B: Urban access**

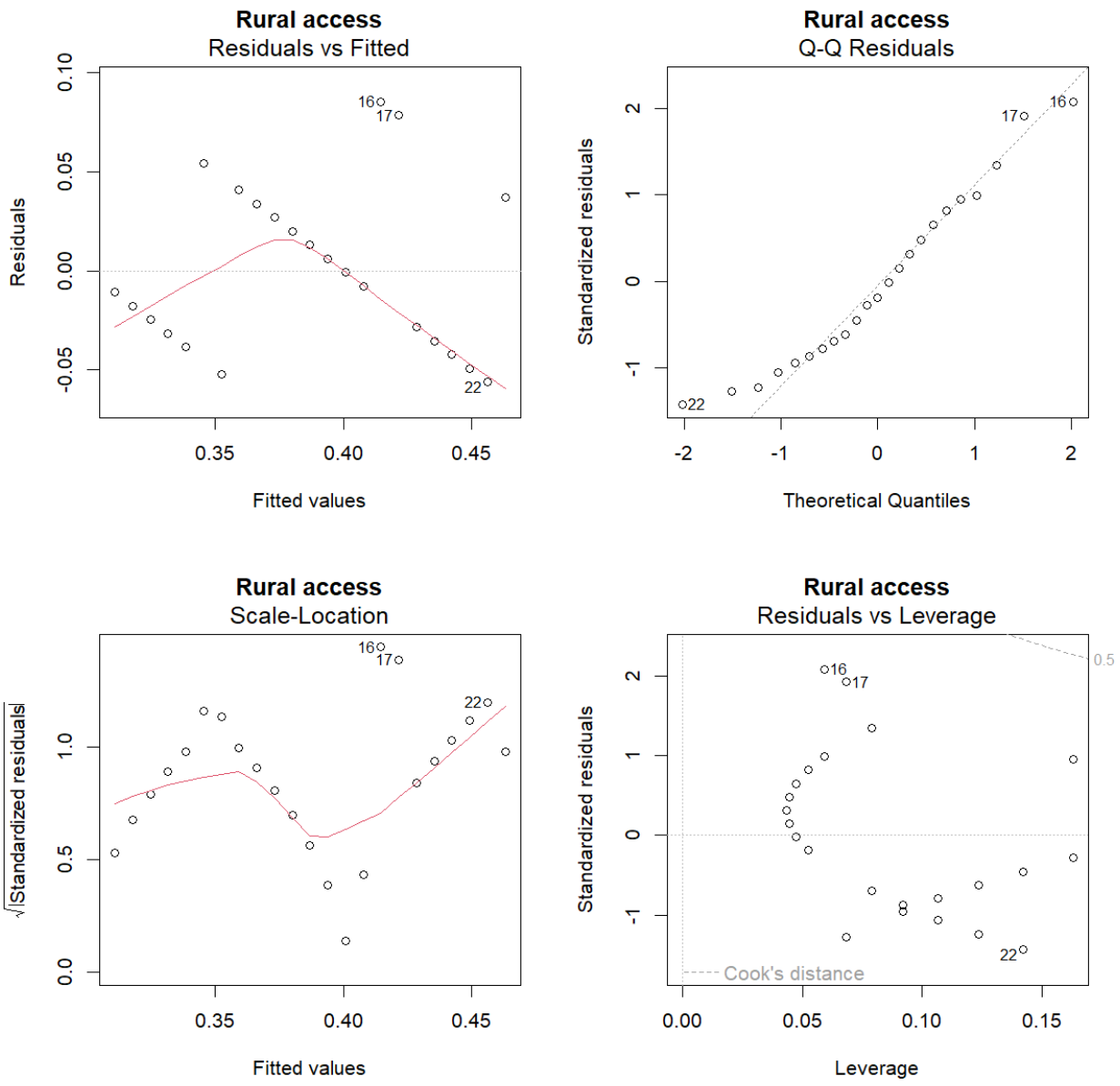


***Figure 4:*Diagnostic C: Rural access**

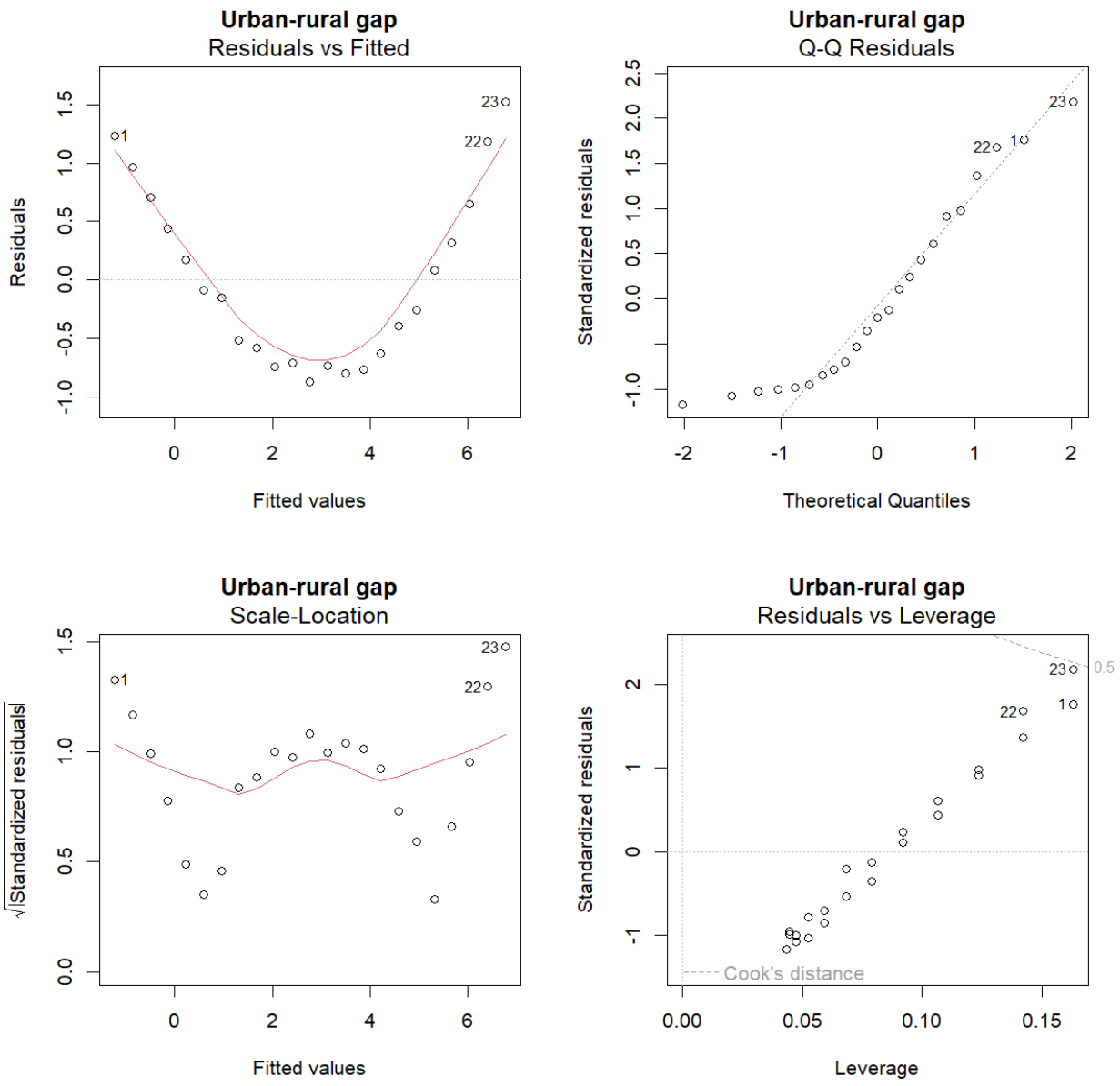


***Figure 4:*DiagnosticD: Urban–rural gap**

3.5 Nonparametric trend analysis

Kendall tau-b for national, urban, rural and the urban–rural gap was 0.9941, 1.0000, 0.6392 and 0.9921, respectively (Table 3). Conventional Kendall p-values are exploratory because annual published estimates are not independent and rounding produces ties. Newey–West regression does not adjust these separate nonparametric p-values.

The Theil–Sen pairwise median slope was 0.2000 (national), 0.3600 (urban), 0.0056 (rural) and 0.3500 (gap) percentage points/year. They describe monotonic variation and differ conceptually from OLS slopes

and endpoint changes. Numerical similarity does not provide independent validation because the estimates use the same WHO modelled series. Their conventional 95% confidence intervals do not incorporate WHO posterior uncertainty or temporal autocorrelation.

The high monotonic association of these series with time may partly reflect WHO model smoothing. Very small unadjusted trend-test p-values must not be taken as the precision of independently observed household trends.

