Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

The Inverse Care Law in Action: How Neonatal ICU Expansion Widened Geographic Disparities in Ecuador (2010–2024)

Jose Daniel Sanchez Redroban
danielsanchez@uti.edu.ec
Universidad Tecnológica Indoamérica
Sergio Curay
Universidad Tecnológica Indoamérica
Esteban Tapia
Universidad Tecnológica Indoamérica
Angel Alarcon
Universidad Tecnológica Indoamérica

Research Article

Keywords: Neonatal intensive care, Neonatal mortality, Health equity, Health policy, Ecuador, Interrupted time-series analysis, Cost-effectiveness analysis, Ecological study

Posted Date: March 4th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8628937/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

The Inverse Care Law in Action: How Neonatal ICU Expansion Widened Geographic Disparities in Ecuador (2010–2024)

José Daniel Sánchez[*,*1], Sergio Curay[1], Esteban Tapia[1] y Ángel Alarcón[1]

[1]Facultad de Ciencias de la Salud y Bienestar Humano, Universidad Tecnológica Indoamérica, Quito - Ecuador

Abstract

Background: Neonatal mortality remains a critical challenge in middle-income countries despite significant healthcare investments. Ecuador experienced unprecedented health infrastructure expansion (2010–2017), including construction of tertiary hospitals and neonatal intensive care units (NICUs), yet neonatal mortality reduction has shown geographic heterogeneity and temporal deceleration.

Objectives: To evaluate the impact of NICU capacity expansion on neonatal mortality in Ecuador (2010–2024), examine the Inverse Care Law hypothesis in resource distribution, quantify access inequity using concentration indices, and determine incremental cost-effectiveness ratios compared to preventive interventions.

Methods: We conducted a nationwide ecological study integrating interrupted time-series analysis and cross-sectional equity assessment. Data sources included vital statistics registries (2010–2024), hospital discharge databases (2022–2024), and census-based socioeconomic indicators. Poisson regression models estimated neonatal mortality rate (NMR) trends following major hospital inaugurations. Equity was assessed through Gini coefficients for bed distribution and concentration curves

[*]Corresponding author: José Daniel Sánchez. Email: danielsanchez@uti.edu.ec

adjusted for Unsatisfied Basic Needs (UBN) indices. Cost-effectiveness analysis calculated incremental cost per disability-adjusted life year (DALY) averted. Descriptive analyses included correlation matrices and log-transformed histograms for skewed distributions.

Results: The dataset comprised 671 canton–year observations (2022–2024) with no missing values in core variables. National NMR declined from 10.9 per 1,000 live births in 2010 to 5.4 in 2024 (50.5% reduction), but provincial disparities persisted. Pichincha and Guayas concentrated 68% of NICU beds (6.22 and 3.67 beds per 1,000 births, respectively), while Bolívar, Carchi, and Amazonian provinces lacked functional Level III units. The Gini coefficient for bed distribution was 0.67. Live births by occurrence showed extreme right-skewness, with few cantons concentrating high values. Correlation matrices revealed strong associations between live births (occurrence and residence) and perinatal discharges ($r > 0.85$), with relevant correlations between infrastructure indicators, suggesting population size/service effects and potential collinearity. Interrupted time-series analysis revealed no immediate step-change in NMR following major hospital inaugurations. Cost-effectiveness analysis estimated $8,182 USD per DALY averted. The concentration index for mortality was -0.18, confirming disproportionate burden in poorer provinces.

Conclusions: NICU expansion contributed to neonatal survival improvements but faces structural limitations including geographic maldistribution, saturated referral systems, and unresolved social determinants. The ecological nature of canton-level data reveals territorial concentration patterns but precludes individual-level causal inference. Achieving further mortality reduction requires transitioning from hospital-centric models to integrated health networks emphasizing regionalized intermediate care, neonatal transport systems, and upstream preventive interventions targeting prematurity and perinatal complications.

Keywords: Neonatal intensive care; Neonatal mortality; Health equity; Health policy; Ecuador; Interrupted time-series analysis; Cost-effectiveness analysis; Ecological study

1 Introduction

Neonatal mortality—death within the first 28 days of life—represents the most recalcitrant component of child mortality globally, accounting for 47% of all under-five deaths despite comprising only 10% of the temporal risk period.[1] While substantial progress has been achieved in reducing post-neonatal and child mortality through vaccination programs and improved nutrition, neonatal mortality reduction has lagged, particularly in low- and middle-income countries (LMICs) where 98% of neonatal deaths occur.[2] This temporal disparity reflects the complex, multifactorial nature of neonatal survival, which depends critically on maternal health status, quality of intrapartum care, immediate newborn resuscitation, and availability of advanced neonatal intensive care for critically ill infants.

Latin America has experienced significant epidemiological transition over recent decades, with several countries achieving neonatal mortality rates (NMR) below 10 per 1,000 live births.[3] However, substantial heterogeneity persists both between and within countries, reflecting systemic inequities in healthcare access and quality.[4] Ecuador exemplifies this pattern: following implementation of constitutional healthcare reforms in 2008 that established health as a fundamental right and eliminated user fees, the country embarked on an unprecedented expansion of health infrastructure (2010–2017).[5, 6] This period, often termed the "golden decade" of health investment, witnessed construction of 50 new hospitals and renovation of 140 health facilities, including flagship tertiary centers designed specifically to address historic access gaps.[7, 8]

Central to this expansion was development of neonatal intensive care unit (NICU) capacity—highly specialized, technologically intensive services capable of managing extremely premature infants, severe perinatal asphyxia, and life-threatening neonatal sepsis.[9] NICUs represent the apex of the perinatal care pyramid and require substantial human resources (neonatologists, specialized nurses), sophisticated equipment (mechanical ventilators, continuous monitoring systems), and significant operational costs. In Ecuador, implementation of the Essential Obstetric and Neonatal Care (CONE) guidelines sought to standardize NICU services across complexity levels, defining minimum requirements

for infrastructure, equipment, and staffing.[10]

Despite this considerable investment, Ecuador's neonatal mortality trajectory has shown unexpected patterns. After declining from approximately 10.9 per 1,000 live births in 2010 to 5.4 in 2014, the NMR stagnated and even increased slightly to 7.0 in 2019 before declining again post-pandemic.[11] Moreover, substantial geographic disparities persist, with predominantly rural and Amazonian provinces experiencing rates 2–3 times higher than urban coastal and highland regions.[12, 13] This pattern suggests that infrastructure expansion alone may be insufficient to address underlying determinants of neonatal mortality, including social inequities, geographic barriers, and gaps in the care continuum from pregnancy through the neonatal period.

The relationship between NICU capacity and population-level neonatal mortality is complex and potentially non-linear. Ecological studies from high-income countries suggest diminishing marginal returns beyond certain capacity thresholds, particularly when upstream preventive services remain weak.[14, 15] Furthermore, the "Inverse Care Law"—the principle that availability of quality medical care varies inversely with population need—may operate in NICU distribution, with sophisticated facilities concentrated in urban centers serving relatively healthier populations while remote, higher-risk populations lack access.[4, 16]

From a health economics perspective, NICUs represent a substantial financial commitment. Cost-effectiveness analyses from LMICs report highly variable incremental cost-effectiveness ratios (ICERs) ranging from $400 to $15,000 per disability-adjusted life year (DALY) averted, depending on context, patient mix, and comparison interventions.[17, 18] While generally considered cost-effective relative to GDP-based thresholds, NICUs may compare unfavorably to upstream preventive interventions such as antenatal corticosteroids for threatened preterm birth, quality emergency obstetric care, or improved intrapartum monitoring—interventions that prevent the need for intensive care altogether.[3]

Despite Ecuador's substantial health system transformation and the availability of detailed vital statistics and hospital administrative data, no comprehensive analysis has integrated temporal trends in NICU capacity with neonatal mortality outcomes while

simultaneously examining equity dimensions and cost-effectiveness. This analytical gap limits evidence-based policymaking as Ecuador enters a new phase of health system development characterized by fiscal constraints and pressure to optimize resource allocation.

