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Articles

Mortality at the county level in the USA-Mexico and USA-Canada border regions

Mortalidad a nivel de condado en las regiones fronterizas Estados Unidos-México y Estados Unidos-Canadá

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Abstract

The areas near a country border have interesting demographics since they are the zones where two cultures collide. The USA has two long land borders with Canada and Mexico. Mortality between 1999-2019 is examined at the county level in the two border regions, compared to the non-border regions of the border states. Analysis is based on single figure indices, with combinations of confounders age, gender and cause of death. Findings confirm differences between border and non-border regions, with opposite results at each border. As far as is known there is no previous mortality study concerning both borders and therefore the contribution of the work is to demonstrate the differences between the border and non-border regions for the two borders and discuss possible reasons. Further, we show that the more detailed analysis at the county level, even with certain data limitations, gives important insights to the topic.

Keywords: county mortality, USA-Mexico border, USA-Canada border, hispanic paradox, single indices.

Resumen

Las áreas cercanas a la frontera de un país tienen una demografía interesante ya que son las zonas donde chocan dos culturas. Estados Unidos tiene dos largas fronteras terrestres con Canadá y México. Se examina la mortalidad entre 1999 y 2019 a nivel de condado en las dos regiones fronterizas, en comparación con las regiones no fronterizas de los estados fronterizos. El análisis se basa en índices, con combinaciones de factores como edad, sexo y causa de muerte. Los resultados confirman diferencias entre regiones fronterizas y no fronterizas y entre fronteras. Hasta donde se sabe, no existe un estudio pre-

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vio de mortalidad en ambas fronteras y así la contribución del trabajo es demostrar las diferencias entre las regiones fronterizas y no fronterizas para las dos fronteras y discutir las posibles razones. El análisis más detallado a nivel de condado, incluso con ciertas limitaciones de datos, brinda información importante sobre el tema.

Palabras clave: mortalidad por condado, frontera entre EUA y México, frontera entre EUA y Canadá, paradoja hispana, índices.

Introduction

Mortality rates are a key indicator of the well-being of a population. The more we know about its patterns, the better we can plan for the future and identify areas for improvement. Mortality is often viewed from a national level, but a recent study in the United States of America (USA) showed that there are significant differences in death rates at the county level (Dwyer-Lindgren et al., 2016). Geographic disparities in mortality have also proved to be persistent. Even as the population of an area is changing, the high or low mortality that the area faces can remain (James et al., 2018). This suggests that geographic location is a steady and useful variable in predicting mortality, even though differences may be due to socioeconomic conditions, ethnicity, behavior and health care, for instance.

Proximity to a country's border is one way of classifying geographic areas. The areas near a country border have interesting properties compared to non-border areas since they are the zones where two cultures collide (Moya et al., 2016). USA has two land borders, with Canada and Mexico, two largely different countries. The USA-Mexico border region tends to be of particular interest because of the different levels of development of the two bordering countries. It has documented inequalities and disadvantages when compared to other regions of the USA and if the border region were considered a state, it would rank last in access to healthcare and per capita income (Moya et al., 2016). Border residents also have lower levels of education and employment (Mills & Caetano, 2016). These disparities have led to a growing body of literature on the mortality and morbidity of the region. On the other side, the USA and Canada experience similar standards of living and have many commonalities with regards to culture and ethnic makeup (Feeny et al., 2010). However, there are still differences in the countries and there has been an interest in the mortality and health effects of the pollution generated at high-trafficked crossings along the USA-Canada border.

In this context, the objective of the article is to analyze, through the use of data from the Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research (CDC WONDER) database for the years 1999 to 2019, the mortality in the border regions, especially when compared to the non-border regions of the border states, so that mortality trends can be explored. This work demonstrates that the county of residence and proximity to the border could be a useful contributor to project mortality, in both border regions. Therefore, the aim of the project is to answer the following research question: how significant are the main differences and similarities in mortality trends at a county level, accounting for age, gender and cause of death, to compare mortality patterns in the border and non-border regions and also between the USA-Mexico and the USA-Canada borders?

Since the purpose is to take a closer look at the mortality in the USA' border regions, one of the contributions of this work is to demonstrate that proximity to the border is a substantial variable in mortality. In addition, the county level analysis for cause of death shows that rates can vary drastically just over county lines. Thus, the county of residence could be used to inform mortality projections.

Through the calculation of the classic mortality measures in this framework, the mortality rates, sub-populations of the border by state, age, gender, and cause of death are analyzed, and varying combinations of confounders in the standardization are used. The findings confirm important differences between the border and non-border regions, with opposite results at each border. When accounting for all confounders, the border region at the Mexican border has lower mortality than the non-border region, and at the Canada border, the border region has higher mortality than the non-border region. The reasons for this are also discussed.

The article is structured as follows. This introduction briefly explains the objective, scope, and contributions of the work. It is followed by a section with the referential framework, presenting some existing theoretical and empirical results about the mortality in the USA-Mexico and the USA-Canada border regions. Then, there is a section about data and methods, with particular focus on the definition of the border areas, which is a subject of some discussion. The following section contains results and discussion. The final section concludes.

Referential framework

Mortality in the USA-Mexico border region: some theoretical and empirical results

A majority (53.5%) of the residents in the USA-Mexico border region are of a Hispanic or Latino origin compared to only 14.9% in the U.S. non-border region (Centers for Disease Control and Prevention, n. d.). Given this, much of the literature on the region focuses on the Hispanic-American population.

Markides and Coreil (1986) concluded that the health status of Hispanics was closer to that of non-Hispanic Whites than to that of non-Hispanic Black Americans, although their socio-economic status is closer to the latter group. This is significant because it is known that lower socio-economic status typically leads to higher morbidity and mortality in the USA (Adler et al., 1994; Crimmins et al., 2009; Sorlie et al., 1995). Markides and Coreil (1986) looked at infant mortality, life-expectancy, cardiovascular diseases, cancer, diabetes and other diseases and found that Mexican Americans fared better than expected on many of them. This pattern of Hispanics being healthier and having lower mortality than Whites despite their lower economic status has been found consistently and has come to be known as the Hispanic paradox (Becker et al., 1988; Hummer et al., 2007; Liao et al., 1998; Shai & Rosenwaike, 1987).

Other studies have found that the paradox only applies to certain subgroups. Liao et al. (1998) show that it is most pronounced in older age groups (over 64). Hummer et al. (2000) divided the Hispanic population based on origin: Mexico, Cuba, Puerto Rico, Central/Southern America, and other Hispanic. They found that when accounting for mortality risk factors all Hispanic subgroups had lower mortality overall than non-Hispanic Whites, the only exception being Puerto Ricans between the ages of 18-44. Palloni and Arias (2004) concluded that the paradox was only true for foreign-born Hispanics excluding Cubans and Puerto-Ricans.

As the paradox emerged, several studies hypothesized that migratory factors were at the source of it, namely the "healthy migrant hypothesis" and the "salmon bias" (Liao et al., 1998; Shai & Rosenwaike, 1987; Sorlie et al., 1993). The healthy migrant hypothesis claims that there is a selection process when it comes to migration, leading to a migrant population healthier than the origin population. The salmon bias suggests that immigrants will migrate back to their home country when they are old. Foreign deaths are not included in the USA mortality data and this would skew the mortality rates lower. Further discussion of these theories can be found, for example, in Kolčić & Polašek (2009), Lu & Qin (2014), and Fuller-Thomson et al. (2015), which propose factors such as migrants being healthier than the average population in their home country, which allows them to migrate, or benefiting from the health care of the new country, or having better health (especially greater height), a higher socioeconomic position, and better cognitive skills, in childhood.

Abraído-Lanza et al. (1999) also tested the two hypotheses based on four subgroups of U.S. Hispanics, using Cox proportional hazards models (Kumar & Klefsjö, 1994), with adjustment for age, income, and education. The resulting hazard ratios of mortality showed that all sub-groups had lower mortality than their non-Hispanic White counterparts, *but neither the "salmon bias" nor the "healthy immigrant hypothesis" could attribute to this difference*. Instead, health behaviors such as smoking and diet, and cultural behaviors like social cohesion may be the reasons.

McDonald and Paulozzi (2019) echoed the hypothesis that behavioral factors like the lower prevalence of smoking among Hispanic Americans could be behind their lower rates of major chronic diseases. Eschbach et al. (2004) tested if the paradox could be attributed to social support. Their results confirmed that living in high-density Mexican American neighborhoods is associated with a positive health and mortality effect. This leads to the possibility that social cohesion and support systems may be factors causing the Hispanic paradox, as neighborhoods with a high percentage of Mexican Americans (or African Americans) are typically economically disadvantaged. Ruiz et al. (2016) present a model for Hispanics and Latinos in which their sociocultural values, which place greater emphasis on social ties and family, may provide some (sociocultural) resilience in the event of illness. There are, however, some health indicators outside the paradox, namely related to diabetes, breast and cervical cancer, and communicable diseases especially tuberculosis and HIV (United States-Mexico Border Health Commission, 2020).

