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Geographical accessibility to public health facilities and the spatial distribution of child mortality, understanding potential access to health in Guatemala

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Abstract (217 words)

Background: Child survival has been associated with different socio-determinant factors at different levels of influence, including access to health care interventions. Under-five mortality rates are used as a population health indicator, since the leading causes of child deaths are largely preventable or amenable, likewise can be used as a proxy variable to explore potential access to health care.

Aim and data: Guatemala has made significant progress in antenatal and child health care, achieving the under-five mortality target set for Sustainable Development Goals; however, differences across regions are expected. The aim of this research to explore variations in geographic accessibility to public health facilities and to identify potential access barriers associated with under–five mortality rates across municipalities in Guatemala. This research used diverse nationally representative data sources, including vital registration, census and spatial data.

Findings: Geographic accessibility to secondary public health care services represents a lesser barrier to potential access to health care services. Potential access barriers associated with variations of under-five mortality rates are related to affordability, accommodation and availability dimensions. Potential access barriers are associated with poverty and the urbanisation of the administrative unit. Under-five mortality rates are reduced when there is higher availability of secondary services and utilisation of other health care providers during birth, such as the Guatemalan Social Security and private services.

Keywords

Potential access to health, geographic accessibility, access barriers, under-five mortality

Background

Global health efforts have succeed and improved child survival in the last three decades. Globally, under-five mortality rates have declined to an average of 38 deaths per 1,000 live births in 2019, with expected variations across regions of the world [1]. The probability of child survival has been associated with different socio-determinant factors at different levels of influence, including birth spacing and timely health care among other factors [2]. Under-five mortality rates are used as a population health indicator, since the leading causes of child deaths are largely preventable or amenable to health care, likewise can be used as a proxy variable to explore access to health care [3].

Access to health care is a dynamic process that distinguish two dimensions, real and potential access. The revised conceptual framework defined potential access as the presence of enabling resources, resources that promote the potential entry and use of the health care services [4]. Potential access concept is closely linked to access to health barriers, since barriers are framed as intermediate factors that might positively or negatively influence access to health outcomes [5]. There are different barriers influencing the potential entry to health care services, these are: accessibility, availability, affordability, accommodation and acceptability [5]. Measuring potential access barriers across geographies can provide understanding health care equity [6].

Similar to other countries in the Latin American region, Guatemala has increased efforts to improve antennal and child health outcomes. Recent estimates have identified that on average Guatemala has reached the aim set by the Sustainable Development Goal Agenda, estimating an under-five mortality rate lower than 25 deaths per 1,000 live birth [7]. Despite the significant progress in child survival, differences within country regions are likely to be found and there are efforts to be made in order to achieve the goal across geographic areas and to leave no one behind. The aim of this research to explore variations in geographic accessibility to public health facilities and identify potential access barriers associated with under–five mortality rates across municipalities in Guatemala.

Data and methods

This research used different data sources representative at the municipality level or ADM-2, the lowest level of data disaggregation of National databases. These data sources include individual level demographic and socioeconomic characteristics from census data, births and deaths from viral registration records and spatial attributes data. The demographic characteristics and vital registration data used in this analysis is representative at the municipality level and the data is representative of the 2018 population, the latest census available. The spatial data was used to create a proxy variable of geographic accessibility. The variables were aggregated to be representative of the 340 ADM-2 units of the country.

Outcome variable

Under-five mortality rate (${}_0M_5$) is defined as the probability of a child born in a specific year dying before reaching the age of five (${}_5q_0$). Under-five mortality rates are estimated at ADM-2 level using vital registrations data following the standard period-abridged life table method using the number of deaths and the mid-year population.

Explanatory variables

The explanatory variables are conceptually framed as proxy indicators of potential access barriers. The selection of the proxy variables was limited by the available data representative for the total number of municipalities. Variations in $_0M_5$ levels are associated with the explanatory variables following an ecological study approach using aggregated level variables [8]. The analysis includes proxy variables for geographic accessibility, affordability, accommodation and availability barriers, each variable being described in the following paragraphs.

Availability measured the number of secondary level facilities, services provided by professional health care workers available within the ADM-2 unit per 10,000 individuals. The accommodation variable accounts for the preferences of health providers, this variable used vital registration data to identify the proportion of births delivered by type of service, public services (primary, secondary or hospitals) and private services or at the Social Security services.

