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The impact of primary health care and specialist physician supply on amenable mortality in Mexico (2000–2015): Panel data analysis using system-Generalized Method of Moments

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ABSTRACT

The study had a three-fold objective: (i) to estimate the amenable mortality rates and trends at a national and state level between 2000 and 2015 in Mexico; (ii) to estimate the contribution and trends of various causes of death to overall amenable mortality; and (iii) to determine the association between health system inputs and amenable mortality for the period 2000–2015. We used a panel dataset for the period 2000–2015. The following health care inputs were used in the analysis: density of general practitioners, specialists and nurses, as well as density of hospital beds. We find that amenable mortality fell from 136 per 100,000 in 2000, to 124.1 per 100,000 in 2015 nationally, with significant heterogeneity in the trends across states. Mortality due to infectious diseases, diseases of childhood, and cardiovascular diseases decreased, while deaths due to other non-communicable diseases, such as diabetes, increased. There was a significant negative association between the density of general practitioners and specialist physicians, and amenable mortality. Our results indicate that reducing the burden of non-communicable diseases must be a health system priority. Improvements in primary health care could lead to improved disease detection and earlier diagnosis which could further reduce amenable mortality in Mexico.

1. Introduction

It has been more than 15 years since the introduction of Seguro Popular (SP), a public health insurance scheme for uninsured people in Mexico. The introduction of SP has been associated with improved access to health care. According to the National Council for the Evaluation of Social Development Policy (CONEVAL), 57.3 million individuals access affordable health care through SP (CONEVAL, 2014) the majority of whom belong to the four poorest deciles of the population (Knaul et al., 2005). SP was rolled out gradually starting in 2003, and by 2005, all 32 Mexican states were enrolled; it complemented the existing social security programmes (Frenk, 2005; Knaul and Frenk, 2005). The SP has no restrictions based on current health status or pre-existing illness, and no co-payments according to type of health care. Moreover, contributions to SP are based on households' ability to pay: households classified in the first two income deciles are exempt from any annual payment, while those belonging to higher deciles make an annual contribution (Knaul and Frenk, 2005). The total benefits package under SP expanded significantly over time. In 2005, it covered 172 interventions, which increased to 336 by 2012, thus potentially affecting health care utilization rates (Mathauer and Behrendt, 2017). The roll-out of SP was accompanied by progress in key health indicators such as maternal and infant mortality and reduced deaths from communicable and nutrition-related illnesses (Agudelo-Botero and Dávila-Cervantes, 2014).

In concert with the introduction of SP, the Mexican government steadily increased its investment in the public health care system from 2.6% of the gross domestic product (GDP) in 2004, to 3.2% of GDP in 2014 (Secretaria de Salud - SSA, 2014). The increased public spending was coupled with improvements in the health infrastructure, with the construction of 2284 outpatient clinics and 262 community, general, and specialized hospitals between 2001 and 2006 (Conti and Ginja,

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2017). In addition, access to general practitioners, specialist physicians, nurses, and hospital beds increased over this period (Knaul et al., 2012). Furthermore, the number of general practitioners (GPs) and specialist physicians per capita increased by 36% and 40% respectively between 2000 and 2013 (INEGI, 2019).

However, it is still unclear whether the additional expenditure on health care resulted in better population health outcomes. For example, while there was a gradual reduction in the catastrophic health care expenditure (expenditure on health care representing over 25% of total household budget) (Ávila-Burgos et al., 2013; King et al., 2009), the rate of reduction declined over time (Nikoloski and Mossialos, 2018). Since the early 2000s, the prevalence of obesity has reached epidemic proportions nationally (OECD, 2017). These factors have contributed to slow growth in life expectancy over the past decade compared to other Organization of Economic Cooperation and Development (OECD) countries. Consequently, in 2016 there was a 5.5-year life expectancy gap between Mexico and the OECD average, an increase from a 4.2-year gap in 2006 (OECD, 2017). Furthermore, there are substantial inequalities in health status. The most marginalized states with the highest proportion of indigenous people have poorer health outcomes than the other states (PAHO, 2012). More specifically, children under the age of 5 in these states are 1.7 times more likely to die (PAHO, 2012).

