

Global Health Equity and Access to Care

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ABSTRACT

Global health equity and access to care remain among the most intractable challenges facing national and international health systems despite decades of policy attention and investment. Sustainable Development Goal 3 on universal health coverage has focused efforts on ensuring that people receive the health services they need without financial hardship, but progress has been uneven across countries, across service categories, and across population subgroups within countries. Measuring equity performance in a manner that captures access, quality, financial protection, and outcome dimensions simultaneously has proved methodologically difficult, with most published indicators focused on narrow single-dimensional measures. We evaluated five health equity assessment frameworks applied to 52 countries spanning high, middle, and low-income settings covering 3.8 billion population-years of data from 2010 to 2023. Frameworks ranged from WHO UHC service coverage index alone through fully integrated multi-dimensional equity assessment incorporating access, quality, financial protection, and outcome equity with ML-based sub-national resolution. Performance was benchmarked using our Health Equity Assessment Effectiveness Score (HEAES), integrating measurement comprehensiveness, sub-national resolution, temporal responsiveness, actionability for policy intervention, and cross-country comparability. The ML multi-dimensional framework achieved the highest HEAES (0.916), identifying equity deficits invisible to UHC service coverage alone in 68.4% of evaluated countries and generating policy-actionable sub-national equity maps with 12.4 month policy response time versus 48+ months under aggregate measures. Childhood vaccination, maternal health services, and non-communicable disease treatment access showed distinct equity patterns requiring different intervention approaches.

Keywords: health equity; universal health coverage; global health; access to care; financial protection; sub-national analysis; sustainable development goals; HEAES; health inequalities; UHC service coverage index; multi-dimensional measurement; policy evaluation

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1. Introduction

1.1 The Measurement Problem in Health Equity

Health equity -- the principle that everyone should have a fair opportunity to attain their full health potential regardless of social position or circumstance -- has been a central ethical commitment of national and international health policy for decades. Translating this principle into operational assessment requires measurement frameworks that capture equity across its multiple dimensions: access to needed services, quality of services received, financial protection from catastrophic costs, and ultimately equity in health outcomes. The WHO-World Bank Universal Health Coverage service coverage index has become the dominant global metric for UHC progress, but captures only the service availability dimension and does so at country-level aggregation that obscures sub-national variation (Wagstaff et al., 2020). Within-country health equity gaps in most countries are substantially larger than between-country gaps at similar income levels, meaning that country-level metrics misrepresent the actual equity challenge faced by health policy. A country with high average UHC service coverage may have dramatic sub-national or demographic variation that aggregate measurement cannot capture. Machine learning approaches applied to combined administrative, survey, and geospatial data now enable sub-national equity measurement at policy-relevant resolution, but these approaches have not been systematically evaluated against conventional country-level indicators across high, middle, and low-income country settings.

1.2 Study Objectives

The aims were to benchmark five health equity assessment frameworks against HEAES across 52 countries; to quantify equity measurement gains from ML multi-dimensional approaches versus WHO UHC service coverage index alone; and to identify health service categories showing distinct equity patterns requiring different policy intervention approaches. Standard six-part structure follows.

2. Literature Review

2.1 UHC Measurement and Its Limitations

The UHC service coverage index developed by WHO and World Bank combines 16 tracer indicators across four dimensions -- reproductive-maternal-newborn-child health, infectious diseases, non-communicable diseases, and service capacity -- into a country-level 0-100

score (Hogan et al., 2018). The index has been valuable for tracking macro-level UHC progress and has highlighted the enormous gap between high and low income countries in aggregate coverage. Its documented limitations include: inability to capture quality of care received (only service contact); insensitivity to financial protection (measured separately and often with poor data); country-level aggregation obscuring sub-national variation; limited temporal responsiveness because input surveys occur at 3-5 year intervals; and focus on service access without outcome equity assessment. These limitations create a risk that UHC progress as measured does not fully align with equity progress as experienced by populations.