The affordability barrier was measured by deriving a household socioeconomic status index using household assets data from the population census. This variable is a living standards indicator and was created using Principal Component Analysis, selecting the values of the first component to create the index. The index was estimated for each household and categorically arranged by quantiles; the affordability variable is the proportion of households within the ADM-2 unit classified at the lowest or highest group.

The accessibility barrier describes the cost to travel to visit the nearest secondary level facility, the closest point of contact with professional health workers of the public health sector. The travel cost variable estimated travel times, procedure that uses different spatial data sources, ranging from point, polylines and raster data. Travel times were estimated following the least-coast path following the road network analysis to allow variations in Land-cover attributes and travel speeds using AccessMod 5.6.0 software [9]. The accessibility variable used in the analysis corresponds to the average of the travel time between each populated settlement and the nearest facility by municipality. The used data sources corresponds to the latest open-access data available at the time of the analysis. Table 1 describes the characteristics of the different datasets used to estimate travel times.

Table 1: Description of data sources used for measuring barriers to potential access to health in Guatemala

Data source	Description	Year	Spatial attribute	Reference
Digital Elevation Model (DEM)	Viewfinder panorama for topography	2012	Raster at 3 arc seconds (≈100 m)	[10]
Land-cover European Space Agency	Land-cover spatially harmonized by Worldpop	2015	Raster at 3 arc seconds (≈100 m)	[11]
Population distribution	Spatially redistributed population counts UN projection	2019	Raster at 3 arc seconds (≈100 m)	[11]
National cartography	Geo-administrative units boundaries	2012	Polygon ADM-2 level	[12]
Populated settlements	Geographic coordinates of the populated settlement centre	2002	Polygons and points	[12]
Public health infrastructure	Primary, secondary services and public hospitals	2009	Points	[12]
Road network	Road network by type of surface	2012	Polylines	[12]

Analysis

Under five-mortality ($_0M_5$) rate at ADM-2 level were associated with the explanatory variables using Generalized Linear Models. The analysis starts with descriptive statistics for the estimated $_0M_5$ rate and followed by a bivariate analysis to for identify differentials in the mean mortality rates grouped by the explanatory variables. This was followed by identifying the association of the explanatory variables using multivariate analysis. The multivariate analysis starts with a linear regression model to test for multicollinearity among the explanatory variables using a variance inflation factor less than 4.

The model residuals were checked to test the linear regression assumptions, finding that this method is not appropriate model fit. The mortality rates where modelled using a Poisson regression to test the assumption of a Poisson probability distribution function. This model identified that the conditional variance exceeded the conditional mean, indicating over dispersion. The negative binomial model is preferred over the poison model. The model selection was based on the lowest Akaike information criteria (AIC) since the parameters are maximum likelihood estimates.

The model strategy distinguished two models, firstly a model including every ADM-2 unit (N=340) and the second model estimates mortality rates removing the municipality that serves as the main geo-political centre of the ADM-1 unit (n = 318). These two models where consider given the distinctive pattern of the explanatory variables for the rural areas. This research tested the presence of a spatial pattern in the distribution of child mortality across ADM-2 units. The spatial pattern was analysed applying rooks spatial weights to adjust for the ADM-2 neighbour contiguity and Moran's I Global Index identified spatial dependence of the outcome variable [13]. Data processing and statistical analysis was conducted using R software.

Results

This research measured geographic accessibility to the nearest secondary public health facility and identified potential access barriers associated with under–five mortality rates across municipalities in Guatemala. This research identified relative short travel times between the populated settlements and secondary public health care facilities, as well as identifying a reduced number of secondary public health care facilities available per 10,000 individuals. This research identified variations in under-five mortality rates associated with different potential access barriers, under-five mortality rates in Guatemala are associated with factors conceptually linked to availability, affordability and accommodation.

The availability indicator estimated the number of public health care facilities available for the overall population living within the ADM-2 unit. The average availability of secondary level facilities was estimated to be 0.27 [± 0.06, 95% CI] secondary public health care facilities per 10,000, variations of this value are expected across municipalities. The coverage of the secondary level health care facilities was found to be lower than the value stablished by law: one-second level facility per 10,000 individuals [14]. The coverage gap is likely to increase in highly densely populated areas, such as the metropolitan area and at the main urban centre at the ADM-1 units.