Table 3: Mann–Kendall and Sen's slope results (recalculated from supplied workbook; provisional pending WDI source verification)

Indicator	Kendall tau-b	Naive p	Sen slope (pp/y)	Sen 95% CI	Interpretation
National	0.9941	3.86e-11	0.2000	0.1529–0.2400	Exploratory
Urban	1.0000	7.74e-23	0.3600	0.2937–0.4286	Exploratory
Rural	0.6392	0.000189	0.0056	0.0000–0.0083	Exploratory
Urban–rural gap	0.9921	1.78e-21	0.3500	0.2875–0.4211	Exploratory

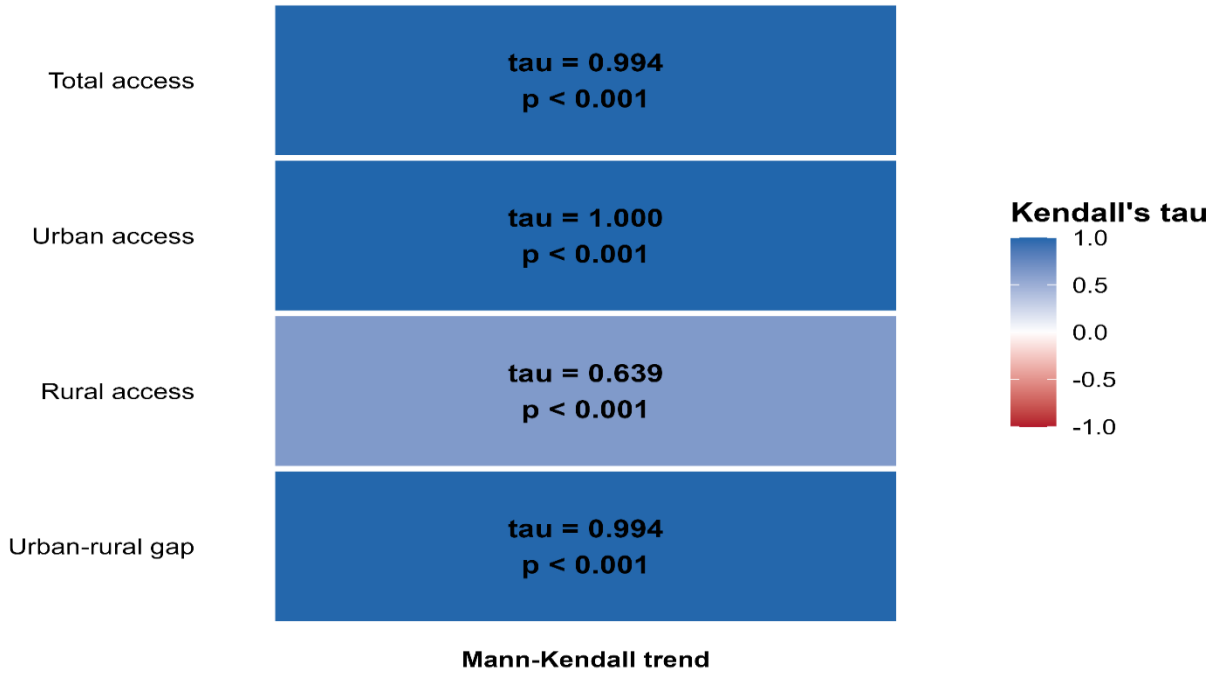


Figure 5: Mann–Kendall trend heatmap

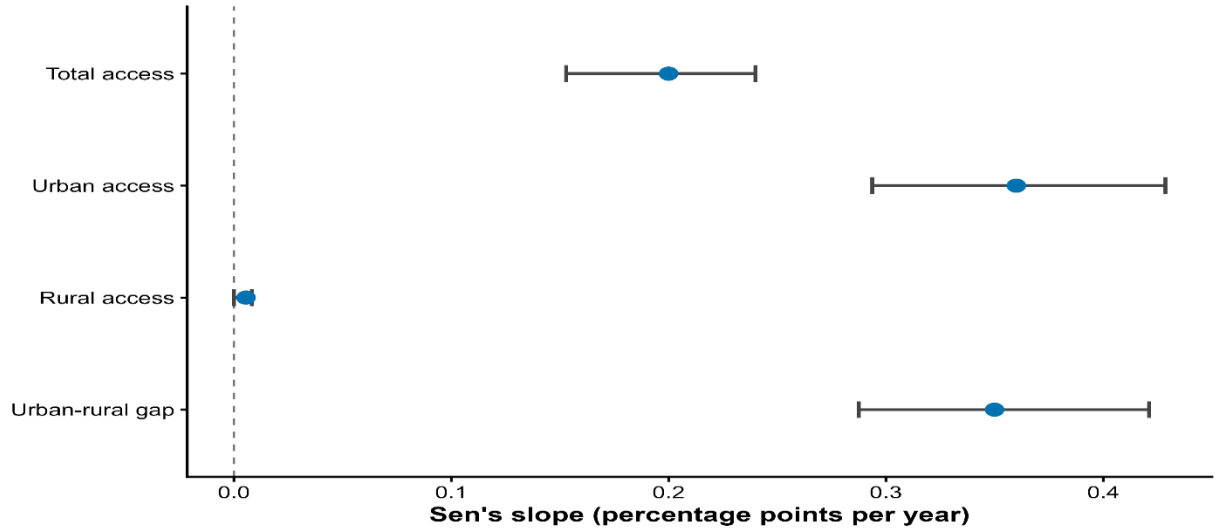


Figure 6: Sen's slope estimates

4.Discussion

4.1 Principal findings

Between 2001 and 2023, the available modelled estimates suggest a marked rise in urban clean-cooking access and little practical progress in rural Somalia. The urban–rural gap increased from 0.0 to 8.3 percentage points. The rural increase from 0.3% to 0.5% is a change of just 0.2 percentage points, and should be interpreted as practical stagnation rather than substantial progress. The linear slope represents a full-period descriptive average. The curved residuals and piecewise sensitivity indicate that rates of change may not have been constant. As the modelled annual values are temporally smooth and interdependent, very small p-values and high Kendall concordance can overstate the precision of claims about changes in unobserved household behaviour.

The descriptive contribution lies in comparing nationally published, urban and rural WHO/WDI annual estimates over a common study window, rather than demonstrating mechanisms of household fuel choice.

4.2 Contextual interpretation of the urban–rural difference

Affordability, infrastructure, LPG supply chains, electricity access and market distance are plausible explanations from the broader literature; none were tested using this four-series aggregate dataset. No assertions of causal drivers are justified by the present analysis.

4.3 Fuel and technology measurement

The WDI indicator refers to the proportion of people primarily using clean fuels and technologies for cooking. These results do not separately measure LPG, electricity, biogas, stove technical performance, exclusive clean-fuel use or fuel stacking. The aggregate measure cannot establish which specific cooking technologies were adopted or how households combined fuels.

4.4 Population and other outcomes beyond study scope