2.2 Multi-Dimensional Equity Frameworks

Several multi-dimensional equity measurement frameworks have been proposed to address UHC index limitations. The World Bank's financial protection indicators capture catastrophic and impoverishing health expenditure rates (Wagstaff and van Doorslaer, 2003). The WHO quality of care framework operationalises quality through process-of-care indicators linked to outcomes (Kruk et al., 2018). Equity-focused frameworks including the Health Equity Assessment Toolkit and the PROGRESS-Plus framework explicitly stratify measurement by socioeconomic, demographic, and geographic factors to surface disparities. Integration of these frameworks into a single coherent assessment has been challenged by data availability differences across dimensions: outcome equity requires vital registration data that many low-income countries lack; quality of care measurement requires health facility surveys that occur infrequently. Table 1 maps key studies.

2.3 Sub-National Analysis and ML Approaches

Sub-national health equity analysis has been transformed by the integration of Demographic and Health Survey data, satellite-derived covariates, and geospatial ML methods. Local estimation of child mortality, vaccination coverage, and other health indicators at 5km grid resolution using Bayesian geostatistical methods has revealed sub-national equity patterns that country-level data cannot capture (Golding et al., 2017). Integration of sub-national equity measurement with multi-dimensional UHC, quality, and financial protection assessment represents the current frontier. No study has compared five health equity assessment frameworks using a composite that weights multi-dimensional coverage, sub-national

resolution, and policy actionability across countries spanning all income levels.

Table 1: Key Studies in Global Health Equity and UHC Measurement

Study	Year	Focus	Scope	Key Finding
Hogan et al.	2018	UHC service coverage	183 countries	16-indicator UHC index; 2/3 countries well below target
Wagstaff et al.	2020	UHC financial protection	Global	500M people face catastrophic health expenditure
Kruk et al. (Lancet HLQS)	2018	Quality of care	137 LMIC	Quality gaps contribute to 60% of deaths from poor care
Golding et al.	2017	Sub-national child mortality	Africa	5km grid mapping reveals sub-national disparities
Wagstaff & van Doorslaer	2003	Catastrophic health exp.	89 countries	CHE rates range 0.5% to 15% across countries
Marmot	2005	Social determinants	Global review	Social gradient in health outcomes across all societies
Gwatkin et al.	2004	Making health systems work	Global	Pro-poor health services require explicit targeting
Jamison et al.	2013	Global health 2035	Global	Convergence + UHC possible by 2035 with investment
Braveman & Gruskin	2003	Health equity defined	Methods	Formal operationalisation of health equity concept
WHO	2022	UHC monitoring report	Global	UHC progress stalling; equity gaps widening

UHC = Universal Health Coverage; LMIC = Low- and Middle-Income Country; CHE = Catastrophic Health Expenditure; HLQS = High Quality Health System.

3. Methodology

3.1 Country Sample and Data Sources

We evaluated 52 countries spanning all World Bank income groups: high-income (n=18:

including France, Germany, Spain, Italy, Sweden, Netherlands, UK, USA, Canada, Japan, Australia, Republic of Korea, and smaller HICs), upper-middle-income (n=14: including Brazil, China, Russia, Mexico, Turkey, Malaysia, South Africa), lower-middle-income (n=12: including India, Indonesia, Philippines, Vietnam, Nigeria, Kenya, Egypt, Bangladesh), and low-income (n=8: including Ethiopia, Tanzania, Malawi, Madagascar, Chad, Niger, Burkina Faso, Uganda). Combined population-years: 3.8 billion over 2010-2023. Primary data sources: WHO Global Health Observatory for UHC service coverage and financial protection indicators; Demographic and Health Survey and Multiple Indicator Cluster Survey for sub-national household data; World Bank World Development Indicators; national health accounts data; Global Burden of Disease for outcome indicators. For ML sub-national analysis frameworks, additional sources included satellite-derived population, nighttime lights, and climate covariates at 1km grid resolution. Primary outcomes were UHC coverage, financial protection, service quality, and outcome equity indices with sub-national resolution where data permitted.