This research estimated travel times from every populated settlement to the nearest secondary health care facility. The average travel time to reach the nearest secondary level facility was 50.7 [± 0.73, 95% CI] minutes and a median of 27.6 minutes. The third quintile indicates that 75% of the settlements in

the country have a travel time lower than 66.7 minutes to the nearest secondary health care facility. Furthermore there is a strong inverse correlation between travel times to secondary level facilities and population density of the administrative unit, this relationship indicating lower travel times in highly urbanised areas. Under the least coast-effective scenario and using motorised transport, these findings suggest a reduced travel cost or geographic barrier. Figure 1 illustrates the inverse relationship between mean travel times and the 2018 population density estimated for 2018, while Figure 2 illustrates the estimated travel time for each populated settlement to the nearest public secondary facility.

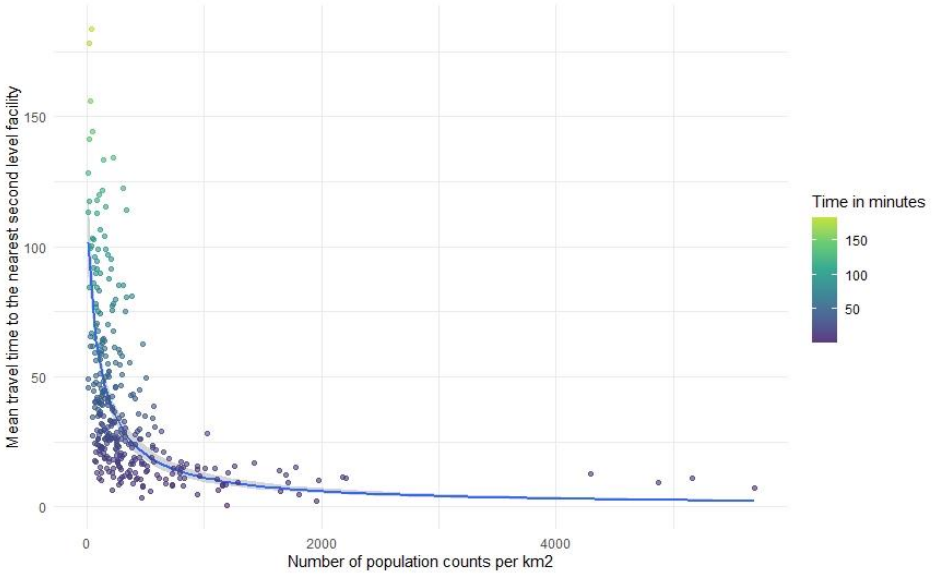

Figure 1: Mean travel time to the nearest secondary health care facility and the population density by ADM-2 unit, Guatemala 2018

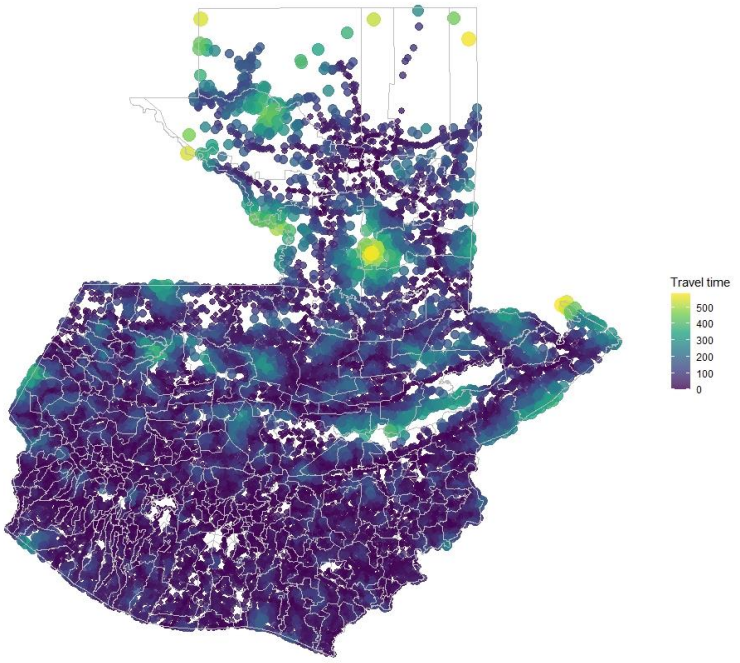

Figure 2: Travel time in minutes from every populated settlement to the nearest secondary public health care facility, Guatemala 2009 health faciltiies and 2002 settlements