Avoidable mortality can be used as an indicator of health system performance, but this topic has received limited attention in Mexico. The concept of avoidable mortality has been around since the late 1970s (Beltrán-Sánchez, 2011). It was first coined by Rutstein et al. (1976) as an alternative measure of quality of health care and was based on the notion that if everything goes well in the medical system, deaths due to certain conditions should not occur. Subsequently, the idea received significant interest among researchers resulting with a handful of studies, mainly based on US and European data (Charlton et al., 1983; Holland et al., 1994; Newey et al., 2004). Over the years, when studying the concept of avoidable mortality, researchers started to distinguish between 'amenable' deaths (i.e. deaths due to conditions amenable to medical interventions) and 'preventable' deaths (i.e. deaths due to conditions that can be prevented by system-wide health policies). In other words, a death can be considered as amenable if it could have been avoided through optimal quality health care (Nolte and McKee, 2004). Preventable deaths, on the other hand, is a broader concept and includes deaths which could have been avoided by public health interventions focusing on wider determinants of public health, such as behaviour and lifestyle factors, socioeconomic status and environmental factors (Nolte and McKee, 2004). The concept of amenable mortality, although sometimes used interchangeably with avoidable mortality, is intended to focus solely on conditions that capture the impact of medical care (Nolte and McKee, 2004).

Amenable mortality ties health system performance to a variety of diseases that should not result in death given the state of medical knowledge and technology (Kossarova et al., 2013). In a seminal study, Franco Marina et al.(Franco Marina et al., 2006) estimated the level and trends of avoidable mortality in Mexico at the national and state level between 1990–1994 and 2000–2004 by specific disease, age group, sex, and income disparity, and found a drop in avoidable mortality of 3% between the two periods. In addition, they found that 39% of all deaths were avoidable, 65% of which were due to non-communicable diseases (NCDs), followed by infectious disease, nutrition and reproductive conditions. Additionally, NCDs accounted for an increasing percentage of overall avoidable mortality over time. This is echoed in a study by Canudas-Romo et al. (2015) who found that certain NCDs (e.g. diabetes) are associated with shorter life expectancy in Mexico. In contrast, Agudelo-Botero & Davila-Cervantes (Agudelo-Botero and Dávila-Cervantes, 2014) found a 2.1% increase in the age-adjusted amenable mortality rate from 149.5 per 100,000 inhabitants in 2001 to 171.3 per 100,000 inhabitants in 2010. However, when considering only states on the Mexico–US border, Agudelo-Botero et al. (Agueldo--Botero et al., 2015) estimated that there had been a 9.1% decrease in amenable mortality between 1999–2001 and 2009–2011. The inconsistencies in these findings may be attributed to differing lists of causes of avoidable or amenable mortality, regional disparities in health outcomes, and geographic heterogeneity. Franco Marina et al. (Franco Marina et al., 2006) use a broad definition of avoidable mortality and include conditions both amenable to medical care and preventable by wider policy changes such as lung cancer and HIV. In contrast, Agudelo-Botero & Davila-Cervantes (Agudelo-Botero and Dávila-Cervantes, 2014) and Agudelo-Botero et al.(Agueldo-Botero et al., 2015) use a definition based on Nolte and McKee (2012), which included only causes of death amenable to medical interventions. However, while most previous studies have focused on describing avoidable or amenable mortality and its trends, none of them have assessed the associations between amenable mortality and its determinants.

Given this background, this study had three objectives:

1. To estimate the amenable mortality rates and trends at a national and state level between 2000 and 2015 in Mexico;
2. To estimate the contribution and trends of various causes of death to overall amenable mortality; and
3. To determine the association between health system inputs and amenable mortality for the period 2000–2015. In particular we are interested in a set of health inputs which are associated with increased healthcare expenditure.

This last objective was designed to ascertain whether increased investments in the public health care sector were associated with commensurate improvements in health outcomes.

2. Methods

2.1. Determining amenable mortality at state level

The data used to estimate the age-standardized amenable mortality rate and its individual components was collected from the following official sources:

(1) General deaths by specific condition, published by the *National Institute of Statistics and Geography* (INEGI, 2019), to allow for the bottom-up approach we have taken (while we also considered using the aggregate CONAPO data for sensitivity analysis, this was not possible, given the bottom-up approach adopted and the narrower definition of amenable mortality); (2) population by age group from 1990 to 2015, published by the *National Population Council* (CONAPO, 2016); and (3) population standardization factors from the WHO World Standard Population ratios (World Health Organization, 2001).