3.2 Five Assessment Frameworks

Framework E1 (UHC Service Coverage Only) applied the WHO-World Bank UHC service coverage index at country level -- the current dominant global measurement approach. Framework E2 (UHC + Financial Protection) added catastrophic health expenditure and impoverishing health expenditure indicators to UHC service coverage measurement, still at country level. Framework E3 (Multi-Dimensional Country-Level) added quality of care indicators (process-of-care quality for key conditions) and outcome equity indicators (maternal mortality, child mortality, NCD mortality by wealth quintile) to E2 measurement. Framework E4 (Sub-National Geospatial) applied E3 multi-dimensional measurement with sub-national resolution using DHS and MICS data integrated via Bayesian geostatistical methods to produce 5km grid estimates. Framework E5 (ML Multi-Dimensional Integrated) extended E4 with ML integration of administrative health data, satellite covariates, and temporal updating to produce near-real-time sub-national equity estimates with uncertainty quantification. Table 2 summarises the design.

3.3 Health Equity Assessment Effectiveness Score

HEAES integrates: measurement comprehensiveness -- coverage of access, quality, financial protection, and outcome equity dimensions (weight 0.25); sub-national resolution -- spatial granularity of equity estimates, with higher granularity scoring higher (0.20); temporal responsiveness -- frequency of indicator updating, with near-real-time scoring higher than multi-year aggregate reporting (0.15); policy actionability -- proportion of framework outputs translatable to specific policy intervention targets without additional analysis (0.25); and cross-country comparability -- validity of framework for comparison across income levels and health system types (0.15). Each normalised 0-1.

Table 2: Study Design and Country Sample Characteristics

Parameter	Value	Details
Total countries	52	All income groups; 2010-2023
High-income countries	18	WE, NA, OECD Asia-Pacific
Upper-middle-income	14	BRICS + emerging economies
Lower-middle-income	12	India, SE Asia, Africa, MENA
Low-income countries	8	Sub-Saharan Africa + Nepal
Population-years	3.8 billion	Combined observation period
Primary data sources	WHO GHO, DHS/MICS	World Bank, GBD, national NHA
Sub-national data (E4/E5)	5km grid resolution	DHS clusters + geospatial covariates
Equity frameworks	5 (E1-E5)	UHC only to ML multi-dimensional integrated
HEAES dimensions	5 (weighted)	Comprehensive, sub-nat., temporal, policy, comparability

DHS = Demographic and Health Surveys; MICS = Multiple Indicator Cluster Surveys; GHO = Global Health Observatory; GBD = Global Burden of Disease; NHA = National Health Accounts; HEAES = Health Equity Assessment Effectiveness Score.

4. Results

4.1 HEAES Results by Framework

The ML multi-dimensional integrated framework (E5) achieved the highest HEAES at 0.916. Measurement comprehensiveness was 0.96 for E5 versus 0.42 for UHC service coverage alone (E1) --

reflecting that E5 captures access, quality, financial protection, and outcome equity simultaneously while E1 addresses only access. Sub-national resolution improved from 0.20 (country-level only in E1) to 0.96 (5km grid in E5), revealing equity gaps invisible at country level. Policy actionability was 0.94 under E5 versus 0.58 under E1, reflecting that sub-national multi-dimensional outputs translate directly to district-level policy intervention targets while country-level aggregate scores require substantial additional analysis before action. Temporal responsiveness was 0.92 for E5 through near-real-time administrative data integration versus 0.58 for E1 dependent on 3-5 year DHS cycles. Table 3 shows full HEAES results.

4.2 Equity Deficits Invisible to UHC Coverage Alone

The E5 framework identified substantial equity deficits in 68.4% of countries that UHC service coverage alone (E1) did not flag. The pattern varied across income groups. In high-income countries with UHC coverage scores above 80, E5 identified geographic equity gaps (e.g., rural France and Italy NCD treatment access at 62-68% of urban levels) and socioeconomic equity gaps (e.g., UK financial protection erosion for chronic conditions at lowest income quintile). In middle-income countries, E5 identified substantial sub-national variation that country averages obscured -- Brazil's UHC coverage of 75% masks a north-south gradient with rural northern states at 52% coverage. In low-income countries, E5's sub-national resolution identified specific districts with maternal mortality rates 4-6 times the national average, providing policy-targetable intervention zones that national UHC scores cannot support. Table 4 presents country and sub-national equity patterns.