This research estimated that the National under-five mortality rate for 2018 was 19.2 deaths per 1,000 live births. Descriptive statistics identified that the average mortality rate at ADM-2 level was 13.9 deaths per 1,000 live births [±1.4, 95% CI]. Different levels of under-five mortality rates are expected across the administrative units, Figure 3 illustrates the rates at ADM-2 level. The average under-five mortality rates for the less urbanized ADM-2 units was 11.9 deaths per 1,000 live births [±1.1, 95% CI]].

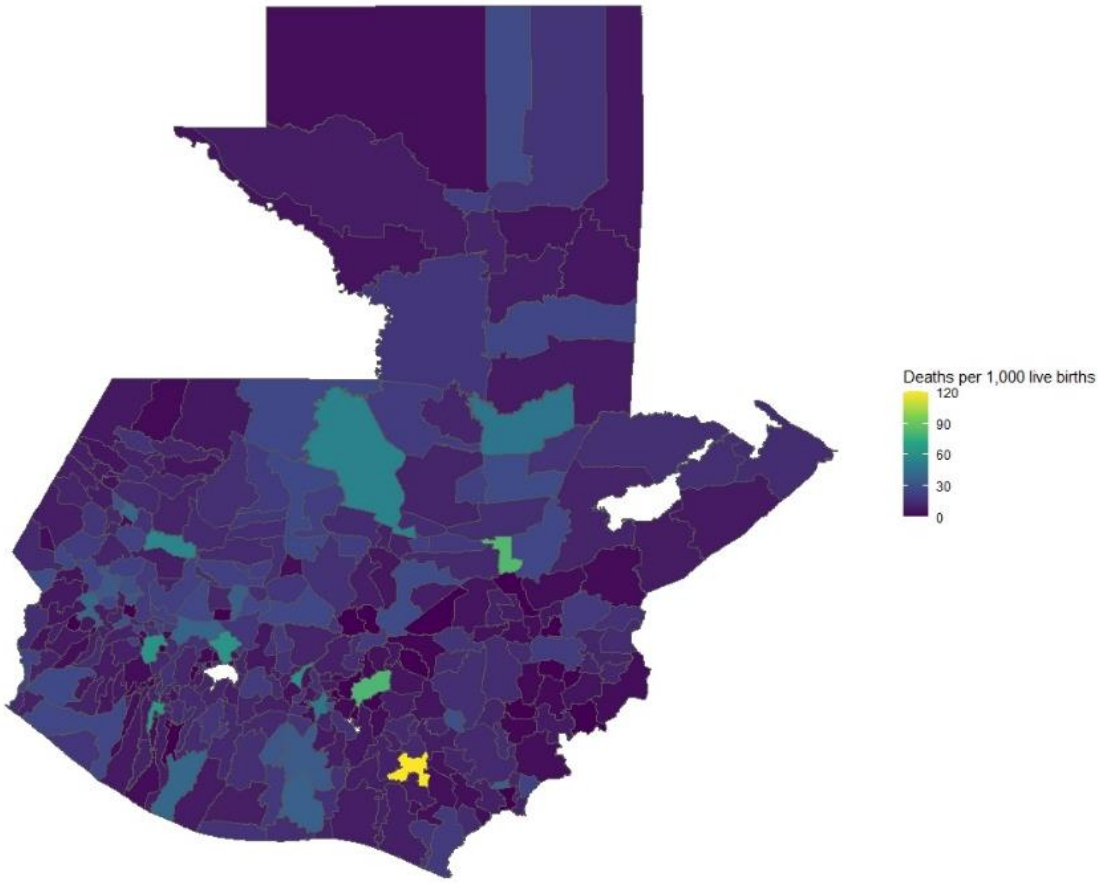

Figure 3: Under-five mortality rates ($_0M_5$) at ADM-2 level, Guatemala 2018

The $_0M_5$ rates were associated with the explanatory variables in order to identify variations in the mortality rates at ADM-2, the model coefficients are described at Table 2. The average under-five mortality rate at municipality level was estimated to be 21.38 deaths per 1,000 live births [±12.7, 95% CI]. Under-five mortality rates at in Guatemala are associated with the level of household wealth at the administrative unit, the population coverage of secondary public health care facilities and the proportion of births attended at private hospitals and the social security service. Under-five mortality rates are likely increase significantly at highly densely populated municipalities and those having a greater proportion of households classified at the lowest wealth group, Figure 4 illustrates increased mortality rates at increased proportion of households