The urban–rural classification does not support separate estimation for nomadic communities, displaced households, administrative regions or federal states. Public health, gender, forest and climate outcomes were not examined and should be treated as potential directions for distinct future research, not outcomes demonstrated here.

4.5 Strengths and limitations

Interpretation is constrained by a short annual series (N = 23) of WHO modelled estimates rather than independent observations, survey sparsity, potential smoothing and temporal dependence, rounded/tied values, and the absence of corresponding WHO 95% uncertainty intervals in the supplied workbook. The inconsistent 2001 national/subgroup baseline and missing documented WDI extraction vintage are unresolved data-quality issues. Residual autocorrelation and systematic curvature limit linear-model inference, and HAC standard errors do not correct model misspecification. Country-level and urban/rural aggregates obscure variation by federal state, district, displacement or nomadic status, and do not identify actual clean stove use, technology performance, individual fuels or fuel stacking. The absolute gap omits relative or population-weighted inequalities. No health, gender, ecological or causal outcomes were measured.

Source verification remains an important prerequisite: the workbook does not establish WDI extraction date or archival series version; the 2001 national weighted-average inconsistency is unresolved; and WHO 95% uncertainty intervals were not supplied. A common-vintage WDI/WHO extraction with interval data and comparisons against Somali survey benchmarks is needed before treating all values as verified. Claims made here apply only to the supplied, provisional annual series.

5. Policy implications

The descriptive evidence points to a widening difference between published urban and rural clean-

cooking access estimates. Rural access remained extremely low despite a positive numerical trend. Programmatic priorities such as rural distribution networks, affordability assistance and reliable supply warrant independent feasibility testing; the time-series dataset does not establish their effectiveness or reveal the causes of the urban–rural difference. Future research should validate the WDI/WHO trajectory against the Somali Health and Demographic Survey and MICS fuel-use tables with harmonized definitions, evaluate WHO uncertainty intervals, and analyze household-level and regionally disaggregated data before drawing causal, health, environmental, gender or nomadic-specific conclusions.