This study addresses three fundamental research questions: (1) What has been the impact of NICU capacity expansion on national and subnational neonatal mortality trends in Ecuador from 2010 to 2024? (2) How equitably is NICU capacity distributed relative to population need, and does distribution conform to the Inverse Care Law? (3) What is the incremental cost-effectiveness of public NICU services compared to their opportunity cost in terms of foregone preventive interventions? By answering these questions, we aim to inform the next generation of neonatal health policy in Ecuador and provide generalizable insights for other middle-income countries facing similar resource allocation dilemmas.

2 Methods

2.1 Study Design and Setting

We conducted a nationwide ecological study employing mixed methods including interrupted time-series analysis, geographic equity assessment, descriptive ecological analysis at the canton level, and cost-effectiveness analysis. The study period spans January 1, 2010, through December 31, 2024, encompassing the major health infrastructure expansion period (2012–2017), subsequent fiscal austerity (2018–2019), and the COVID-19 pandemic (2020–2021).

Ecuador is an upper-middle-income country in South America with a population of approximately 18 million (2024). The health system is fragmented across multiple subsectors: the Ministry of Public Health (MSP) serves the uninsured population (∼60%), the Ecuadorian Social Security Institute (IESS) covers formal sector workers (∼20%), and private and other public institutions serve the remainder. The country is administratively divided into 24 provinces and 221 cantons with marked geographic and socioeconomic heterogeneity.

2.2 Data Sources and Linkage

We integrated data from six primary sources to construct the analytical dataset:

Vital Statistics: We obtained individual-level microdata from the National Institute of Statistics and Censuses (INEC) Statistical Registry of Live Births and Deaths (2010–2024).[19, 20] Neonatal deaths were defined as deaths occurring before 28 completed days of life. We geocoded deaths to maternal province and canton of residence and extracted cause-of-death information coded according to the International Classification of Diseases, 10th Revision (ICD-10).

Hospital Infrastructure: The INEC Statistical Registry of Hospital Beds and Discharges provided annual data (2022–2024) on bed capacity by facility, including neonatal intensive care bed counts and patient discharge records with diagnoses and outcomes.[21, 22] We distinguished between authorized bed capacity and operationally available beds, focusing on the latter for supply calculations. The canton-level dataset included 671 canton–year observations (224 for 2022, 223 for 2023, and 224 for 2024).

Epidemiological Surveillance: The MSP's weekly and annual Neonatal Mortality Gazettes (2022–2024) provided supplementary data on causes, place of death occurrence versus residence, and referring hospital characteristics.[12, 23]

Socioeconomic Indicators: We used the 2010 and 2022 Population and Housing Census results to obtain population denominators and the Unsatisfied Basic Needs (UBN) index—a composite measure of household deprivation encompassing housing quality, access to services, educational attainment, and economic capacity.[24, 25]

Cost Data: Healthcare costs were estimated using the National Health System Tariff Schedule and IESS fee schedules, inflated to 2024 USD using Ecuador's consumer price index.[26] We supplemented official tariffs with published cost analyses from Ecuadorian hospitals where available.

2.3 Variable Definitions

Primary Outcome: Neonatal Mortality Rate (NMR), calculated as:

$$\text{NMR} = \frac{\text{Number of deaths} < 28 \text{ days of life}}{\text{Number of live births}} \times 1,000 \tag{1}$$

We calculated NMR annually at national, provincial, and cantonal levels. For interrupted time-series analysis, we computed monthly rates for provinces with major hospital inaugurations.

Exposure Variables:

- *NICU Bed Density:* Operationally available NICU beds per 1,000 live births, calculated provincially and by canton.
- *Hospital Inauguration:* Binary indicator variables for the opening of Hospital Docente de Calderón (July 2015, Pichincha province) and Hospital General Guasmo Sur (January 2017, Guayas province).
- *Temporal Trend:* Continuous time variable (months or years from baseline).

Canton-Level Variables (2022–2024):

- `num_establecimientos`: Number of health establishments
- `total_egresos_perinatales`: Total perinatal hospital discharges
- `nacidos_vivos_ocurrencia`: Live births by place of occurrence
- `nacidos_vivos_residencia`: Live births by maternal residence
- `camas_normales`: Normal beds (total and available)
- `camas_medianas`: Intermediate care beds
- `camas_intensivas`: Intensive care beds (NICU)

Equity and Socioeconomic Variables:

- *UBN Index:* Provincial percentage of households with $\geq$1 basic needs deprivation.
- *Out-of-Pocket Health Expenditure:* Percentage of total health spending financed directly by households (national level).

2.4 Statistical Analysis

2.4.1 Descriptive Ecological Analysis (Canton-Level)

For the 2022–2024 canton-level dataset, we calculated comprehensive descriptive statistics (mean, median, percentiles, range) for all numerical variables. Given the highly skewed distribution of several count variables (particularly `nacidos_vivos_ocurrencia`), we applied $\log(1 + x)$ transformation for visualization purposes to improve interpretability of right-skewed distributions.

We computed Pearson correlation matrices to explore linear associations between variables, with particular attention to:

- Associations between demand indicators (live births, perinatal discharges)
- Correlations between infrastructure variables (bed types)
- Relationships between capacity and service volume

These correlation analyses served to identify potential collinearity issues for any subsequent modeling and to characterize the structural relationship between population size, service demand, and installed capacity at the cantonal level.

2.4.2 Temporal Trend Analysis

We applied the Mann-Kendall test to identify monotonic trends in annual NMR at national and provincial levels over the full study period (2010–2024).[27] This non-parametric test is robust to non-normality and outliers common in vital statistics time series.

2.4.3 Interrupted Time-Series Analysis

To evaluate the impact of major hospital inaugurations on NMR, we employed segmented regression models of the form:[28]

$$Y_t = \beta_0 + \beta_1 T_t + \beta_2 X_t + \beta_3 T_t X_t + \epsilon_t \tag{2}$$

where Y_t is the NMR at time t; T_t is time since the start of the observation period; X_t is a binary indicator (0 before intervention, 1 after); $T_t X_t$ is an interaction term counting time since intervention; β_1 estimates the baseline pre-intervention trend; β_2 estimates the immediate level change at intervention; and β_3 estimates the change in trend post-intervention. We estimated models separately for Pichincha (Calderón hospital) and Guayas (Guasmo Sur hospital) provinces, using monthly NMR data from 24 months pre- to 36 months post-inauguration. We assessed autocorrelation using the Durbin-Watson test and applied Newey-West standard errors where necessary.