in the lowest socioeconomic group. Conversely, mortality rates are likely to decrease at municipalities with: greater proportion of household classified in the highest wealth group, increased availability secondary public health facilities and increased proportion of births delivered at private facilities and the social security service.

Table 2: Negative binomial model to associate under-five mortality rates at ADM-2 level associated with proxy variables for potential access barriers, Guatemala 2018

	Incidence rate ratio	95% CI		p value
(Intercept)	21.376	9.110	50.597	<0.0001
Proportion of households at the lowest wealth group	1.018	1.004	1.033	<0.01
Proportion of households at the highest wealth group	0.983	0.967	0.998	<0.05
Mean travel time to nearest second level facility	1.000	0.998	1.002	0.832
Primary level facilities per 10,000 individuals	0.980	0.887	1.085	0.414
Second level facilities per 10,000 individuals	0.773	0.617	0.978	<0.05
Population density per Km^2	1.000	1.000	1.000	<0.0001
Proportion of indigenous population	0.999	0.996	1.003	0.704
Proportion of rural households	0.996	0.992	1.001	0.117
Proportion of births at public hospitals	1.000	0.992	1.009	0.958
Proportion of births at social security	0.981	0.966	0.998	<0.05
Proportion of births at private hospitals	0.976	0.955	0.998	<0.05
Proportion of births at public secondary services	1.008	0.990	1.026	0.375
Tetha	1.959			
Standard error	0.181			
2 x log-likelihood	-2393.433			
AIC	2419.400			
Moran I statistic	-0.02839			

