LUND UNIVERSITY
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The complex relationship between education and sex-specific life expectancy in Costa Rica

An analysis at the district level for 1984, 2000 and 2011

by

Marcos David Castillo Bastos

ma3304ca-s@student.lu.se

This paper explores associations between education and life expectancy by sex at the district level in Costa Rica for the Census years 1984, 2000 and 2011. Previous research on the topic have shown mixed results on the gradient between SES and health outcomes for Costa Rica. This ecological study is the first to use districts as the unit of observation, which allows for a more elaborate analysis including several sociodemographic and health care controls, as well as age-specific mortality rates and mortality by causes of death. Results showed a strong positive relationship between education and life expectancy for women for all years, but for men results were less consistent. The association with education seems to be larger for the age groups adult and old-age adults, with a relevant link found to cardiovascular diseases, lung-related diseases and injuries.

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1 Introduction

Life expectancy at birth is one of the most widely used health indicators in the world. It measures the overall mortality level of a population and has been characterized as a dimension of human development (Desai, 1991). For its importance, researchers have tried over time to find what are the determinants of life expectancy and how it is associated with other variables in an economy.

One of the most widely researched associations with life expectancy over time has been the one with socioeconomic status (SES). Even with the drastic changes that the world has experienced and continues to experience in mortality with the epidemiological transition, the role of SES and education remains as present as ever. Both in developed countries as in developing countries, a positive gradient between SES and life expectancy seems to exist, meaning that individuals with higher SES also live longer on average (Ezzati et al., 2008). This gradient implies that inequalities in income or education could translate into inequalities in health outcomes, so it becomes necessary to study and understand this relationship to close gaps and prevent future inequalities in the indicator.

The literature has suggested that life expectancy inequalities are becoming more associated with health practices and risk factors than to health care indicators, especially in developed countries, where the prevalence of chronic diseases is higher and where the role of health behaviors matters most (Clarke et al., 2010; Cutler & Lleras-Muney, 2006). The critical factor here is that those health behaviors have been proven to be related to SES, and especially to education (Curran et al., 1999; Humbert et al., 2006), so they become a link between SES and health outcomes, among others that have been pointed out.

Costa Rica has one of the highest life expectancies in the American continent with a high level for a country given its per capita income (Castillo & Rivera, 2017). In addition, one area in the country -Nicoya, Pacific Coast- has been broadly documented worldwide for exhibiting exceptionally high longevity in males (Rosero-Bixby, Dow & Rehkopf, 2013). The strength of the health care system has been often suggested as the driver of that high life expectancy, while others have suggested that traditional diets have an important role improving health (Rosero-Bixby & Dow, 2009). However, Costa Rica also shows high socioeconomic inequality, with apparent differences between the urban and the rural areas, which raises the interest in studying life expectancy disparities in the country (Gindling, 2009).

Life expectancy at birth in Costa Rica has been increasing steadily in the last decades, but at a slower rate for men than for women, which is widening the already prominent gap between sexes. Authors have shown that one of the reasons for the high life expectancy is the exceptionally high life expectancy at age 60 for males in the country in the past century (Rehkopf et al., 2013). Considering this fact, the question is if after a certain point, men experience a harder time improving that already high life expectancy at older ages, or if women are doing something better that is driving their life expectancy higher. Rosero-Bixby (2018) suggests that there is only so much the health care system can contribute to raising life expectancy, as health behaviors are what can drive that life expectancy higher.

The association between SES and health has been scarcely researched for Costa Rica, with inconsistent findings on the gradient. However, most of the research has used rudimentary analysis that could be subject to bias, and use cantons as the unit of observation, which restricts the variability of the estimates.

For the Costa Rican case, a source of data may have been overlooked in the past: information by district. Districts are the smallest unit of observation in the Costa Rican case in which it is still possible to obtain valid life expectancy estimates. Besides, information on socioeconomic, demographic and health care variables can also be obtained by district, which allows for a richer analysis of the relationships between life expectancy and SES. More specifically, education is one of the main components of SES, and in Latin America the relationship between education and income is especially high (Contreras & Gallegos, 2007), which makes education a very appropriate and complete indicator of SES.

1.1 Aim and research question

Considering the available data and the interest to study how SES is related to life expectancy in the country, this research will aim to explore sex-specific life expectancy at birth at the district level, in what ways is average education related to it, and the evolution of the relationship in the past decades. The study will be limited to Census years in which it is possible to obtain enough information at the district level, so the considered years will be 1984, 2000 and 2011. The specific research question to be answered with this study is the following:

Is sex-specific life expectancy at birth positively related to average completed education at the district level in Costa Rica for the years 1984, 2000 and 2011 and has this relationship increased through the years because of higher rates of deaths associated with lifestyle decisions?

1.2 Outline of the Thesis

This introduction is followed by a background on Costa Rica, which includes both socioeconomic, health care and demographic context of the country. Next, theories on the topic will be discussed as well as previous research for several countries and Costa Rica in specific, followed by the explanation on data and methods. Finally, results will be shown and discussed compared to previous research and theories, finishing with a conclusion of the thesis.

2 Background on Costa Rica

2.1 Socioeconomic background

Costa Rica is a small Central American country that has been characterized for achieving stronger social development than economic in the last decades, as education and especially health indicators are substantially high for the country's average income (Rosero-Bixby & Dow, 2016).

Costa Rica is administratively divided into seven provinces, which are divided into 82 cantons. Those cantons represent the most important administrative units in the country since they have a municipality and a significant level of financial autonomy. However, cantons often group very socially and geographically unequal areas, which can complicate analysis. Cantons are divided into 463 districts (as of 2019) (Vargas, 2018). Districts are the smallest administrative unit in the country, and although they are strongly dependent on cantonal governments, each district has representatives in the municipalities (Otey, 2018). According to the last Census in 2011, districts have a population that can have from around 500 to 70000 inhabitants and can go from around 0.5km^2 to over 2200km^2 in area (INEC, 2018).

Almost half of the population live in the Central Valley, where the bigger cities and the capital are located, while the coasts and the north are mostly rural. Table 1 presents several indicators for Costa Rica comparing 1984, 2000 and 2011 (The Census years).

Regarding economic terms, Costa Rica has a mixed economy in which there is an open market while the state has control in health, education and energy, among other areas (Homedes & Ugalde, 2002). GDP per capita in the country for 2017 was around US$9,808 (constant 2010), just slightly over the Latin American average of US$9,377. The country has experienced sustained real economic growth from the 1940s, which was only severely interrupted by a crisis in the 1980s. It took over a decade for the country to recover from the negative growth rates, high unemployment and huge fiscal deficit (Mesa-Lago, 1985).

Costa Rica has transitioned from being an economy dedicated to agricultural exports (mainly coffee and banana) at the beginning of the last century, to a service-oriented economy (Rosero-Bixby, 2018). During the 1940s, several social reforms were implemented with a focus on well-being. However, arguably the most relevant structural reform in the country was the abolishment of the army in 1949, which not only allowed the government to invest more in education and health, but also provided political stability for decades, contrary to the experience of most countries in Latin America in the past century (Camacho, 1999). The share of people employed in agricultural labor was close to 10% at the beginning of the 2010s.

Table 1. Indicators for Costa Rica for Census years

Indicators	**1984**	**2000**	**2011**
GDP per capita (in constant thousand US$ PPP)	4.415	6.230	8.450
Employment in agriculture (% of employed)	32.4	15.8	10.9
Population (in millions)	2.659	3.925	4.600
Life expectancy at birth (in years)	74.0	77.5	78.9
Mortality rate, male adult (per 1000 male adults)	142	126	119
Mortality rate, female adult (per 1000 female adults)	93	71	63
Mortality rate, infant (per 1000 live births)	20	11	9
Total fertility rate	3.45	2.37	1.89
Births attended by skilled health staff (% total)	91*	96.6	98.4
Health expenditure (% of GDP)	7.6*	6.6	8.1
Age dependency ratio (% of working age population)	65.9	57.3	46.8
Age dependency ratio, old (% of working age population)	7.1	8.9	11.3
Cause of death, communicable, maternal, perinatal or malnutrition (% of total)	16.2	8.8	6.4

*Data for 1980

Source: INEC (2019), Rosero-Bixby (1994), World Bank (2019)

2.2 The Health Care System

In the 1920s several sanitary and public health programs were implemented, but it was in the 1940s when an ambitious social security system began, slowly extending its coverage to about 70% of the population in the early 1960s when all hospitals became part of the system. Specific programs for rural areas and marginalized urban areas began in the 1960s as well (Sáenz et al., 2011).

During the crisis in 1980, several reforms were implemented to reduce excessive costs while still providing the necessary services for the population (Mesa-Lago, 1985), which according to some authors, were the reasons the country suffered no harm in health indicators because of the crisis (contrary to education indicators) (Rosero Bixby, 1994).

2.3 The demographic transition

At the beginning of the past century, Costa Rica already exhibited lower mortality rates than most Latin-American countries, possibly because of the social homogeneity and equal distribution of the land in the country (Mata Jiménez & Rosero Bixby, 1988). However, mortality began its sustained decrease after 1941 with the health reform, while in the 1970s with the introduction of programs targeted to rural and marginalized areas, child mortality decreased dramatically (Rosero Bixby, 1994). In 2011 the infant mortality rate was below 10 per 1000 live births.

2.3.1 Life Expectancy

From 1940 to 1960, overall life expectancy at birth in the country experienced an increase of almost 20 years, fueled by the health reforms in the country, and although during the 1960s the increase was restrained, after the 1970s the growth of the indicator has been rather constant, even during the crisis in the 1980s (Méndez & Araya, 2001) . Figure 1 shows yearly life expectancy estimates for Costa Rica since 1950.

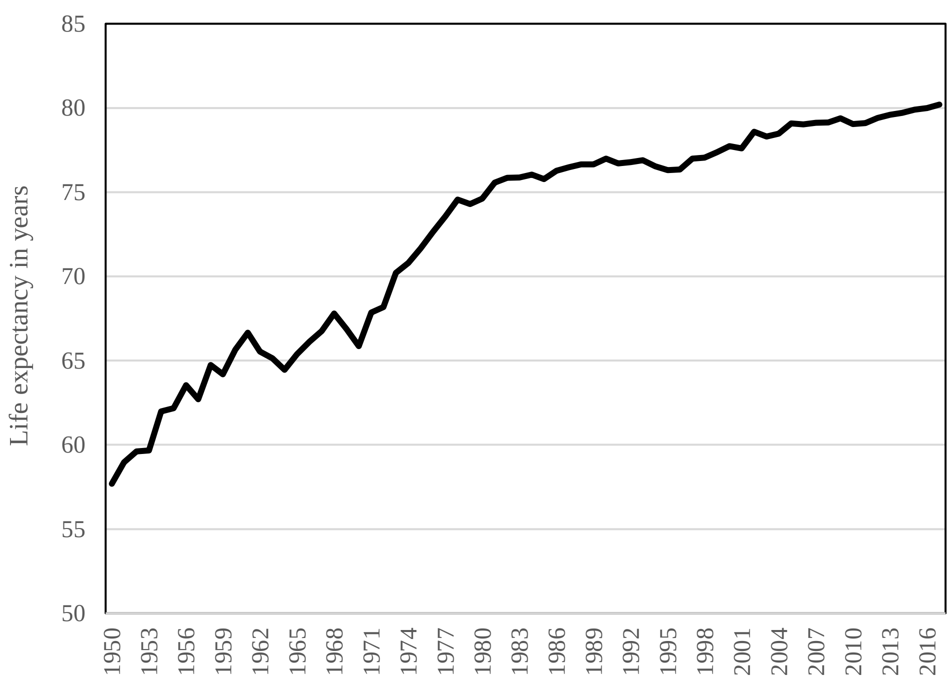

Figure 1. Life expectancy at birth for Costa Rica. 1950-2017
Source: INEC (2018)

As in most countries in the world, the first large increases in life expectancy in Costa Rica were powered by decreases in infant mortality, and they continued with the epidemiological transition from communicable diseases to chronic ones (Amuna & Zotor, 2008). The percentage of deaths by communicable, maternal, perinatal and malnutrition has continued to decrease in the country, and by 2011 it was 6.4% of the total, so mortality by non-communicable, accidents and injuries keep increasing their share of the total deaths.

Table 2 shows life expectancy at birth since 1920 for men and women, where it is possible to notice how the sex gap in life expectancy has been increasing in the last century. This gap seems to be widening both by the slow growth of the male life expectancy, but also a steady pace for the female one.

Table 2. Life expectancy at birth by sex for Costa Rica. 1920-2017

Year	Total	Men	Women	Gap
1920	35.10	34.60	35.50	0.90
1930	42.23	41.50	43.01	1.51
1940	46.93	46.06	47.85	1.79
1950	57.69	54.18	57.06	2.88
1960	65.66	61.13	64.15	3.02
1970	65.86	63.85	67.20	3.35
1980	74.62	71.60	76.88	5.28
1990	77.00	74.31	79.21	4.90
2000	77.40	74.81	80.29	5.48
2010*	79.04	76.64	81.59	4.95
2017	80.20	77.50	82.60	5.10

*Indicates change of source

Sources: 1920-2010 from Méndez & Araya (2001), 2010-2017 from INEC (2018)

3 Theory

In this section, several theories on the relationship between SES, education and health will be discussed, exploring the different proposed channels of action and the "fundamental" associations that preserve that relationship over time, and why education works as a good indicator of SES. In addition, previous results for developed and developing countries will be commented, as well as for the specific Costa Rican case.

3.1 Theoretical framework

In the medical field, the focus on health is given to individuals, inspecting their genetics, diseases and lifestyles, but it fails to take into account the exposure individuals have in the social environment (Marmot, Kogevinas & Elston, 1987). Theory on the topic proposes that social forces have an effect on health and disease through diverse mechanisms, namely "risk factors". Furthermore, socioeconomic status is considered to be a "fundamental cause" of disease, meaning that changes in the mechanisms will not affect the intrinsic relationship between SES and health (Link & Phelan, 1995).

To explain health inequalities, the chain of causation implies that social forces affect risk factors like lifestyle and exposure to disease, and thus health is influenced by them (Marmot, Kogevinas & Elston, 1987). It follows that in general, population with lower SES are more vulnerable to disease which leads to lower health outcomes, while individuals with higher SES reduce their risks of having a disease as they have are more educated and have more information and can more easily implement healthy behaviors (Link & Phelan, 1995). Social structures are responsible for shaping the characteristics and behaviors of individuals, so social stratification can at least partly explain the SES differentials in morbidity and mortality (Williams, 1990).

The channels of causation are multiple and can affect health outcomes by affecting access to medical care and psychosocial factors, and a combination or interaction of both effects, thus making people of lower SES even more vulnerable to diseases. The psychosocial factors of individuals can be grouped in health behaviors, social ties, perceptions of control, and stress (Williams, 1990).

Health behaviors indicate practices that enhance better health or reduce the risk of diseases. In specific, people of higher SES are more likely to have better nutrition since they know about and can afford healthier diets, reducing the consumption of sugars, sodium, saturated and trans-fat and increased consumption of vitamins, minerals, water and dietary fiber. Diets associated with lower risk of chronic diseases are more costly than the more unhealthy ones (Aggarwal, Monsivais & Drewnowski, 2012). A healthier diet can help decrease cholesterol levels in the blood, reduce body mass index (BMI) and thus obesity prevalence, and improve several bodily systems like cardiovascular, immune and digestive, among other beneficial properties. Better nutrition is associated with lower risk of developing cardiovascular diseases (CVD), diabetes, and some types of cancer (including stomach, colorectal and kidney and breast cancer, among others), and higher survival rates for those illnesses (Adler & Stewart, 2010; Kushi et al., 2012; Luepker et al., 1994)

On the other hand, people of lower SES may experience barriers to being more physically active in comparison to their more advantaged counterparts, as less disposable income may become a limitation, or by lack of knowledge on the importance of exercise (Humbert et al., 2006). As with good nutrition, a physically active lifestyle is also associated with a lower risk of diseases by decreasing cholesterol and fat levels, improving circulation and immune system and reducing stress and aging processes. The prevalence and mortality of causes related to CVD, diabetes, some respiratory diseases and some types of cancer (Adler & Stewart, 2010; Gordon-Larsen et al., 2006; Kushi et al., 2012).

Smoking is a detrimental practice to multiple organs and systems in the body, which include the immune, respiratory and cardiovascular ones, making individuals more vulnerable to developing several chronic diseases. Among these, one can find chronic obstructive pulmonary disease (COPD), CVD and multiple types of cancer (lung, esophagus, throat, leukemia, among others), as well as worsening other conditions like respiratory infections and asthma (Adler & Stewart, 2010; Kushi et al., 2012). Although decades ago, smoking was a practice prevalent in all sectors of society, it is becoming more common among those with lower SES, since those with higher education and income have access to more information about the harmful long-term effects of tobacco use and have the resources to stop the habit (Adler & Stewart, 2010).