The deaths were classified as amenable deaths based on an established list of conditions considered amenable to medical care (Nolte and McKee, 2012) (Table 1). The study's focus on amenable mortality means that we have not included mortality due to conditions that could be prevented through health policies or other system-wide policies (e.g. deaths due to homicides or lack of access to water and sanitation) although some research has focused on these (Elo et al., 2014; Alvarez et al., 2019; Aburto et al., 2016). Inter alia, we considered conditions such as selected childhood infections, diabetes, treatable cancers, cerebrovascular disease, and hypertension as amenable mortality (Nolte and McKee, 2012). We also included 50% of deaths due to ischaemic heart disease as deaths amenable to medical intervention (Nolte and McKee, 2012). We only take half of the deaths due to ischaemic heart disease as the other half of deaths could have been prevented by more general, system-wide health policies (Nolte and McKee, 2012). The upper age limit of the registered death was set to 75 years, while younger age limits were applied to selected conditions such as diabetes (under 50), certain childhood infectious intestinal and respiratory diseases (under 15), and leukaemia (under 45) (Nolte and McKee, 2012). Different age limits were set for diabetes as preventability of deaths at older ages from

Table 1
List of causes/diseases branded as 'amenable'.

Mortality causes	Age groups	International Classification of Diseases (ICD) 10th revision
Infectious diseases		
Intestinal infections	0–14	A00-A09
Tuberculosis	0–74	A15-A19
Other infections (diphtheria, tetanus, septicaemia, poliomyelitis)	0–74	A36,A35, A80
Whooping cough	0–14	A37
Measles	1–14	B05
Tumours		
Malignant neoplasm of colon and rectum	0–74	C18–C21
Malignant neoplasm of skin	0–74	C44
Malignant neoplasm of breast	0–74	C50
Malignant neoplasm of cervix uteri	0–74	C53
Malignant neoplasm of cervix uteri and body of uterus	0–74	C54, C55
Malignant neoplasm of testis	0–74	C62
Hodgkin's disease	0–74	C81
Leukaemia	0–44	C91–C95
Diabetes	0–49	E10-E14
Ischaemic heart disease: 50% of deaths	0–74	I20–I25
Other circulatory disease		
Chronic rheumatic heart disease	0–74	I05–I09
Hypertensive heart disease	0–74	I10–I13, I15
Cerebrovascular disease	0–74	I60–I69
Respiratory disease		
Respiratory diseases (excluding pneumonia and influenza)	1–14	J00-J09, J20-J99
Influenza	0–74	J10-J11
Pneumonia	0–74	J12-J18
Surgical conditions		
Peptic ulcer disease	0–74	K25–K27
Appendicitis	0–74	K35–K38
Abdominal hernia	0–74	K40–K46
Cholelithiasis and Cholecystitis	0–74	K80–K81
Nephritis and nephrosis	0–74	N00–N07, N17–N19, N25–N27
Benign prostatic hyperplasia	0–74	N40
Misadventures to patients during surgical and medical care	0–74	Y60–Y69, Y83–Y84
Maternal, congenital and perinatal conditions		
Maternal deaths	0–74	O00–O99
Congenital cardiovascular anomalies	0–74	Q20-Q28
Perinatal deaths, all causes (excluding stillbirths)	0–74	P00–P96
Other conditions		
Diseases of the thyroid	0–74	E00-E07
Epilepsy	0–74	G40-G41

Source: Nolte and McKee (2012)

diabetes, and in particular the effectiveness of good diabetic control in reducing vascular complications, remain controversial (Nolte and McKee, 2012).

The causes of death were classified according to the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) (ICD-10, 2016). The age-standardized amenable mortality rates by state and year were calculated using the following equation:

$$AM = \sum_x \left(\frac{d_x}{p_x} P_x \right) \Big/ \sum_x P_x$$

where, AM is the amenable mortality; d_x is the number of deaths in age group x by number or condition; p_x is the population in age group x; and P_x is the proportion of the population in age group x relative to the standard population. Numbers of deaths were calculated based on the data as it was reported. The causes of deaths we are using for the analysis are precisely specified and refer to deaths below the age of 75, thus reducing the chance of including so-called 'garbage codes'. The age-standardized mortality rates were calculated for the entire country as well as on a state level. The age-standardized mortality rates were also calculated for the main types of amenable mortality.

2.2. Panel data analysis using system Generalized Method of Moments

Apart from calculating the amenable mortality rates, we aimed to estimate the association between health system supply-side factors and amenable mortality. To date, there have been some efforts to model the determinants of mortality (Basu et al., 2019; Gerry et al., 2014). Some of these, however, could not be directly replicated in our case for the following reasons. First, the use of a mixed effects model still doesn't address the endogeneity issue and should therefore be coupled with an instrumental variable approach – an extremely difficult endeavour in the context of a middle-income country. Second, we were interested in the wider set of 'determinants' while focusing on health care supply variables, particularly those that are a function of increased healthcare expenditure. Hence, our methodological approach was appropriate to the objectives that we wanted to achieve. We used three statistical models to assess the associations between health system supply and amenable mortality: 1) Model 1 used ordinary least squares (OLS); 2) Model 2 used fixed effects regression; and 3) Model 3 used the system Generalized Method of Moments (system-GMM). The OLS and fixed effects represented the upper and lower bounds respectively for the coefficient of the autoregressive term (Bond, 2002).