Starting from Markides and Coreil (1986) it has often been found that diabetes rates are higher in Hispanics and along the USA-Mexico border region (McDonald & Paulozzi, 2019; Salinas et al., 2013). Stoddard et al. (2010) found that 25.9% of adults with diabetes living along either side of the border were undiagnosed, but that Mexicans and Mexican immigrants were significantly more likely to be undiagnosed than USA-born Hispanics or non-Hispanic Whites. Early diagnosis is important to reduce diabetes-related mortality. Díaz-Apodaca et al. (2010) found that the overall prevalence of diabetes in the border region was 17.6%, compared to the USA national estimate of 6.3%, and that there is "inverse relationship between diabetes and education and socio-economic level".

Breast cancer and cervical cancer also have higher rates among Hispanic women along the border region (Herrera et al., 2012, McDonald & Paulozzi, 2019). Mortality from both cancers can be reduced with early detection which requires regular preventative screenings. Banegas et al. (2012) found that Hispanic women in the border region had higher knowledge of breast cancer prevention, but they were not receiving the recommended screening procedures. A lack of education is not the problem. Herrera et al. (2012) studied the higher prevalence of cervical cancer in the border region. They ran multivariable logistic regression analyses to determine which variables could be contributing to lower rates of cervical cancer screenings in the area and found that lack of health insurance coverage had a clear correlation. Both studies imply that women in the USA-Mexico border region suffer from barriers to adequate health care, especially preventative screenings, which could be leading to the increased rates of breast and cervical cancer in the region.

Hispanics and residents in the border region have higher rates of mortality from infectious diseases (Markides & Coreil, 1986), especially chronic infections, tuberculosis, and HIV (McDonald & Paulozzi, 2019). These diseases disproportionately affect poor communities which leaves the border region at risk. Additional risk factors active at the border are increased mobility and migration, closeness of social interactions, and limited access to healthcare (Moya et al., 2016).

Mortality in the USA-Canada border region: some theoretical and empirical results

Compared to the USA-Mexico border, there is much less literature on the health of residents living in the USA-Canada border region. This may be because the USA and Canada enjoy similar standards of living and have more in common culturally and ethnically than the USA and Mexico. However, when it comes to health and mortality, there are a few notable differences between the two countries, namely, their health care systems and inequality (Siddiqi & Hertzman, 2007). The existing works, for instance Siddiqi & Hertzman (2007), Feeny et al. (2010) and Krueger et al. (2009), are mainly focused on comparing the whole populations of the two countries.

Feeny et al. (2010) compared the health and mortality of USA residents versus Canada residents on three metrics: health-related quality of life, life expectancy and health-adjusted life expectancy. People in Canada had more favorable outcome on all three. The authors explored the potential explanations as "access to health care over the full life span (universal health insurance) and lower levels of social and economic inequality, especially among the elderly". Regarding inequality, when they compared only the White populations of both countries, they found that the health statuses were much more similar.

Krueger et al. (2009) studied how similar USA residents and Canada residents are with regards to health lifestyles. Using data for health behaviors, fertility measures, and cause-specific mortality, they applied general linear models to determine if healthy lifestyles between the two countries converge at the border. Results confirmed that Canada residents in general have healthier lifestyles than USA residents and supported their hypothesis that these healthy lifestyles converge at the border. In spite of this, there is concern on the air pollution and its effects near Canadian border crossings. In response, the two countries jointly formed the Canada-U.S. Border Air Quality Strategy (BAQS) to reduce the transborder air pollution.

The Ambassador Bridge is the most heavily trafficked border crossing in terms of commercial trade (Bureau of Transportation Statistics, n. d.). It connects Windsor, Ontario, to Detroit, Michigan. Band et al. (2006) studied the mortality and cancer rates from 1979 to 1999 of Windsor compared to those in the province of Ontario as a whole. They calculated the standardised mortality ratios for causes of death associated with long term air pollution exposure including lung cancer, bronchitis, and emphysema, and standardised cancer incident ratios (Breslow & Day, 1987) for lung cancer. Results documented significantly increased incidence of lung cancer and mortality from bronchitis, emphysema, circulatory diseases and lung cancer in Windsor.

The second busiest border crossing is the Peace Bridge crossing connecting Buffalo, New York, to Fort Erie, Ontario (Bureau of Transportation Statistics, n. d.). A health study of Erie County studied the prevalence of asthma at the crossing (Oyana et al., 2004). Spatial analysis techniques proved that there was a significant cluster of asthma cases in the crossing proximity. The closer a resident is to it the higher is the probability of having asthma (living within 0.5 km of the crossing increases the risk of asthma by 15 times compared to just 2 km away).

While significant differences are observed on the border with Mexico, this is not the case in the states bordering Canada, but there is also a distinction in the number of immigrants from the two bordering countries. The highest number of immigrants in the USA come from Mexico. According to Pew Research Center (2023), there are 11.2 million Mexican immigrants living in the USA as of 2018, 25.0% of all immigrants. Additionally, over 2 million Mexican immigrants live within the border region (Israel & Batalova, 2020). The number of Canadian immigrants was only 797 thousand in 2019, of which 33 thousand were unauthorized, and they tend to live in large metropolitan areas in California, Florida, New York, and Texas, not near the Canadian border (Israel & Batalova, 2021). Further, according to the same source, most of them arrived in the USA before 2000, having been in the country for decades. Therefore, it can be expected that Mexican immigrants will have a larger effect on their border region than Canadian immigrants.

Nevertheless, the lack of literature available on the mortality in the USA-Canada border region is disappointing. Since there is only a small body of research, there is less direction and precedent, compared to the USA-Mexico border. In a way, this work is also a contribution to reduce the gap.

Information sources and methodology

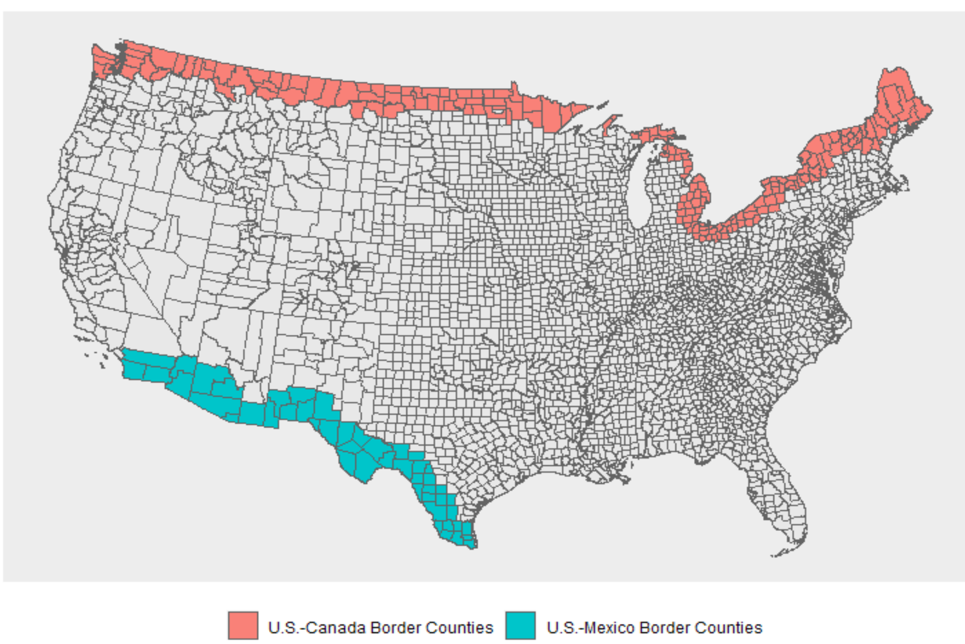
Defining the border areas

The boundary line between the USA and Mexico spans 3 145 km and touches four U.S. states: California, Arizona, New Mexico and Texas. The border between the USA and Canada is 8 891 km and borders 13 states: Alaska (not contiguous, therefore excluded from the analysis), Washington, Idaho, Montana, North Dakota, Minnesota, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire and Maine.

Because mortality data is available at the county level, we need a definition of the border area (BA) that includes whole counties. The United States-Mexico Border Health Commission (2020) defines the border region as the 48 counties that lie within 100 km of the border, citing the La Paz Agreement, signed in 1983 to improve the environment in the border area. We shall adopt this definition. According to the Border Health Security Act of 2021-117th Congress (2021-2022) "the term 'United States-Canada border area' means the area located in the United States and Canada within 100 km of the border between the United States and Canada". As a result, there are 182 USA-Canada border counties located in the United States.