6. Conclusion

Across the supplied 2001–2023 WHO/WDI modelled series, urban clean-cooking access increased considerably while rural access remained extremely low and nearly stagnant in practical terms. The urban–rural absolute difference widened to 8.3 percentage points in 2023. These are descriptive population-level estimates; serial dependence, model-based smoothing, baseline inconsistency and source-vintage uncertainty limit inferential interpretation. The evidence does not identify causes or measure health, gender, environmental or nomadic-specific outcomes.

Declarations

Ethical Approval and accordance

This study used exclusively publicly available and aggregated secondary data obtained from the World Bank World Development Indicators database. No human participants, identifiable personal data, biological materials, or live animals were involved. Therefore, ethical approval from an institutional review board or ethics committee was not required. The study was conducted in accordance with relevant ethical and research integrity guidelines.

Consent to participate

Not applicable. This study used only publicly available aggregated secondary data and did not involve direct participation or recruitment of human subjects.

Availability of data and materials

The source is the World Bank World Development Indicators (WDI), codes EG.CFT.ACCS.ZS, EG.CFT.ACCS.UR.ZS and EG.CFT.ACCS.RU.ZS. The precise extraction date, series vintage and WHO uncertainty intervals remain unavailable in the supplied analytic workbook. A verified same-vintage extract and processed yearly data should accompany the resubmission. The supplied workbook is the current provisional reproduction dataset.

https://data.worldbank.org/indicator/EG.CFT.ACCS.ZS?locations=SO

https://data.worldbank.org/indicator/EG.CFT.ACCS.UR.ZS?locations=SO

https://data.worldbank.org/indicator/EG.CFT.ACCS.RU.ZS?locations=SO

Competing interests

The authors declare that they have no competing interests.

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not applicable

Authors' contributions

Fatima Abdijabbar Ibrahim[1,2]

Conceptualization: Formulated the primary research idea, refined the study objectives, and designed the overall research framework.

Data Curation & Formal Analysis: Conducted data extraction from the World Bank World Development Indicators database, performed statistical processing, and executed the econometric models (Newey–West HAC linear regression, Mann–Kendall trend tests, and Sen's slope estimation).

Writing – Original Draft Preparation: Lead writer for the Introduction, Methodology, Results, and Abstract sections.

Nasro Salad Ahmed[1,2]

Conceptualization & Design: Collaborated on defining the study scope, structuring the research protocol, and establishing the analytical variables.

Data Curation & Visualizations: Assisted in data validation, dataset preparation, and generated the graphical illustrations (trend plots, diagnostic figures, and correlation heatmaps).**Writing – Original Draft Preparation:** Co-authored the Results and Methodology sections, ensuring accurate representation of statistical outputs.

Omar Aweis Ali[2,3]

Investigation & Literature Review: Conducted the literature search on energy poverty, clean cooking dynamics, and urban–rural energy transitions in Sub-Saharan Africa and fragile contexts.

Writing – Review & Editing: Contributed to drafting and revising the Discussion section, specifically contextualizing findings within regional trends and fuel stacking paradigms.

Abdiaziz Yusuf Abdullahi

Supervision & Methodology Validation: Provided technical oversight on the statistical methodology, econometric specifications, and time-series model diagnostic checks.

Writing – Review & Editing: Critically revised the manuscript for methodological rigour, theoretical clarity, and structural coherence.

Yasir Mohamed Abdinur[2,4]

Policy Analysis & Synthesis: Evaluated the policy implications regarding Somalia's National Electricity Law, energy sector reforms, and SDG Target 7.1 alignment.

Writing – Review & Editing: Drafted the Policy Implications and Conclusion sections, and provided final manuscript proofreading and editing for journal submission.

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Editorial verification note — remove before submission

This integrated manuscript retains the original article structure, bibliography and illustrative figures, and replaces the main analytical text and tabulated statistical estimates. Pending tasks: independently retrieve a dated, same-vintage WDI/WHO export; resolve national-versus-subgroup inconsistency in 2001; incorporate original WHO 95% uncertainty intervals if available; independently verify Somalia survey benchmarks; confirm software versions; and regenerate the original plotted figures using the final validated series. Tables with em dashes intentionally omit unverified metrics rather than inventing values. The response letter must be reconciled against the final source-verified manuscript before resubmission.