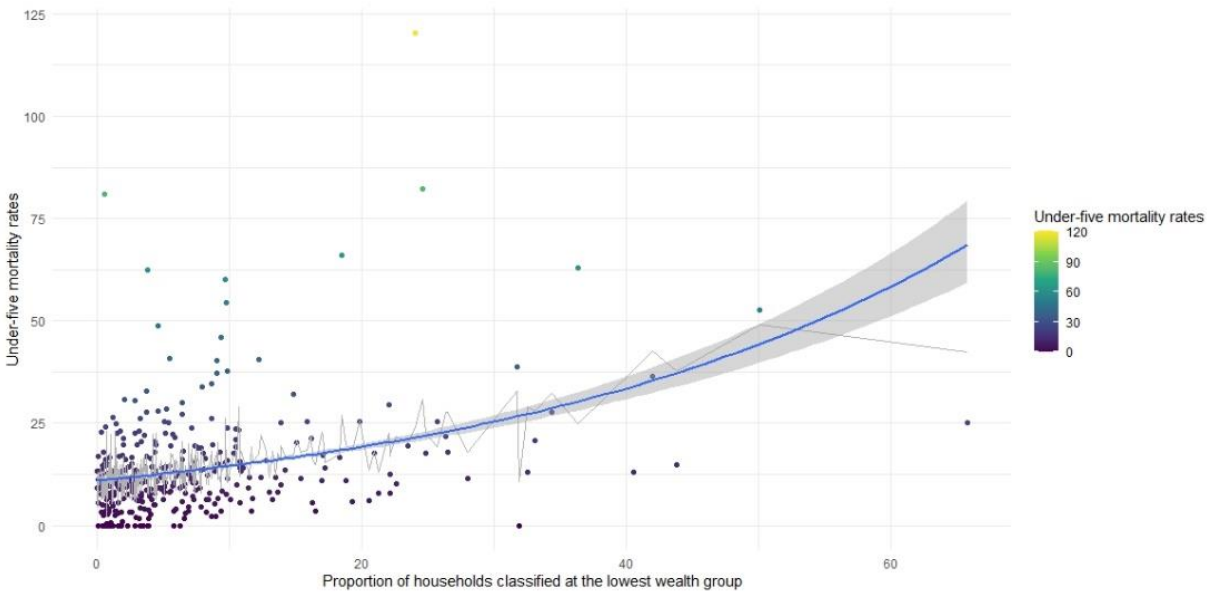

Figure 4:Under-five mortality rates and fitted values for variations associated with the proportion of households classified at the lowest socioencomic group, Guatemala 2018

This research identified that the average under-five mortality rate for rural ADM-2 units only was estimated to be 8.0 deaths per 1,000 live births [±4.5, 95% CI]. Under-five mortality rates in rural municipalities are associated with the level of wealth and the population coverage of the second level

facilities, regression coefficients are shown at Table 3. Different from the previous model, the mortality rates in rural municipalities are likely to increase at administrative units with an increased proportion of rural households and increased proportion of indigenous population. This analysis controlled for child mortality associated with geographic accessibility, measured in travel time to the nearest second level facility or the nearest facility with a General Practitioner, finding no significant association. Additionally, the spatial correlation test identified the Moran I statistic being close to zero, highlighting the random distribution or the absence of a spatial pattern for the under-five mortality rates.

Table 3: Negative binomial model to associate under-five mortality rates for rural ADM-2 only, Guatemala 2018

	Incidence rate ratio	**95% CI**		**p value**
(Intercept)	7.959	3.471	18.342	<0.0001
Proportion of households at the lowest wealth group	1.019	1.005	1.034	<0.01
Proportion of households at the highest wealth group	0.977	0.963	0.991	<0.01
Mean travel time to nearest second level facility	0.999	0.997	1.001	0.369
Primary level facilities per 10,000 individuals	0.975	0.886	1.064	0.494
Second level facilities per 10,000 individuals	0.788	0.645	0.967	<0.05
Population density per Km^2	1.000	1.000	1.000	0.439
Proportion of indigenous population	1.003	1.000	1.006	<0.05
Proportion of rural households	1.004	1.000	1.008	<0.1
Proportion of births at public hospitals	1.009	1.001	1.016	<0.05
Proportion of births at social security	0.991	0.976	1.007	0.275
Proportion of births at private hospitals	0.985	0.965	1.005	0.136
Proportion of births at public secondary services	1.004	0.988	1.020	0.632
Tetha	2.648			
Standard error	0.284			
2 x log-likelihood	-2114.780			
AIC	2140.8			
Moran I statistic	0.0499			

Source: Author's own analysis

Discussion

This research estimated geographic accessibility to the nearest public health facility and identified potential access barriers by exploring under–five mortality rates across geographic areas in Guatemala. These findings contribute upon understanding the spatial distribution of the public health care facilities and the effect a potential access over a health outcome. Travel times following the least-coast path were used to explore the spatial distribution of health services and to derive a geographic accessibility measure. This research used a population health outcome, under-five mortality rates, to explore potential access barriers, finding barriers related with accessibility, affordability, accommodation and availability. The findings of this research highlights that geographic accessibility alone is likely to represent a lesser influence for access to health care services, compared to availability and affordability barriers.

Travel times derived following the least-cost path method found that travel times to the nearest secondary public health care facility are relative short. Under the optimal travel scenario using motorized transport, population living in half of the populated settlements of the country are likely to travel less than 30 minutes to the nearest secondary facility, a considerable shorter than the two hours standard stablished for Emergency Obstetric Care services [15, 16]. Different form this result, the availability of secondary health care facilities is reduced. On average, there are 1.02 primary health care facilities and 0.27 secondary health care facilities per 10,000 individuals. These values being lower than the population coverage parameters stablished by the national policy framework.