We constructed a panel data set for all 32 states, from 2000 to 2015, using data from official government sources. We used the following equation to estimate overall population health:

$$AM_{it} = \beta_0 + \beta_1 X_{it} + \varepsilon_{it}$$

where the logarithm of the age-adjusted amenable mortality, $\boldsymbol{AM_{it}}$, in state $\boldsymbol{i}$ at time $\boldsymbol{t}$ is a function of the health input variables $\boldsymbol{(X)}$. In making these calculations, we took into account, firstly, that the state-specific amenable mortality rates are based on previous estimates, and secondly, that some explanatory variables are endogenous (Gerry et al., 2014). We, therefore, adopted the system-GMM dynamic approach and estimated overall population health using the following equation (Gerry et al., 2014):

$$AM_{it} = \beta_0 + \beta_1 AM_{i,t-1} + \beta_2 X_{it} + \varepsilon_{it}$$

The selection of the independent variables was based on two main factors: 1) a comprehensive review of the literature; and 2) constructing a model that was as representative as possible, while accounting for the most common factors associated with amenable mortality and taking into account variables that are a function of the increased healthcare spending during our study period (Conti and Ginja, 2017). We used the logarithm of age-adjusted amenable mortality as a dependent variable in this exercise. We assumed that the dependent variable was state-dependent, and so we included an auto-regressive term (i.e. a lagged value of the dependent variable). More specifically, as noted in our third research objective, one of the main goals of this work was to explore the link between amenable mortality and health inputs that are a function of increased healthcare expenditure. To take account of this, our set of independent variables includes: density of specialist physicians and nurses and the availability of hospital beds per 100,000 population. We selected these variables as their density increased during the study period, due to an increase in overall healthcare spending Conti and Ginja (2017); Knaul et al. (2012); INEGI (2019)). Moreover, these are the most common healthcare inputs used in analytical endeavours in the context of low and middle income countries (World Development Indicators, 2021). In addition, and to account for the level of socio-economic development across federal units, we also included the level of development reflected by the Gross Regional Product (GRP) per capita, in real terms. We did not age-standardize the independent variables, following the established practice in cross-regional research

(Gerry et al., 2014).

We omitted health expenditure as one of the independent variables for the following reason: different levels of per capita health expenditure may translate into variable levels of health inputs per federal district, given differences both in health care consumption patterns and labour costs across the different regions or districts. In other words, two regions might spend the same per capita amount of health resources but on a different mix of inputs. Therefore, our selected supply-side independent variables – GPs, specialist physicians, nurses and hospital beds – capture how health care expenditure is translated into health care inputs. Nevertheless, in the supplementary materials we also report the results when including proxies for public health expenditure (i.e. regional real health expenditure per capita as well as regional health expenditure as a share of gross regional product). Further information about the sources of the variables is provided in *Supplementary material*.

We used a system-GMM approach to address problems of endogeneity, such as: reversed causality, time-invariant heterogeneity, or unobserved factors, which posed significant threats to the validity of the findings, potentially leading to biased estimates. In the case of reverse causality, for example, the density of GPs could have an impact on amenable mortality, but amenable mortality itself could also have an impact upon the authorities' decision to allocate more (or fewer) health resources to a particular state. In addition, there may have been unobservable, constant factors, such as cultural practices, that could have an impact on amenable mortality, and result in unobserved heterogeneity. System-GMM has been used previously to assess cross-country determinants of economic growth (Roodman, 2008). Further details on the technique and specification of the System-GMM are provided in *Supplementary material*.

All the analyses were done using STATA version 14 SE (StataCorp, College Station, Texas, USA).

2.3. Ethical considerations

The study was a mathematical modelling study based on aggregated data, and there were no study participants, so participant-informed consent and the need for ethics approval do not apply.

3. Results

3.1. Levels and trends of amenable mortality

Table 2 summarizes the level and trends of amenable mortality, overall and by specific conditions, at a national level from 2000 to 2015 (Supplementary material Table A1 summarizes the contribution of specific conditions to the overall amenable mortality rate). The overall age-standardized amenable mortality rate was 136.0 per 100,000 population in 2000 and 124.1 per 100,000 population in 2015, a 9% decrease. NCDs, including cardiovascular conditions, tumours, and diabetes accounted for more than 60% of amenable mortality. Cardiovascular diseases such as ischaemic heart disease had the highest amenable mortality rate with 55 deaths per 100,000 individuals in 2015, accounting for approximately 44% of amenable deaths. Malignant neoplasms were the second largest contributor, accounting for 13% of all amenable deaths. Perinatal conditions and respiratory conditions, such as influenza and pneumonia, accounted for about 8% each.