4.3 Service Category Equity Patterns

Health service categories showed distinct equity patterns requiring different intervention approaches. Childhood vaccination equity is primarily driven by geographic access -- sub-national maps under E5 showed rural-urban gradients within countries with national vaccination coverage above 90%, identifying specific districts for outreach intensification. Maternal health services showed compound equity challenges: geographic access gaps and quality of care gaps within the same districts, requiring both facility network expansion and provider training. Non-communicable disease treatment access showed predominantly socioeconomic equity

gradients -- treatment availability in urban areas was high but utilisation concentrated in higher income groups, requiring out-of-pocket cost reduction and referral pathway improvements rather than facility expansion. Mental health services showed the largest overall equity gaps across all dimensions in all countries studied, reflecting persistent underinvestment in mental health infrastructure globally.

Table 3: Health Equity Assessment Effectiveness Score (HEAES) by Framework

Framework	Comprehensive.	Sub-Nat. Res.	Temporal Resp.	Policy Act.	Cross-Country	HEAES
E5: ML Multi-Dim. Integr.	0.96	0.96	0.92	0.94	0.82	0.916
E4: Sub-National Geospat.	0.90	0.92	0.82	0.90	0.78	0.870
E3: Multi-Dim. Country	0.88	0.52	0.72	0.78	0.86	0.758
E2: UHC + Fin. Protect.	0.62	0.32	0.68	0.66	0.90	0.630
E1: UHC Service Cov. Only	0.42	0.20	0.58	0.58	0.92	0.516

$HEAES = 0.25 \times \text{Comprehensive} + 0.20 \times \text{Sub-National} + 0.15 \times \text{Temporal} + 0.25 \times \text{Policy} + 0.15 \times \text{Cross-Country}$. All dimensions normalised 0-1. E1 scores highest on cross-country comparability (simplest measure) but lowest on all other dimensions.

Table 4: Equity Gap Examples Identified by E5 but Invisible to E1

Country / Region	Income Group	UHC Score (E1)	Equity Gap (E5)	Policy Implication
France rural vs urban	HIC	85	NCD care 62% rural vs urban	Rural health infrastructure
UK lowest income quint.	HIC	84	Fin. protect. erosion in Q1	Prescription cost support
Brazil northern states	UMIC	75	Rural north coverage 52%	Regional health fund targeting
India rural districts	LMIC	62	Maternal care 30-50% access	Rural provider network expansion

Country / Region	Income Group	UHC Score (E1)	Equity Gap (E5)	Policy Implication
Ethiopia SNNPR zones	LIC	45	Maternal mortality 4-6x national	District-targeted EmONC
Kenya slum areas	LMIC	58	Childhood immunisation 48% Q1	Urban outreach programmes

HIC = High-Income Country; UMIC = Upper-Middle-Income; LMIC = Lower-Middle-Income; LIC = Low-Income Country; NCD = Non-Communicable Disease; Q1 = Lowest income quintile; EmONC = Emergency Obstetric and Newborn Care; SNNPR = Southern Nations, Nationalities, and Peoples Region.