The R package "sf" (simple features) is used to standardize the measurement between country and county borders. When we include any county that has a portion within 100 km of the Mexico border, we agreed on the same 48 counties. Replicating to the Canadian border defines 182 USA-Canada border counties, see Figure 1.

Figure 1. USA-Mexico and USA-Canada border counties



Source: U.S. Census Bureau (author's colouring)

Data source

The main data source is the Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research (CDC WONDER) database. The Underlying Cause of Death dataset is used to identify one cause of death from death certificates, classified by the Tenth Revision of the International Classification of Diseases (ICD-10). The dataset covers deaths from the years 1999 to 2019 compiled by the National Center for Health Statistics (NCHS). Death counts lower than ten and their subsequently calculated mortality rates are "suppressed" to avoid identifiable information and counts lower than 20 are marked "unreliable". The accompanying population estimates are always the mid-interval estimates from the U.S. Census Bureau reports in 1990, 2000 and 2010 (Centers for Disease Control and Prevention, n. d.). The variables that will be used are age, gender, Hispanic origin and cause of death. For cause of death, will be used the nine ICD-10 chapters with the highest national death counts and aggregate the remaining ones into an "other cause" category, see Table 1.

Table 1. Cause of death categories in the USA, ICD-10 chapters, 1999-2019

ICD-10 Chapter	Description	% of U.S. deaths
I00-I99	Diseases of the circulatory system	33.4%
C00-D48	Neoplasms	23.1%
J00-J98	Diseases of the respiratory system	9.7%
V01-Y89	External causes of morbidity and mortality	7.5%
G00-G98	Diseases of the nervous system	5.7%
E00-E88	Endocrine, nutritional, and metabolic diseases	4.2%
F01-F99	Mental and behavioral disorders	4.1%
K00-K92	Diseases of the digestive system	3.7%
A00-B99	Certain infectious and parasitic diseases	2.6%
Other	Other cause	5.9%

Source: CDC WONDER database (author's calculations)

When the cause of death is being used to segment the population, some counties have too small of a population to have reliable death counts in each category. Therefore, these small counties were removed from the analysis. In Table 2, the effect of exclusion is shown to be minimal and the percentage of the population removed is evenly distributed among regions.

Table 2. County size distribution in the border areas (BA), 1999-2019

Area	County Size	Count	Person-years*	%
MEXICO BA	Large	37	284 874 362	99.8%
	Small	11	569 199	0.2%
Mexico Non-BA	Large	267	1 180 517 467	99.8%
	Small	45	2 450 741	0.2%
Canada BA	Large	167	449 247 625	99.8%
	Small	15	960 037	0.2%
Canada Non-BA	Large	387	1 054 940 675	99.7%
	Small	50	2 762 587	0.3%

* Person-years is a measurement that considers both the number of people in the study and the period of time each person is followed up. For example, a study that follows 1 000 people for two years would contain 2 000 person-years of data. The concept is explained, for instance, in Sheps (1966).
Source: CDC WONDER database (author's calculations)

Methods

Methodology is based on widely used classic single indices to summarize and compare mortality. The notation utilized by Kim et al. (2020) is follow, with some modifications. In this paper, ten-year age groups for the standardized rates, also known as age-adjusted rates will be taken.

The crude mortality rate (CMR) is the most basic mortality index.

(1) $$CMR_c = \frac{Observed\ deaths}{Total\ exposed\ to\ risk} = \frac{\sum_i d_{i,c}}{\sum_i t_{i,c}},$$

where $d_{i,c}$ is the number of observed deaths in ten-year age group i and in county c, and $t_{i,c}$ is the corresponding population.

The directly standardized mortality rate (DSMR) is a weighted average. For instance, in the case of age standardization the weights are the age proportions in the standard population, which are multiplied by the age-specific crude mortality rates observed in the target population.

(2) $$DSMR_c = \frac{\sum_i T_i \left(\frac{d_{i,c}}{t_{i,c}}\right)}{\sum_i T_i},$$

where T_i is the population of the standard population in ten-year age group *i*. Even if ten-year age groups are taken for the standardized rates, when the geographical areas under consideration are small or sparsely populated, the DSMR can be incalculable because the observed deaths by age group are too low to be reliable or may not even be reported.

The indirectly standardized mortality rate (ISMR) is an approximation of the DSMR.

(3) $$ISMR_c = CMRstandard \ x \ \frac{Observed\ deaths}{Expected\ deaths} = \frac{\sum_i D_i}{\sum_i T_i} \ x \ \frac{\sum_i d_{i},_c}{\sum_i t_{i},_c \left(\frac{D_i}{T_i}\right)},$$

where D_i is the number of observed deaths in the standard population in ten-year age group, *i*. The advantage of the ISMR is that the number of observed deaths by age group in the population of interest is not required, only the age distribution of the population and the total observed deaths are needed. This is an important benefit when the population of interest is too small to have reliable death data by age group.

Finally, the standardized mortality ratio (SMR) compares the ISMR of the population of interest with the CMR in the standard population.

(4) $$SMR_c = \frac{\text{Observed deaths}}{Expected\ deaths} = \frac{\sum_i d_{i},_c}{\sum_i t_{i},_c \left(\frac{D_i}{T_i}\right)}.$$

The SMR allows for the comparison of the population of interest and the standard population to be more intuitive. Since it uses an indirect method of standardization and is dependent on the age distribution of the study population, it should not be used to directly compare the mortality between two different study populations (Schoenbach & Rosamond, 2000). As some of the counties are small, which leads to suppressed or unreliable death counts when divided into age groups, indirect standardization via the SMR will be used.

If the difference in SMR is significant compared to the standard population, or if it can be attributed to random variability will be seen by calculating confidence intervals. There are several methods, but the one designated in a recent small area mortality study will be utilized (Kim et al., 2020).

(5) $$95\%\ Confidence\ Interval = \left[\frac{SMR}{exp\left(\frac{1.96}{\sqrt{d_c}}\right)},\quad SMR*exp\left(\frac{1.96}{\sqrt{d_c}}\right)\right].$$

If the confidence interval does not include 1, the SMR will be significantly higher/lower when compared to the standard population.

Results and discussion

USA-Mexico border area

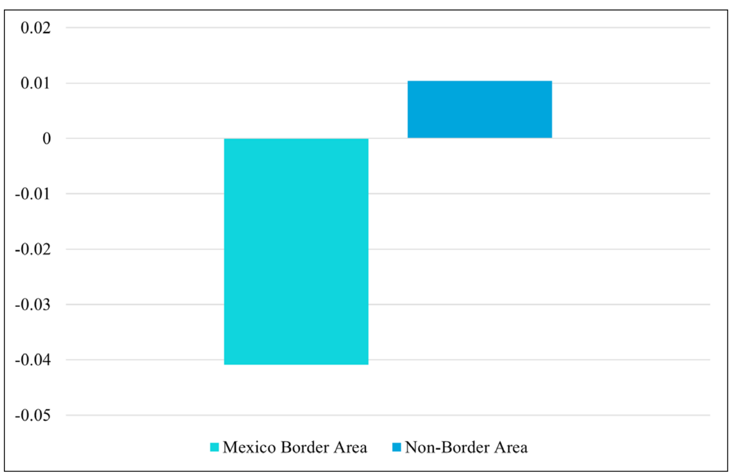
First, the SMRs for the USA-Mexico border area and for the non-border area is calculated. The full area of the border states was used as the standard population, age was used as the only confounder of standardization, and 95% confidence interval was calculated. The results are shown in Table 3 and Figure 2. Since 95% confidence interval for the SMR of the USA-Mexico border area does not include 1, can be concluded that its mortality is significantly lower than in the standard population. On the other hand, the non-border area has a SMR significantly higher.