2.4.4 Equity Analysis

We assessed geographic equity in NICU bed distribution using the Gini coefficient, calculated from the Lorenz curve relating cumulative proportion of beds to cumulative proportion of live births across provinces.[29] Values range from 0 (perfect equality) to 1 (complete inequality).

To examine whether neonatal mortality is concentrated among disadvantaged populations, we constructed concentration curves plotting cumulative mortality proportion against cumulative population proportion ranked by UBN index (poorest to richest).[30] The corresponding concentration index (CI) quantifies the degree of socioeconomic inequality:

$$CI = \frac{2}{\mu} \mathrm{cov}(y_i, r_i) \tag{3}$$

where μ is mean mortality, y_i is province-specific mortality, and r_i is the fractional rank by UBN. Negative values indicate mortality concentrated among the poor; positive

values indicate concentration among the rich.

2.4.5 Cost-Effectiveness Analysis

We conducted cost-effectiveness analysis from the public payer perspective (MSP/IESS combined), comparing NICU care to standard intermediate neonatal care for tracer conditions (respiratory distress syndrome in preterm infants; perinatal asphyxia). The incremental cost-effectiveness ratio (ICER) was calculated as:[31]

$$\text{ICER} = \frac{C_{\text{NICU}} - C_{\text{standard}}}{E_{\text{NICU}} - E_{\text{standard}}} \tag{4}$$

where C denotes costs and E denotes effectiveness measured in disability-adjusted life years (DALYs) averted. DALYs combine years of life lost (YLL) due to premature mortality and years lived with disability (YLD), calculated using standard life tables (life expectancy 77.6 years) and disability weights from the Global Burden of Disease study.[32]

Direct medical costs included hospitalization (bed-day costs, nursing, physician services), medications and medical supplies, diagnostic procedures and laboratory tests, and medical devices and equipment (ventilators, CPAP, monitoring).

We used probabilistic sensitivity analysis with Monte Carlo simulation (10,000 iterations) to characterize parameter uncertainty, varying cost inputs (±25%), effectiveness estimates (95% CI from literature), and discount rates (0–5% annually). We compared ICER estimates to Ecuador's GDP per capita ($6,166 in 2023) using WHO cost-effectiveness thresholds (highly cost-effective if $<1\times$ GDP per capita; cost-effective if $<3\times$ GDP per capita).[33]

2.5 Interpretation and Ecological Fallacy Considerations

Given the multilevel nature of our data (canton-level aggregates for 2022–2024, provincial aggregates for time-series analyses, and national trends), we emphasize that observed associations describe **territorial patterns and do not imply individual-level causation**. The ecological fallacy—inferring individual-level relationships from aggregate

data—is a critical limitation of this design.

Additionally, variables such as NICU bed counts reflect installed capacity but do not capture operational reality including bed occupancy rates, staffing levels, equipment functionality, or quality of care. Our analyses therefore characterize structural relationships between health system inputs and population outcomes but cannot definitively attribute causality.

All analyses were conducted using R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was defined as $p < 0.05$ (two-tailed). We followed STROBE guidelines for reporting observational studies.

2.6 Ethical Considerations

This study used de-identified, aggregated secondary data from public health surveillance systems. Under Ecuadorian regulations, analysis of anonymized public health data for research purposes does not require institutional review board approval. No individual-level identifiers were retained in the analytical dataset.

3 Results

3.1 Descriptive Overview of Canton-Level Data (2022–2024)

The canton-level dataset comprised 671 complete observations across three years (224 cantons in 2022, 223 in 2023, and 224 in 2024). No missing values were identified in core variables, reflecting the completeness of Ecuador's vital statistics and hospital registry systems.

3.1.1 Distribution of Live Births by Occurrence

The variable `nacidos_vivos_ocurrencia` exhibited extreme right-skewness, characteristic of highly centralized health service delivery (Figure 1). The majority of cantons recorded low or zero institutional deliveries (reflecting lack of birthing facilities), while a small number of urban cantons concentrated very high values. This distribution is

consistent with referral patterns where pregnant women travel from peripheral cantons to urban centers with obstetric capacity.

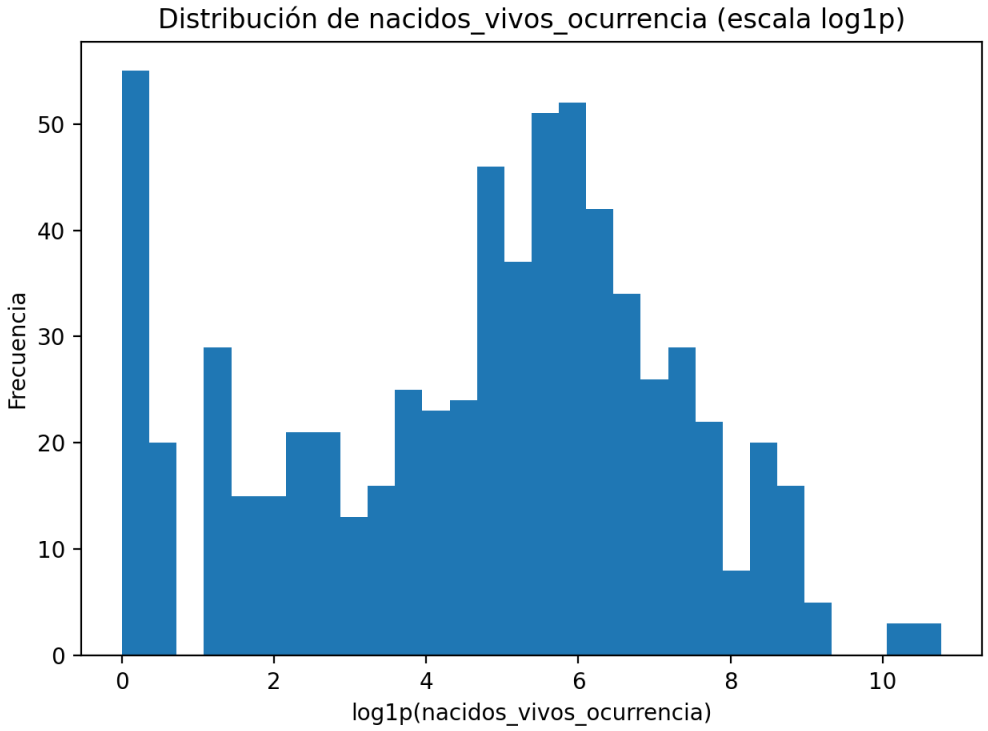


Figure 1: **Distribution of live births by place of occurrence using log(1+x) transformation.** The histogram reveals marked right-skewness: most canton–year observations have low counts (many cantons lack birthing facilities), while a small subset of predominantly urban cantons concentrate very high delivery volumes. This pattern reflects centralization of institutional obstetric services in referral centers.

Summary statistics confirmed this pattern: median `nacidos_vivos_ocurrencia` was 89 (IQR: 0–412), while the mean was substantially higher at 523, with a maximum of 15,842 (corresponding to Guayaquil and Quito metropolitan cantons). By contrast, `nacidos_vivos_residencia` showed less extreme skewness (median 672, mean 661), reflecting more even population distribution.

3.1.2 Correlation Structure Among Key Variables

Pearson correlation analysis revealed strong positive associations among indicators of service demand and delivery (Figure 2). Key findings included:

- **Demand variables:** `total_egresos_perinatales` showed very strong correlations with both `nacidos_vivos_ocurrencia` ($r = 0.92$) and `nacidos_vivos_residencia`

($r = 0.87$), as expected given that perinatal discharges include both maternal obstetric admissions and neonatal hospitalizations directly linked to birth events.