The change in cause-specific amenable mortality varied. For example, mortality rate due to cardiovascular conditions dropped by 6%, while mortality rate due to perinatal conditions dropped by 30%. Marked improvements in the amenable mortality rate were also seen for other conditions. Mortality rate due to intestinal problems and tuberculosis decreased by 68% and 56% respectively. Conversely, respiratory diseases, especially influenza and pneumonia, increased markedly by 5% and 6%, respectively. Mortality rate due to diabetes increased by 22%, and as a result, diabetes accounted for 6% of the total amenable mortality in 2015 (up from 4% in 2000).

Table 2
Age-standardized amenable mortality rate (per 100,000) for Mexico, 2000–2015 – overall and by condition.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Change
Overall Amenable Mortality Rate	136.0	133.1	132.1	130.7	127.8	128.4	125.0	126.3	126.9	131.3	127.5	124.3	124.3	121.5	126.4	124.1	−9%
By Condition																	
Cardiovascular	58.5	57.7	57.7	57.1	56.0	55.2	53.9	56.3	56.6	58.3	57.3	55.3	55.0	53.4	55.0	55.0	−6%
Malignant Neoplasms	17.3	16.9	16.7	16.3	16.4	16.4	16.3	16.2	16.2	15.9	15.6	15.3	15.7	15.4	16.5	16.7	−3%
Cervical and Breast Cancer	12.7	12.3	12.1	11.6	11.7	11.5	11.3	11.0	10.9	10.9	10.4	10.1	10.2	9.6	10.2	10.2	−20%
Perinatal Deaths	13.9	13.1	13.5	12.4	12.1	12.1	11.3	11.1	11.0	11.0	10.7	11.0	10.7	9.7	9.8	9.7	−30%
Respiratory	9.0	8.2	8.2	8.2	8.2	8.5	8.8	8.2	8.3	10.9	9.3	8.7	9.1	9.4	11.2	9.4	5%
Influenza and Pneumonia	8.6	7.8	7.7	7.8	7.8	8.2	8.5	7.8	7.9	10.4	8.8	8.4	8.9	9.1	11.5	9.6	6%
Nephritis and nephrosis	9.6	10.1	9.0	9.5	9.5	9.6	9.6	9.3	9.6	9.9	9.5	9.3	8.9	8.4	9.1	9.2	−5%
Diabetes	6.4	6.5	7.0	7.1	7.3	7.5	7.4	7.4	7.7	8.0	7.9	7.4	7.4	7.6	7.9	7.8	22%
Tuberculosis	4.3	4.4	3.9	3.8	3.0	3.0	2.7	2.4	2.5	2.4	2.5	2.6	2.2	2.3	2.0	1.9	−56%
Intestinal	1.9	1.7	1.6	1.5	1.4	1.4	1.2	1.1	0.9	0.8	0.7	0.7	0.7	0.7	0.6	0.6	−68%

Fig. 1 shows the rate of amenable mortality according to state in 2000 and in 2015. There was an overall reduction in amenable mortality across states over the period of this study, but the reduction was varied across states. For example, amenable mortality dropped by a fifth in states such as Mexico City and Baja California, while it increased by 25% in Guerrero, by 20% in Campeche, and by 12% in Durango. However, the distribution of amenable mortality at state level was generally similar in 2000 and 2015.

Changes in disease-specific mortality also varied across states. Only two states had a reduced incidence of diabetes-related amenable mortality. In contrast, over half the states showed a decrease in mortality due to cardiovascular conditions. The largest change was in perinatal deaths: mortality decreased in approximately 90% of states. The disaggregated data helped to explain the variability across various states. For example, deaths due to cardiovascular diseases (which accounted for almost half of the total amenable mortality) were highest in the northern states of Chihuahua, Sonora and Coahuila, which explains the higher amenable mortality in these states. While amenable mortality decreased in most states, in some states the overall amenable mortality increased due to rising numbers of deaths attributable to cardiovascular diseases and diabetes. Supplementary material Tables A2, A3 and A4 show the changes in mortality due to cardiovascular disease, diabetes and perinatal deaths, respectively.

3.2. *Results of the regression analysis and system Generalized Method of Moments*

Table 3 shows the associations between health system supply-side factors and amenable mortality according to the three models described in the Methods section.