Table 3. SMR by USA-Mexico BA

BA	Obs. deaths	Exp. deaths	SMR	95% CI	Significant*
Mexico BA	1 950 101	2 033 177	0.9591	[0.9578, 0.9605]	Low
Non-BA	8 088 962	8 005 886	1.0104	[1.0097, 1.0111]	High

*Significantly high or low at 5% level compared to the standard population
Source: CDC WONDER database (author's calculations)

Figure 2. SMR by USA-Mexico BA



Source: CDC WONDER database (author's calculations)

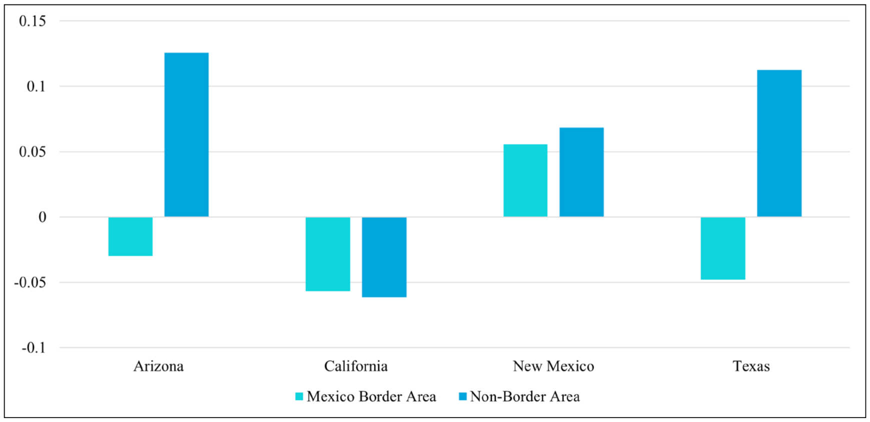
To investigate the distribution further, the SMRs by state and border area were calculated next (Table 4 and Figure 3) with the same standard population. The SMRs in the border region are most different in Arizona and Texas. In both cases, the border area has significantly lower mortality and the non-border area has significantly higher mortality. In New Mexico, both areas have significantly higher mortality than the standard population, though the border area's is slightly lower. On the other hand, both areas in California had the lowest SMR of any group, so they were both significantly lower than the standard population.

Table 4. SMR by state (USA-Mexico BA)

State	Mexico BA		Non-BA	
	SMR	Significant	SMR	Significant
Arizona	0.9702	Low	1.1256	High
California	0.9431	Low	0.9386	Low
New Mexico	1.0557	High	1.0683	High
Texas	0.9521	Low	1.1127	High

Source: CDC WONDER database (author's calculations)

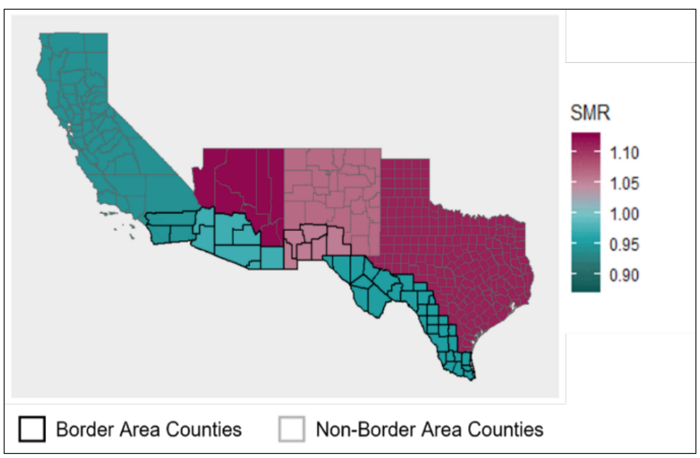
Figure 3. SMR by state (USA-Mexico BA)



Source: CDC WONDER database (author's calculations)

These results can also be seen geographically in Figure 4. The magenta shades show the areas with SMRs greater than 1 and the teal shaded areas have SMRs under 1.

Figure 4. SMR by State (USA-Mexico BA map)



Source: CDC WONDER database (author's calculations)

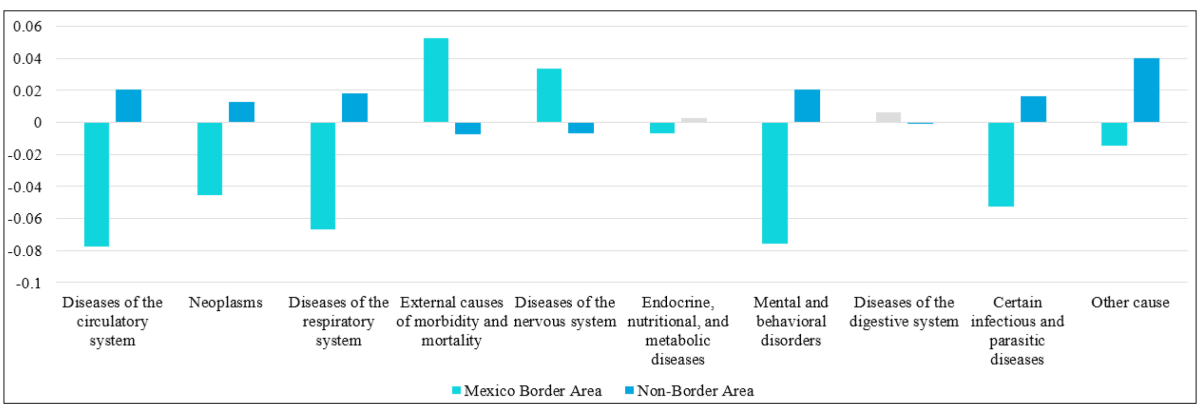
Third, the cause of death was explored by standardizing with respect to age (Table 5 and Figure 5). In the border region, most of the causes of deaths SMRs are significantly lower than in the standard, but there are two that are significantly higher: 'External causes of morbidity and mortality' and 'Diseases of the nervous system'.

Table 5. SMR by cause of death (USA-Mexico BA)

Cause of death	Mexico BA		Non-BA	
	SMR	Significant	SMR	Significant
Diseases of the circulatory system	0.9226	Low	1.0205	High
Neoplasms	0.9547	Low	1.0125	High
Diseases of the respiratory system	0.9333	Low	1.0182	High
External causes of morbidity & mortality	1.0528	High	0.9924	Low
Diseases of the nervous system	1.0338	High	0.9934	Low
Endocrine, nutritional, and metabolic diseases	0.9933	Low	1.0024	-
Mental and behavioral disorders	0.9245	Low	1.0202	High
Diseases of the digestive system	1.0063	-	0.9994	-
Certain infec. and parasitic diseases	0.9475	Low	1.0165	High
Other cause	0.9855	Low	1.0402	High

Source: CDC WONDER database (author's calculations)

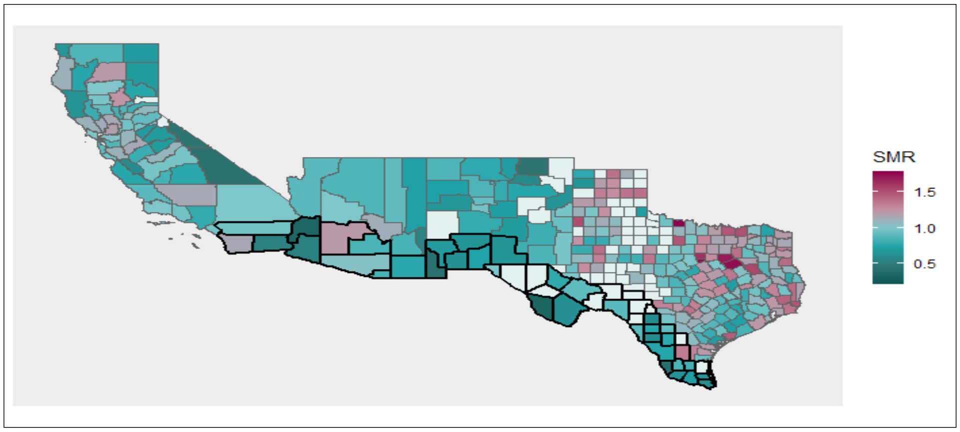
Figure 5. SMR by cause of death (USA-Mexico BA)



Source: CDC WONDER database (author's calculations)

To investigate the causes of death further, the analysis on the county level was ran, see the maps below (Figure 6 and Figure 7). For the 'Diseases of the nervous system', the individual border counties which have the highest rates of death are Maricopa County, Arizona, and San Diego County, California. These are the two most populous counties in the border area, so they have a great effect on the overall SMR.