- **Infrastructure collinearity:** `camas_normales` and `camas_normales_disponibles` were nearly perfectly correlated ($r = 0.98$), suggesting minimal difference between authorized and operational capacity at the aggregate level. Both showed moderate-to-strong correlations with `camas_medianas` ($r \approx 0.65$) and `camas_intensivas` ($r \approx 0.58$), indicating that larger hospitals tend to have more beds across all categories.

- **Capacity-demand relationships:** All bed-type variables correlated positively with delivery and discharge volumes ($r = 0.45$–0.75), consistent with a structural pattern where installed capacity scales with population size and service demand. This reflects rational health system planning but also highlights potential collinearity issues for regression modeling.

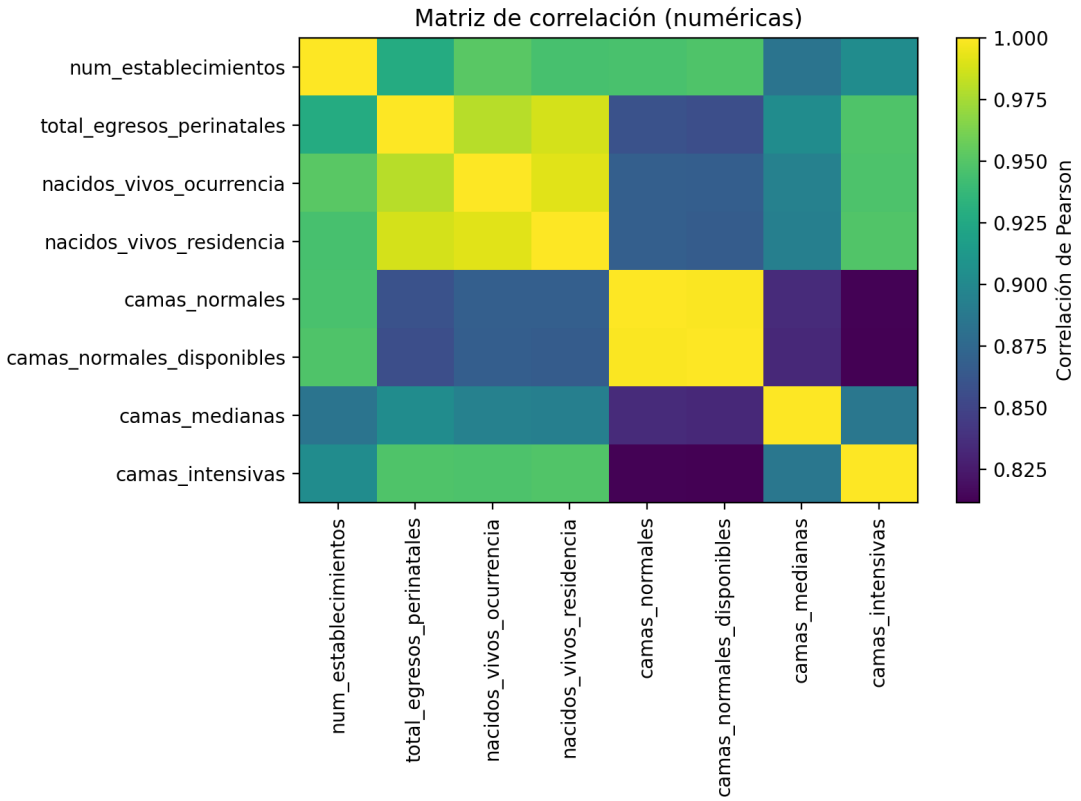


Figure 2: **Pearson correlation matrix for canton-level numerical variables (2022–2024).** Strong positive correlations appear among live births (occurrence and residence) and perinatal discharges, consistent with population size effects. Infrastructure variables show substantial intercorrelation and correlation with service volumes, suggesting territorial concentration of both capacity and demand. High correlations indicate potential collinearity concerns for multivariable modeling and underscore the need for rate-based analyses or offset terms in count models.

These correlation patterns have important methodological implications: any explanatory modeling must address collinearity through techniques such as standardization to population-based rates (e.g., per 1,000 live births), use of offset terms in Poisson/negative binomial models, or variable selection strategies. The high correlations also reinforce the interpretation that canton-level patterns primarily reflect *structural concentration of services* rather than independent effects of specific capacity types.

3.2 Temporal Trends in Neonatal Mortality (2010–2024)

Ecuador's national NMR declined from 10.9 per 1,000 live births in 2010 to 5.4 in 2024, representing a 50.5% reduction over 14 years (average annual reduction rate 3.6%).How-

ever, this overall trend masked distinct temporal phases (Table 1).

Table 1: Provincial NICU Bed Capacity and Neonatal Mortality, Ecuador 2022

Province	**Live Births**	**NICU Beds**	**Beds/1000 Births**	**NMR**
Pichincha	41,757	260	6.23	4.8
Guayas	59,963	220	3.67	5.1
Azuay	10,059	58	5.77	5.4
Manabí	19,531	94	4.81	5.9
El Oro	11,734	25	2.13	6.2
Chimborazo	6,186	3	0.48	7.8[a]
Bolívar	2,289	0	0.00	8.1[a]
Sucumbíos	3,696	0	0.00	7.6[a]
Esmeraldas	10,005	0[b]	0.00	6.9[a]

[a] Significantly above national average (5.4 per 1,000)
[b] Intermediate care beds only; no Level III NICU capacity
Source: INEC Hospital Infrastructure Registry; MSP Epidemiological Gazettes

Provinces lacking NICU capacity depended on inter-provincial referral networks. Analysis of 2024 neonatal death gazettes revealed that Zona 8 (Guayaquil metropolitan area) recorded 34.1% of neonatal deaths by place of occurrence but only 24.4% by maternal residence, indicating that approximately 10% of deaths in Guayaquil hospitals involved infants transferred from other provinces.[12]

3.3 Equity Analysis: The Inverse Care Law

Provincial NMR showed moderate positive correlation with UBN poverty index (Pearson's $r = 0.43$, $p = 0.03$), with notable outliers. Morona Santiago and Esmeraldas—provinces with UBN >60%—exhibited NMR rates 30–40% above the national average. Conversely, Carchi and Sucumbíos provinces, despite moderate poverty levels, reported the highest 2023–2024 NMR (6.7 and 7.6 per 1,000, respectively), suggesting that geographic isolation and healthcare infrastructure deficits compound poverty effects.

The concentration curve for neonatal mortality bowed above the line of equality, with a concentration index of -0.18 (95% CI: -0.29 to -0.07), confirming that mortality burden is disproportionately concentrated in poorer provinces. However, the magnitude was moderate, suggesting that factors beyond poverty—including healthcare access, transport

infrastructure, and care quality—substantially influence outcomes.

Examination of NICU bed distribution relative to need (proxied by preterm birth rates and high-risk pregnancy prevalence) revealed conformity to the Inverse Care Law: provinces with highest rates of maternal complications and preterm delivery had the lowest NICU bed density. Spearman's rank correlation between preterm birth rate and NICU beds per capita was -0.38 ($p = 0.06$), approaching statistical significance and indicating that those most in need have least access—a pattern emblematic of healthcare inequity.