A number of findings emerged from the models. Firstly, the autoregressive term was positive and significant, suggesting persistence in the amenable mortality series (i.e. strong correlation between present and past values of the amenable mortality). In addition, the density of GPs and specialist physicians was negatively associated with amenable mortality rate. More specifically, a unit increase in the density of GPs and specialist physicians was associated with a 0.6% and 0.5% reduction in the overall amenable mortality, respectively. The system-GMM estimates passed the necessary diagnostic tests to confirm its validity. More specifically, the Hansen test value was 0.502 and the parameter value for the autoregressive term (0.767) lay between the values obtained through fixed effects (0.470) and OLS (0.907), as expected. Finally, the estimates passed the general rule that the number of instruments was smaller than the number of groups used in the model.

As mentioned in the methodological part of the paper, while our principal modelling does not include a proxy for public health expenditure, in Supplementary material Table A5 and A6 we also report the findings with the inclusion of proxies for public health expenditure (real public health spending per capita and public health expenditure as a share of gross regional product) as independent variables. The findings suggest that the public health expenditure variable is insignificant, without affecting the sign and significance of the other variables in the model.

4. Discussion

Our study has some important findings. First, we found a 9% drop in the national level of amenable mortality. Second, there was significant heterogeneity in levels and trends of amenable mortality across various states. This heterogeneity across states explains the small change in amenable mortality at a national level. Lastly, the results from the analytical model showed that the density of GPs and specialist physicians at a state level was associated with lower amenable mortality.

At national level, the reduction in amenable mortality in Mexico found in this study is less than that experienced in other middle- and high-income countries. For example, Nolte and McKee (2012) found a considerably greater reduction in amenable mortality in three European countries and the US over a similar time period. Between 1999 and 2007, amenable mortality among men fell by the following amounts: France 27.7%, Germany 24.3%, UK 36.9% and US 18.5%. Among women, similar decreases were also recorded: France 23.4%, Germany 22.7%, UK 31.9%, and US 17.5%. Similarly, in Brazil, Hone et al. (2017) found a 20% reduction in amenable mortality from municipalities with the lowest governance score, rising to 26% in municipalities with the highest governance score over the period 2000–2012. However, their analysis only included about one quarter of the 5565 municipalities in the country.

We found significant heterogeneity in levels of amenable mortality across different states. The amenable mortality was highest in northern states, mostly due to higher mortality resulting from diabetes and cardiovascular diseases. This result is consistent with the results of a recent study which found that the northern and central states of Mexico had the highest rates of obesity, diabetes, and mortality from ischaemic heart disease (González-Pier et al., 2016). Furthermore, this is in line with the findings by Aburto et al. (2016) who also found that mortality due to ischaemic heart disease is higher in the northern states.

Our study also documented different trends in amenable mortality across states. Although there was significant heterogeneity in amenable mortality across states, some causes of amenable mortality such as tuberculosis, perinatal illnesses and cervical and breast cancer, decreased in almost all states. This is consistent with the results of a study, which found a decrease in perinatal mortality in Mexico (Aburto et al., 2018). Some of the reasons for the reduction in perinatal mortality may be programmes such as "Hospital Amigo del Niño y la Niña" (Boy and Girl Hospital Friend) initiative, "Maternal Lactation Education", and the implementation of maternal milk banks. Furthermore, economic development is known to be associated with a reduction in childhood mortality, and Mexico had a cumulative growth in GDP of 8.3% during the study period (Bhalotra, 2006).

However, while perinatal mortality dropped, mortality due to NCDs such as diabetes rose in most states during the study period. Aburto, Riffe, and Canudas-Romo (Aburto et al., 2018) found that the increase in diabetes paralleled the sharp increase in obesity rates in the country. The rise in deaths attributable to diabetes has paralleled a rise in the diabetes prevalence rate. Official data suggests that the prevalence of diabetes at national level has witnessed a steady rise from 7.5% in 2000 to 12.6% in 2013 (IDF, 2015). Importantly, mortality due to diabetes has increased despite the continuing policy efforts of the national authorities such as the National Action Plan for Diabetes (2001–2006) which led to the creation of "Grupos de Mutua Ayuda" in each state to provide education, metabolic control, and adherence to treatment, for people with diabetes. The more recent National Plan for Diabetes (2007–2012) – including mass media campaigns for self-care, active screening and care campaigns – has not translated into a sufficient reduction of increased risk for mortality associated with obesity (Secretaria de Salud, 2011).