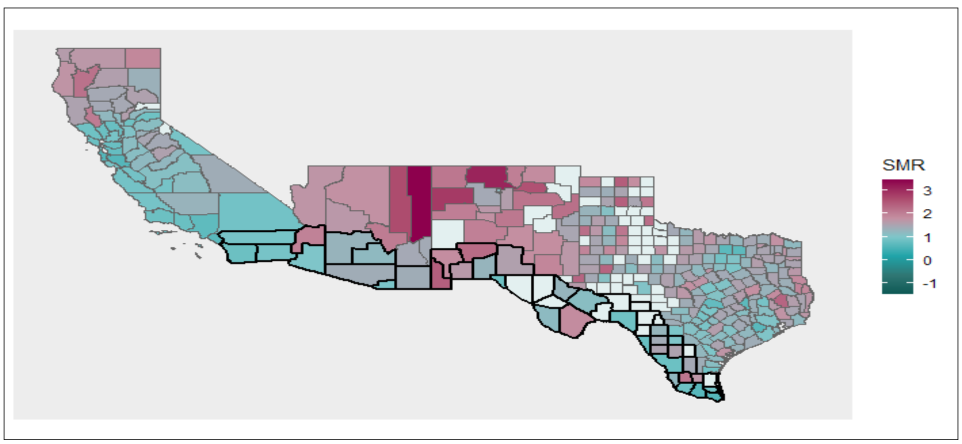
Figure 6. Cause of death: diseases of the nervous system (USA-Mexico BA map)



Source: CDC WONDER database (author's calculations)

Regarding 'External causes of morbidity and mortality', the non-border areas of Arizona and New Mexico have consistently high SMRs, but these are counteracted by the low rates in California and Texas.

Figure 7. Cause of death: external causes of morbidity and mortality (USA-Mexico BA map)



Source: CDC WONDER database (author's calculations)

It was expected that 'Endocrine, nutritional and metabolic diseases' might be significantly higher in the border region, but that was not the case. We have concluded that the low mortality rates in the border region of California and Arizona are offsetting the high rates in the border regions of New Mexico and Texas. The non-border area of Texas tends to have higher rates of 'Endocrine, nutritional and metabolic diseases' which causes the SMRs to be more even.

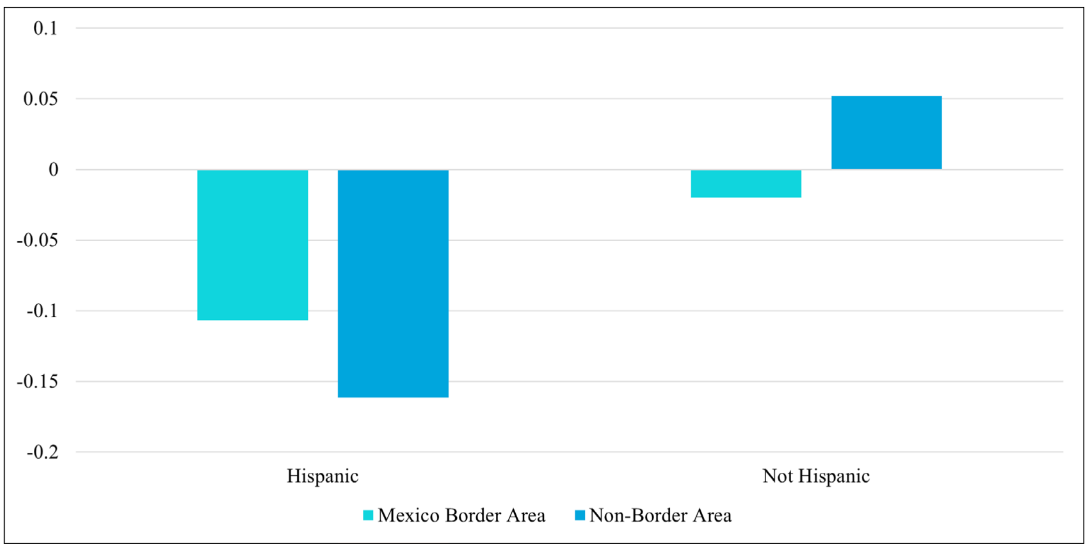
As much of the research on the USA-Mexico region focuses on the Hispanic or Latino population, due to their large proportion in the area and the Hispanic paradox, the next division examined was dividing the border regions into "Hispanic or Latino" and "Not Hispanic nor Latino". Results are shown in Table 6 and Figure 8. The Hispanic populations in the border area and the non-border area have significantly lower mortality than the standard population, which is in line with the existing research. In addition, the mortality of the non-Hispanic population in the border area is significantly lower than the mortality of the population, compared to the non-border area, which further suggests that it is not only the Hispanic population that is causing the border area to have lower mortality.

Table 6. SMR by Hispanic origin (USA-Mexico BA)

Origin	Mexico BA		Non-BA	
	SMR	Significant	SMR	Significant
Hispanic or Latino	0.8932	Low	0.8385	Low
Not Hispanic nor Latino	0.9801	Low	1.0521	High

Source: CDC WONDER database (author's calculations)

Figure 8. SMR by Hispanic origin (US-Mexico BA)



Source: CDC WONDER database (author's calculations)

Gender is the next most common confounder to add to the standardization. Women have a longer expected lifespan than men and therefore lower mortality rates. Consequently, it would be expected that a population with a higher proportion of women would have lower mortality. However, the distribution of gender doesn't vary between different geographies as much as age does, so we wouldn't expect it to have as great of an impact on the SMRs. When gender is added as a variable in the standardization for the USA-Mexico border, the border area SMR decreases slightly from 0.9591 to 0.9575, but both are significantly low, and the non-border area increases by an even smaller differential from 1.0104 to 1.0108. When we standardize with either gender or cause of death as the only confounder, or with both, the expected deaths are strikingly similar and there is no difference in the SMRs in the border and non-border regions (Table 7).

Table 7. SMR by USA-Mexico BA and standardization confounders

Confounders in standardization	Mexico BA		Non-BA	
	SMR	Significant	SMR	Significant
Age	0.9591	Low	1.0104	High
Gender	0.9993	-	1.0002	-
Cause of death	0.9993	-	1.0002	-
Age + Gender	0.9575	Low	1.0108	High
Age + Cause of death	0.9591	Low	1.0104	High
Gender + Cause of death	0.9993	-	1.0002	-
Age + Gender + Cause of death	0.9576	Low	1.0108	High

Source: CDC WONDER database (author's calculations)

USA-Canada border

Just as with the USA-Mexico border, the first measure of comparison was the standardized mortality ratios for the USA-Canada border area versus the non-border area, where the twelve border states are combined to make up the standard population. The results in Table 8 and Figure 9 show that, in contrast to the USA-Mexico border area, the USA-Canada border area has an SMR that is significantly higher than the standard population and the SMR of the non-border area is significantly lower.

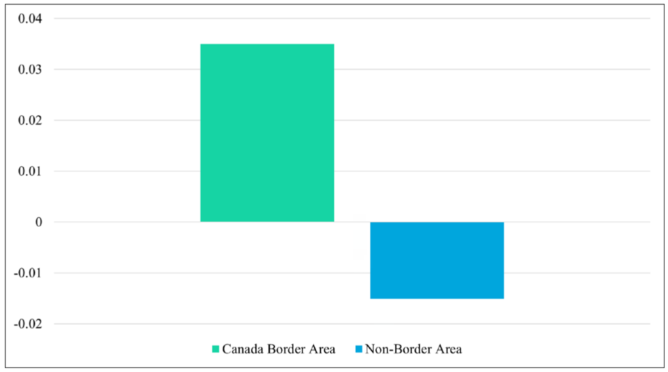
Table 8. SMR by USA-Canada BA

BA	Observed deaths	Expected deaths	SMR	95% CI	Significant
Canada BA	4 132 324	3 992 665	1.0350	[1.0340, 1.0360]	High
Non-BA	9 099 417	9 239 076	0.9849	[0.9842, 0.9855]	Low

Source: CDC WONDER database (author's calculations)

The SMR by state and border area was calculated with the same standard population as the first portion, see Table 9 and Figure 10. There are six areas with SMRs over 1.05 and six areas with SMRs lower than 0.95 which provide further insight. The six areas with SMRs higher than 1.05 are the border areas of Montana, Maine, Michigan, Ohio and Pennsylvania, and the non-border area of Ohio. Since five of the six areas with the highest SMRs are from the border region, these states mainly contributed to the overall high mortality at the border. The six areas with SMRs under 0.95 are the border areas of New Hampshire, Vermont and Washington and the non-border areas of North Dakota, Minnesota and New York. Figure 11 shows that these areas are not clustered, low and high SMRs are dispersed along the border.