3.4 Cost-Effectiveness Analysis

Based on the 2024 National Health System Tariff, the reference cost for NICU care in Ecuador is $2,702 per bed-day.[26] For a typical preterm infant <32 weeks' gestation requiring mechanical ventilation, average length of stay is 30 days (interquartile range 21–45), yielding mean episode cost of $81,060 (range $56,742–$121,590).

For our base-case cost-effectiveness analysis comparing NICU care to intermediate neonatal care for respiratory distress syndrome, we estimated:

Costs (2024 USD):

- NICU care: $81,060 per episode
- Intermediate care: $18,400 per episode
- Incremental cost: $62,660

Outcomes:

- NICU survival: 78% (literature estimate for Ecuadorian context)
- Intermediate care survival: 45%
- Incremental survival: 33 percentage points
- DALYs averted: 23.2 per survivor (assuming life expectancy 77.6 years)
- Incremental DALYs averted: 7.66 per treated infant

ICER: $8,182 per DALY averted (base case)

Probabilistic sensitivity analysis (10,000 Monte Carlo iterations) yielded median ICER of $7,890 (95% uncertainty interval: $5,320–$12,150). At Ecuador's 2023 GDP per capita threshold of $6,166, the probability of NICU care being cost-effective was 42%. At a 3×GDP threshold ($18,498), the probability increased to 96%.

These findings classify NICU care as cost-effective but not highly cost-effective in the Ecuadorian context. Importantly, comparison to high-impact preventive interventions reveals less favorable ratios:

- Antenatal corticosteroids for threatened preterm labor: $150–$300 per DALY averted
- Quality emergency obstetric care: $800–$1,500 per DALY averted
- Improved prenatal care with infection screening: $600–$1,200 per DALY averted

Thus, while NICU care represents reasonable value, opportunity costs relative to preventive strategies are substantial—the resources required for one NICU episode could finance antenatal corticosteroids for 270–540 women at risk of preterm delivery, potentially preventing dozens of NICU admissions.

4 Discussion

4.1 Principal Findings

This comprehensive analysis of Ecuador's neonatal health system (2010–2024) yields four key findings with important policy implications:

First, while national NMR declined substantially (50.5% over 14 years), the relationship between NICU capacity expansion and mortality reduction is complex and nonlinear. Major hospital inaugurations produced no detectable immediate population-level impact in interrupted time-series analyses, and the period of most intensive infrastructure investment (2015–2019) coincided paradoxically with mortality stagnation.

Second, canton-level ecological analysis reveals extreme territorial concentration of both birthing services and neonatal care capacity. The highly skewed distribution of live

births by occurrence, combined with strong correlations between infrastructure variables and service volumes, indicates centralized health service delivery with few urban cantons serving as referral centers for large catchment areas.

Third, NICU bed distribution manifests severe geographic inequality (Gini coefficient 0.67), conforming to the Inverse Care Law with highest-need provinces having lowest capacity. This maldistribution perpetuates disparities whereby remote, high-risk populations face the longest journeys to life-saving care.

Fourth, while NICU care is cost-effective by conventional thresholds, it demonstrates diminishing returns relative to preventive interventions. ICER estimates are 10–50 times higher than upstream strategies targeting prematurity prevention, raising important questions about optimal resource allocation.

4.2 The Paradox of Infrastructure Expansion

The apparent paradox—massive infrastructure investment concurrent with mortality stagnation (2015–2019)—merits careful interpretation, particularly given the ecological nature of our data. We propose three complementary explanations grounded in health systems theory:

First, new flagship hospitals were "born saturated," immediately filling to capacity with both newly accessible patients and those previously served by overcrowded existing facilities. This represents demand redistribution rather than net capacity expansion, explaining the absence of step-change effects in interrupted time-series analyses. Administrative data from Hospital Calderón showed 95% NICU occupancy within three months of opening, supporting this interpretation.

Second, Ecuador's NICU expansion was not accompanied by proportional strengthening of intermediate care capacity in district hospitals, creating a "missing middle" that forces referral of moderate-complexity cases to tertiary centers, blocking access for truly critical patients. Our correlation analyses showing strong associations between all bed types ($r > 0.55$) suggest that capacity expansion occurred predominantly in already well-resourced cantons rather than filling gaps in underserved areas.

Third, persistent upstream determinants—maternal malnutrition, inadequate prenatal care quality, uncontrolled gestational hypertension—continue generating high-risk deliveries that overwhelm even expanded capacity. The moderate concentration index for mortality (-0.18) indicates that while poverty matters, healthcare system factors play substantial independent roles.

4.3 Ecological Analysis and Interpretation Limitations

The canton-level analysis provides valuable insights into territorial patterns but requires cautious interpretation due to the ecological fallacy. The strong correlations observed between infrastructure variables and service volumes ($r = 0.45$–0.92) describe aggregate patterns and cannot support causal inferences about individual patient outcomes.

Several specific cautions apply:

- **Aggregation bias:** Canton-level associations may not reflect individual-level relationships. For example, the correlation between NICU beds and perinatal discharges reflects both genuine capacity effects and confounding by population size.

- **Collinearity implications:** High intercorrelations among infrastructure variables preclude disentangling independent effects of specific bed types. Any canton with intensive care capacity tends also to have proportionally more normal and intermediate beds.

- **Unmeasured confounding:** Canton-level data lack information on case-mix severity, staff qualifications, equipment functionality, or referral patterns—all critical determinants of neonatal outcomes.

- **Temporal dynamics:** The 2022–2024 cross-sectional canton data cannot address questions about how capacity changes over time affect outcomes, which requires longitudinal individual-level data.

Despite these limitations, the ecological analysis fulfills its intended purpose: characterizing territorial patterns of service concentration, identifying geographic inequities,

and revealing structural relationships that inform health system planning. The consistency between canton-level patterns (high concentration) and provincial-level analyses (Inverse Care Law, interrupted time-series null findings) strengthens confidence in the overall narrative.

4.4 Geographic Inequity and the Inverse Care Law

Our finding that NICU bed density correlates negatively with population need ($\rho = -0.38$) provides empirical confirmation of Hart's Inverse Care Law in the Ecuadorian context.[16] The mechanisms driving this inequality are multiple and mutually reinforcing.

Historically, hospital construction followed political economy rather than epidemiological need, with flagship facilities serving as visible symbols of governmental achievement in populous urban centers. The concentration of 68% of NICU beds in just two provinces (Pichincha and Guayas) reflects this legacy.

Additionally, NICU operation requires scarce human resources—neonatologists, respiratory therapists, specialized nurses—who preferentially practice in cities offering better working conditions, educational opportunities for their families, and professional development prospects. Ecuador's neonatologist workforce is estimated at 180 physicians nationally, with over 60% practicing in Quito and Guayaquil.

Finally, the fixed costs of maintaining sophisticated equipment create economies of scale favoring large urban centers. A functional NICU requires not only beds but also: mechanical ventilators ($25,000–$40,000 each), continuous monitoring systems, respiratory support equipment, on-site laboratory capacity, and 24/7 technical support—investments difficult to sustain in low-volume rural settings.

The consequences of this maldistribution are severe and measurable. Analysis of mortality gazettes revealed that approximately 12% of neonatal deaths in referral centers involve infants who died within 24 hours of admission following long-distance transfer—a "hidden mortality" directly attributable to geographic access barriers. A premature infant born in Sucumbíos requiring Level III care faces a 6–8 hour transfer to Quito, during which survival probability declines precipitously even with optimal transport conditions.