Under-five mortality rates at ADM-2 level were used to identify potential access barriers across geographic areas in Guatemala. Guatemala has made progress in child mortality reduction, having similar rates to other Latin American countries [17]. The analysis of potential access barriers associated with under-five mortality rates provide guidance about factors that can be modified to make progress and achieve the SDG goals. This research identified variations in the levels of under-five mortality rates associated with availability and affordability dimensions. Furthermore, the null association between travel times to second level facilities and child mortality levels highlights that geographic accessibility might not represent one of the greatest barriers in access to health care for children across geographies in Guatemala. This finding is aligned to previous research, observing a marginal effect in the relationship between distance and child mortality in other Global South country settings [18, 19].

Mortality rates where associated with the proportion of the population categorised in the lowest or highest household socioeconomic group in order to identify affordability barriers. This research found that mortality rates are likely to increase in the administrative units with increased proportion of households in the lowest socioeconomic group, while declining at greater levels of household socioeconomic. The increased mortality rates for the poorest administrative units can be explained by the method used to construct the household socioeconomic index. The household socioeconomic index is constructed using assets data providing a proxy indicator of the living standards. A lower socioeconomic index indicate poorer living standards and an increased proportion of households classified in the lowest group might highlight increased barriers for access to services, such as safe water sources, access to electricity, sanitation and increased indoor air pollution [20], these are relevant environmental factors associated with infectious diseases [21], malnutrition [22] and child survival [2].

This research identified differences in under-five mortality rates associated with the availability of health care services. Mortality rates at the ADM-2 level are likely to decline with the increased number of second level facilities per 10,000 individuals. An increased availability of secondary health care services is likely to be observed in less densely populated areas and these services are nearest public health service with professional health care workers. These findings are aligned to previous research, studying the effect of increased service provision of professional health care workers over the reduction of infant and child mortality in Mozambique [23]. Previous chapter results analysing individual level data have identified that bypassing behaviour seeking for health care services at second level facilities is associated with seeking for services for maternal and child services and for health conditions that require greater resolution capacity. Increased capacity to deliver health care

services in these facilitates can potentially prevent greater costs to access to professional health care services, providing services to treat morbidities and prevent child mortality.

This research identified that access to other health care providers is associated with variations in the levels of under-five mortality rates. Under-five mortality rates are likely to decline in those administrative units having a greater proportion of births delivered at the Guatemalan Social Security and private health care facilities. This relationship can potentially be explained by greater access to a range of health care services and greater capacity to afford health care services. The Guatemalan Social Security is a social protection regime that provides health care services to employees from the formal sector of the economy. They provide a comprehensive range of services to affiliated employees, including the spouse and under-five years' old children, this scheme can promote utilisation of health care and therefore preventing mortality.

Previous research conducted in other Global South countries have identified that access to health insurance has a positive effect in increasing utilisation of health care and reducing child mortality [24, 25]. The decline of under-five mortality rates at increased proportion of births at private health care facilities might be an indicator of a greater household income. Greater income might be related to greater possibility to afford private health care providers, providing services according to the demand at the time of need. Greater proportion of births at private facilities might indicate a greater acceptability or patient satisfaction for private health care providers, given the increased perceived quality of these services providing comprehensive and timely treatment compared to public health care services [26]. These results are different to previous research conducted in other Latin American Cities, finding a mortality reduction at increased access to public health care services [27].

Under-five mortality rates variations are associated with the geographic distribution of the population, finding that mortality rates increased at administrative units having higher population density values. Increased levels of under-five mortality rates at highly urbanised areas might be explained by greater barriers to access to health care services and health outcomes related to socio-environmental urban dynamics. Increased levels of under-five mortality at urban areas can potentially be related with the economic globalisation of the country and the fast urbanisation from the last decades[28]. This finding is opposed to previous research conducted with the 1,964 and 1,973 population censuses, in which higher under-five mortality rates were estimated at rural areas and in Guatemala City [29].

The urbanisation process in Guatemala has occurred with limited urban planning measures, the urban and peri-urban areas having an unsuitable water discharge and waste management system [30] and ground-level air pollution levels above WHO recommendations [31]. Additionally from the environmental challenges in highly densely populated areas, previous research has identified reduced social capital in these areas related to urban violence [32], the legacy from post-conflict and displaced population [33]. The capacity of the public health care services in highly densely populated areas is likely to be reduced, relying on private health care providers when there is a health care need [34], this condition is likely to undermine access to health care services for those with less financial resources and those living in slums [35, 36]. These findings are similar to previous research identifying a "urban penalty" for child and adult mortality in countries of Sub-Saharan Africa [37].