Figure 9. SMR by USA-Canada BA



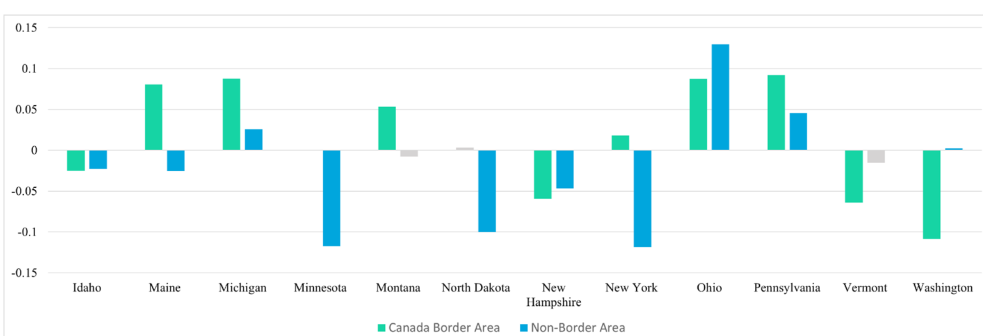
Source: CDC WONDER database (author's calculations)

Table 9. SMR by state (USA-Canada BA)

State	Canada BA		Non-BA	
	SMR	Significant	SMR	Significant
Idaho	0.9748	Low	0.9772	Low
Maine	1.0807	High	0.9744	Low
Michigan	1.0878	High	1.0259	High
Minnesota	1.000	-	0.8826	Low
Montana	1.0534	High	0.9922	-
North Dakota	1.0034	-	0.9001	Low
New Hampshire	0.9407	Low	0.9534	Low
New York	1.0183	High	0.8816	Low
Ohio	1.0877	High	1.1297	High
Pennsylvania	1.0921	High	1.0457	High
Vermont	0.9362	Low	0.9849	-
Washington	0.8913	Low	1.0025	High

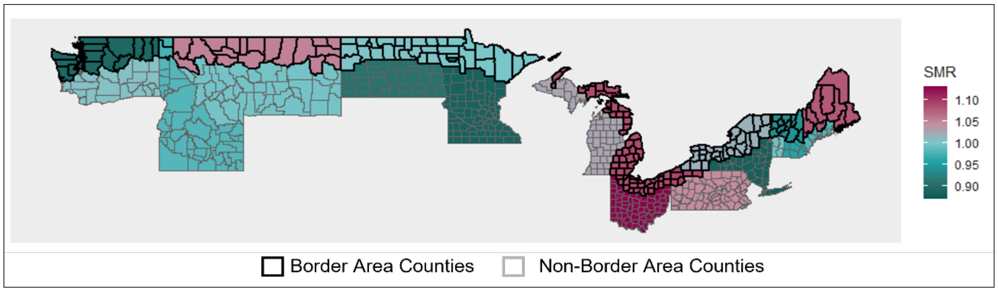
Source: CDC WONDER database (author's calculations)

Figure 10. SMR by state (USA-Canada BA)



Source: CDC WONDER database (author's calculations)

Figure 11. SMR by state (USA-Canada BA map)



Source: CDC WONDER database (author's calculations)

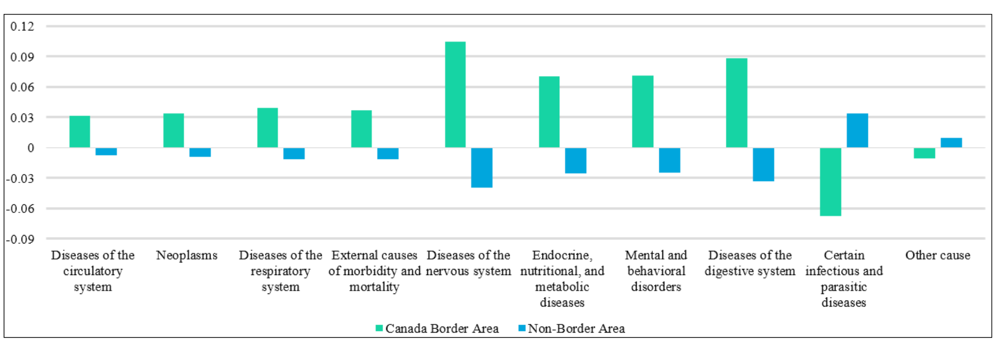
When the population is divided by cause of death (Table 10 and Figure 12), the Canada border area is shown to have a significantly high SMR for 8 out of 10 causes of death. The causes of death that the border region is significantly low for are 'Certain infectious and parasitic diseases' and 'Other cause'.

Table 10. SMR by cause of death (USA-Canada BA)

Cause of death	Canada BA		Non-BA	
	SMR	Significant	SMR	Significant
Diseases of the circulatory system	1.0312	High	0.9924	Low
Neoplasms	1.0340	High	0.9907	Low
Diseases of the respiratory system	1.0395	High	0.9888	Low
External causes of morbidity and mortality	1.0371	High	0.9885	Low
Diseases of the nervous system	1.1047	High	0.9606	Low
Endocrine, nutritional and metabolic diseases	1.0707	High	0.9748	Low
Mental and behavioral disorders	1.0710	High	0.9752	Low
Diseases of the digestive system	1.0885	High	0.9668	Low
Certain infect. and parasitic diseases	0.9323	Low	1.0340	High
Other cause	0.9892	Low	1.0094	High

Source: CDC WONDER database (author's calculations)

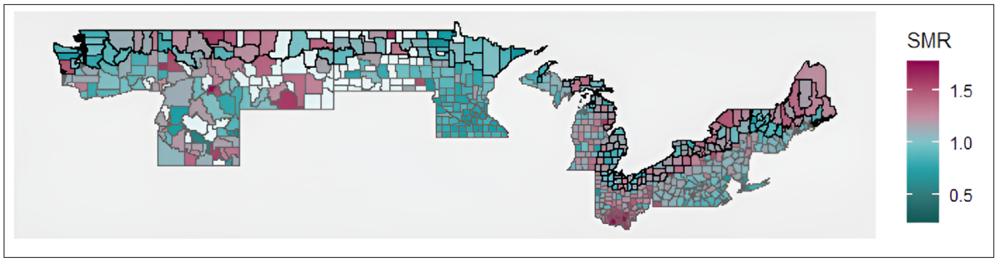
Figure 12. SMR by cause of death (USA-Canada BA)



Source: CDC WONDER database (author's calculations)

Due to the concerns of heightened rates of respiratory illnesses near the high-trafficked border crossings, we will take a closer look at the 'Diseases of the respiratory system'. There are counties with high SMRs for this cause of death along the border (Figure 13), however, the clustering of poor SMRs is in southern Ohio, a non-border area. This region has 5 of the top 6, and 10 of the top 20 worst county SMRs. Since the research for BAQs is focused on the small area immediately next to the border crossings, county-level data may be too wide of an area to show any difference.

Figure 13. Cause of death: diseases of the respiratory system (USA-Canada BA map)



Source: CDC WONDER database (author's calculations)

Different standardizations for this border were also carried out and the results were consistent with the USA-Mexico border in that the gender and cause of death variables did not have much effect on the SMRs, see Table 11.

Table 11. SMR by USA-Canada BA and standardization confounders

Confounders in standardization	Canada BA		Non-BA	
	SMR	Significant	SMR	Significant
Age	1.0350	High	0.9849	Low
Gender	1.0460	High	0.9804	Low
Cause of death	1.0460	High	0.9804	Low
Age + Gender	1.0341	High	0.9853	Low
Age + Cause of death	1.0350	High	0.9849	Low
Gender + Cause of death	1.0460	High	0.9804	Low
Age + Gender + Cause of death	1.0343	High	0.9855	Low

Source: CDC WONDER database (author's calculations)

Border comparison

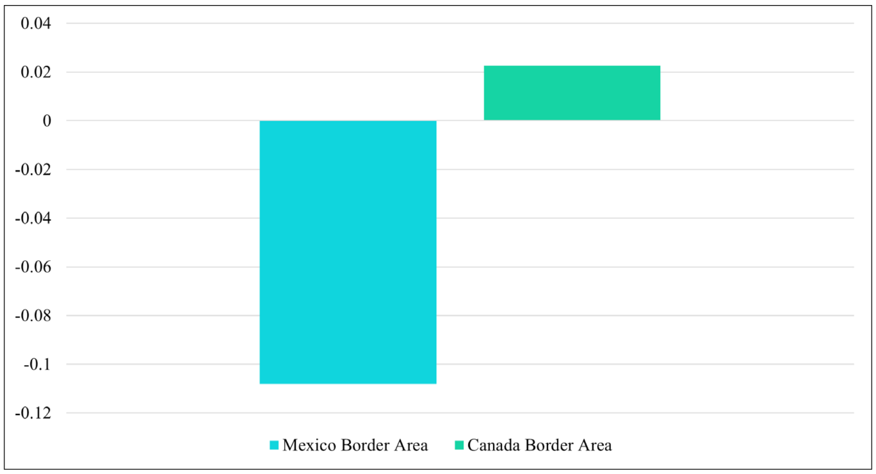
For the previous two subsections, it has been using the border states collectively to make up the standard population. Now, to compare the two borders to the same population, it will be used the entire USA as the standard. In Table 12, standardized by age, 95% confidence intervals of the SMRs are shown. The USA-Mexico border area is still significantly lower, and the USA-Canada border area is still significantly higher, see Figure 14. This shows that the border areas not only have significantly different mortality than the non-border areas but than the overall USA population.