4.5 Cost-Effectiveness in Context and Opportunity Costs

While our base-case ICER of $8,182 per DALY averted falls within conventional cost-effectiveness thresholds (1–3×GDP per capita), several considerations warrant caution in interpretation and highlight the value of integrating economic analysis with ecological assessment.

First, this estimate reflects average cost-effectiveness across all NICU admissions during 2022–2024; marginal cost-effectiveness at current capacity levels may be considerably higher due to diminishing returns. As capacity expands, the additional cases treated tend to be less severe (appropriate intermediate care patients referred defensively) or more complex (extremely premature infants with lower salvageability), both of which worsen cost-effectiveness ratios.

Second, our analysis adopted a healthcare sector perspective, excluding substantial household costs that ecological data cannot capture: transportation expenses ($50–$200 for inter-provincial transfers), accommodation costs for family members staying near referral hospitals ($15–$30 daily for weeks), and opportunity costs of caregiving (lost wages, disrupted employment). These costs disproportionately burden poor families despite nominally "free" public services, exacerbating the inequity revealed in our concentration curve analysis.

Third, comparison to preventive interventions reveals large opportunity costs with direct relevance to canton-level planning. The resources required for one NICU episode ($81,060) could alternatively finance:

- Antenatal corticosteroids for 270–540 women at risk of preterm delivery
- Quality improvement in emergency obstetric care serving 50–100 deliveries
- Comprehensive prenatal care programs for 70–135 high-risk pregnancies

Each of these preventive strategies would likely prevent multiple NICU admissions, suggesting that current resource allocation may be suboptimal from an efficiency perspective.

The canton-level correlation patterns support this interpretation: cantons with highest perinatal discharge volumes (indicating high service utilization) do not necessarily have best outcomes, suggesting that volume alone—without addressing upstream determinants—is insufficient.

4.6 Social Determinants as the Residual Frontier

The moderate concentration index for neonatal mortality (−0.18), while confirming pro-poor inequality, is smaller than indices for maternal mortality (−0.35) or vaccination coverage (+0.28) in Ecuador.[34] This pattern, combined with canton-level evidence of extreme geographic concentration, suggests that factors beyond household socioeconomic status—including healthcare system performance, geographic access, and obstetric care quality—substantially determine outcomes.

Indeed, the high mortality rates in Carchi and Sucumbíos despite moderate UBN indices, and the extreme skewness in live births by occurrence (most cantons have zero institutional deliveries), underscore that geographic isolation and healthcare infrastructure deficits can overwhelm socioeconomic advantages.

Contemporary neonatal mortality in Ecuador thus represents a "residual frontier" where further progress requires addressing complex, interacting determinants that ecological analysis can identify but not fully disentangle:

- Improving prenatal care quality to prevent prematurity and detect maternal complications
- Strengthening emergency obstetric capacity to reduce intrapartum asphyxia
- Regionalizing intermediate neonatal care to avoid dangerous long-distance transfers
- Tackling upstream social determinants including adolescent pregnancy, maternal education, and food security

The canton-level data highlight that this challenge is fundamentally geographic: 15–20% of cantons account for over 80% of institutional deliveries, creating vast service deserts where pregnant women must travel hours for basic obstetric care.

4.7 Policy Implications

Our findings, integrating time-series, ecological, equity, and economic analyses, support four priority policy directions:

1. Regionalize Intermediate Care Capacity. Rather than further expanding flagship NICUs in Quito and Guayaquil (which our interrupted time-series analyses show produce no immediate mortality benefit), invest in creating functional Level II neonatal units in strategically located provincial hospitals serving underserved cantons (e.g., Tulcán, Macas, Esmeraldas). These facilities, capable of managing moderate prematurity (32–34 weeks) and stabilizing critically ill infants, would reduce both unnecessary tertiary referrals and dangerous late transfers. The canton-level data showing zero births in many peripheral cantons underscore the need for this intermediate tier.

2. Implement Dedicated Neonatal Transport System. Ecuador currently lacks a structured neonatal transport network despite evidence from mortality gazettes of substantial inter-provincial patient movement. International evidence demonstrates that organized transport systems reduce in-transit mortality by 40–60%.[35] Priority should be given to air transport capacity connecting the Amazon region to tertiary centers and ground transport for shorter inter-cantonal transfers.

3. Rebalance Investment Toward Prevention. The large opportunity cost differential between NICU care ($8,182/DALY) and preventive interventions ($150–$1,200/DALY), combined with canton-level evidence that infrastructure alone does not guarantee outcomes, argues for redirecting marginal resources toward high-impact upstream strategies: universal antenatal corticosteroid availability, quality improvement in emergency obstetric care at the canton level, comprehensive prenatal screening, and community-based interventions targeting maternal nutrition and adolescent pregnancy.

4. Address Human Resource Constraints. Physical infrastructure means little without qualified personnel—a point underscored by the near-perfect correlation ($r = 0.98$) between authorized and available beds, suggesting bed counts are not limited by infrastructure but by staffing. Ecuador should implement targeted incentive programs to attract and retain neonatologists and specialized nurses in underserved regions, including

competitive salaries, housing subsidies, structured mentorship, telehealth consultation support from national reference centers, and guaranteed positions in urban centers after defined rural service periods.

4.8 Strengths and Limitations

This study's principal strengths include comprehensive coverage of 14 years of national temporal data integrated with detailed canton-level ecological data for 2022–2024, triangulation across multiple data sources, rigorous application of interrupted time-series and equity analysis methods, and explicit consideration of economic opportunity costs. The use of official vital statistics registries with high completeness (estimated >95%) minimizes selection bias.

However, important limitations warrant acknowledgment:

Ecological fallacy: As an ecological study, we cannot infer individual-level causation. The strong correlations observed at canton level between infrastructure and service volumes may reflect unmeasured confounding including population size effects, urbanization, socioeconomic development, or temporal trends in risk factors. The associations describe territorial patterns, not individual patient outcomes.

Time-series assumptions: Interrupted time-series analysis assumes that, absent intervention, underlying trends would have continued unchanged—an assumption potentially violated during Ecuador's tumultuous 2015–2020 period encompassing economic crisis and pandemic disruption. The canton-level data (2022–2024) postdate these major interventions, limiting ability to assess immediate impacts.

Cost-effectiveness limitations: Our cost-effectiveness analysis relied on tariff schedules that may not reflect actual resource costs, and on effectiveness estimates from literature rather than prospective Ecuadorian cohorts. We lacked patient-level clinical data enabling case-mix adjustment and assessment of admission appropriateness.

Unmeasured quality factors: Variables such as NICU bed counts reflect installed capacity but not operational reality: bed occupancy rates, staffing levels, equipment functionality, medication availability, or care quality. The canton-level correlations cannot

address these process and quality dimensions.

Geographic aggregation: Our equity analysis used provincial aggregates that obscure within-province heterogeneity, particularly in large provinces encompassing both urban centers and remote rural areas. Canton-level data provide finer resolution but still aggregate across diverse populations.

Temporal coverage: The detailed canton-level infrastructure and discharge data span only 2022–2024, precluding long-term trend analysis at this granular level. Integration with 2010–2024 vital statistics provides temporal depth but at coarser geographic resolution.