This research identified higher levels of under-five mortality rates in highly densely populated areas, as well as finding variations in the mortality rates for rural areas only. The mortality rates in rural areas increase in those administrative units with a higher proportion of births at public hospitals. This finding has to be interpreted cautiously, since at the individual level this association is opposite from what it is expected. Previous research conducted in the Guatemala Western Highlands has found that increasing the use of skilled professional services has improved neonatal and prenatal health outcomes in short time [38]. At the environmental level, it is hypothesized that the increased number of births might in public hospitals might indicate the reduced capacity of the lower levels of the public health care system to provide Emergency Obstetric Care. Under-five mortality rates likely to increase in those areas having a greater proportion of indigenous population and households located in rural areas. This research used an interaction term to test the effect of geographic accessibility over increased levels of under-five mortality rates for indigenous and rural areas, finding no significant association. Consequently, these findings might potentially be explained by other individual level or socio-cultural factors, including reduced human capital [39] and lower levels of utilisation of health care services related to mistrust [40] among indigenous population.

This research has some limitations that have to be consider for the interpretation of the findings, these limitations are related to the data available and methodological considerations. The method used to estimate travel times assumes that the individual departs from the populated settlement and follows the least-cost-path and have access to motorized transport, therefore the estimated travel times might not reflect the actual or empirical times [41]. The geographic accessibility measure assumes that the population will seek for health care at the nearest public health facility and that there is no competition. The accuracy of the catchment areas is subjected to the spatial resolution of the raster data, the time accuracy of the covariates and limitations of the dasymetric distribution method.

There are relevant limitations related to the under-five mortality rates, the estimated mortality rates are limited to the quality and completeness of the vital registration data. This reach found lower values for ${}_0M_5$ estimated by the period life table method compared to the child mortality estimates from the 2014-2015 DHS. Vital registrations are likely to misreport deaths, particularly in rural areas; missing data is a relevant limitation since it can introduce a systematic error. This research used a place-base methodological approach to understand potential access barriers across geographic areas [42, 43].This method assumes null mobility between administrative units, therefore it is possible that at the individual level, the health outcome and the explanatory variables, corresponds to the same geographic administrative unit. This research used the smallest spatial unit for data aggregation available, the ADM-2. However, the precision of the areal unit estimates, such as mortality and explanatory variables, are subjected to spatial limitations related to the modifiable unit areal problem [44].

The potential access barriers where measured following a concept and data from an ecological approach. Ecological studies are subjected to different limitations, including the misinterpretation of the explanatory variables due to a cofounder effect, cross-level bias and collinearity [8]. Despite these limitations, this research provides useful evidence about geographic accessibility and potential access barriers associated with under-five mortality rates. The strength of this research is the use of the most recent census data, as well as including vital registration data to include four barriers in the potential access analysis.

Conclusion

This research measured geographic accessibility to the nearest public health facility and identified potential access barriers associated with under–five mortality rates across geographic areas in Guatemala. Geographic accessibility to public health care services represents a lesser barrier to travel to secondary level public health facilities. Potential access barriers associated with variations of under-five mortality rates are related to affordability, accommodation and availability dimensions.

Under-five mortality rates at municipality level are associated with the level of wealth and poverty of the administrative unit. This research found that increased levels of living standards and increased availability of secondary public health care services have a positive effect for the decline of under-five mortality rates. Under-five mortality rates are higher at greater levels of population density or urbanisation, areas likely to have limited capacity to provide public health care services and likely to rely on private services. The increased household living standards might indicate an ability to afford private and timely health care services to prevent mortality. This research found that the use of other health care providers, such as the Guatemalan Social Security services could potentially reduce access to health care barriers and have a positive effect preventing child mortality.

Increasing the capacity to provide services to the population at second level facilities can potentially improve access to public health care services and prevent child mortality in Guatemala. Second level facilities are the service with the closes access to professional health workers, strengthening the service provision of this level can prevent greater costs from travelling to hospitals and prevent mortality across age groups. Improving potential access to secondary level public health care services might be particularly important for populations with increased financial vulnerabilities and less access to quality living standards, both urban and rural areas.

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