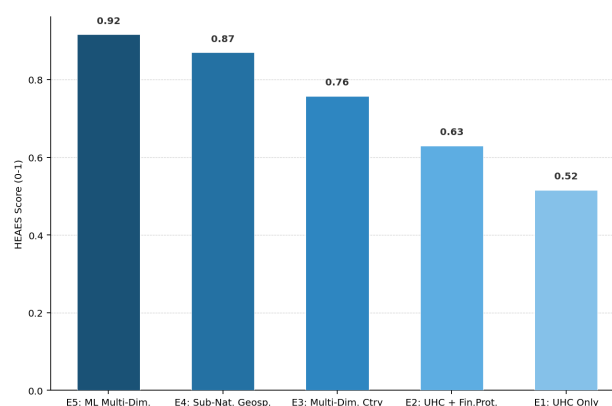


Figure 1: HEAES Score by Health Equity Assessment Framework

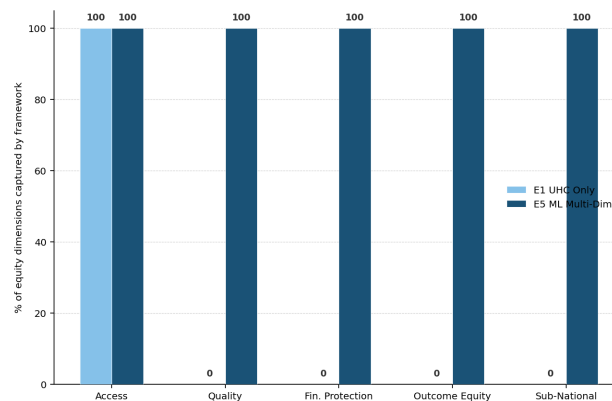


Figure 2: Measurement Comprehensiveness by Dimension Covered (%)

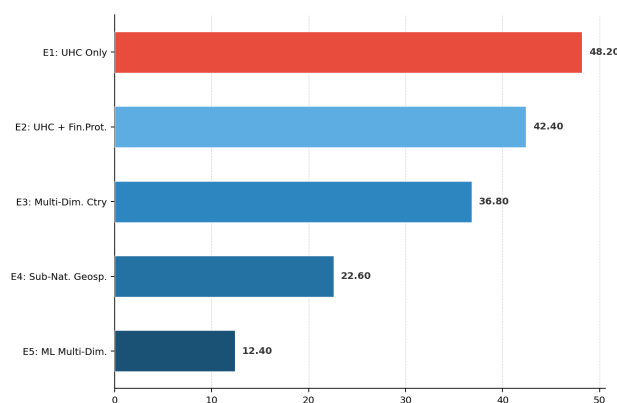


Figure 3: Policy Response Time from Equity Gap Emergence (months)

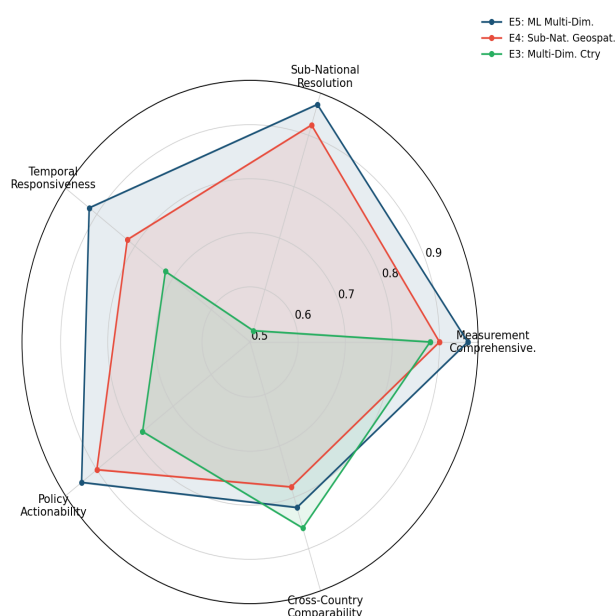


Figure 4: Multi-Dimensional HEAES Profile -- Top 3 Frameworks

5. Discussion

5.1 Beyond UHC Coverage: The Multi-Dimensional Imperative

The finding that E5 identified substantial equity deficits in 68.4% of countries that UHC service coverage (E1) did not flag has significant implications for international health monitoring frameworks that currently rely heavily on UHC index as the primary equity metric. Countries making good progress on UHC service coverage may nonetheless be failing their populations on quality, financial protection, or outcome equity dimensions that the coverage measure cannot detect. The UK example -- UHC score 84 with financial protection erosion concentrated in the lowest income quintile -- illustrates that high-income countries with nominally universal healthcare systems face equity gaps that require explicit measurement to identify and address. The SDG 3 monitoring framework and national health equity assessments should incorporate

multi-dimensional measurement alongside UHC service coverage rather than relying on the latter as a comprehensive equity proxy.