Alcohol consumption is another practice that can be related to health through several channels. Firstly, long-term effects of alcohol have been linked to higher risks of developing multiple types of cancer, including liver, larynx, breast and colon, among others. Second, numerous serious conditions like epilepsy, pancreatitis, cirrhosis and hypertension have also been associated with long-term consumption of alcohol. Third, alcohol drinking during pregnancy can cause low birth weight and fetal damage. Fourth, short-term alcohol consumption can lead to intoxication and reduction of awareness, which has been linked to accidents and injuries. Finally, alcohol consumption can worsen the treatment of other diseases by interacting with medication or damaging the immune system (Butt et al., 2011; Mäkelä, 1999). As with smoking, excessive drinking of alcohol has been associated with populations of lower SES, generally because of sustained consumption to cope with stress and lack of education or resources to stop the habit (Curran et al., 1999; Mäkelä, 1999).

A third channel that connects SES to health disparities is the exposure to the environment, specifically when hazards and resources and distributed according to SES. Populations with low SES are more commonly subject to environmental threats like toxic waste, water and air pollution, noise, crowdedness and toxins, while also having fewer resources to ameliorate their effects. Adverse environment conditions as these have been strongly associated with communicable diseases mainly, but also to affections in immune, respiratory and digestive systems (Adler & Stewart, 2010; Marmot, 1994). However, the role of the environment on health has been decreasing substantially as countries grow richer and as psychosocial factors take more relevance (Adler & Stewart, 2010).

Besides the health practices, another channel connecting SES and health are the social ties, which are related to social integration and support of individuals, since these factors can reduce mortality risk by improving biological pathways, for example, married individuals experience lower death rates than single or divorced ones. Individuals in higher SES have access to stronger support and better integration in communities, which allows them to learn more about healthy lifestyles, support to quit habits and to deal with stressful situations (Luepker et al., 1994; Williams, 1990).

Perceptions of control and mastery affect health when the sense of powerlessness in certain environments can demoralize and discourage individuals to actively cope with their problems (Williams, 1990). Income inequality in societies can generate an influence in the way individuals make choices and behave; individuals in lower (relative) levels of the SES hierarchy could suffer from relative deprivation, meaning that seeing and understanding that they have "less" than the group above them could affect their mortality and morbidity. The precise channels for relative deprivation to affect health outcomes are related to a decreased sense of one's control over health, over one's work, less social support, less use of skills and lower participation in social circles, all of which can lead to changes in the health practices mentioned above (Marmot, 1994).

Finally, stress in occupational, residential or family environments can have direct and indirect effects on health (Williams, 1990). On the one hand long-term stress can directly cause damage to health by affecting bodily systems like the neuroendocrine and immune ones (Marmot, 1994), as well as generating pressure in the sympathetic nervous system, causing changes in heart rate, blood pressure and cortisol (Adler & Stewart, 2010). In addition, stress has been associated with accelerating the aging process and to the growth and development of tumors (C. Kessler et al., 1992). On the other hand, stress can interact with other factors and indirectly affect health by changing behaviors in the individual, as increasing smoking or alcohol consumption, worsening in good nutrition habits, slower response to stimulus and decreasing socialization. Individuals in lower SES are exposed to environments with more stressors, including financial limitations, relative deprivation, demanding occupations and higher rates of unemployment, divorce and discrimination, while at the same time they carry fewer resources to be able to cope with those stressors (Adler & Stewart, 2010; Williams, 1990).

Another factor linking SES and health outcomes is the differential access to health care since unequal access to medical care can have consequences on prevention of diseases, diagnosis and the adequate treatment of them (Adler & Stewart, 2010). Individuals of lower SES are the ones with more barriers to quality health care, even in countries with a universal health care system. Among the reasons for this, authors suggest attitudes and education towards medical care, the costs of some services and the availability of options are limited for those of lower SES, while in comparison people of higher SES have more resources to make a better use of the services (Marmot, 1994; Williams, 1990). Insurance coverage is not enough to guarantee homogenous quality and access, as individuals are restrained by factors such as travel times, transportation, flexibility in scheduling and sense of control (Adler & Stewart, 2010). Some authors claim the role of health insurance is only relevant for a certain time but in the long run it becomes less important (Cutler & Lleras-Muney, 2006).

Psychosocial factors, environmental exposure and access to medical care have been explained as channels through which social stratification is related to health outcomes disparities. However, those channels commonly interact with each other, usually worsening the influence of lower SES on health at different levels. On the individual level, practices like excessive alcohol consumption are commonly linked to smoking, or bad diets with lack of physical activity, while stress from the environment or from relative deprivation can worsen those practices. The lack of support from social ties, on the other hand, may preclude the individual from having coping mechanisms, raising stress levels, while the uneven distribution of environmental hazards and lack of access to quality health care contribute to strengthen negative effects on health (Adler & Stewart, 2010; Williams, 1990).

However, would this mean that as countries develop and their living standards improve for the population, health inequalities are expected to reduce? Evidence has shown that this is not the case. The differences created by SES are persistent even when the main mortality causes change: as some of the prevention for disease risks becomes more widespread (for example through sanitation and immunization), other risks emerge or are discovered and the SES gradient remains strong (Link & Phelan, 1995; Williams, 1990).

People in low SES conditions will remain more vulnerable as they may not know about the risks or may not have the resources to protect themselves from them, since SES is related to several disease outcomes and the mechanisms through which they are linked are multiple. In addition, even if risk factors change drastically in a population, fundamental social forces will still have effects on health because the social and economic resources can be used in a diversity of ways and environments (Link & Phelan, 1995). Some illnesses that used to only affect groups of higher SES in the past, with time become more prevalent in all groups, until ultimately affecting more the vulnerable groups. Some examples of this pattern are prevalence of coronary heart-disease and chronic diseases related to smoking which have had a positive or non-significant gradient with SES in the past, but as risk factors and information on the disease becomes more available, the gradient becomes negative (Marmot, 1994;

Williams, 1990). Another example is the emergence of HIV in the 1980s, the SES effect was evident since transmission was higher in areas of lower SES (Link & Phelan, 1995).

In regard to the components of SES, the most common dimensions of social stratification are education, income and occupation, since they can be seen as objective and defined indicators in a society (Williams, 1990). Education in particular is considered to have a strong influence on health outcomes, since it has both direct and indirect effects on health. On the one side, it is strongly correlated to income and it is a strong predictor of occupation. Education provides better opportunities in the labor market which translates to higher income (Kabir, 2008). Some studies have shown that for developing countries, when both education and income are included to explain life expectancy disparities, the effect of income is removed, since education encompasses it (Messias, 2003).

On the other side, education may raise people's health awareness to make better decisions regarding health (Kabir, 2008), and in interaction with psychosocial factors, educated individuals are more likely to choose healthier diets, know more about health risks and use health care in a better way (Fuchs, 1979). More educated individuals are also more attentive and responsive to information about health and diseases, while believing and trusting more in scientific research (Williams, 1990). In addition, education plays a role in the self-management of diseases, as more educated individuals are more apt to understand and adhere to therapies for diseases, as for example treatment for diabetes (Smith, 2004).

An additional view on the topic gives education a more active role on health outcomes. Education stimulates the brain, and this could have positive biological effects on individuals, by improving cognitive functions and abilities to solve problems, which then can help individuals make better decisions regarding their health. In the same line of thought, education could delay the appearance of illnesses like dementia and Alzheimer (Smith, 2004)

Furthermore, mother's education is the most important determinant of mortality in children, thus strongly impacting life expectancy in a region. Education in mothers raises their negotiation power, increases the likelihood of seeking medical attention when their children are sick and are more likely to prevent diseases or treat them better (Williamson & Boehmer, 1997). For this reason, when exploring education's effects on health, female education should be analyzed separately.

Finally, the direction of causality has been extensively debated, since it can be argued that health may affect social conditions, for example, if poor health can cause downward mobility or if it restricts social interaction to get support. Furthermore, a third factor can be affecting both variables at the same time, like genetics or conditions in early life (Link & Phelan, 1995). The current psychosocial factors in an individual do not depend entirely in the current SES of individuals, since there are hereditary effects of other factors, as for example health conditions in the past. Low birthweight for example is a condition related strongly to child mortality and to future SES (Williams, 1990).

Nonetheless, although the possibilities of reverse causality and heredity cannot be completely denied, evidence from medical sociology and social epidemiology have demonstrated a strong causal effect of social conditions on health (Link & Phelan, 1995). In addition, multiple natural experiments with the use of longitudinal data and quasi-natural experiments, have shown a causal effects of SES on health outcomes in a diversity of contexts and countries (Kawachi, Adler & Dow, 2010), as well as other studies using data from twins have shown health returns to schooling (Fujiwara & Kawachi, 2009; Lundborg, 2013). For this reason, it has been proposed that to reduce health disparities in a country, it is not enough to intervene exclusively in risk factors, since to substantially reduce those disparities it is necessary to deal with the fundamental causes of disease, meaning, the social causes behind them (Olshansky et al., 2012).

3.2 Previous research

According to the theoretical framework explained in the previous section, the negative gradient found between SES and mortality should persist or even increase over time, because of the several fundamental mechanisms through which SES, and specially education, can affect health outcomes. In this section, empirical evidence on the topic will be discussed, both across and within countries, with a focus on the developing world, as well as specifically for the Costa Rican case.

Contemporary evidence has shown that the association between SES and health outcomes has remained strong in the last decades, however, the specific channels through which the relationship acts have changed and depend on the country. Generally, the trends found for several developed countries point out to larger gains in life expectancy for the populations in higher SES in comparison to the lower SES groups, partially explained in many cases by the effect of mortality by CVD and smoking-related diseases becoming more prevalent among lower SES groups (Kalediene & Petrauskiene, 2000; Olshansky et al., 2012; Singh & Siahpush, 2006).

Several studies using data for high-income countries have found persistent inequalities in life expectancy related to SES differentials, where higher income inequality is usually the strongest predictor of health disparities in a country. Interestingly, income does not always appear to have an independent, significant effect on health outcomes (Jagger et al., 2008; Vogli et al., 2005). Research in European countries has shown solid, substantial and increasing educational gradients in life expectancy, especially (but not exclusively) for men, with a predominant role of CVD generating larger inequalities (Kalediene & Petrauskiene, 2000; Spoerri et al., 2006; Vogli et al., 2005).

In a study for the United States (USA) counties from 1960 to 1999, Ezzati et al. (2008) showed that overall inequality in life expectancy has increased in the country, with stagnation or increase in mortality for the population in lower SES, even when overall life expectancy has been increasing steadily in the country during that period. The increase of mortality by diseases related to smoking, diabetes and other non-communicable diseases out weighted the effect of reductions in CVD mortality during the period, which could partially explain the increases in the SES gradient in life expectancy.

Meara et al. (2008) found similarly that for the USA, gains in life expectancy in the last years have been secluded to the better educated groups in the country, so the educational gap in life expectancy is widening. In the same way, other studies have showed that the predictive power of education on life expectancy and healthy life expectancy is becoming stronger than other important variables like urbanization and race (Crimmins & Saito, 2001; Olshansky et al., 2012).

Additionally, studies on have found that both individual and neighborhood SES have independent effects on health outcomes, through several causes of death and self-reported health (Chandola et al., 2003; Clarke et al., 2005; Goldman et al., 2006).

For developing countries, Kabir (2008) found that average adult education was a highly significant determinant of life expectancy, while other indicators like per capita real income and expenditure on health fail to have a significant effect on health outcomes. Similarly, Habearer et al. (2015) found for the American countries a strong socioeconomic and education gradient on life expectancy and healthy life expectancy, with a larger gradient for men.

In the case of Brazil, Messias (2003) showed that the illiteracy rate was strongly associated with life expectancy, and the predictive power of income on life expectancy is removed when education is included in the regressions. For Chile, it was found that mortality for oral and pharyngeal cancer (diseases associated with smoking) was greater among populations with lower levels of education (Ramirez, Vásquez-Rozas & Ramírez-Eyraud, 2015), with a similar result found for Colombia in all types of cancer (Jaramillo & Vélez, 2004).

Regarding the specific mechanisms through which SES are related to health outcomes, the analysis becomes more complex since it is difficult to disentangle the specific channels, however, several studies have used mortality causes and prevalence of certain factors (like smoking and obesity rates) as an approach to identify them. In an elaborate study about the determinants of life expectancy inequalities among US counties, Dwyer-Lindgreen et al. (2017) found that SES components like education and race had stronger predictive power than health care factors like insured population and physicians per population. However, behavioral and metabolic risk factors, which can be related to SES and health outcomes, like obesity prevalence, smoking and hypertension prevalence had the strongest predictive power explaining the life expectancy inequalities.

Marmot (1999) showed that both within and across countries, many psychosocial factors, like social support, psychosocial work environment and control/mastery can be predictors of health disparities, specifically in heart diseases. Meara et al. (2008) showed that trends in diseases related to smoking can help explain a large share of the educational differentials found in life expectancy in the US. Also for the US, Singh & Siahpush (2006) find that psychosocial characteristics, social support and integration are important factors producing health inequalities, as populations in more deprived groups have higher rates of homicide and suicide, which differs substantially to better-off groups.

One factor that is often overlooked in the literature is the specific role that gender interacting with SES has health outcomes. Women live longer than men in almost all the countries in the world, and besides biological factors, many authors point out to better health behaviors and gender roles as explanations for this gap (Emslie & Hunt, 2008). On one side, studies have shown that women handle better stressful situations and can receive stronger support during difficult situations (Bendelow, 1993; Pietilä & Rytkönen, 2008). On the other side, with knowledge, women do a better use of health care services and have healthier practices (Austad, 2006; Bertakis et al., 2000). Relating this to the SES gradient on life expectancy, it is expected that women will exhibit a steeper positive gradient than men. However, previous findings have not been consistent on this outcome, and usually depend on the cause of death: in many cases the slope on overall mortality seems to be flatter for women than for men, but it seems to be steeper for women in the case of mortality for CVD in developed countries (Koskinen & Martelin, 1994; Phillips & Hamberg, 2015). Additionally, it has been found that for some causes of death, like breast cancer, there is reverse SES gradient for women (greater wealth worse health) (Phillips & Hamberg, 2015).

For developing countries, Monteiro et al. (2004) showed how obesity is becoming a larger problem for populations of lower SES in comparison to the past where it affected more people of higher SES, and the association seems to be getting worse for women than for men, similar to what was found by Barquera et al. (2013) for Mexican adults and by Bustamante et al. (2007) for Peruvian young adults. For adults in Chile, studies have shown that CVD risk factors like drinking, smoking, obesity and physical inactivity were higher in populations of lower SES (Jadue H et al., 1999; Palomo G et al., 2007). For Colombia, it has been shown that the environment in populations of low SES is associated with higher mortality in respiratory diseases and all causes (Blanco-Becerra et al., 2014), while risk factors like diet and stress were not related to SES, possibly because of the unhealthier diets of the urban population with higher SES (Alfaro-Faeth et al., 2015; de Rovetto et al., 2012).

In the Costa Rican case, research on the topic has been limited. Most of the studies have been ecological at the canton level because of the lack of data linking mortality to socioeconomic characteristics at the individual level, although some recent analyses have been done using health surveys. Rosero-Bixby (1994) performed a comprehensive study on the adult mortality decrease for the country from 1920 to 1990, and found that when comparing data from 1973 to 1984, higher income cantons are correlated to higher CVD mortality for old-age adults, as well as for mortality by all causes. However, this correlation was not found for younger adults.

More recently, studies on child mortality and violent deaths for the 2008-2012 period have also shown geographical inequalities and the importance of the environment on health, but find that rural cantons and those with lower development have higher mortality rates (García, 2013; García & Ammazzini, 2014). Llorca & Ortún (2010) conducted an analysis on specific causes of death of avoidable mortality for the period 2000-2005 and revealed that cantons with higher income are associated with higher mortality rates in breast, uterine and skin cancer, and in drinking-related hepatitis, while cantons with lower income presented higher mortality in prostate cancer and maternal mortality.

With the use of individual level data obtained from the Costa Rican Study on Longevity and Healthy Aging (CRELES), it was found that there are no consistent SES gradients on health outcomes for old-age adults, since the gradient is surprisingly positive for mortality and metabolic syndrome (the better educated and wealthier are worse off), but negative for quality of life, depression and disabilities. When behaviors are being considered, some risk factors like cholesterol levels are not related to SES, while others like hypertension and obesity are higher among high SES individuals, and others like smoking and lack of exercise are higher among low SES populations (Rosero-Bixby & Dow, 2009). A follow-up study using life expectancy at age 60 also found lacking SES gradients; moreover, male life expectancy seems to be lower for the more educated and those living in cities (Rosero-Bixby, 2018).

Although there does not seem to be consistency in the results for SES gradients and health outcomes for Costa Rica, it must be considered that most of these studies performed basic correlation analysis, which are subject to bias since characteristics like education, income and urbanization cannot be disentangled without the use of more complex statistical methods. Sex differences in the gradient have not been properly analyzed before.