Our results show that primary health care (measured using the density of GPs as a proxy) was related to amenable mortality. Using a cross-country regression analysis for 18 wealthy OCED countries, Macinko et al. (2003) found that the number of doctors per 100,000 population was negatively associated with all-cause premature mortality. Similarly, in Germany, Sundmacher (Sundmacher and Busse, 2011) found that higher physician supply was associated with significantly lower avoidable cancer mortality. Basu et al. (2019) found that a total of 10 additional primary care physicians per 100,000 population in the US was associated with reductions in cardiovascular, cancer, and respiratory mortality of 0.9%, 1.0% and 1.4%, respectively. Finally, we found that the density of specialist physicians was negatively associated with amenable mortality. In the Mexican context, a significant number of specialist physicians operate at office-based practices or have a dual hospital-primary care practice (OECD, 2016). Increasing the number of GPs and specialist physicians could further reduce amenable mortality.

As previously stated, in this paper we only take into consideration

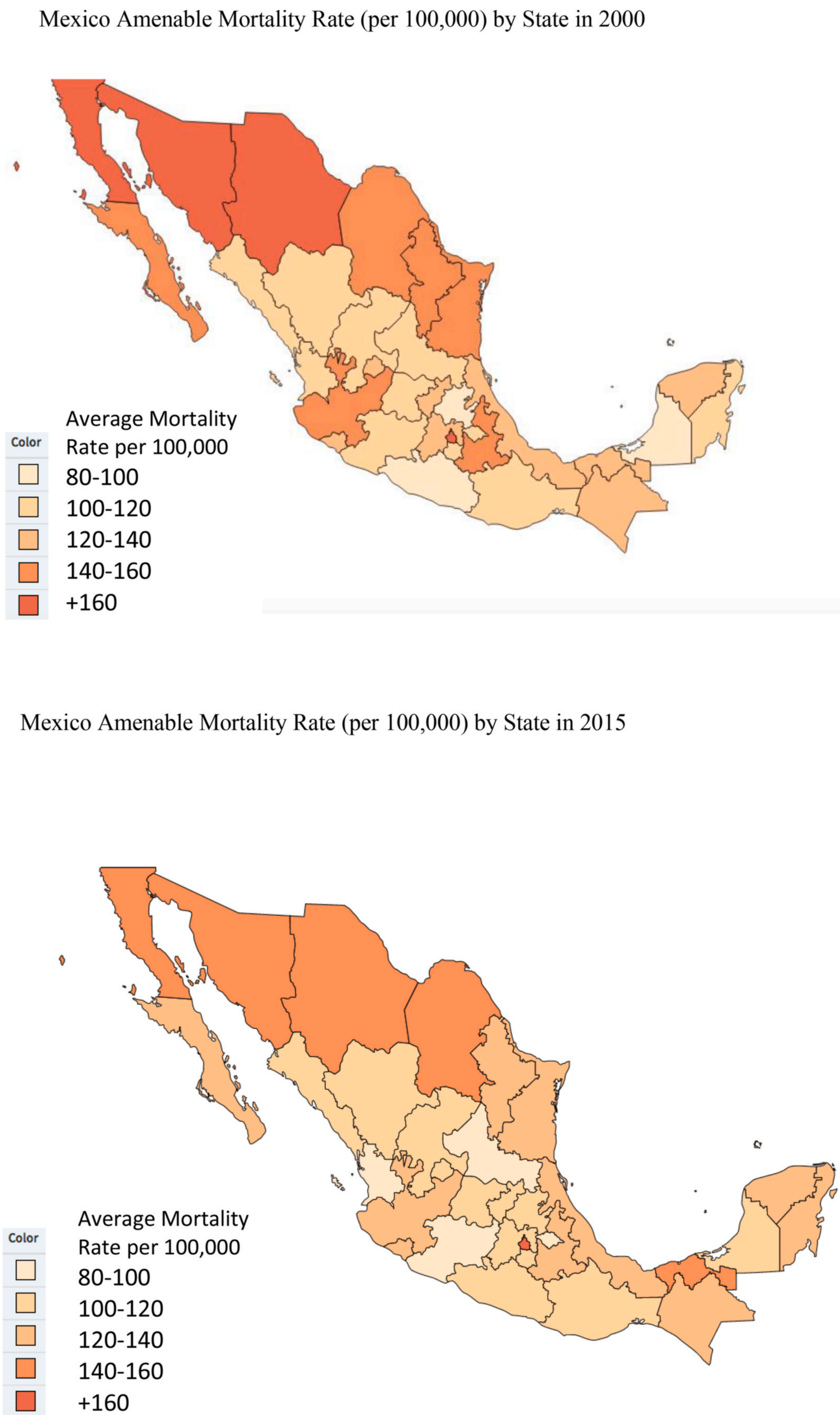

Fig. 1. Amenable mortality rate in Mexico in 2000 and 2015 by state.