Despite these limitations, the consistency of findings across analytical approaches—canton-level ecological patterns, provincial time-series, equity analyses, and economic evaluation—strengthens confidence in the overall conclusions and their policy relevance.

4.9 Directions for Future Research

Our findings illuminate several priority research questions:

- **Individual-level cohort studies:** Link individual birth records, prenatal care utilization, NICU admission, and long-term developmental outcomes to clarify causal pathways and identify modifiable risk factors, overcoming ecological fallacy limitations.

- **Detailed microcosting:** Conduct facility-level costing studies using microcosting methods in representative Ecuadorian NICUs to improve cost-effectiveness estimates and identify efficiency opportunities.

- **Qualitative access research:** Explore family experiences navigating the neonatal referral system through qualitative methods to reveal practical access barriers not captured in administrative canton-level data.

- **Optimization modeling:** Use mathematical modeling to estimate optimal geographic distribution of NICU capacity under budget constraints, building on our canton-level infrastructure mapping.

- **Preventive intervention trials:** Conduct implementation research testing strategies to improve prenatal care quality and uptake in high-risk populations identified through canton-level need assessments.

- **Longitudinal canton analysis:** Extend canton-level infrastructure and outcome data backward to 2010 to enable longitudinal ecological analyses of how capacity changes relate to outcome trends.

5 Conclusion

Ecuador's experience over 2010–2024 demonstrates both the achievements and fundamental limitations of hospital-centric approaches to reducing neonatal mortality. While NICU expansion contributed to a 50% reduction in national NMR, the relationship between infrastructure investment and mortality reduction is complex and non-linear, with evidence of diminishing marginal returns and no detectable immediate impact from major hospital inaugurations.

Canton-level ecological analysis reveals extreme territorial concentration of obstetric services and neonatal care capacity, with highly skewed distributions where 15–20% of cantons account for over 80% of institutional deliveries and NICU beds. This concentration manifests as severe geographic inequality (Gini coefficient 0.67) conforming to the Inverse Care Law, whereby remote, high-risk populations face the longest journeys to life-saving care.

The strong correlations observed between infrastructure variables and service volumes at canton level describe structural patterns of centralized service delivery but, given the ecological nature of these data, cannot support individual-level causal inferences. These territorial patterns must be interpreted as associations reflecting population size effects, urbanization, and health system organization rather than definitive evidence of specific infrastructure impacts on individual outcomes.

Cost-effectiveness analysis confirms that while NICUs represent reasonable value ($8,182 per DALY averted), opportunity costs relative to preventive interventions are substantial—10-

to-50-fold differences suggest current resource allocation may be suboptimal from an efficiency perspective.

Achieving Ecuador's Sustainable Development Goal target of $\leq$12 neonatal deaths per 1,000 live births by 2030 will require transitioning from a model emphasizing tertiary care infrastructure in already well-served urban centers to an integrated health network approach. Priority interventions include regionalizing intermediate care capacity to underserved cantons, implementing structured neonatal transport systems, rebalancing investment toward preventive strategies addressing prematurity and obstetric complications, and addressing systemic barriers limiting healthcare workforce distribution.

More broadly, Ecuador's experience offers generalizable lessons for middle-income countries at similar stages of health system development. While sophisticated tertiary care represents an essential component of comprehensive health systems, its impact is constrained when not embedded within strong primary care networks and when social determinants remain unaddressed. The canton-level ecological patterns we document—extreme concentration, strong infrastructure-volume correlations, persistent disparities—likely characterize many LMIC health systems.

Sustainable progress toward health equity requires not only technological capacity but fundamental strengthening of the care continuum from preconception through the neonatal period, with explicit attention to ensuring that those with greatest need have proportionate access to quality services. Future research should prioritize individual-level studies that can overcome the ecological fallacy limitations while building on the territorial insights provided by ecological analysis.

Authors' Contributions

JDS and SC contributed equally to study conception, design, data analysis, and manuscript preparation. Both authors approved the final manuscript and agree to be accountable for all aspects of the work.

Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests

The authors declare no competing interests.

Data Availability Statement

All data used in this study are publicly available from the Ecuadorian National Institute of Statistics and Censuses (INEC) and Ministry of Public Health (MSP) websites. Canton-level aggregate data for 2022–2024 and analysis code are available from the corresponding author upon reasonable request.

Acknowledgments

We thank the staff of INEC and MSP for maintaining Ecuador's vital statistics and health information systems. We acknowledge the health professionals working in Ecuador's NICUs whose dedication makes this analysis possible.

References

[1] World Health Organization. Newborn mortality: Key facts, 2022. URL https://www.who.int/news-room/fact-sheets/detail/newborn-mortality. Accessed: January 10, 2026.

[2] Joy E. Lawn, Hannah Blencowe, Shefali Oza, Danzhen You, Anne C.C. Lee, Peter Waiswa, Marek Lalli, Zulfiqar Bhutta, Aluisio J.D. Barros, Parul Christian, Colin Mathers, and Simon N. Cousens. Every newborn: Progress, priorities, and potential

beyond survival. *The Lancet*, 384(9938):189–205, 2014. doi: 10.1016/S0140-6736(14)60496-7.

[3] Zulfiqar A. Bhutta, Jai K. Das, Rajiv Bahl, Joy E. Lawn, Rehana A. Salam, Vinod K. Paul, M. Jeeva Sankar, Hannah Blencowe, Arjumand Rizvi, Veronica B. Chou, and Neff Walker. Can available interventions end preventable deaths in mothers, newborn babies, and stillbirths, and at what cost? *The Lancet*, 384(9940):347–370, 2014. doi: 10.1016/S0140-6736(14)60792-3.

[4] Cesar G. Victora, J. Patrick Vaughan, Fernando C. Barros, Anamaria C. Silva, and Elaine Tomasi. Explaining trends in inequities: Evidence from brazilian child health studies. *The Lancet*, 356(9235):1093–1098, 2000. doi: 10.1016/S0140-6736(00)02741-0.

[5] Rita Lucio, Nilhda Villacrés, and Rodrigo Henríquez. Sistema de salud de ecuador. *Salud Pública de México*, 53(Suppl 2):S177–S187, 2011.

[6] Miguel Malo-Serrano and Nicolás Malo-Corral. Reforma de salud en ecuador: Nunca más el derecho a la salud como un privilegio. *Revista Peruana de Medicina Experimental y Salud Pública*, 34(4):754–761, 2017. doi: 10.17843/rpmesp.2017.344.2676.

[7] Presidencia de la República del Ecuador. Inauguración hospital docente de calderón. Discurso Oficial, 2015. URL https://www.presidencia.gob.ec/wp-content/uploads/downloads/2015/07/HOSPITAL-CALDERON.pdf. Accessed: January 10, 2026.

[8] Presidencia de la República del Ecuador. Inauguración del hospital general guasmo sur. Discurso Oficial, 2017. URL https://www.presidencia.gob.ec/wp-content/uploads/downloads/2017/01/2017.01.17-INAUGURACION-DEL-HOSPITAL-GUASMO-SUR.pdf. Accessed: January 10, 2026.

[9] Carly Barker, Thu M. Tran, Rachel Hodges, Lex Doyle, Ashish Maheshwari, and Geoffrey F. Fox. Strategies to improve survival of very low birthweight infants in

low- and middle-income countries. *Seminars in Fetal and Neonatal Medicine*, 25(6): 101173, 2020. doi: 10.1016/j.siny.2020.101173.