4 Hypotheses of the study

Based on the theory on the topic and previous research, it is expected that for the Costa Rican case:

1. *The relationship between average education and life expectancy at the district level is positive for both men and women, with a steeper slope for women*. Districts with higher average education imply more educated individuals, which should exhibit higher life expectancy as they engage in better health practices and experience less stress. Women are more likely to have healthy practices, so their association with life expectancy should be stronger than for men.

2. *There has been a statistically significant increase in the association between education and life expectancy for both men and women*. As child mortality, mortality by communicable diseases and maternal mortality become less relevant and people live longer, mortality by chronic diseases and violent deaths takes up a larger share of the total mortality, which then leaves more room for education to have an impact on life expectancy.

3. *The association between education and life expectancy has become stronger for the older age groups than for the younger ones, for both men and women*. Chronic diseases affect more those in older groups, so those age groups should be the ones more prone to have an educational gradient.

4. *The relationship between education and mortality for causes of deaths related to health behaviors has been increasing for men and women*. The educational gradient should become stronger to mortality rates by causes of death that can be prevented with healthy practices, like CVD, lung-related diseases and diabetes.

5 Data

For the analysis of the hypothesis, data on the variables were obtained from different sources. This section will describe the materials, transformations performed, selection of relevant variables, and other data issues that should be considered.

5.1 Source Material

Because of its level of disaggregation, data at the district level is in many cases not easy to obtain for Costa Rica, since it is usually only available in Census data, which restricts the years the analysis can be conducted. However, as mentioned before, districts are preferred over cantons since they represent the smallest unit of analysis at which life expectancy could be calculated, so more units can be included in the dataset. In addition, cantons in Costa Rica can include large areas in which there are dramatic differences between districts, so grouping them in one unit could bias the results.

Data for mortality rates by district was obtained from the National Institute of Census and Surveys of Costa Rica (INEC in Spanish). The death certificate database contains information on sex, age, year of death, cause of death and district of residence of the individuals from 1973 onwards. The population data was obtained from the 1984, 2000 and 2011 Census, which represents the only way to obtain disaggregated population data by sex and age at the district level. Sociodemographic information was also obtained from Census data. Data on health care services was obtained from the Costa Rican Social Security Fund (CCSS in Spanish) but only for 2011. Georeferenced data was obtained from the Territorial Information National System of Costa Rica (SNIT in Spanish). All information is of public access.

5.2 Transformation of data

From 1984 to 2011, 52 new districts were created in the country, which means that to compare one to one, it is necessary to use the district base from 1984. Most of these new districts are small ones which were segregated from larger ones, usually in urban areas, while another important portion were large areas with small populations that were created as a new district from several others, usually in rural areas. If the new district formed part of the first case, they were grouped to the former district, and if they belonged to the latter one, they were united to the one closest in geographical proximity. It should be noted that a few of these new districts in the urban areas (León XIII, Purral, Los Guido) had larger populations than the former district and nowadays are considered zones of high poverty. However, it is unlikely that these modifications would affect the results.

To calculate life expectancy by district, several procedures were performed. Firstly, to avoid unstable rates for districts with small populations, mortality data for districts was pooled for 5 years, meaning that for 1984, deaths were grouped for the years 1982-1986, and for 2011, the range was 2009-2013.

Second, there exists a debate on the minimum number of people in a location to generate valid estimates of life expectancy, since districts with small populations could bias the results as they may not have deaths in some age groups. Having zero deaths can overestimate the life expectancy of these districts. For this reason, it was decided that districts should have at least 2,000 women and 2,000 men in 1984 (the year of the smallest population). Districts with populations lower than that were grouped with districts geographically adjacent to them.

After dealing with these issues, age-specific mortality rates were calculated for every district by sex. However, some districts presented zero deaths at certain age ranges. To avoid bias because of this and following Chiang (1984), for these districts the mortality rates of a known population were used instead. To better fit the Costa Rican context, for rural districts in this condition, the age-specific mortality rates of the overall rural population were used, and the mortality rates of urban population were used for urban districts. Sex-specific life expectancy at birth was calculated for every district using standard life tables methods.

The set of districts went from 472 in 2011 to 276 once the previous issues were dealt with. The rest of the variables included for the analysis were grouped to fit this set of districts.

5.3 Selection of variables

Following the literature review and the available data for the country and the period, the following variables were decided to include in the empirical analysis.

Life expectancy (at birth): the dependent variable to be used as the main health outcome. Life expectancy has been widely used as one of the main health outcome indicators since it represents a complete index of mortality (Ezzati et al., 2008). It can be interpreted as the average time individuals are expected to live at the time of birth in a district.

Average education: total average years of schooling by individuals aged 25 or older in each district. This measurement is considered the most powerful correlate to good health (Fuchs, 1979). It also represents the variable of interest and its expected relationship with life expectancy should be positive.

Urbanization: percentage of the population living in cities. Urbanization has been considered to have a positive effect on health outcomes, since it allows urban inhabitants to have access to better medical care and socio-economic facilities (Kabir, 2008). However, urbanization has also shown to change structure of diets, physical activity and obesity patterns in populations (Popkin, 1999), thus having a negative effect on health. For this case, urbanization is expected to have a negative association with life expectancy.

Dependency ratio (old-age): ratio of people aged 65 or older over people in working ages (15 to 65). This is one of the main demographic controls in the analysis, since it is expected that in districts with higher dependency ratio, there is going to be higher deaths, so life expectancy will be shorter, meaning that the expected sign on life expectancy is negative.

Migration: percentage of migrants in the district. It is expected to have a negative association with life expectancy since migrants in Costa Rica are in a large majority Nicaraguans which live in poor and stressful conditions (Acuña González & Olivares Ferreto, 2000).

Insured: percentage of the population covered by social insurance. Although coverage from the CCSS is quite high in the country, most studies include this control in their analysis. It is expected that the coefficient will have a positive sign on life expectancy.

Population by EBAIS: EBAIS are the most basic medical care units in the Costa Rican health care system. This variable represents the number of people by EBAIS in each Health Area (not by district). It is expected that districts with lower population by EBAIS will receive better attention from the health care services, so its association with *Life expectancy* should be negative.

Hospital: dummy variable that takes the value of ”1” if there is a Hospital in the district. The reason to include this variable is to control for internal migration of ill individuals. Some authors have suggested that the “negative” gradient of SES on life expectancy in Costa Rica could be explained by selection bias because some ill adults (Rosero Bixby, 1994), especially those with chronic diseases, could migrate to areas closer to health services, thus artificially raising the mortality rates. It is then expected that this variable will have a negative relationship with life expectancy.

6 Methods

The analysis was carried out for three years: 1984, 2000 and 2011, which is when Census data is available. The main analysis will be conducted comparing the differences between 1984 and 2011, but information for 2000 will be useful to identify trends.

To evaluate the proposed hypothesis, an ecological study will be performed. This type of epidemiological analysis looks for associations between the prevalence of a disease in a population and the exposure to causes or factors (Morgenstern, 1995). In this case, the unit of analysis is based on a geographical attribute, the district. With the use of aggregated data, it is not possible to explore directly the relationship between the factors and the disease in individuals, but often can these relationships be inferred from population information (Saunders & Abel, 2014).

It must be considered that there are several methodological problems with the use of ecological studies. Two of the main issues are confounding and the ecological fallacy. The first issue relates to when two factors may seem linked but in reality they are associated with a third variable. The second one is related to the error when conclusions obtained from population data are given at the individual level (García & Ammazzini, 2014; Saunders & Abel, 2014). Nonetheless, the purpose of this study is not to give causal inference of the associations found, or to interpret the results at the individual level.

Moreover, ecological studies represent a practical way to study the relationships given the lack of data available, and they represent a great tool to quantify associations between disease risk and the socioeconomic environment of the individuals, which several studies have shown that are related to individuals' life choices and conditions (Clarke et al., 2005; Morgenstern, 1995).

The methodology consists of the following steps: first, a descriptive analysis of the evolution of sex-specific life expectancy at the district level for the years 1984, 2000 and 2011 in the country, to obtain insight on how inequality in life expectancy has improved or gotten worse. A geographic representation of the results will also be given. This first step will provide the necessary context for the following steps of the analysis.

Second, a regression analysis will be used to analyze specifically how *Life expectancy (LE)* is related to *Education.* Generally, *Life expectancy* in a district can be considered as a function of the year (Y), average education (E), socioeconomic (S) and health care (H) factors in that district, so the relationship could be expressed as:

$$LE = f(Y, E, S, H)$$

In the described expression, socioeconomic factors are related to *Urbanization*, *Migrants* and *Dependency ratio*, while health care factors encompass *Insured* population, *Population by EBAIS* and *Hospital.* This functional relationship can also be described through an Ordinary Least Squares (OLS) regression as:

$$LE = \beta_0 + \beta_1 ear + \beta_2 Education + \beta_S S + \beta_h H + \varepsilon$$

Where *Life expectancy* is explained by *Year* and its coefficient β_1, *Education* and its coefficient β_2, a set of socioeconomic explanatory variables S with their respective coefficients β_s, a set of explanatory health care variables H and their respective coefficients β_h, and an error term ε. Subscripts are omitted since the unit of observation is only the district. Three sets of models will be conducted for the pooled dataset: a basic one (1) with only *Education* as explanatory, a second one (2) with the socioeconomic controls, and a third one (3) with socioeconomic and health care controls.

Those first models will bring insight into the relationship between *Education* and *Life Expectancy* has been generally for the three years, which allows us to assess the first hypothesis of the study. However, to test if there have been statistical changes in the relationship over the years, as a third step, a model including an interaction term between *Education* and *Year* will be performed. The model will take a form like this:

$$LE = \beta_0 + \beta_1 Year + \beta_2 Education + \beta_3 Education * Year + \beta_S S + \beta_h H + \varepsilon$$

This interaction term and its coefficient β_3 will allow interpreting how the coefficient for *Education* is modified or not by the *Year* variable, while at the same time including independent coefficients for *Year* and *Education*. The second hypothesis (significant increase in the relationship between *Education* and *Life expectancy)* will be assessed with the results of this step.

As a fourth step, once the interaction models have shown the evolution of the relationship between the variables, it will become of interest to explore more deeply what has originated the changes. For this, the outcome variables will now be age-specific mortality rates (*ASMR)*, which allows us to see in which specific age ranges the changes have happened. The four age ranges decided for this analysis were: i. 0 to 4 (child mortality) ii. 15 to 44 (young adults) iii. 45 to 64 (adults) iv. 65 and older (old-age adults). The range 5 to 14 was not included since mortality rates are very low for all districts. An interaction model will be used for each age range and sex, with information for the years 1984 and 2011. The outcome of these models will be used to evaluate the third hypothesis (stronger increase of the relationship for older groups). The equation for these models will generally take the following form:

$$ASMR = \beta_0 + \beta_1 Year + \beta_2 Education + \beta_3 Education * Year + \beta_S S + \beta_h H + \varepsilon$$

As a final step, in an attempt to identify through which channels the relationship between *Education* and *Life expectancy* has changed, an analysis using mortality by causes of deaths will be conducted. This analysis will be done only for the age ranges in which an important change of the educational coefficient was observed in step 4, and only for 1984 and 2011.

The causes of death can be found grouped by the INEC, but for the purpose of this study, they were grouped again in 11 main ones, according to their relationship to risk factors and what previous literature on the topic have used. In specific, the causes included are: Cardiovascular disease (CVD), Lung-related disease (respiratory chronic diseases and lung cancer), Alcohol-related, Diabetes, Accidents (traffic and others), Injuries (suicide or homicide), Stomach cancer, Prostate cancer (for men), Uterus cancer (for women), Breast cancer (for women) and Cancer (other).

The fourth hypothesis is related to these models, since it is expected that *Education* will have a stronger negative association with mortality in causes of death preventable by health practices. In general, these models will follow this form, where CDMR indicates the cause of death mortality rate:

$$CDMR = \beta_0 + \beta_1 Year + \beta_2 Education + \beta_3 Education * Year + \beta_S S + \beta_h H + \varepsilon$$

For sensitivity analysis, regressions will be conducted again with other SES variables instead of average education. The first will be a categorical variable, *Educational group*, grouping completed education in 3 groups (Lowest, Middle and Highest), and the second one, percentage of the population over 25 with High School diploma *Perc High School*. Both variables will be used for the main models, but for the ASMR and CDMR ones, they will only be conducted for *Perc High School*.

For all the models, results will be interpreted at the 5% of statistical significance.

7 Empirical Analysis

7.1 Results

7.1.1 Descriptive statistics

Since the analysis was conducted by sex, for 3 years and for 276 districts, the entire dataset contains a total of 1656 observations. Table 3 presents the summary statistics for the variables in the analysis. The average *Life expectancy* was 79.19, with a minimum value of 59.45 years and a maximum of 93.85 years, while *Education* has a mean of 6.58 completed years of school.

Table 3. Summary statistics for the variables included in the analysis

	Obs	**Mean**	**Std. Dev.**	**Min**	**Max**
Life Expectancy	1656	79.19	4.80	59.45	93.85
Education	1656	6.58	2.16	1.99	12.94
Urbanization	1656	0.40	0.40	0.00	1.00
Insured	1656	0.78	0.11	0.19	0.93
Migrant	1656	0.06	0.06	0.00	0.33
Pop by EBAIS	1656	4839	4534	2133	37327
Dependency ratio	1656	0.09	0.03	0.03	0.29
Perc High School	1656	0.11	0.10	0.00	0.56
Perc White collar	1656	0.14	0.14	0.00	0.57
Hospital	1656	0.11	0.32	0.00	1.00
ASMR 0-4	1656	0.32	0.23	0.00	2.37
ASMR 15-44	1656	0.11	0.07	0.00	0.92
ASMR 45-65	1656	0.53	0.28	0.00	4.55
ASMR 65+	1656	3.88	1.31	0.00	12.19

It must be noted that these values are from the pooled dataset so represent data from 1984, 2000 and 2011 with no sex separation. To obtain a better understanding of the *Life Expectancy* and *Education* evolution over time, the following tables will present disaggregated statistics. Table 4 shows population-weighted sex-specific *Life Expectancy* by year and compares it to the Life Expectancy obtained from the totals in the country. There is a slight overestimation of the *Life Expectancy* in comparison to the raw totals, but the values remain very similar to each other, especially for 2011.

Table 4. Weighted average and standard deviation for Life Expectancy by year and sex

	1984		**2000**		**2011**	
	Avg	**Total**	**Avg**	**Total**	**Avg**	**Total**
Female	78.05	77.94	81.31	81.09	83.40	83.25
	(2.42)		(2.41)		(2.02)	
Male	73.80	73.48	75.98	75.61	77.38	77.18
	(3.30)		(2.98)		(2.49)	
Gap	4.25	4.46	5.33	5.47	6.02	6.07

When comparing standard deviation of *Life expectancy* in the districts, one can find that for men there is higher inequality in every period in comparison to women. However, inequality has been decreasing for both sexes since 1984. Life expectancy has increased over 5 years for women during the period, but only about 3.6 years for men, which is of interest since in 1984 women already had a gap of over 4 years in comparison to men. This leads to a gap of over 6 years in the year 2011.

In the case of *Education*, there has been a sustained increase of the mean in each census year, and a slight reduction in the standard deviation over time. In addition, there has been an increase in the minimum and maximum average education in every year, as presented in the following Table.

Table 5. Summary statistics for average education by year

	Mean	**Std. Dev.**	**Min**	**Max**
1984	5.63	1.81	1.99	10.48
2000	7.19	1.73	3.63	11.80
2011	8.31	1.73	4.89	12.95

The Appendix A shows a geographical representation of *Life expectancy* by sex and *Education* by district for Costa Rica for each Census year, grouping the results by quintile in each case. Regarding *Life expectancy,* both for men and for women there does not seem to be a clear pattern, since high longevity is found scattered all over the country. However, some small specific areas in the Península de Nicoya (the Blue-zone area), the north-west and the south-east of the country seem to consistently have high longevity by men and women. For *Education*, the concentration in the center of the country, where the cities are, is evident as expected.

7.1.2 Regression models

Life expectancy

Table 6 presents the results for the pooled models. The first three sets of models show the OLS models as controls are added. As expected, the coefficient for *Year* is significant and positive in all the specifications, both for 2000 and for 2011, as *Life expectancy* has improved significantly in comparison to 1984.