Table 12. SMR by BA

BA	Obs. deaths	Exp. deaths	SMR	95% CI	Significant
Mexico BA	1 950 101	2 186 455	0.8919	[0.8906, 0.8932]	Low
Canada BA	4 132 324	4 040 869	1.0226	[1.0216, 1.0236]	High

Source: CDC WONDER database (author's calculations)

Figure 14. SMR by border area



Source: CDC WONDER database (author's calculations)

The same variations of confounders in standardization in the previous sections are applied in Table 13. All variations in the Mexico border region produced a significantly low SMR and the Canada border was always significantly high. Adding gender or cause of death to the standardization did affect the SMR, albeit slightly. In this case, adding either gender or cause of death (or both) caused both borders' SMRs to move further from 1, that is, the USA-Mexico border's SMR was reduced further and the USA-Canada border area's increased, making them both more significant.

Table 13. SMR by BA and standardization confounders

Confounders in standardization	Mexico BA		Canada BA	
	SMR	Significant	SMR	Significant
Age	0.8919	Low	1.0226	High
Gender	0.8205	Low	1.1026	High
Cause of death	0.8207	Low	1.1026	High
Age + Gender	0.8884	Low	1.0226	High
Age + Cause of death	0.8919	Low	1.0226	High
Gender + Cause of death	0.8205	Low	1.1026	High
Age + Gender + Cause of death	0.8883	Low	1.0228	High

Source: CDC WONDER database (author's calculations)

Conclusions

Despite the heavy interest in mortality at the USA-Mexico border, the analysis shows that the overall mortality in the border area is significantly lower than mortality in the border states and lower than the United States as a whole. It was also found that the causes of death that the border population has been shown to be at an increased risk for do not apply to all counties within the 100 km of the border. Instead, these are issues only in certain counties or states. For instance, diabetes mellitus has been shown to have high rates in the border region (McDonald & Paulozzi, 2019; Salinas et al., 2013), but we found that this was mainly in New Mexico and Texas and that when the Arizona and California border regions are included, the area actually has low levels of death from 'Endocrine, nutritional and metabolic diseases'.

Given the depth of research on the Hispanic paradox in the border region, the area was analysed by Hispanic origin. The results support the paradox since both the border and non-border Hispanic population had significantly low SMRs. In addition, the SMR for the non-Hispanic border population was also significantly low giving novel evidence that it is not only the ethnicity of the border region that is causing the low SMR.

The mortality at the USA-Canada border has not been a common topic of research, but it was found that there is a significantly higher level of mortality in the area, and that these elevated rates are shown for 8 out of the 10 cause of death categories.

With regards to the different methods of standardization used, it can be state that age is the most important confounder in standardization as it has the greatest effect on the SMR. Through all the analysis, standardization by cause of death had the smallest effect on the SMR, only changing the result in the ten-thousandths place, or not at all.

Proximity to the border is a substantial variable in mortality. The Hispanic paradox is largely irrelevant in Canada and migration flows are entirely different. Cross-border traffic at the large points of entry into Ontario have more transportation of commercial goods and tourism, which is different from Mexico-USA migration flows, which are mainly for employment, for much longer periods, permanent in many cases (Anderson, n. d.; Ontario Ministry of Economic Development, Job Creation and Trade, 2021; Orraca Romano, 2015). As discussed, the main limitation of this study was the suppressed death counts in the WONDER database. It was overcame this by removing the smallest counties from the analysis, but having the unsuppressed death data would have been ideal. Access to this information would also make it possible to use direct standardization instead of indirect standardization, which would have been preferable. It would also to be able to analyse the mortality for a shorter time period, as this would allow to compare the mortality across time and analyse trends. There is potential for further research to investigate time trends and determine if the differences are diverging or converging with time. To further explore the context of the cross-border differences and higher mortality that was found at the USA-Canada border is also an interesting topic.

Through this research and analysis, it was proved that geography and proximity to the border is a substantial variable in mortality. It is well known that age and gender are two variables that have a strong correlation with mortality, but when accounting for these confounders, there were still significant differences at both borders. It was evidenced that age is the most important confounder as it had the greatest effect on the SMR. In addition, the county level analysis for cause of death showed that rates can vary drastically just over county lines. Thus, the county of residence should be used to inform mortality projections.

References

Abraído-Lanza, A. F., Dohrenwend, B. P., Ng-Mak, D. S. & Turner, J. B. (1999). The Latino mortality paradox: a test of the "salmon bias" and healthy migrant hypotheses. *American Journal of Public Health, 89*(10), 1543-1548. https://doi.org/10.2105/AJPH.89.10.1543

Adler, N. E., Boyce, T., Chesney, M. A., Cohen, S., Folkman, S., Kahn, R. L. & Syme, S. L. (1994). Socioeconomic status and health: the challenge of the gradient. *American Psychologist, 49*(1), 15-24. https://doi.org/10.1037//0003-066x.49.1.15

Anderson, B. (n. d.). *The border and the Ontario economy.* Cross-Border Transportation Centre-University of Windsor. http://cbinstitute.ca/wp-content/uploads/2015/09/The-Border-and-the-Ontario-Economy.pdf

Band, P. R., Zielinski, J. M., Jiang, H. & Liu, L. (2006). Canada-US border air quality strategy (BAQS): preliminary results of mortality and cancer incidence in Windsor, Canada. *WIT Transactions on Ecology and the Environment, 86*, 777-783. https://www.witpress.com/Secure/elibrary/papers/AIR06/AIR06076FU1.pdf

Banegas, M. P., Bird, Y., Moraros, J., King, S., Prapsiri, S. & Thompson, B. (2012). Breast cancer knowledge, attitudes, and early detection practices in United States-Mexico border Latinas. *Journal of Women's Health, 21*(1), 101-107. https://doi.org/10.1089/jwh.2010.2638

Becker, T. M., Wiggins, C., Key, C. R. & Samet, J. M. (1988). Ischemic heart disease mortality in Hispanics, American Indians, and non-Hispanic whites in New Mexico, 1958-1982. *Circulation, 78*(2), 302-309. https://doi.org/10.1161/01.cir.78.2.302

Breslow, N. E. & Day, N. E. (1987). *Statistical methods in cancer research. Volume II-The design and analysis of cohort studies* (IARC Scientific Publications No. 82). International Agency for Research on Cancer. https://publications.iarc.fr/Book-And-Report-Series/Iarc-Scientific-Publications/Statistical-Methods-In-Cancer-Research-Volume-II-The-Design-And-Analysis-Of-Cohort-Studies-1986

Bureau of Transportation Statistics. (n. d.). *US-Canada ports of entry.* U.S. Department of Transportation. Retrieved on August 7, 2023 from https://data.bts.gov/Research-and-Statistics/US-Canada-Ports-of-Entry/s8z8-5vi3

Centers for Disease Control and Prevention. (n. d.). *About multiple cause of death with U.S.-Mexico border regions, 1999-2020.* CDC WONDER Online Database. Retrieved on August 7, 2023 from http://wonder.cdc.gov/ucd-border.html

Crimmins, E. M., Kim, J. K. & Seeman, T. E. (2009). Poverty and biological risk: the earlier "aging" of the poor. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 64A*(2), 286-292. https://doi.org/10.1093/gerona/gln010

Díaz-Apodaca, B. A., Ebrahim, S., McCormack, V., De Cosío, F. G. & Ruiz-Holguín, R. (2010). Prevalence of type 2 diabetes and impaired fasting glucose: cross-sectional study of multiethnic adult population at the United States-Mexico border. *Revista Panamericana de Salud Pública, 28*(3), 174-181. https://iris.paho.org/handle/10665.2/9638?locale-attribute=en

Dwyer-Lindgren, L., Bertozzi-Villa, A., Stubbs, R. W., Morozoff, C., Kutz, M. J., Huynh, C., Barber, R. M., Shackelford, K. A., Mackenbach, J. P., Van Lenthe, F. J., Flaxman, A. D., Naghavi, M., Mokdad, A. H. & Murray, C. J. L. (2016). US county-level trends in mortality rates for major causes of death, 1980-2014. *JAMA, 316*(22), 2385-2401. https://doi.org/10.1001/jama.2016.13645

Eschbach, K., Ostir, G. V., Patel, K. V., Markides, K. S. & Goodwin, J. S. (2004). Neighborhood context and mortality among older Mexican Americans: Is there a barrio advantage? *American Journal of Public Health, 94*(10), 1807-1812. https://doi.org/10.2105/AJPH.94.10.1807