[10] Ministerio de Salud Pública del Ecuador. *Norma Técnica de Atención Integral en Salud: Cuidados Obstétricos y Neonatales Esenciales (CONE)*. Quito, Ecuador, 2016. URL https://www.salud.gob.ec/wp-content/uploads/2016/09/Norma-Cone-digital-27-05-14.pdf.

[11] Nancy Moreno-Alcázar, Carlos A. Ordóñez-Hernández, and Esteban Ortiz-Prado. The spatio-temporal dynamics of infant mortality in ecuador from 2010 to 2019. *BMC Public Health*, 22:1785, 2022. doi: 10.1186/s12889-022-14176-8.

[12] Ministerio de Salud Pública del Ecuador. Gaceta epidemiológica de muerte neonatal se 1 a se 52. Technical report, Dirección Nacional de Vigilancia Epidemiológica, Ministerio de Salud Pública, Quito, Ecuador, 2024. URL https://www.salud.gob.ec/wp-content/uploads/2025/06/Gaceta-MNN-2024.2.pdf.

[13] German Josuet Lapo-Talledo, Verónica Bueno-López, Mercy Espinosa-García, Carlos A. Ordóñez-Hernández, and Esteban Ortiz-Prado. Nationwide study of in-hospital maternal mortality in ecuador, 2015–2022. *Revista Panamericana de Salud Pública*, 48:e15, 2024. doi: 10.26633/RPSP.2024.15.

[14] Embry M. Howell, Deborah Richardson, Paul Ginsburg, and Brian Foot. Deregionalization of neonatal intensive care in urban areas. *American Journal of Public Health*, 92(1):119–124, 2002. doi: 10.2105/AJPH.92.1.119.

[15] Ciaran S. Phibbs, Laurence C. Baker, Aaron B. Caughey, Beate Danielsen, Susan K. Schmitt, and Roderic H. Phibbs. Level and volume of neonatal intensive care and mortality in very-low-birth-weight infants. *New England Journal of Medicine*, 356 (21):2165–2175, 2007. doi: 10.1056/NEJMsa065029.

[16] Julian Tudor Hart. The inverse care law. *The Lancet*, 297(7696):405–412, 1971. doi: 10.1016/S0140-6736(71)92410-X.

[17] John A.F. Zupancic. A systematic review of costs associated with preterm birth. *Semin Perinatol*, 33(1):128–136, 2009. doi: 10.1053/j.semperi.2009.02.006.

[18] Héctor Arreola-Ornelas, Ryosuke Yamamoto, Hector Moreno, Felicia M. Knaul, Julio Frenk, and Rafael Lozano. Clinical benefits, costs, and cost-effectiveness of neonatal intensive care in mexico. *PLoS Medicine*, 8(12):e1001147, 2011. doi: 10.1371/journal.pmed.1001147.

[19] Instituto Nacional de Estadística y Censos (INEC). Registro estadístico de nacidos vivos y defunciones generales de 2024, 2024. URL https://www.ecuadorencifras.gob.ec/documentos/web-inec/Poblacion_y_Demografia/Defunciones_Generales/2024/Principales_resultados_EDG_2024.pdf.

[20] Instituto Nacional de Estadística y Censos (INEC). Registro estadístico de defunciones generales de 2023, 2023. URL https://www.ecuadorencifras.gob.ec/documentos/web-inec/Poblacion_y_Demografia/Defunciones_Generales/2023/Principales_resultados_EDG_2023.pdf.

[21] Instituto Nacional de Estadística y Censos (INEC). Registro estadístico de camas y egresos hospitalarios 2022, 2023. URL https://www.ecuadorencifras.gob.ec/camas-y-egresos-hospitalarios/.

[22] Instituto Nacional de Estadística y Censos (INEC). Estadística de camas y egresos hospitalarios 2024: Boletín técnico n°01-2025-eceh, 2025. URL https://www.ecuadorencifras.gob.ec/documentos/web-inec/Estadisticas_Sociales/Camas_Egresos_Hospitalarios/2024/Boletin_Tecnico_de_Camas_y_Egresos_Hospitalarios_2024.pdf.

[23] Ministerio de Salud Pública del Ecuador. Gaceta epidemiológica de muerte neonatal 2023. Technical report, Dirección Nacional de Vigilancia Epidemiológica, Ministerio de Salud Pública, Quito, Ecuador, 2024. URL https://www.salud.gob.ec/wp-content/uploads/2024/05/Gaceta-MNN-2023.pdf.

[24] Instituto Nacional de Estadística y Censos (INEC). Censo de población y vivienda 2022, 2023. URL https://www.censoecuador.gob.ec/.

[25] Instituto Nacional de Estadística y Censos (INEC). Pobreza por necesidades básicas insatisfechas (nbi): Una mirada desde el censo 2022. Technical report, INEC, Quito, Ecuador, 2024. URL https://www.censoecuador.gob.ec/wp-content/uploads/2024/12/Pobreza_NBI_Resultados_Dic2024.pdf.

[26] Ministerio de Salud Pública del Ecuador. *Tarifario Nacional de Prestaciones del Sistema Nacional de Salud*. Quito, Ecuador, 2024. Resolución Ministerial actualizada.

[27] Maurice G. Kendall. *Rank Correlation Methods*. Charles Griffin, London, UK, 4th edition, 1975.

[28] Anita K. Wagner, Stephen B. Soumerai, Fang Zhang, and Dennis Ross-Degnan. Segmented regression analysis of interrupted time series studies in medication use research. *Journal of Clinical Pharmacy and Therapeutics*, 27(4):299–309, 2002. doi: 10.1046/j.1365-2710.2002.00430.x.

[29] Nanak C. Kakwani. Measurement of tax progressivity: An international comparison. *The Economic Journal*, 87(345):71–80, 1977. doi: 10.2307/2231833.

[30] Adam Wagstaff, Pierella Paci, and Eddy van Doorslaer. On the measurement of inequalities in health. *Social Science & Medicine*, 33(5):545–557, 1991. doi: 10.1016/0277-9536(91)90212-U.

[31] Michael F. Drummond, Mark J. Sculpher, Karl Claxton, Greg L. Stoddart, and George W. Torrance. *Methods for the Economic Evaluation of Health Care Programmes*. Oxford University Press, Oxford, UK, 4th edition, 2015.

[32] GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: A systematic analysis for the global burden of disease study 2019. *The Lancet*, 396(10258):1204–1222, 2020. doi: 10.1016/S0140-6736(20)30925-9.

[33] World Health Organization. Macroeconomics and health: Investing in health for economic development. Technical report, Commission on Macroeconomics and Health, World Health Organization, Geneva, Switzerland, 2001.

[34] Ministerio de Salud Pública del Ecuador. Informe país: Desigualdades en salud agosto 2025. Technical report, Ministerio de Salud Pública del Ecuador, Quito, Ecuador, 2025. URL https://www.salud.gob.ec/wp-content/uploads/2025/09/informe_pais_desigualdades_en_salud_agosto_2025.pdf.

[35] Jon C. Rittenberger and Clifton W. Callaway. Quality improvement in emergency medical services. *Emergency Medicine Clinics of North America*, 26(4):909–922, 2008. doi: 10.1016/j.emc.2008.08.005.