Table 6. OLS results for Life expectancy by sex

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Year (Ref: 1984)								
2000	3.622***	3.605***	2.096***	2.446***	2.145***	2.686***	3.188***	4.320***
	(0.348)	(0.291)	(0.340)	(0.294)	(0.369)	(0.323)	(1.144)	(1.017)
2011	5.871***	5.775***	5.166***	5.105***	4.790***	5.095***	2.108*	6.477***
	(0.387)	(0.322)	(0.377)	(0.323)	(0.436)	(0.381)	(1.261)	(1.119)
Education	-0.887***	-0.144**	0.353***	0.703***	0.256**	0.638***	0.173	0.817***
	(0.076)	(0.064)	(0.112)	(0.097)	(0.121)	(0.106)	(0.166)	(0.145)
Year & Education (Ref: 1984)								
2000 & *Education*							-0.129	-0.249*
							(0.165)	(0.144)
2011 & *Education*							0.348**	-0.200
							(0.165)	(0.144)
Urbanization			-6.593***	-4.481***	-5.414***	-3.551***	-5.329***	-3.651***
			(0.481)	(0.415)	(0.482)	(0.420)	(0.484)	(0.424)
Migrant			-2.533	3.879*	-0.160	4.891**	-0.191	4.178*
			(2.415)	(2.117)	(2.509)	(2.232)	(2.533)	(2.265)
Dep ratio			-21.385***	-19.124***	-10.464**	-10.671***	-11.440**	-10.546**
			(4.787)	(4.071)	(4.792)	(4.130)	(4.782)	(4.136)
Insured					-1.884	-3.401*	-1.648	-4.295**
					(1.962)	(1.783)	(2.028)	(1.848)
Pop by EBAIS					0.019	0.037**	0.018	0.037**
					(0.022)	(0.019)	(0.022)	(0.019)
Hospital					-2.879***	-2.091***	-2.850***	-2.090***
					(0.313)	(0.271)	(0.311)	(0.271)
Constant	79.045***	78.974***	76.699***	77.519***	77.721***	79.529***	78.049***	79.206***
	(0.483)	(0.411)	(0.513)	(0.443)	(1.313)	(1.190)	(1.326)	(1.205)
Observations	828	828	828	828	828	828	828	828
R-squared	0.233	0.327	0.384	0.421	0.445	0.467	0.451	0.469

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Regarding the coefficient for *Education*, there are changes as controls are added. The coefficient is negative in the basic model (Model 1), but it switches to positive in the following models, possibly because of the inclusion of *Urbanization*, which is highly significant and negative across models. The magnitude for the coefficient of *Education* appears to be higher for women than more men, and in both cases it seems to decrease when health care controls are included (Model 3).

The variables *Dependency ratio* and *Hospital* are also significant and negatively associated with *Life expectancy*, as expected. On the other hand, the coefficients for *Population by EBAIS* and *Migrant* are significant and positive for women, contrary to what was expected.

Model 4 shows the outcome of the model with interactions. In this case, the coefficient for *Education* is no longer significant for men, but the interaction between *Education* and 2011 shows a significant and positive coefficient, which indicates that the association between *Education* and *Life expectancy* became significant for 2011, but it was not before. In the case of women, the interactions are not significant, but the coefficient for *Education* is positive and significant, so *Education* seems to be associated with female *Life expectancy* for all the years included.

Sensitivity analyses were conducted for Models 3 and 4 and are shown in the Appendix B on Tables B1 for the different variables used. When using *Educational group,* it is found that districts with the highest average education have significantly higher *Life expectancy* than those with the lowest average education, but the interactions are not significant, meaning that there has been no change in the association over time, similar to what the main model indicates. In the case of men, a negative gradient was found for *Educational group* and *Life expectancy* (higher education associated with lower life expectancy), however, the interaction coefficient is significant, positive and larger in magnitude, which means that for men, education seemed to be negatively related to *Life expectancy*, but this reversed in 2011.

For *Perc High School,* a positive association between the variable and *Life expectancy* was found for men, but the interactions were not. In the case of women, the coefficient was also found significant and positive, but the interactions, both for 2000 and for 2011 were statistically significant and negative, which means that in comparison to 1984, the association with *Life Expectancy* has been decreasing.

Age-specific mortality rates

With the help of the interaction model it seems that the association between *Education* and *Life expectancy* for men only became significant for the 2011 year. On the other hand, for women, the relationship has always been significant, and it seems it has not changed in magnitude from 1984 to 2011. To better understand what changes have occurred during the period, the age-specific mortality rates analysis will be conducted.

Table 7 shows the results of the models for mortality by age ranges for men. As it stands, the interactions between *Education* and the year 2011 are significant for the age groups of adults (45 to 64 years) and old-age adults (65 and older). The coefficient of the interaction is negative which as expected means that districts with higher education are associated with lower mortality in men in adults and old-age adults.

Table 7. OLS results for age-specific mortality rates for men

	0-4 years	**15 to 44 years**	**45 to 64 years**	**65 and older**
Year (Ref: 1984)				
2000	-0.327***	-0.009	-0.098	-0.231
	(0.060)	(0.021)	(0.076)	(0.365)
2011	-0.367***	0.040*	-0.039	0.186
	(0.066)	(0.023)	(0.084)	(0.403)
Education	-0.031***	-0.017***	-0.015	0.099*
	(0.009)	(0.003)	(0.011)	(0.053)
Year & Education (Ref: 1984)				
2000 & *Education*	0.009	0.005*	-0.009	-0.072
	(0.009)	(0.003)	(0.011)	(0.053)
2011 & *Education*	-0.000	-0.003	-0.036***	-0.224***
	(0.009)	(0.003)	(0.011)	(0.053)
Urbanization	0.107***	0.068***	0.312***	1.239***
	(0.025)	(0.009)	(0.032)	(0.155)
Migrant	0.573***	0.202***	0.608***	-2.216***
	(0.132)	(0.047)	(0.168)	(0.809)
Dep ratio	1.456***	0.538***	3.062***	5.147***
	(0.250)	(0.088)	(0.317)	(1.526)
Insured	0.139	0.052	0.400***	1.852***
	(0.106)	(0.038)	(0.134)	(0.648)
Pop by EBAIS	-0.001	-0.000	0.000	-0.001
	(0.001)	(0.000)	(0.001)	(0.007)
Hospital	0.121***	0.055***	0.166***	0.668***
	(0.016)	(0.006)	(0.021)	(0.099)
Constant	0.444***	0.117***	0.136	2.052***
	(0.069)	(0.025)	(0.088)	(0.423)
Observations	828	828	828	828
R-squared	0.486	0.291	0.439	0.386

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

For women, the models are presented in Table 8. No interaction terms are significant for 2011, which goes in line with what was shown in the interaction model in Table 6. However, one important flag to notice is that for the group of old-age adults, the coefficient for *Education* is no longer significant, which means that for that age group, higher average education in the district does not seem to be associated with lower mortality.

Table 8. OLS results for age-specific mortality rates for women

	0-4 years	**15 to 44 years**	**45 to 64 years**	**65 and older**
Year (Ref: 1984)				
2000	-0.281***	-0.013	-0.166***	-0.513*
	(0.052)	(0.010)	(0.049)	(0.301)
2011	-0.334***	0.007	-0.204***	-0.737**
	(0.058)	(0.010)	(0.054)	(0.331)
Education	-0.039***	-0.006***	-0.033***	-0.083*
	(0.007)	(0.001)	(0.007)	(0.043)
Year & Education (Ref: 1984)				
2000 & *Education*	0.015**	0.001	0.006	0.005
	(0.007)	(0.001)	(0.007)	(0.042)
2011 & *Education*	0.011	-0.002	-0.000	-0.036
	(0.007)	(0.001)	(0.007)	(0.043)
Urbanization	0.129***	0.017***	0.136***	0.811***
	(0.022)	(0.004)	(0.021)	(0.125)
Migrant	0.314***	0.042**	0.060	-1.677**
	(0.117)	(0.021)	(0.110)	(0.670)
Dep ratio	1.582***	0.325***	0.839***	4.210***
	(0.213)	(0.039)	(0.201)	(1.223)
Insured	0.002	0.016	0.371***	2.148***
	(0.095)	(0.017)	(0.090)	(0.546)
Pop by EBAIS	0.000	-0.000	-0.001	-0.005
	(0.001)	(0.000)	(0.001)	(0.006)
Hospital	0.094***	0.014***	0.073***	0.564***
	(0.014)	(0.003)	(0.013)	(0.080)
Constant	0.454***	0.057***	0.318***	2.210***
	(0.062)	(0.011)	(0.059)	(0.356)
Observations	828	828	828	828
R-squared	0.444	0.189	0.326	0.296

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Interestingly, for both women and men, two control variables that were not relevant in previous models, have a significant association with *Life Expectancy* in both sexes. On one hand, *Migrant* is significant for all age groups and sexes (except female adults), and *Insured* is significant for adults and old-age adults. What becomes even more surprising is the sign of the coefficients, since they are not always the expected ones. For *Migrant*, the coefficients are positive (as expected) except for the old-age adults, both for men and women. For *Insured*, the coefficients are positive, not the expected one. This means that for the older age groups, the percentage of migrants in the district represents a positive link to mortality, while the percentage of insured population seems to increase mortality.

Sensitivity analysis using *Perc High School* showed associations for all age groups but no increases for the coefficient in 2011. Table B2 in the Appendix shows the results.

Mortality rates by causes of death

The analysis by age groups revealed some interesting facts on how the relationship between *Education* and *Life expectancy* is characterized, and the two older age groups seem to be key to explain changes and associations between these two variables. For this reason, in this section specific mortality causes and their link to *Education* will be analyzed for the age groups "45 to 64" and "65 and older". This will help better understand through which causes the relationship holds or has changed, and in which *Education* seems to be unrelated to health outcomes.

- Adults (45 to 64)

In the case of males, the significant interactions between 2011 and *Education* are given for mortality by CVD, lung-related diseases, diabetes and accidents. All the signs of those coefficients are negative, which means that in comparison to 1984, in 2011 districts with more *Education* were associated with less mortality for men in those causes. On the other hand, in mortality by injuries, the coefficient for *Education* was significant and negative, which means that, as could be expected, for both years, districts with higher education present lower mortality rates by injuries. Table 9 shows these results.

For women, results are quite different, as presented on Table 10. With the interaction 2011 and *Education*, the coefficient is only significant in one cause of death, CVD, and it presents a positive sign. Nonetheless, the coefficient for *Education* in that model is also significant and negative, and its magnitude is larger than the one for the interaction. This means that overall for both years, more education in a district is associated with less mortality for women in CVD, however, the magnitude seems to be lower in 2011 than in 1984. Besides that regression, the only other model with a significant coefficient for *Education* is in alcohol-related deaths, also with the expected negative sign.

Sensitivity analysis using *Perc High School* show only a couple of significant associations for this age group. In the case of men, none of the interactions (only lung-related at the 10% level), while for the *Education* coefficient it is significant for injuries only. For women, the decreasing magnitude for 2011 in CVD is also found as in the main model. Table B3 in the Appendix B shows the results for the causes of death with significant coefficients for *Education* or its interactions.

Table 9. OLS results for mortality rates by causes of death. Male. Age group 45-64.

	Cardio	Lung	Alcohol	Diabetes	Accidents	Injuries	Stomach	Prostate	Cancer
Year 2011	0.007	-0.022	-0.018	0.028***	0.039*	0.003	-0.019	0.001	-0.055**
	(0.033)	(0.016)	(0.015)	(0.009)	(0.022)	(0.013)	(0.019)	(0.006)	(0.022)
Education	-0.004	-0.002	-0.000	0.000	-0.001	-0.006***	0.004	-0.000	-0.002
	(0.005)	(0.003)	(0.002)	(0.001)	(0.003)	(0.002)	(0.003)	(0.001)	(0.003)
2011 & Education	-0.018***	-0.006**	-0.000	-0.003***	-0.008***	0.001	-0.004	-0.000	0.003
	(0.004)	(0.002)	(0.002)	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)	(0.003)
Urbanization	0.146***	0.037***	0.028***	0.021***	0.002	0.004	-0.006	0.004	0.041***
	(0.017)	(0.009)	(0.008)	(0.005)	(0.011)	(0.007)	(0.010)	(0.003)	(0.012)
Migrant	0.142*	0.091**	0.069*	-0.016	0.159***	0.134***	-0.128***	0.010	-0.074
	(0.079)	(0.039)	(0.036)	(0.021)	(0.052)	(0.031)	(0.045)	(0.013)	(0.054)
Dep ratio	1.232***	0.244***	0.281***	0.069*	0.183*	0.051	-0.016	0.054**	0.237**
	(0.155)	(0.077)	(0.070)	(0.042)	(0.101)	(0.061)	(0.089)	(0.026)	(0.104)
Insured	0.108*	0.085***	0.077***	0.004	0.022	0.023	0.013	0.005	0.088**
	(0.059)	(0.029)	(0.027)	(0.016)	(0.039)	(0.023)	(0.034)	(0.010)	(0.040)
EBAIS	0.001	0.000	-0.000	0.000*	-0.001	-0.000	0.000	-0.000	-0.001**
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hospital	0.053***	0.011**	0.014***	0.008***	0.030***	0.012***	0.007	0.002	0.016**
	(0.010)	(0.005)	(0.004)	(0.003)	(0.006)	(0.004)	(0.006)	(0.002)	(0.007)
Constant	-0.002	-0.022	-0.045**	-0.002	0.052**	0.038**	0.053**	-0.001	0.027
	(0.038)	(0.019)	(0.017)	(0.010)	(0.025)	(0.015)	(0.022)	(0.007)	(0.026)
Observations	552	552	552	552	552	552	552	552	552
R-squared	0.463	0.290	0.237	0.161	0.123	0.110	0.219	0.031	0.149

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 10. OLS results for mortality by causes of death. Female. Age group 45-64.

	Cardio	Lung	Alcohol	Diabetes	Accide nt	Injuries	Stomach	Uterus	Breast	Cancer
Year 2011	-0.134***	-0.046***	0.003	0.019*	0.011	-0.004	-0.030**	-0.025**	0.004	0.007
	(0.026)	(0.014)	(0.008)	(0.012)	(0.008)	(0.004)	(0.013)	(0.011)	(0.011)	(0.021)
Education	-0.020***	-0.001	-0.003**	-0.001	-0.001	-0.000	0.001	-0.003	-0.001	0.001
	(0.004)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)
2011 & Education	0.007**	0.002	0.001	-0.003*	-0.001	0.001*	0.001	0.000	-0.001	-0.004
	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)
Urbanization	0.051***	-0.002	0.008*	0.010	0.007*	-0.000	-0.012*	0.007	0.020***	0.033***
	(0.013)	(0.007)	(0.004)	(0.006)	(0.004)	(0.002)	(0.007)	(0.006)	(0.005)	(0.011)
Migrant	0.090	-0.011	-0.008	-0.008	0.025	0.009	-0.053*	0.053*	-0.046*	-0.089*
	(0.061)	(0.033)	(0.020)	(0.028)	(0.019)	(0.010)	(0.031)	(0.027)	(0.026)	(0.052)
Dep ratio	0.222*	0.004	-0.019	0.049	0.015	0.003	-0.006	0.013	0.106**	0.275***
	(0.116)	(0.062)	(0.037)	(0.053)	(0.035)	(0.020)	(0.059)	(0.051)	(0.048)	(0.097)
Insured	0.253***	0.017	0.009	-0.018	0.014	-0.014*	0.023	0.063***	-0.020	-0.032
	(0.047)	(0.025)	(0.015)	(0.021)	(0.014)	(0.008)	(0.024)	(0.021)	(0.020)	(0.040)
EBAIS	-0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000*	-0.000	-0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hospital	0.012	0.005	0.006***	0.001	0.003	0.002	0.003	0.009***	0.008**	0.010
	(0.007)	(0.004)	(0.002)	(0.003)	(0.002)	(0.001)	(0.004)	(0.003)	(0.003)	(0.006)
Constant	0.040	0.044***	0.021**	0.041***	0.003	0.015***	0.026*	-0.004	0.032**	0.081***
	(0.031)	(0.016)	(0.010)	(0.014)	(0.009)	(0.005)	(0.015)	(0.014)	(0.013)	(0.026)
Observations	549	549	549	549	549	549	549	549	549	549
R-squared	0.288	0.187	0.034	0.031	0.028	0.029	0.152	0.132	0.088	0.101

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

- Old-age adults (65 and older)

For men, as presented in Table 11, a similar pattern seen with the age group 45 to 65 is seen in this age group. The interaction is significant and negative for mortality for CVD, lung-related diseases and accidents, while mortality for injuries is associated with *Education*. However, the case of CVD mortality is different. For this age group, the coefficient for *Education* is positive and statistically significant, but its interaction with 2011 is negative and with a larger magnitude, which means that more education in a district was associated with higher cardiovascular mortality in 1984, but in 2011 the link reversed and now it is associated with lower mortality in that cause.

In the case of women (Table 12), it is possible to find more differences compared to the group of adults, since the coefficients for interactions are significant in several causes of death, namely, diabetes, injuries and alcohol-related diseases. For those, the interaction of 2011 and *Education* is negative, as expected. However, the interaction is also positive for mortality by other types of cancer, and the coefficient is positive, which means that in 2011, higher educated districts are related to higher mortality by cancer. This could be the reason why for this age group, education does not seem to be associated with overall mortality, since the positive effect for cancer could out-weight the negative effect of the other causes of death.