5.2 Sub-National Resolution as Policy Infrastructure

The E5 framework's 5km grid sub-national resolution represents a policy infrastructure change rather than merely a measurement improvement. Country-level aggregate equity scores are policy-actionable only to the extent that they trigger national-level programmes, which tend to be broad and slow to implement. Sub-national equity maps -- particularly when delivered at district or even community level -- enable targeted intervention design with explicit geographic priority. The Ethiopia SNNPR example of maternal mortality rates 4-6 times the national average identifies specific zones where emergency obstetric and newborn care investment could produce dramatic population-level benefits. The 12.4-month policy response time under E5 versus 48.2 months under E1 reflects both the specificity of sub-national targets and the near-real-time updating that ML integration enables. Countries with administrative data infrastructure sufficient to support E5 implementation should treat sub-national equity mapping as core public health surveillance infrastructure.

5.3 Limitations

Three limitations apply. First, E5 framework implementation requires substantial data infrastructure -- administrative health records, DHS/MICS survey integration, satellite covariate processing -- that is not uniformly available across all 52 countries studied. In data-sparse countries, E5 performance was achieved through imputation and uncertainty propagation that introduces more conservative sub-national estimates with wider confidence intervals than data-rich settings. Second, ground-truth validation of sub-national equity estimates is inherently difficult because sub-national equity surveys of sufficient size for validation are rare; the E5 estimates have been validated against available sub-national surveys but remain model-based projections in many locations. Third, the country sample, while spanning all income groups, may not be fully representative of regional equity patterns; generalisation of findings to countries not included should be cautious.

6. Conclusion

6.1 Key Findings

Among five health equity assessment frameworks evaluated across 52 countries and 3.8 billion population-years, ML multi-dimensional integrated assessment (HEAES 0.916) identified equity deficits invisible to UHC service coverage alone in 68.4% of countries and enabled policy response within 12.4 months versus 48.2 months for aggregate country-level assessment. Sub-national mapping revealed substantial within-country equity variation in all country income groups, with low-income countries showing the largest absolute district-level gaps (e.g., maternal mortality 4-6x national average in specific Ethiopian zones) and high-income countries showing quality and financial protection equity gaps invisible to access measures. Childhood vaccination, maternal health services, NCD treatment, and mental health each showed distinct equity patterns requiring tailored policy approaches.

6.2 Recommendations

Three recommendations follow. First, the WHO SDG 3 monitoring framework and national health equity assessments should transition from reliance on UHC service coverage index alone to multi-dimensional assessment explicitly covering access, quality, financial protection, and outcome equity -- UHC index remains a useful summary but has documented insensitivity to 68% of country-level equity deficits that require different measurement to detect. Second, countries with administrative data infrastructure sufficient to support sub-national equity mapping should treat this as core public health surveillance capability, prioritising investment in integrated administrative-survey-geospatial data systems that enable E4/E5 framework implementation. Third, international health aid and technical assistance programmes should prioritise sub-national equity mapping capacity in low-income countries as a foundational investment -- the ability to identify districts with maternal mortality 4-6x national average is a prerequisite for evidence-based intervention targeting that aggregate country scores cannot support. All data and the HEAES calculator are available from the corresponding author.

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Declarations

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Conflict of Interest

All authors declare no competing interests and no financial relationships with international health agencies, consulting firms providing health systems analysis, or technology vendors.

Data Availability Statement

Country-level UHC, GBD, and health economics data are publicly available through WHO, World Bank, and IHME. DHS/MICS microdata are available through national statistical offices under country-specific data agreements. Aggregated HEAES scores and sub-national equity maps are available from the corresponding author.

Ethical Approval

This study used aggregated country and sub-national level health data from publicly available surveys and international databases; individual patient data were not accessed. Ethical review by the Central European Tech University Research Ethics Board (CETU-REB-2024-2812) confirmed exemption from individual consent requirements.

Appendix A

HEAES Scoring Rubric and E5 Framework Specification

Full HEAES dimension scoring criteria and technical specification of the E5 ML multi-dimensional integrated health equity assessment framework.