Table 3
Regression results: OLS, fixed effects and system-GMM using amenable mortality rate as a dependent variable.

Variable	OLS (1)	Fixed Effects (2)	System-GMM (3)
Amen. Mortality (t-1), log	0.907***	0.470***	0.767***
	(0.019)	(0.081)	(0.170)
GRP per capita, log	0.006	0.036	0.093
	(0.004)	(0.021)	(0.077)
GPs per 100,000 people	−0.0003	−0.0009	−0.006***
	(0.0002)	(0.0007)	(0.002)
Specialists per 100,000 people	−0.0001	−0.0005	−0.005***
	(0.0002)	(0.0006)	(0.002)
Beds per 100,000 people	0.0004*	0.0008*	−0.001
	(0.0001)	(0.0003)	(0.003)
Nurses per 100,000 people	−0.00001	0.0001	0.003*
	(0.0001)	(0.0003)	(0.001)
Intercept	0.363***	2.11***	
	(0.100)	(0.326)	
Observations	448	448	448
Groups	32	32	32
Instruments			26
Hansen Test			0.502

*** denotes significance at 1%, ** at 5% and * at 10%. The reported numbers are parameter estimates from respective regression analyses. All models are estimated with robust standard errors which are reported in parentheses. In the system-GMM estimations, lagged values of the endogenous variables are used as instruments for themselves. The standard two step procedure is used. Moreover, the same set of instrumented are used in the levels as well as in the differences equations. Year dummies also included but not reported in the table.
OLS – Ordinary Least Squares.
System-GMM: system-Generalized Method of Moments.
GRP – Gross Regional product.
GPs – General Practitioners.

amenable mortality, i.e. mortality due to conditions amenable to medical care. While there has been a burgeoning literature on the impact of preventive interventions (e.g. access to clean water and clean sanitation) or other, system-wide policies, which would prevent deaths like homicides (Aburto and Beltrán-Sánchez, 2019), these broader definitions of avoidable mortality fall outside this paper's remit.

There are some limitations to this study. While previous evidence indicates that socioeconomic factors such as inequality and level of education are significant determinants of health outcomes, we did not include them in the model, because the available data was inconsistent by year and the quality was limited. We used only the most common correlates of amenable mortality. The quality of the data used could also be considered as an additional limitation to this work, but the approach adopted mitigated some of these risks. Firstly, by taking into account deaths occurring below the age of 75 and causes of deaths that mostly affect adults, we reduced some of the imprecision associated with death counts, particularly for the older population (over 85) and for children (Aburto et al., 2016). Second, while changes over time in the reporting of causes of death could also be mentioned as problematic in Mexico, the ICD-10 chapter level underlying the cause of death codes used in our analysis is reported as capable of returning reliable estimates of the disease burden in the population, as previously documented in existing research (Wright, 2017). However, there are some limitations regarding the link between amenable mortality and enrolment in various health insurance schemes (e.g. Seguro Popular, IMSS), which, given the nature of the data we used, cannot be tackled in this paper.

5. Conclusion and policy implications

This study assessed the trends in amenable mortality in Mexico over the period 2000–2015, at national and state levels, and assessed the determinants of these trends. The decrease in amenable mortality over the study period was driven mostly by a reduction in diseases of childhood. We also found a significant increase in amenable mortality due to diabetes during a period when the prevalence of diabetes was also increasing. Finally, using a state-level panel data analysis, we found a strong negative association between the density of GPs and specialist physicians and amenable mortality.

Based on the association between physician density and amenable mortality reduction, it is recommended that Mexico allocates more resources to primary care, to match similarly sized economies. Currently not all Mexican citizens register with a primary care doctor and primary care has not been developed as a distinct medical specialty (OECD, 2016). Mexico only has 2.2 practising physicians per 1000 population, and although it is comparable to the density of physicians in Brazil (2.1), it is much lower than that of Argentina (3.9) (OECD, 2016). More resources and better training could increase physician availability and access in disadvantaged areas and reduce dependence on the hospital sector, thus contributing to further reductions in amenable mortality.

At the start of 2020, SP was replaced by Health Institute for Wellbeing (INSABI), which should allow all Mexican citizens to access public hospitals or clinics without paying, while also covering the cost of medications (Agren, 2020). To what extent this policy change will contribute to further reduction in amenable mortality remains to be seen.

Author credit statement

Zlatko Nikoloski and Elias Mossialos designed the study. Zlatko Nikoloski and Andres Madriz Montero conducted the data work with assistance from Sarah Albala. Sarah Albala assisted with the preparation of the paper figures. All authors participated in the drafting of the final version of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2021.113937.

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