The sensibility analysis using *Perc High School* presented more associations for this age group than for the adults one. For men, the interaction was significant and negative for CVD mortality, consistent to the main results, while the education coefficient was significant and negative for injuries and stomach cancer. In the case of women, the positive sign of the interaction was also found, as with the main model. Table B4 shows these results.

Table 11. OLS results for mortality by causes of death. Male. Age group 65 and older.

	Cardio	Lung	Alcohol	Diabetes	Accidents	Injuries	Stomach	Prostate	Cancer
Year 2011	0.142	0.106	0.053	0.089***	0.188***	-0.004	-0.224***	0.053	-0.104
	(0.213)	(0.098)	(0.033)	(0.030)	(0.045)	(0.021)	(0.079)	(0.050)	(0.093)
Education	0.076**	-0.014	-0.001	0.007	0.008	-0.008***	-0.020	-0.000	0.007
	(0.032)	(0.015)	(0.005)	(0.005)	(0.007)	(0.003)	(0.012)	(0.008)	(0.014)
2011 & Education	-0.160***	-0.044***	-0.003	0.000	-0.027***	0.002	-0.002	0.003	0.019
	(0.027)	(0.013)	(0.004)	(0.004)	(0.006)	(0.003)	(0.010)	(0.006)	(0.012)
Urbanization	0.526***	0.333***	0.048***	0.028*	0.046**	0.007	0.096**	0.073***	0.140***
	(0.110)	(0.051)	(0.017)	(0.015)	(0.024)	(0.011)	(0.041)	(0.026)	(0.048)
Migrant	-0.553	-0.677***	-0.041	-0.275***	0.123	0.276***	-0.581***	-0.165	-0.244
	(0.507)	(0.234)	(0.079)	(0.071)	(0.108)	(0.049)	(0.189)	(0.118)	(0.221)
Dep ratio	4.390***	0.405	0.330**	-0.239*	0.331	0.015	-0.251	0.117	0.447
	(0.989)	(0.457)	(0.155)	(0.139)	(0.211)	(0.095)	(0.368)	(0.231)	(0.431)
Insured	0.975**	0.478***	-0.049	-0.010	-0.197**	0.035	0.367***	0.053	-0.205
	(0.379)	(0.175)	(0.059)	(0.053)	(0.081)	(0.037)	(0.141)	(0.088)	(0.165)
EBAIS	-0.001	-0.002	-0.001	-0.000	-0.001	-0.000	0.000	-0.001	0.000
	(0.004)	(0.002)	(0.001)	(0.001)	(0.001)	(0.000)	(0.002)	(0.001)	(0.002)
Hospital	0.169***	0.147***	0.012	0.031***	0.038***	0.011*	0.001	0.038***	0.064**
	(0.062)	(0.029)	(0.010)	(0.009)	(0.013)	(0.006)	(0.023)	(0.014)	(0.027)
Constant	0.390	0.194*	0.074*	0.039	0.218***	0.036	0.277***	0.085	0.522***
	(0.245)	(0.113)	(0.038)	(0.034)	(0.052)	(0.024)	(0.091)	(0.057)	(0.107)
Observations	552	552	552	552	552	552	552	552	552
R-squared	0.431	0.307	0.105	0.322	0.102	0.095	0.319	0.197	0.143

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12. OLS results for mortality by causes of death. Female. Age group 65 and older.

	Cardio	**Lung**	**Alcohol**	**Diabetes**	**Accident**	**Injuries**	**Stomach**	**Uterus**	**Breast**	**Cancer**
Year 2011	-0.656***	-0.173**	0.128***	0.253***	0.005	0.013**	-0.104*	-0.033	-0.020	-0.213***
	(0.191)	(0.083)	(0.026)	(0.040)	(0.039)	(0.006)	(0.058)	(0.030)	(0.028)	(0.080)
Education	-0.044	-0.035***	0.000	0.004	-0.016***	0.002**	-0.001	-0.010**	0.006	-0.018
	(0.029)	(0.012)	(0.004)	(0.006)	(0.006)	(0.001)	(0.009)	(0.004)	(0.004)	(0.012)
2011 & Education	-0.025	0.010	-0.011***	-0.021***	0.000	-0.002**	-0.004	0.002	0.001	0.024**
	(0.024)	(0.011)	(0.003)	(0.005)	(0.005)	(0.001)	(0.007)	(0.004)	(0.004)	(0.010)
Urbanization	0.406***	0.009	0.026**	0.031	0.054***	-0.004	0.024	0.038**	-0.001	0.106**
	(0.098)	(0.043)	(0.013)	(0.021)	(0.020)	(0.003)	(0.030)	(0.015)	(0.014)	(0.041)
Migrant	-0.139	-0.410**	-0.052	-0.205**	0.031	0.025*	-0.368***	-0.006	0.077	0.005
	(0.458)	(0.198)	(0.062)	(0.096)	(0.093)	(0.014)	(0.140)	(0.071)	(0.067)	(0.191)
Dep ratio	3.389***	-0.617	-0.190	-0.086	0.510***	-0.034	-0.206	0.107	0.121	0.749**
	(0.868)	(0.376)	(0.118)	(0.182)	(0.176)	(0.026)	(0.265)	(0.135)	(0.126)	(0.363)
Insured	1.274***	0.437***	0.092*	-0.040	0.146**	-0.003	0.132	0.024	0.121**	0.275*
	(0.352)	(0.152)	(0.048)	(0.074)	(0.071)	(0.011)	(0.107)	(0.055)	(0.051)	(0.147)
EBAIS	-0.002	-0.001	-0.001	0.001	-0.001	-0.000	0.001	-0.001	-0.000	-0.001
	(0.004)	(0.002)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)
Hospital	0.210***	0.101***	0.004	0.040***	0.020*	0.001	0.014	0.026***	0.002	0.064***
	(0.055)	(0.024)	(0.007)	(0.011)	(0.011)	(0.002)	(0.017)	(0.009)	(0.008)	(0.023)
Constant	0.700***	0.420***	-0.017	0.096**	0.037	-0.003	0.151**	0.089**	-0.070**	0.207**
	(0.227)	(0.098)	(0.031)	(0.048)	(0.046)	(0.007)	(0.069)	(0.035)	(0.033)	(0.095)
Observations	552	552	552	552	552	552	552	552	552	552
R-squared	0.387	0.213	0.169	0.186	0.057	0.047	0.201	0.080	0.092	0.104

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7.2 Discussion

This ecological study provides insight on how *Education* is related to *Life expectancy*, for men and women, and allows us to characterize the relationship in more depth. It also analyzes the relationship between education and age-specific mortality rates, as well as with mortality by several causes of death. For Costa Rica, an analysis like this had never been done at the district level, which allows for a larger amount of observations to be studied for every census year, while still being able to provide information on *Life expectancy* and mortality rates.

One first finding is that there seems to have been reductions in the inequality of *Life expectancy* among the districts in the country. When one compares 1984 to 2011, the standard deviation of the life expectancies has decreased for both male and female *Life expectancy*. In other countries, especially the US, the phenomenon has been the opposite, so Costa Rica seems to be experiencing both increases in *Life expectancy* and decreases in its inequality. On the other hand, there seem to be no geographical patterns on the distribution of life expectancy in the country, on the contrary to education which is highly concentrated in the cities.

However, the gap in *Life expectancy* between men and women is widening, and considering the results obtained, one explanation for this can be the responsiveness of women to education. This widening sex gap is seen in several developed countries, and many point out to lifestyle behaviors and reaction to stress as key factors. In specific, cigarette smoking has been identified as the largest contributor to the gap in developed countries (Oksuzyan, Brønnum-Hansen & Jeune, 2010).

In the Costa Rican case, the relationship between *Education* and *Life expectancy* seems to be stronger for women, since for all the years considered, the link remains significant and positive, meaning that districts with higher average education are associated with higher female *Life expectancy*. Sensitivity analysis showed consistent results to this.

For men, the coefficient is also positive, but only significant for 2011, which means that it is a rather recent phenomenon. On the other hand, the sensitivity analysis was not consistent, as *Perc High School* revealed no association between the SES variable and *Life expectancy*, while *Educational group* showed a negative association that reversed to positive in 2011. This finding could help explain why previous research for Costa Rica have failed to find a SES gradient on health outcomes, since most of the previous studies use overall mortality, so the lack of a relationship for men could hide the strong relationship existing for women. On the opposite, this finding goes against what has been seen recently by many in both developed and developing countries, where the gradient for men is stronger than for women.

A statistically significant increase in the association of *Education* and *Life expectancy* was found for men but not for women. In the case of men, the relationship has only become significant for the year 2011, in which districts with higher *Education* would have on average higher *Life expectancy*. This may represent the beginning of an educational gradient on life expectancy for men in Costa Rica, which would go in hand with contemporary evidence for developed countries, as certain diseases begin to affect more those worse off.

For women, the coefficient for education remains significant for all the years. However, sensitivity analysis showed a decrease in the magnitude of the coefficient for women in 2000 and 2011 (except for *Educational group*). When comparing to what has been found in other countries, the Costa Rican case is similar regarding the gradient for men, since the association seems to be becoming stronger, but not with women.

When exploring the relationship for age groups and their mortality, once again there are sex differences in the results. For men, the interaction terms were significant for the age groups "45 to 64", and "65 and older", which means that there have been important changes in the association between education and mortality in those groups for men comparing 2011 to 1984. This is expected since for those groups is where mortality for chronic diseases is more relevant, so the role of education should become stronger with time.

In the case of women, once again the interaction terms were not significant, which means that there have been no changes for any age group during the period. However, it was found that *Education* seems to fail to have an association with mortality for the age group 65 and older. This result is quite unexpected, so it makes it even more important to study mortality by causes to understand the underlying factors explaining this.

The analysis by mortality by causes of death provided very useful evidence that can help explain some of the results found up until now. For men, for both groups (adult and old-age adults), *Education* has become significant in the association with mortality by CVD, lung-related diseases and accidents. As expected, this association is negative, meaning that districts with higher education should have on average less mortality by these causes.

In the case of women, there are no clear patterns. For the group of adults, for CVD mortality, the magnitude of the association with *Education* actually seems to be decreasing, meaning that the gradient may disappear or reverse in the future. There is no association between *Education* and any other mortality cause, except for alcohol-related diseases in which the coefficient is negative as expected.

For the group of old-age women, mortality from alcohol-related diseases and diabetes became negatively related to education in 2011, as expected, but mortality from cancer seems to now be positively related to it. Since deaths from cancer are higher than those from alcohol-related diseases and diabetes, it is possible that the lack of association found between education and mortality at old-age women is given because of the out-weighting effect of a positive gradient of education on cancer mortality. Mortality by alcohol is low for women, but it seems to be getting more negatively related to SES for both age groups.

The role of mortality by CVD should be considered separately, not only because it remains the largest mortality cause in the country for both sexes but because its relationship with *Education* can help explain some of the results found before. In the case of men one interesting fact is that for the old-age group, the relationship between education and mortality by CVD was positive, but it became negative in 2011. For adult women, the relationship is decreasing and there is no association for the old-age group. It seems like death by CVD is becoming more prominent in men of lower SES, and surprisingly, in women of higher SES, while in the past, it was the opposite.

These findings are consistent to what has been found by Bixby (1994) in Costa Rica, who found a positive gradient of SES in mortality by heart-related diseases for adults, potentially fueled by male mortality. On the other hand, more recently Rosero & Dow (2009) found no gradient for that same age group. Their study showed that for some risk factors, lower SES individuals are better, including obesity, hypertension, cholesterol and triglycerides, while smoking, sedentarism and higher carbohydrate diets are less prevalent in those with higher SES. The sign of the associations of these risk factors and SES could explain why the coefficient of education changes so abruptly over time and between sexes. Monteiro et al. (2004) explain that as countries with middle-income transition to higher income, their SES-obesity gradients reverses from positive to negative, which could be the case for Costa Rican men, but not for women.

The other key factor is smoking, since it is a behavior related not only to lung-related diseases but can also promote mortality of diseases like CVD and other types of cancer, among others. For men, the link with *Education* and this cause of death became significant in 2011, while for women it has always been significant. This would go in line with Rosero & Dow (2009), who showed that smoking seems to be more prevalent in old-age adults with lower SES. However, smoking rates have been decreasing significantly for years, especially since the introduction of the Anti-Tabacco Law in 2012, and in 2016 Costa Rica had the second lowest rate in Latin America (behind Panama). Death by lung-related diseases has decreased in the period for both men and women, so the effect of smoking on health could become smaller over time.

The third factor of interest is the role of disease-unrelated mortality, which includes mortality by injuries (homicide and suicide) and by accidents (work and traffic). As expected, the relationship between education and mortality by these causes is stronger for men. In the case of accidents, the negative gradient appeared for 2011 but not before. For injuries, the coefficient has remained negative, so those districts with lower SES experience higher mortality for homicide and suicide for men, which is similar to what was found by García (2013) for violent deaths in the country. However, it is likely that the gradient is becoming stronger for younger age groups.

In the case of women, a positive relationship was found for *Education* and mortality by injuries for the old-age group, but it reversed for 2011, while it became negative for mortality by accidents. However, mortality rates by these causes are relatively low for women, since men are disproportionately more affected by them. Nonetheless, these aspects require special attention since mortality by injuries has been increasing in the country for both men and women, and rates are especially high in cities.

Sensitivity analysis using the *Perc High School* in the district as the *Education* variable showed fewer relationships between education and the mortality by different causes of death, but some associations remain, like the reversing or decreasing of the coefficient for CVD mortality in both men and women, the link with lung-related diseases, and the positive gradient with cancer for women.

When comparing 2011 to 1984, it seems that contrary to what was found for other countries, in Costa Rica a SES gradient does not seem to be increasing clearly. A concern that comes up is if this lack of association appears because higher levels of education do not translate to better health behaviors in the population (unresponsiveness), or, because there are opposing forces cancelling the overall link, like a positive SES gradient in cancer mortality but a negative one in lung-related diseases.

Unhealthy behaviors by those of higher SES could be leading some causes of death to be affecting them more, like CVD and cancer (for women). Another explanation, as suggested by Rosero-Bixby & Dow (2009), is that it is possible that traditional lifestyles like low-calorie diets can protect certain low SES populations from non-communicable diseases, thus driving them to lower mortality by certain causes.

A final point to be discussed is the difference between mortality and morbidity. It is possible that a SES gradient is clear in the prevalence of certain diseases in the country, but that coverage of the health care system levels up the mortality rates, thus showing no clear gradient in mortality.

This study shows several important relationships between *Education* and *Life expectancy,* and performing an analysis for mortality by different causes of deaths resulted in a better understanding of the relationships. However, more in-depth examination would require exploring how the specific risk factors like nutrition, smoking prevalence and physical activity connect to SES, as well as SES and prevalence of diseases, not just mortality rates.

7.3 Limitations

Several limitations in data and methods can be listed for this study. Although some of these limitations have been mentioned in previous sections, in this one, they will be discussed in relation to how the outcomes or interpretations can be affected.

First, a few studies have raised concerns on the quality of the death certificates and census data (Llorca Castro & Ortún Rubio, 2010), with some suggesting this could be a cause of the low mortality rates for adult and old-age adults in the country (Glei, Barbieri & Santamaría-Ulloa, 2019). Nonetheless, several studies have made estimates of mortality rates with complementary data and have confirmed the exceptionally low mortality in Costa Rica for adults, especially for males (Bixby & Antich, 2010; Rosero-Bixby, 2018). Regardless of this, socioeconomic and demographic variables can always suffer from measurement errors. However, it is unlikely that they would cause substantial changes in the outcomes of the regressions (Dwyer-Lindgren et al., 2017).

Second, the calculation of the *Life expectancy* variable can be subject to error. This error can be given mainly by two factors: one, the small number of observations in some of the districts, and two, internal migration of the ill. The first factor relates to the fact that in many districts for some years (1984 and 2000 specifically) the population size was not enough to generate valid life expectancy estimations, as suggested by Toson & Baker (2003) which set the minimum population size to 5000 inhabitants. This bias could underestimate the mortality for those districts with low population, thus projecting a life expectancy higher than what it should be. The second factor arrives as it is likely that ill people will move closer to health care services like hospitals and clinics, thus artificially increasing the mortality for those districts and neighboring districts, while reducing it for those districts in rural areas. To deal with this issue, the variables *Hospital* and *Dependency ratio* were included in the analysis, but they only control partially for the bias.

Third, related to the methodology, the issue comes with the use of ecological studies. On one side, even if districts are small units, there may still be inequalities in factors that cannot be captured by the average rates. On the other hand, as previously mentioned, the relationships can only be interpreted for the average population, not for individuals. In addition, there is the issue of confounding, especially when the analyses were conducted for three separate years, so global, national or regional conditions may be having an impact on the relationships found, and it is not possible to find data to control for all the relevant variables. For example, the Census of 1984 was carried out only a few years after the crisis of the early 1980s, while the country was still recovering, in contrast to the 2000 Census when the country was experiencing strong economic growth. In addition, causality should be considered, as districts with more healthy populations could thrive better and show higher education in the long run, so the results found should be considered only as associations between the variables.