Feeny, D., Kaplan, M. S., Huguet, N. & McFarland, B. H. (2010). Comparing population health in the United States and Canada. *Population Health Metrics, 8*, Article 8. https://doi.org/10.1186/1478-7954-8-8

Fuller-Thomson, E., Brennenstuhl, S., Cooper, R. & Kuh, D. (2015). An investigation of the healthy migrant hypothesis: Pre-emigration characteristics of those in the British 1946 birth cohort study. *Canadian Journal of Public Health/Revue Canadienne de Santé Publique*, *106*(8), e502-e508. https://doi.org/10.17269/CJPH.106.5218

Herrera, D. G., Schiefelbein, E. L., Smith, R., Rojas, R., Mirchandani, G. G. & McDonald, J. A. (2012). Cervical cancer screening in the US-Mexico border region: a binational analysis. *Maternal and Child Health Journal, 16*(2), 298-306. https://doi.org/10.1007/s10995-012-1130-8

Hummer, R. A., Powers, D. A., Pullum, S. G., Gossman, G. L. & Frisbie, W. P. (2007). Paradox found (again): infant mortality among the Mexican-origin population in the United States. *Demography, 44*(3), 441-457. https://doi.org/10.1353/dem.2007.0028

Hummer, R. A., Rogers, R. G., Amir, S. H., Forbes, D. & Frisbie, W. P. (2000). Adult mortality differentials among Hispanic subgroups and non-Hispanic whites. *Social Science Quarterly, 81*(1), 459-476. https://www.jstor.org/stable/42864393

Israel, E. & Batalova, J. (2020, November 5). *Mexican immigrants in the United States*. Migration Policy Institute. https://www.migrationpolicy.org/article/mexican-immigrants-united-states-2019

Israel, E. & Batalova, J. (2021, June 15). *Canadian immigrants in the United States*. Migration Policy Institute. https://www.migrationpolicy.org/article/canadian-immigrants-united-states-2021#distribution

James, W., Cossman, J. & Wolf, J. K. (2018). Persistence of death in the United States: the remarkably different mortality patterns between America's Heartland and Dixieland. *Demographic Research, 39*, Article 33, 897-910. https://doi.org/10.4054/DemRes.2018.39.33

Kim, I., Lim, H.-K., Kang, H.-Y. & Khang, Y.-H. (2020). Comparison of three small-area mortality metrics according to urbanity in Korea: the standardized mortality ratio, comparative mortality figure, and life expectancy. *Population Health Metrics, 18*, Article 3. https://doi.org/10.1186/s12963-020-00210-7

Kolčić, I. & Polašek, O. (2009). Healthy migrant effect within Croatia. *Collegium antropologicum, 33*(1), 141-145. https://pubmed.ncbi.nlm.nih.gov/19563160/

Krueger, P. M., Bhaloo, T. & Rosenau, P. V. (2009). Health lifestyles in the United States and Canada: Are we really so different? *Social Science Quarterly, 90*(5), 1380-1402. https://doi.org/10.1111/j.1540-6237.2009.00660.x

Kumar, D. & Klefsjö, B. (1994). Proportional hazards model: a review. *Reliability Engineering & System Safety, 44*(2), 177-188. https://doi.org/10.1016/0951-8320(94)90010-8

Liao, Y., Cooper, R. S., Cao, G., Durazo-Arvizu, R., Kaufman, J. S., Luke, A. & McGee, D. L. (1998). Mortality patterns among adult Hispanics: findings from the NHIS, 1986 to 1990. *American Journal of Public Health, 88*(2), 227-232. https://doi.org/10.2105/AJPH.88.2.227

Lu, Y. & Qin L. (2014). Healthy migrant and salmon bias hypotheses: a study of health and internal migration in China. *Social Science and Medicine, 102*, 41-48. https://doi.org/10.1016/j.socscimed.2013.11.040

Markides, K. S. & Coreil, J. (1986). The health of Hispanics in the southwestern United States an epidemiologic paradox. *Public Health Reports, 101*(3), 253-265. https://pubmed.ncbi.nlm.nih.gov/3086917/

McDonald, J. A. & Paulozzi, L. J. (2019, April). Parsing the paradox: hispanic mortality in the US by detailed cause of death. *Journal of Immigrant and Minority Health, 21*(2), 237-245. https://doi.org/10.1007/s10903-018-0737-2

Mills, B. A. & Caetano, R. (2016). Alcohol use and related problems along the United States-Mexico border. *Alcohol Research: Current Reviews, 38*(1), 79-81. https://pubmed.ncbi.nlm.nih.gov/27159814/

Moya, E. M., Chávez-Baray, S. M., Wood, W. W. & Martinez, O. (2016). Nuestra casa: an advocacy initiative to reduce inequalities and tuberculosis along the US-Mexico border. *International Public Health Journal, 8*(2), 107-119. http://www.ncbi.nlm.nih.gov/pmc/articles/pmc6150456/

Ontario Ministry of Economic Development, Job Creation and Trade. (2021). *Ontario and Michigan partnering on cross-border transportation technologies.* Government of Ontario. https://news.ontario.ca/en/release/1000752/ontario-and-michiganpartnering-on-cross-border-transportation-technologies

Orraca Romano, P. P. (2015). Immigrants and cross-border workers in the U.S.-Mexico border region. *Frontera Norte, 27*(53), 5-34. https://doi.org/10.17428/rfn.v27i53.97

Oyana, T. J., Rogerson, P. & Lwebuga-Mukasa, J. S. (2004). Geographic clustering of adult asthma hospitalization and residential exposure to pollution at a United States-Canada border crossing. *American Journal of Public Health, 94*(7), 1250-1257. https://doi.org/10.2105/AJPH.94.7.1250

Palloni, A. & Arias, E. (2004). Paradox lost: explaining the hispanic adult mortality advantage. *Demography, 41*(3), 385-415. https://doi.org/10.1353/dem.2004.0024

Pew Research Center. (2023). *Data and Resources*. https://www.pewresearch.org/hispanic/data-and-resources/

Ruiz, J. M., Hamann, H. A., Mehl, M. R. & O'Connor, M-F. (2016). The Hispanic health paradox: from epidemiological phenomenon to contribution opportunities for psychological science. *Group Processes & Intergroup Relations, 19*(4), 462-476. https://doi.org/10.1177/1368430216638540

Salinas, J. J., Su, D. & Al Snih, S. (2013). Border health in the shadow of the Hispanic paradox issues in the conceptualization of health disparities in older Mexican Americans living in the Southwest. *Journal of Cross-Cultural Gerontology, 28*(3), 251-266. https://doi.org/10.1007/s10823-013-9202-9

Schoenbach, V. J. & Rosamond, W. D. (2000). *Understanding fundamentals of epidemiology. An evolving text*. University of North Carolina at Chapel Hill. http://www.epidemiolog.net/evolving/FundamentalsOfEpidemiology.pdf

Shai, D. & Rosenwaike, I. (1987). Mortality among Hispanics in metropolitan Chicago: an examination based on vital statistics data. *Journal of Chronic Diseases, 40*(5), 445-451. https://doi.org/10.1016/0021-9681(87)90178-0

Sheps, M. C. (1966). On the person years concept in Epidemiology and Demography. *The Milbank Memorial Fund Quarterly, 44*(1), 69-91. https://doi.org/10.2307/3349039

Siddiqi, A. & Hertzman, C. (2007). Towards an epidemiological understanding of the effects of long-term institutional changes on population health: a case study of Canada versus the USA. *Social Science & Medicine, 64*(3), 589-603. https://doi.org/10.1016/j.socscimed.2006.09.034

Sorlie, P. D., Backlund, E., Johnson, N. J. & Rogot, E. (1993). Mortality by Hispanic status in the United States. *JAMA, 270*(20), 2464-2468. https://jamanetwork.com/journals/jama/article-abstract/409364

Sorlie, P. D., Backlund, E. & Keller, J. B. (1995). US mortality by economic, demographic, and social characteristics: the National Longitudinal Mortality Study. *American Journal of Public Health, 85*(7), 949-956. https://ajph.aphapublications.org/doi/pdf/10.2105/AJPH.85.7.949

Stoddard, P., He, G., Vijayaraghavan, M. & Schillinger, D. (2010). Disparities in undiagnosed diabetes among United States-Mexico border populations. *Revista Panamericana de Salud Pública, 28*(3), 198-206. https://iris.paho.org/handle/10665.2/9634?locale-attribute=en

United States-Mexico Border Health Commission. (2020). *Healthy border 2020: a prevention & health promotion initiative*. US Department of Health and Human Services. https //www.hhs.gov/sites/default/files/res_2805.pdf

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