Fourth, *Life expectancy* is an important and aggregated index of mortality in a country, but it does not provide information on the quality of the health experienced. This could be captured using Health Life Expectancy which is a form of life expectancy weights for health states, and could indicate if the extra longevity achieved in the country is spent in better or worse health situation. However, data for this indicator was not available for the country at the district level.

Fifth, although sensitivity analysis seems to present overall similar results to the main models, especially in some key associations, in some cases there is no consistency of the results, particularly for men.

Finally, although the use of mortality by causes of death provided some understanding on how education can be related to mortality rates, the specific links or risk factors like diet, stress or physical activity were not analyzed.

8 Conclusion

The aim of this study was to explore the relationship between *Education*, as a proxy for SES, and *Life expectancy* in Costa Rica in the last decades. *Education* represents one of the most powerful components of SES, and it is strongly correlated to health outcomes through a diversity of channels, so districts with higher education should have on average higher life expectancy. In the Costa Rican case, findings for an educational or SES gradient have been inconsistent. With the help of district data, it was possible to conduct an analysis which provided the necessary insight to answer the research question and assess the hypotheses of this study.

The first hypothesis stated that the relationship between average education and *Life expectancy* at the district level is positive for both men and women, with a steeper slope for women. It was found that there is a strong, clear and consistent positive association between average education and female life expectancy, but this is not the case for men, as it only seems significant for 2011 and not robustly (no relationship found in the sensitivity analysis).

Next, the second hypothesis suggested an increase in the association between education and life expectancy, because of the larger role of chronic diseases and its SES gradient. However, this does not seem to be the case for Costa Rica. For women, the relationship remains the same and in some cases may even be decreasing in magnitude, while for men it does seem to be increasing but not consistently.

Third, the association between *Education* and *Life expectancy* should be stronger for the older age groups, once again because of the role of chronic diseases. In this case, it seems like there is some supportive evidence in the case of men. For the group of adults (45 to 64 years old) and old-age adults (65 years and older), a negative association can be found between *Education* and mortality (higher education, lower mortality), which is what was expected. Sensitivity analysis, however, finds no change in the coefficients over time. In the case of women, as with overall life expectancy, there is no statistically significant change in the *Education* coefficient for any age-specific mortality rates.

The fourth hypothesis is related to the association between *Education* and mortality by causes of death that can be prevented with health behaviors. This analysis turned out key to understand better the ways *Education* could be related to mortality. In general, it was found that education indeed seems to be negatively related to mortality by causes like CVD, lung-related and alcohol-related diseases. However, some positive associations between education and mortality have also been found, especially for 2011, like CVD for both men and women, and cancer for women, which means that in some cases, those better off could be having risk factors that increase their mortality for these causes. Heterogeneity in gradients for SES and CVD are not uncommon, as interactions with race and gender have shown diverse results in other countries, potentially related to lifestyle behaviors (Walsemann, Goosby & Farr, 2016). Another important issue is that the association between education and mortality by injuries and accidents seems to be positive and strong, especially for men, which is also expected.

The separate analysis for men and women proved to be fundamental to find critical relationships between the variables, something not done by others for the Costa Rican case with the same rigor. The lack of SES gradients found for Costa Rica could be explained because of the "unresponsiveness" of men, but the strong gradient for women goes against what the literature for the country has shown and in general what has been seen for other countries.

This positive association found between *Education* and *Life expectancy* or the negative associations found between *Education* and mortality rates imply a negative gradient of SES and mortality, which has not been found consistently for the country before. The inclusion of relevant control variables and the use of districts instead of cantons could have helped find and identify these relationships more clearly.

Finally, to answer the research question, in general, it has been possible to show that in Costa Rica, for men, education could be becoming associated positively to life expectancy, specifically because of its link to adult and old-age mortality and on CVD, lung-related diseases and accidents mortality. For women, the association has been strong for decades, but it is likely that it could be slowly decreasing in magnitude, because of a positive association between education and CVD and cancer mortality.

Given the lack of research for Costa Rica, the results of this study and its limitations, future research on the topic should aim to find relationships between SES and health outcomes using individual data, exploring specific risk factors and health practices as channels of associations, ensuring that the analysis is separated by sex and age ranges.

Costa Rica has been used as an example of how to achieve great health outcomes with low resources (Rosero Bixby, 1994) as its health system has undoubtedly been responsible for the relatively outstanding life expectancy, but there is only so much that can be done to prevent or treat diseases when health practices are damaging to health. It is here when the role of SES could help explain differences in mortality. In light of the results of this study, one could conclude that the widening of the *Life expectancy* sex gap in the recent decades could be hiding a process of better practices in women that prevents them from dying from certain diseases in comparison to men in the country.

References

Acuña González, G. & Olivares Ferreto, E. (2000). La población migrante nicaragüense en Costa Rica: realidades y respuestas, 1. ed., San José, Costa Rica: Fundación Arías para la Paz y el Progreso Humano : Centro para la[s] Naciones Unidas para los Asentamientos Humanos, CNUAH-Hábitat : International Development Research Center.

Adler, N. E. & Stewart, J. (2010). Health Disparities across the Lifespan: Meaning, Methods, and Mechanisms: Health Disparities across the Lifespan, *Annals of the New York Academy of Sciences*, vol. 1186, no. 1, pp.5–23.

Aggarwal, A., Monsivais, P. & Drewnowski, A. (2012). Nutrient Intakes Linked to Better Health Outcomes Are Associated with Higher Diet Costs in the US, *PLOS ONE*, vol. 7, no. 5, p.e37533.

Alfaro-Faeth, F., Ceciliano-Alvarado, F., Esquivel-Gutiérrez, Y., Fonseca-Murillo, A. & Mena-Sequeira, L. (2015). Caracterización y Tendencias de Los Fondos de Pensión Complementaria En Costa Rica.

Amuna, P. & Zotor, F. B. (2008). Epidemiological and Nutrition Transition in Developing Countries: Impact on Human Health and Development: The Epidemiological and Nutrition Transition in Developing Countries: Evolving Trends and Their Impact in Public Health and Human Development, *Proceedings of the Nutrition Society*, vol. 67, no. 1, pp.82–90.

Austad, S. N. (2006). Why Women Live Longer than Men: Sex Differences in Longevity, *Gender Medicine*, vol. 3, no. 2, pp.79–92.

Barquera, S., Campos-Nonato, I., Hernández-Barrera, L., Pedroza, A. & Rivera-Dommarco, J. A. (2013). Prevalencia de obesidad en adultos mexicanos, 2000-2012, *Salud Pública de México*, vol. 55, pp.S151–S160.

Bendelow, G. (1993). Pain Perceptions, Emotions and Gender, *Sociology of Health and Illness*, vol. 15, pp.273–294.

Bertakis, K. D., Azari, R., Helms, L. J., Callahan, E. J. & Robbins, J. A. (2000). Gender Differences in the Utilization of Health Care Services, *The Journal of Family Practice*, vol. 49, no. 2, pp.147–152.

Bixby, L. R. & Antich, D. (2010). Estudio Longitudinal de Mortalidad de Adultos Costarricenses 1984-2007, *Población Y Salud en Mesoamérica*.

Blanco-Becerra, L. C., Miranda-Soberanis, V., Barraza-Villarreal, A., Junger, W., Hurtado-Díaz, M. & Romieu, I. (2014). Efecto Del Nivel Socioeconómico Sobre La Asociación Entre Contaminantes Atmosféricos y Mortalidad En Bogotá, Colombia, *Salud Pública de México*, vol. 56, no. 4, pp.371–378.

Bustamante V, A., Seabra, A. F., Garganta, R. M. & Maia, J. A. (2007). Efectos de La Actividad Física y Del Nivel Socioeconómico En El Sobrepeso y Obesidad de Escolares, Lima Este

2005, *Revista Peruana de Medicina Experimental y Salud Publica*, vol. 24, no. 2, pp.121–128.

Butt, P., Beirness, D., Gliksman, L., Paradis, C. & Stockwell, T. (2011). Alcohol and Health in Canada: A Summary of Evidence and Guidelines for Low-Risk Drinking, *Ottawa, ON: Canadian Centre on Substance Abuse*.

C. Kessler, R., Foster, C., S. Webster, P. & S. House, J. (1992). The Relationship between Age and Depressive Symptoms in Two National Surveys, Vol. 7.

Camacho, J. R. Q. (1999). Costa Rica Contemporánea: Raíces Del Estado de La Nación, Editorial Universidad de Costa Rica.

Castillo, M. & Rivera, S. (2017). Costa Rica Según Los Principales Indicadores Internacionales de Desarrollo: Actualización 2016-2017, San José: Observatorio del Desarrollo.

Chandola, T., Bartley, M., Wiggins, R. & Schofield, P. (2003). Social Inequalities in Health by Individual and Household Measures of Social Position in a Cohort of Healthy People, *Journal of Epidemiology & Community Health*, vol. 57, no. 1, pp.56–62.

Chiang, C. L. (1984). The Life Table and Its Applications.

Clarke, C. A., Glaser, S. L., Keegan, T. H. M. & Stroup, A. (2005). Neighborhood Socioeconomic Status and Hodgkin's Lymphoma Incidence in California, *Cancer Epidemiology and Prevention Biomarkers*, vol. 14, no. 6, pp.1441–1447.

Clarke, C. A., Miller, T., Chang, E. T., Yin, D., Cockburn, M. & Gomez, S. L. (2010). Racial and Social Class Gradients in Life Expectancy in Contemporary California, *Social Science & Medicine*, vol. 70, no. 9, pp.1373–1380.

Contreras, D. & Gallegos, S. (2007). Descomponiendo la desigualdad salarial en América Latina: ¿una década de cambios?, [e-book] CEPAL, Available Online: https://repositorio.cepal.org//handle/11362/4761 [Accessed 3 April 2019].

Crimmins, E. M. & Saito, Y. (2001). Trends in Healthy Life Expectancy in the United States, 1970–1990: Gender, Racial, and Educational Differences, *Social Science & Medicine*, vol. 52, no. 11, pp.1629–1641.

Curran, G., Stoltenberg, S., Hill, E., Mudd, S., Blow, F. & Zucker, R. (1999). Gender Differences in the Relationships among SES, Family History of Alcohol Disorders and Alcohol Dependence., *Journal of studies on alcohol*, vol. 60, no. 6, pp.825–832.

Cutler, D. M. & Lleras-Muney, A. (2006). Education and Health: Evaluating Theories and Evidence, National bureau of economic research.

de Rovetto, C. R., Agudelo, J. C., Conde, L. H. & Pradilla, A. (2012). Presión arterial por edad, género, talla y estrato socioeconómico en población escolarizada de Cali, Colombia, *Colombia Médica*, vol. 43, p.11.

Desai, M. (1991). Human Development: Concepts and Measurement, *European Economic Review*, vol. 35, no. 2–3, pp.350–357.

Dwyer-Lindgren, L., Bertozzi-Villa, A., Stubbs, R. W., Morozoff, C., Mackenbach, J. P., van Lenthe, F. J., Mokdad, A. H. & Murray, C. J. (2017). Inequalities in Life Expectancy among US Counties, 1980 to 2014: Temporal Trends and Key Drivers, *JAMA Internal Medicine*, vol. 177, no. 7, pp.1003–1011.

Emslie, C. & Hunt, K. (2008). The Weaker Sex? Exploring Lay Understandings of Gender Differences in Life Expectancy: A Qualitative Study, *Social Science & Medicine*, vol. 67, no. 5, pp.808–816.

Ezzati, M., Friedman, A. B., Kulkarni, S. C. & Murray, C. J. (2008). The Reversal of Fortunes: Trends in County Mortality and Cross-County Mortality Disparities in the United States, *PLoS medicine*, vol. 5, no. 4, p.e66.

Fuchs, V. R. (1979). Economics, Health, and Post-Industrial Society, *The Milbank Memorial Fund Quarterly. Health and Society*, vol. 57, no. 2, pp.153–182.

Fujiwara, T. & Kawachi, I. (2009). Is Education Causally Related to Better Health? A Twin Fixed-Effect Study in the USA, *International Journal of Epidemiology*, vol. 38, no. 5, pp.1310–1322.

García, H. A. C. (2013). Las Muertes Violentas En Costa Rica y Sus Inequidades Geográficas, *Población y Salud en Mesoamérica*.

García, H. A. C. & Ammazzini, I. B. (2014). Las Inequidades Geográficas En La Mortalidad Infantil En Costa Rica, Período 2008-2012, *Población y Salud en Mesoamérica*, vol. 12, no. 1, p.7.

Gindling, T. H. (2009). South–South Migration: The Impact of Nicaraguan Immigrants on Earnings, Inequality and Poverty in Costa Rica, *World Development*, vol. 37, no. 1, pp.116–126.

Glei, D., Barbieri, M. & Santamaría-Ulloa, C. (2019). Costa Rican Mortality 1950–2013: An Evaluation of Data Quality and Trends Compared with Other Countries, *Demographic Research*, vol. 40, no. 29, pp.835–864.

Goldman, N., Kimbro, R. T., Turra, C. M. & Pebley, A. R. (2006). Socioeconomic Gradients in Health for White and Mexican-Origin Populations, *American Journal of Public Health*, vol. 96, no. 12, pp.2186–2193.

Gordon-Larsen, P., Nelson, M. C., Page, P. & Popkin, B. M. (2006). Inequality in the Built Environment Underlies Key Health Disparities in Physical Activity and Obesity, *Pediatrics*, vol. 117, no. 2, pp.417–424.

Haeberer, M., Noguer, I. & Mújica, O. J. (2015). Desigualdades educacionales en mortalidad y supervivencia de mujeres y hombres de las Américas, 1990-2010, *Revista Panamericana de Salud Pública*, vol. 38, pp.89–95.

Homedes, N. & Ugalde, A. (2002). Privatización de Los Servicios de Salud: Las Experiencias de Chile y Costa Rica, *Gaceta Sanitaria*, vol. 16, no. 1, pp.54–62.

Humbert, M. L., Chad, K. E., Spink, K. S., Muhajarine, N., Anderson, K. D., Bruner, M. W., Girolami, T. M., Odnokon, P. & Gryba, C. R. (2006). Factors That Influence Physical Activity Participation Among High- and Low-SES Youth, *Qualitative Health Research*, vol. 16, no. 4, pp.467–483.

INEC. (2018). Sistema de Consultas | INSTITUTO NACIONAL DE ESTADISTICA Y CENSOS, Available Online: http://www.inec.go.cr/sistema-de-consultas [Accessed 26 November 2018].

INEC. (2019). Esperanza de Vida Creció, Nacimientos Disminuyeron, Available Online: http://www.inec.go.cr/noticia/esperanza-de-vida-crecio-nacimientos-disminuyeron [Accessed 2 April 2019].

Jadue H, L., Vega M, J., Escobar S, M. C., Delgado B, I., Garrido G, C., Lastra M, P., Espejo E, F. & Peruga U, A. (1999). Factores de Riesgo Para Las Enfermedades No Transmisibles: Metodología y Resultados Globales de La Encuesta de Base Del Programa CARMEN (Conjunto de Acciones Para La Reducción Multifactorial de Las Enfermedades No Transmisibles), *Revista médica de Chile*, vol. 127, no. 8, pp.1004–1013.

Jagger, C., Gillies, C., Moscone, F., Cambois, E., Van Oyen, H., Nusselder, W. & Robine, J.-M. (2008). Inequalities in Healthy Life Years in the 25 Countries of the European Union in 2005: A Cross-National Meta-Regression Analysis, *The Lancet*, vol. 372, no. 9656, pp.2124–2131.

Jaramillo, F. L. O. & Vélez, L. P. M. (2004). Mortalidad por cáncer en Colombia 2001, *CES Medicina*, vol. 18, no. 2, pp.19–36.

Kabir, M. (2008). Determinants of Life Expectancy in Developing Countries, *The Journal of Developing Areas*, vol. 41, no. 2, pp.185–204.

Kalediene, R. & Petrauskiene, J. (2000). Inequalities in Life Expectancy in Lithuania by Level of Education, *Scandinavian Journal of Public Health*, vol. 28, no. 1, pp.4–9.

Kawachi, I., Adler, N. E. & Dow, W. H. (2010). Money, Schooling, and Health: Mechanisms and Causal Evidence, *Annals of the New York Academy of Sciences*, vol. 1186, no. 1, pp.56–68.

Koskinen, S. & Martelin, T. (1994). Why Are Socioeconomic Mortality Differences Smaller among Women than among Men?, *Social Science & Medicine*, vol. 38, no. 10, pp.1385–1396.

Kushi, L. H., Doyle, C., McCullough, M., Rock, C. L., Demark-Wahnefried, W., Bandera, E. V., Gapstur, S., Patel, A. V., Andrews, K. & Gansler, T. (2012). American Cancer Society Guidelines on Nutrition and Physical Activity for Cancer Prevention: Reducing the Risk of Cancer with Healthy Food Choices and Physical Activity, *CA: a cancer journal for clinicians*, vol. 62, no. 1, pp.30–67.

Link, B. G. & Phelan, J. (1995). Social Conditions As Fundamental Causes of Disease, *Journal of Health and Social Behavior*, pp.80–94.

Llorca Castro, F. & Ortún Rubio, V. (2010). Mortalidad innecesariamente prematura y sanitariamente evitable en Costa Rica, *Revista Española de Salud Pública*, vol. 84, no. 6, pp.771–787.

Luepker, R. V., Murray, D. M., Jacobs Jr, D. R., Mittelmark, M. B., Bracht, N., Carlaw, R., Crow, R., Elmer, P., Finnegan, J. & Folsom, A. R. (1994). Community Education for Cardiovascular Disease Prevention: Risk Factor Changes in the Minnesota Heart Health Program., *American journal of public health*, vol. 84, no. 9, pp.1383–1393.

Lundborg, P. (2013). The Health Returns to Schooling—What Can We Learn from Twins?, *Journal of Population Economics*, vol. 26, no. 2, pp.673–701.

Mäkelä, P. (1999). Alcohol-Related Mortality as a Function of Socio-Economic Status, *Addiction*, vol. 94, no. 6, pp.867–886.

Marmot, M. (1999). Epidemiology of Socioeconomic Status and Health: Are Determinants Within Countries the Same as Between Countries?, *Annals of the New York Academy of Sciences*, vol. 896, no. 1, pp.16–29.

Marmot, M. G. (1994). Social Differentials in Health within and between Populations, *Daedalus*, vol. 123, no. 4, pp.197–216.

Marmot, M. G., Kogevinas, M. & Elston, M. A. (1987). Social/Economic Status and Disease, *Annual review of public health*, vol. 8, no. 1, pp.111–135.

Mata Jiménez, L. & Rosero Bixby, L. (1988). National Health and Social Development in Costa Rica: A Case Study of Intersectorial Action.

Meara, E. R., Richards, S. & Cutler, D. M. (2008). The Gap Gets Bigger: Changes In Mortality And Life Expectancy, By Education, 1981–2000, *Health Affairs*, vol. 27, no. 2, pp.350–360.

Méndez, F. & Araya, O. (2001). Evolución de La Esperanza de Vida Al Nacimiento En Costa Rica 1900-2000, *San José: inec*.

Mesa-Lago, C. (1985). Health Care in Costa Rica: Boom and Crisis, *Social Science & Medicine*, vol. 21, no. 1, pp.13–21.

Messias, E. (2003). Income Inequality, Illiteracy Rate, and Life Expectancy in Brazil, *American Journal of Public Health*, vol. 93, no. 8, pp.1294–1296.

Monteiro, C. A., Moura, E. C., Conde, W. L. & Popkin, B. M. (2004). Socioeconomic Status and Obesity in Adult Populations of Developing Countries: A Review, *Bulletin of the World Health Organization*, vol. 82, pp.940–946.

Morgenstern, H. (1995). Ecologic Studies in Epidemiology: Concepts, Principles, and Methods, *Annual Review of Public Health*, vol. 16, pp.61–81.

Oksuzyan, A., Brønnum-Hansen, H. & Jeune, B. (2010). Gender Gap in Health Expectancy, *European Journal of Ageing*, vol. 7, no. 4, pp.213–218.

Olshansky, S. J., Antonucci, T., Berkman, L., Binstock, R. H., Boersch-Supan, A., Cacioppo, J. T., Carnes, B. A., Carstensen, L. L., Fried, L. P., Goldman, D. P., Jackson, J., Kohli, M., Rother, J., Zheng, Y. & Rowe, J. (2012). Differences In Life Expectancy Due To Race And Educational Differences Are Widening, And Many May Not Catch Up, *Health Affairs*, vol. 31, no. 8, pp.1803–1813.

Otey, J. (2018). Reventazón es el nuevo distrito de Siquirres | Crhoy.com, *CRHoy.com | Periodico Digital | Costa Rica Noticias 24/7*, Available Online: https://www.crhoy.com/nacionales/reventazon-es-el-nuevo-distrito-de-siquirres/ [Accessed 29 May 2019].

Palomo G, I., Icaza N, G., Mujica E, V., Núñez F, L., Leiva M, E., Vásquez R, M., Alarcón L, M. & Moyano D, E. (2007). Prevalencia de Factores de Riesgo Cardiovascular Clásicos En Población Adulta de Talca, Chile, 2005, *Revista médica de Chile*, vol. 135, no. 7, pp.904–912.

Phillips, S. P. & Hamberg, K. (2015). Women's Relative Immunity to the Socio-Economic Health Gradient: Artifact or Real?, *Global Health Action*, [e-journal] vol. 8, Available Online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4422842/ [Accessed 23 May 2019].

Pietilä, I. & Rytkönen, M. (2008). Coping with Stress and by Stress: Russian Men and Women Talking about Transition, Stress and Health, *Social Science & Medicine*, vol. 66, no. 2, pp.327–338.

Popkin, B. M. (1999). Urbanization, Lifestyle Changes and the Nutrition Transition, *World Development*, vol. 27, no. 11, pp.1905–1916.

Ramirez, V., Vásquez-Rozas, P. & Ramírez-Eyraud, P. (2015). Mortalidad Por Cáncer Oral y Faríngeo En Chile, Años 2002-2010, *Revista Clínica de Periodoncia, Implantología y Rehabilitación Oral*, vol. 8, no. 2, pp.133–138.

Rehkopf, D. H., Dow, W. H., Rosero-Bixby, L., Lin, J., Epel, E. S. & Blackburn, E. H. (2013). Longer Leukocyte Telomere Length in Costa Rica's Nicoya Peninsula: A Population-Based Study, *Experimental Gerontology*, vol. 48, no. 11, pp.1266–1273.

Rosero Bixby, L. (1994). La Disminución de La Mortalidad de Adultos En Costa Rica, *Notas de Población*.

Rosero-Bixby, L. (2018). High Life Expectancy and Reversed Socioeconomic Gradients of Elderly People in Mexico and Costa Rica, *Demographic Research*, vol. 38, pp.95–108.

Rosero-Bixby, L. & Dow, W. H. (2009). Surprising SES Gradients in Mortality, Health, and Biomarkers in a Latin American Population of Adults, *The Journals of Gerontology: Series B*, vol. 64B, no. 1, pp.105–117.

Rosero-Bixby, L. & Dow, W. H. (2016). Exploring Why Costa Rica Outperforms the United States in Life Expectancy: A Tale of Two Inequality Gradients, *Proceedings of the National Academy of Sciences*, vol. 113, no. 5, pp.1130–1137.

Rosero-Bixby, L., Dow, W. H. & Rehkopf, D. H. (2013). The Nicoya Region of Costa Rica: A High Longevity Island for Elderly Males, *Vienna yearbook of population research / Vienna Institute of Demography, Austrian Academy of Sciences*, vol. 11, pp.109–136.

Sáenz, M. del R., Acosta, M., Muiser, J. & Bermúdez, J. L. (2011). Sistema de salud de Costa Rica, *Salud Pública de México*, vol. 53, pp.s156–s167.

Saunders, C. & Abel, G. (2014). Ecological Studies: Use with Caution, *The British Journal of General Practice*, vol. 64, no. 619, pp.65–66.

Singh, G. K. & Siahpush, M. (2006). Widening Socioeconomic Inequalities in US Life Expectancy, 1980–2000, *International Journal of Epidemiology*, vol. 35, no. 4, pp.969–979.

Smith, J. (2004). Unravelling the SES Health Connection, Working Paper Series, Available Online: http://www.ifs.org.uk/wps/wp0402.pdf [Accessed 9 May 2019].

Spoerri, A., Zwahlen, M., Egger, M., Gutzwiller, F., Minder, C. & Bopp, M. (2006). Educational Inequalities in Life Expectancy in German Speaking Part of Switzerland 1990-1997: Swiss National Cohort, *Swiss Medical Weekly*, vol. 136, no. 9–10, pp.145–148.

Toson, B. & Baker, A. (2003). Life Expectancy at Birth: Methodological Options for Small Populations, *National statistics methodological series*, vol. 33.

Vargas, M. P. C. (2018). Importancia de la gestión pública en el ámbito municipal, *El Mundo CR*, Available Online: https://www.elmundo.cr/opinion/importancia-de-la-gestion-publica-en-el-ambito-municipal/ [Accessed 29 May 2019].

Vogli, R. D., Mistry, R., Gnesotto, R. & Cornia, G. A. (2005). Has the Relation between Income Inequality and Life Expectancy Disappeared? Evidence from Italy and Top Industrialised Countries, *Journal of Epidemiology & Community Health*, vol. 59, no. 2, pp.158–162.

Walsemann, K. M., Goosby, B. J. & Farr, D. (2016). Life Course SES and Cardiovascular Risk: Heterogeneity across Race/Ethnicity and Gender, *Social Science & Medicine*, vol. 152, pp.147–155.

Williams, D. R. (1990). Socioeconomic Differentials in Health: A Review and Redirection, *Social psychology quarterly*, vol. 53, no. 2, pp.81–99.

Williamson, J. B. & Boehmer, U. (1997). Female Life Expectancy, Gender Stratification, Health Status, and Level of Economic Development: A Cross-National Study of Less Developed Countries, *Social Science & Medicine*, vol. 45, no. 2, pp.305–317.

World Bank. (2019). World Development Indicators, Available Online: https://databank.worldbank.org/data/source/world-development-indicators/preview/on# [Accessed 11 February 2019].

Appendix A

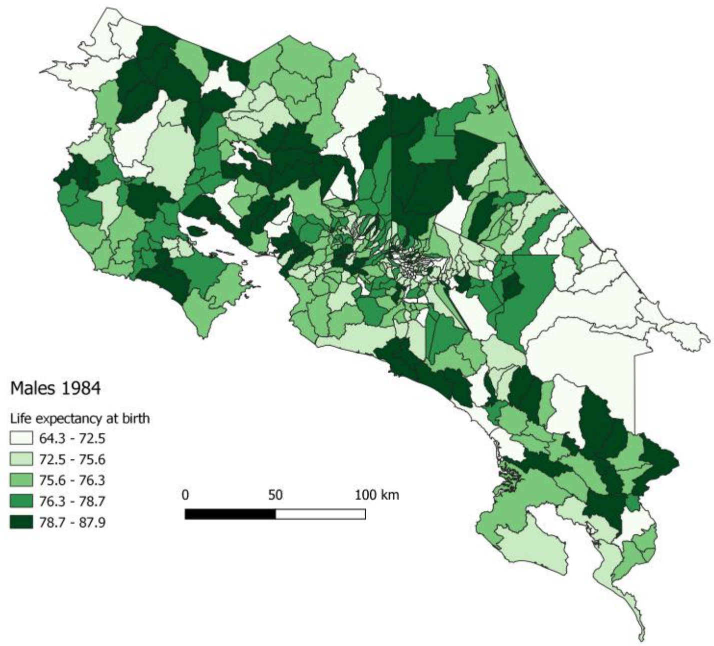

Figure 2. Life expectancy at birth for men in 1984, Costa Rica

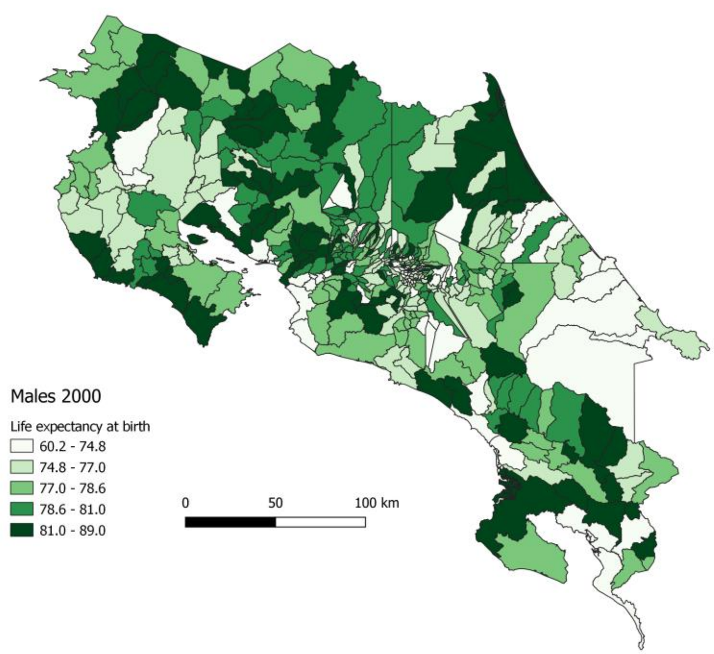

Figure 3. Life expectancy at birth for men in 2000, Costa Rica

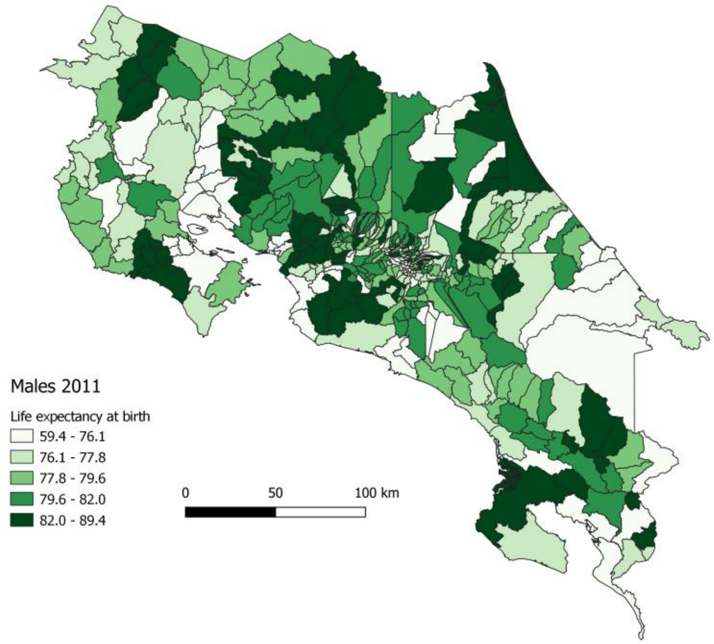

Figure 4. Life expectancy at birth for men in 2011, Costa Rica

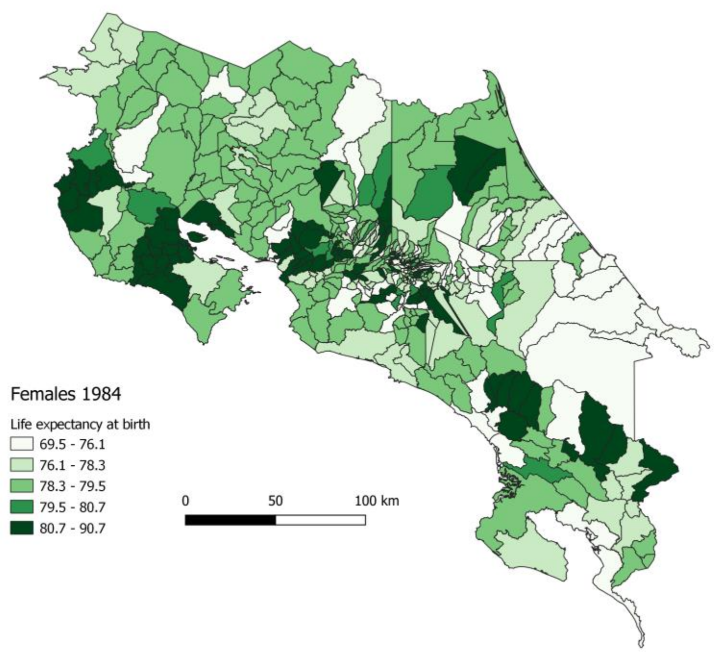

Figure 5. Life expectancy at birth for women in 1984, Costa Rica

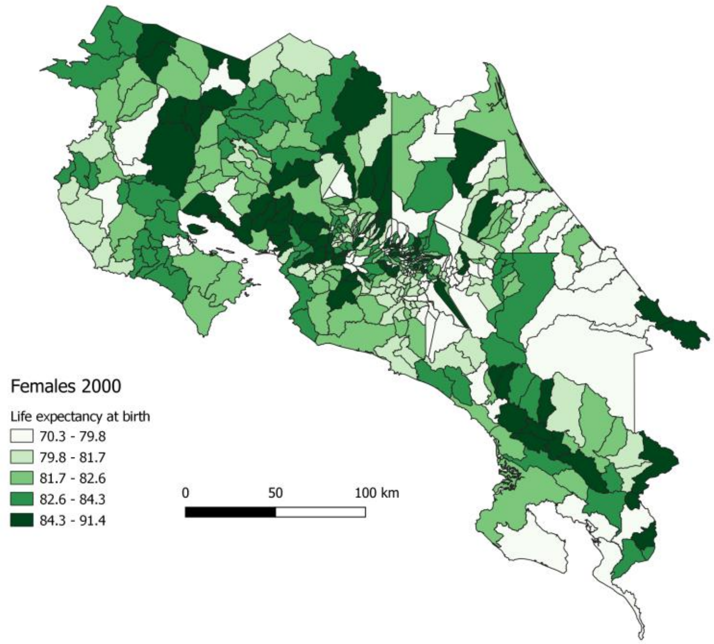

Figure 6. Life expectancy at birth for women in 2000, Costa Rica

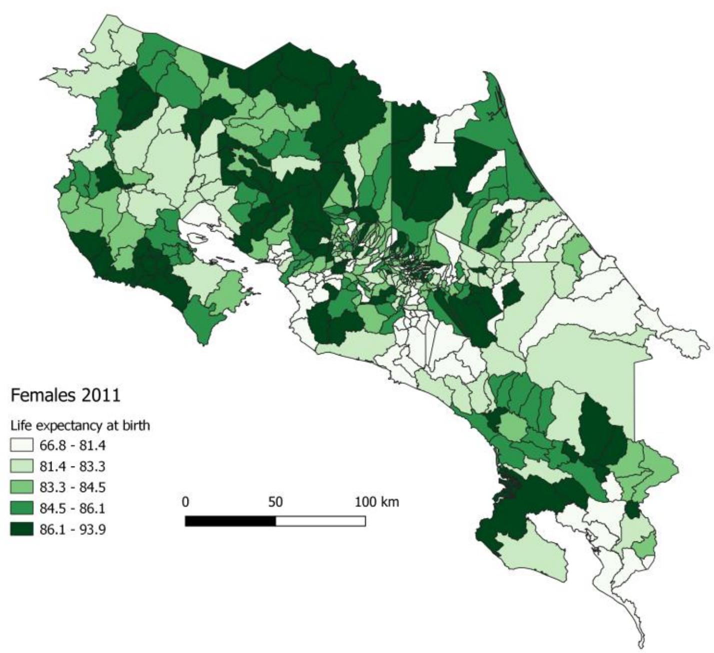

Figure 7. Life expectancy at birth for women in 2011, Costa Rica

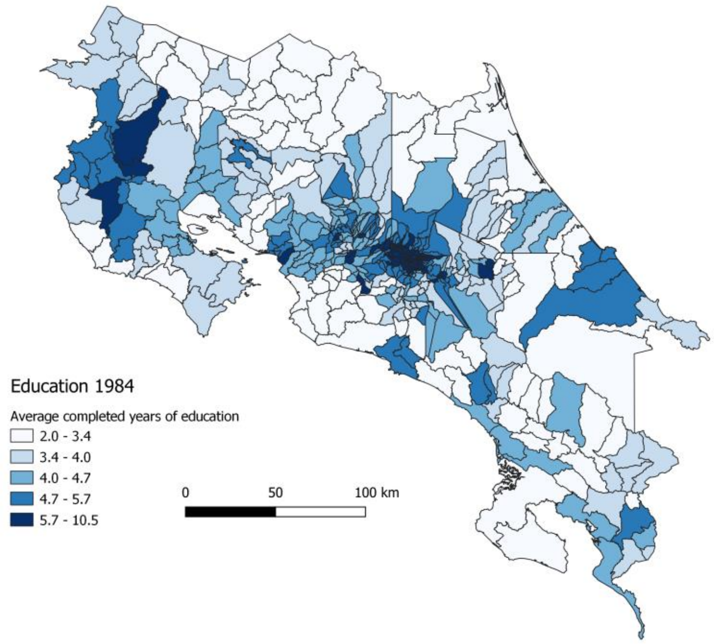

Figure 8. Average completed years of education in 1984, Costa Rica

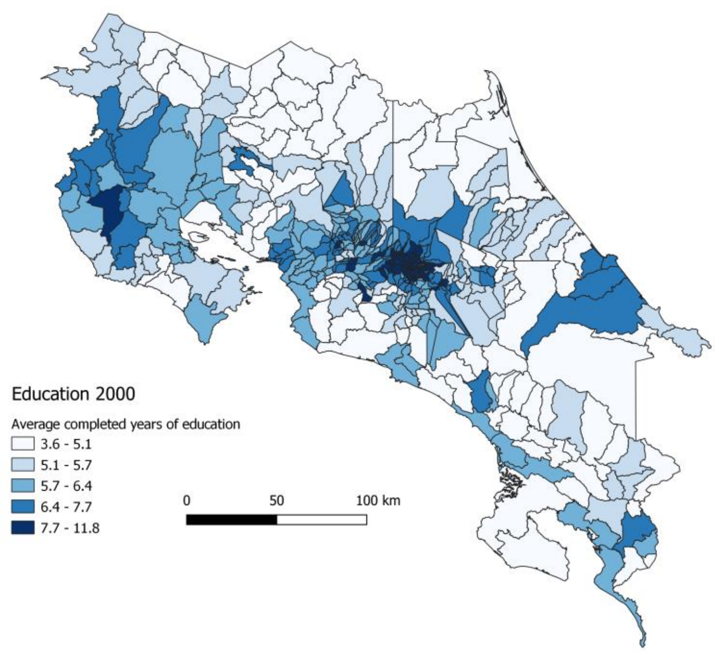

Figure 9. Average completed years of education in 2000, Costa Rica

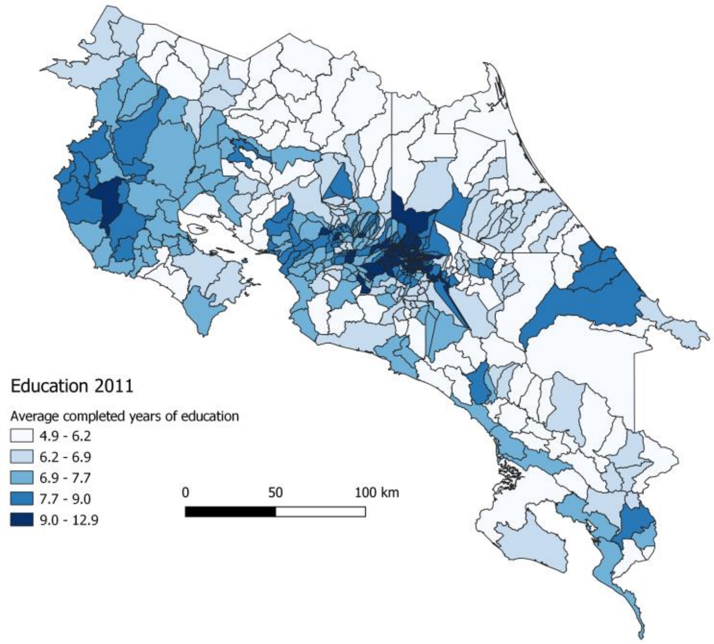

Figure 10. Average completed years of education in 2011, Costa Rica

Appendix B. Sensitivity analysis

Table B 1. OLS results for Life expectancy by sex and educational variable

	Educational group		**Perc High School**	
	Male	**Female**	**Male**	**Female**
Year (Ref: 1984)				
2000	2.646***	3.947***	3.175***	3.688***
	(0.647)	(0.569)	(0.562)	(0.488)
2011	4.166***	6.804***	5.105***	6.224***
	(0.740)	(0.651)	(0.668)	(0.576)
Educational group (Ref: lowest)				
Middle	-1.200**	0.319		
	(0.551)	(0.484)		
Highest	-0.910	1.796***		
	(0.664)	(0.584)		
Year & Educational group				
2000 & Middle	-0.330	-0.298		
	(0.750)	(0.660)		
2000 & Highest	-0.459	-0.726		
	(0.761)	(0.669)		
2011 & Middle	1.032	0.017		
	(0.762)	(0.670)		
2011 & Highest	1.438*	-0.625		
	(0.763)	(0.671)		
Perc High School			0.060	0.139***
			(0.040)	(0.029)
Year & Perc High School				
2000 & Perc High School			-0.050	-0.059**
			(0.038)	(0.028)
2011 & Perc High School			0.007	-0.059**
			(0.037)	(0.028)
Perc White collar				
Year & Perc White collar				
2000 & Perc White collar				
2011 & Perc White collar				
Socioeconomic controls	Yes	Yes	Yes	Yes
Health care controls	Yes	Yes	Yes	Yes
Constant	77.506***	80.087***	78.973***	81.328***
	(1.256)	(1.105)	(1.293)	(1.274)
Observations	828	828	828	828
R-squared	0.385	0.410	0.381	0.466

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B 2. OLS results for age-specific mortality rates by sex

	0-4 years		**15 to 44 years**		**45 to 64 years**		**65 and older**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Year (Ref: 1984)								
2000	-0.304***	-0.244***	-0.004	-0.009**	-0.190***	-0.174***	-0.648***	-0.567***
	(0.029)	(0.025)	(0.010)	(0.005)	(0.035)	(0.024)	(0.174)	(0.144)
2011	-0.392***	-0.313***	0.001	-0.009*	-0.310***	-0.261***	-1.174***	-1.105***
	(0.034)	(0.030)	(0.012)	(0.005)	(0.042)	(0.028)	(0.206)	(0.169)
Perc High School	-0.004**	-0.006***	-0.004***	-0.001***	-0.010***	-0.007***	-0.009	-0.021**
	(0.002)	(0.002)	(0.001)	(0.000)	(0.002)	(0.001)	(0.011)	(0.009)
2000 & Perc High School	0.002	0.004***	0.002***	0.000	0.002	0.003**	-0.001	0.005
	(0.002)	(0.001)	(0.001)	(0.000)	(0.002)	(0.001)	(0.011)	(0.008)
2011 & Perc High School	0.001	0.003**	0.001	-0.000	-0.001	0.003**	-0.019*	0.003
	(0.002)	(0.001)	(0.001)	(0.000)	(0.002)	(0.001)	(0.010)	(0.008)
Urbanization	0.071***	0.094***	0.059***	0.011***	0.348***	0.122***	1.471***	0.792***
	(0.022)	(0.019)	(0.008)	(0.003)	(0.027)	(0.018)	(0.135)	(0.109)
Migrant	0.563***	0.315***	0.240***	0.047**	0.870***	0.140	-1.349	-1.362**
	(0.136)	(0.120)	(0.047)	(0.022)	(0.167)	(0.112)	(0.825)	(0.681)
Dep ratio	1.398***	1.542***	0.619***	0.335***	3.697***	0.990***	7.177***	4.904***
	(0.258)	(0.220)	(0.090)	(0.040)	(0.318)	(0.205)	(1.569)	(1.252)
Insured	0.054	-0.082	0.036	0.003	0.532***	0.350***	2.636***	2.152***
	(0.102)	(0.092)	(0.035)	(0.017)	(0.125)	(0.085)	(0.618)	(0.521)
Pop by EBAIS	-0.001	0.000	-0.000	-0.000	0.002	-0.001	0.004	-0.003
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.007)	(0.006)
Hospital	0.127***	0.100***	0.057***	0.015***	0.163***	0.076***	0.642***	0.571***
	(0.016)	(0.014)	(0.006)	(0.003)	(0.020)	(0.013)	(0.099)	(0.079)
Constant	0.390***	0.371***	0.060**	0.042***	-0.037	0.207***	1.827***	1.866***
	(0.073)	(0.066)	(0.026)	(0.012)	(0.090)	(0.061)	(0.446)	(0.375)
Observations	828	828	828	828	828	828	828	828
R-squared	0.481	0.437	0.305	0.187	0.465	0.335	0.386	0.301

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B 3. OLS results for mortality by causes of death by sex Age group 45 to 64.

	Male						Female			
	Cardio	**Lung**	**Alcohol**	**Injuries**	**Stomach cancer**	**Cancer**	**Cardio**	**Lung**	**Alcohol**	**Stomach cancer**
Year 2011	-0.111***	-0.047***	-0.033***	0.002	-0.049***	-0.045***	-0.131***	-0.041***	-0.001	-0.024***
	(0.019)	(0.009)	(0.008)	(0.008)	(0.011)	(0.013)	(0.015)	(0.008)	(0.005)	(0.008)
Education	-0.002	0.000	-0.001*	-0.001**	-0.001	-0.000	-0.004***	-0.001	-0.001*	0.000
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
2011 & Education	-0.001	-0.001*	0.001	0.001	0.000	0.001	0.002**	0.001	0.000	-0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Urbanization	0.137***	0.027***	0.041***	-0.001	0.001	0.028**	0.039***	-0.005	0.007*	-0.011
	(0.017)	(0.008)	(0.008)	(0.007)	(0.010)	(0.012)	(0.014)	(0.008)	(0.004)	(0.007)
Migrant	0.221**	0.086**	0.117***	0.160***	-0.114**	-0.102*	0.134*	0.003	0.008	-0.049
	(0.087)	(0.042)	(0.040)	(0.036)	(0.052)	(0.062)	(0.071)	(0.039)	(0.023)	(0.037)
Dep ratio	1.379***	0.168**	0.384***	0.066	-0.024	0.167	0.204	0.041	-0.011	0.001
	(0.163)	(0.079)	(0.074)	(0.067)	(0.097)	(0.116)	(0.133)	(0.073)	(0.042)	(0.069)
Insured	0.167***	0.072***	0.072***	0.021	0.061*	0.093**	0.243***	0.031	0.015	0.024
	(0.054)	(0.026)	(0.024)	(0.022)	(0.032)	(0.038)	(0.045)	(0.025)	(0.014)	(0.023)
EBAIS	0.001	0.000	0.000	-0.000	0.000	-0.001*	-0.000	-0.000	-0.000	-0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Hospital	0.061***	0.012*	0.014**	0.012**	0.011	0.023**	0.014	0.008	0.009**	0.001
	(0.014)	(0.007)	(0.006)	(0.006)	(0.008)	(0.010)	(0.011)	(0.006)	(0.004)	(0.006)
Constant	-0.065*	-0.017	-0.050***	0.013	0.040*	0.023	-0.022	0.026	0.006	0.029*
	(0.038)	(0.018)	(0.017)	(0.015)	(0.022)	(0.027)	(0.032)	(0.017)	(0.010)	(0.016)
Observations	552	552	552	552	552	552	549	549	549	549
R-squared	0.376	0.205	0.235	0.086	0.188	0.108	0.235	0.135	0.026	0.117

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B 4. OLS results for mortality by causes of death by sex Age group 65 and older.

	Male						Female		
	Cardio	**Lung**	**Alcohol**	**Accidents**	**Injuries**	**Stomach cancer**	**Lung**	**Uterus**	**Cancer**
Year 2011	-0.795***	-0.152***	0.008	0.023	-0.022*	-0.296***	-0.138***	-0.038**	-0.084*
	(0.117)	(0.055)	(0.019)	(0.026)	(0.012)	(0.045)	(0.050)	(0.019)	(0.047)
Education	0.003	-0.004	-0.002*	0.000	-0.003***	-0.007***	-0.006**	-0.002*	-0.003
	(0.007)	(0.003)	(0.001)	(0.002)	(0.001)	(0.003)	(0.003)	(0.001)	(0.003)
2011 & Education	-0.017***	-0.004	0.001	-0.002*	0.001**	0.004	0.003	0.001	0.005**
	(0.006)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.001)	(0.003)
Urbanization	0.667***	0.337***	0.054***	0.044*	0.005	0.103**	-0.002	0.020	0.108**
	(0.107)	(0.051)	(0.017)	(0.024)	(0.011)	(0.041)	(0.046)	(0.017)	(0.043)
Migrant	-0.162	-0.589**	-0.024	0.152	0.339***	-0.479**	-0.404*	0.007	-0.247
	(0.550)	(0.260)	(0.089)	(0.123)	(0.056)	(0.209)	(0.235)	(0.087)	(0.220)
Dep ratio	4.940***	0.511	0.485***	0.475**	0.189*	-0.232	-0.550	0.173	0.775*
	(1.033)	(0.488)	(0.167)	(0.232)	(0.105)	(0.392)	(0.442)	(0.164)	(0.413)
Insured	1.463***	0.475***	-0.020	-0.108	0.057	0.410***	0.232	-0.006	0.105
	(0.340)	(0.161)	(0.055)	(0.076)	(0.035)	(0.129)	(0.147)	(0.055)	(0.137)
EBAIS	0.001	-0.003	-0.001	-0.001	-0.000	0.001	-0.000	-0.001	0.000
	(0.006)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)
Hospital	0.076	0.142***	0.020	0.055***	0.012	0.025	0.123***	0.024*	0.063*
	(0.087)	(0.041)	(0.014)	(0.019)	(0.009)	(0.033)	(0.037)	(0.014)	(0.035)
Constant	0.325	0.136	0.048	0.177***	-0.019	0.190**	0.414***	0.076**	0.255***
	(0.239)	(0.113)	(0.039)	(0.054)	(0.024)	(0.091)	(0.104)	(0.039)	(0.097)
Observations	552	552	552	552	552	552	551	551	551
R-squared	0.331	0.211	0.094	0.058	0.088	0.273	0.139	0.036	0.087

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1