More than One Hundred Years of Improvements in Living Standards: The Case of Colombia

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Abstract

We examine the long-term trends observed in the living standard of the Colombian population during the past one hundred years. We construct a historical index of human development for Colombia (HIHDC) for the 19th and 20th centuries by gender. We find that there were no major advances in living standards during the nineteenth century due to the stagnation of Colombia's GDP per capita as a result of the lack of dynamism in exports. On the contrary, significant advances in all components of the HIHDC were seen in the twentieth century, especially those for women. During the first half of the century, improvements in the quality of life were mainly driven by a higher per capita income, while improvements after the 1950s were driven by greater public investment, for example, in education and health. Next, we analyze health achievements. We construct a new dataset using statistics reported by the Colombian government, which included annual information on the main diseases and causes of mortality during the period of 1916-2014 disaggregated by territorial units. The data show that the percentage of deaths from tuberculosis, pneumonia, and gastrointestinal diseases decreased significantly throughout the century. On the contrary, deaths caused by cancer and heart diseases have increased considerably in recent decades. Econometric results show that the decline in the total mortality rate and in the mortality rate for waterborne diseases was largely related with the expansion of aqueducts and sewerage services.

Keywords: Human Development, Mortality, Waterborne Diseases, Sewerage, Aqueducts, Public Health

JEL classifications: I00; I15; I18; N36; O10

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I. Introduction

Colombia's nineteenth century demographic regime may be characterized as Malthusian, with low levels of per capita income, low and constant levels of population growth, very high mortality and fertility rates, and very low life expectancy and human capital accumulation. In general, the century was characterized by a very poor economic performance and low living standards in a mainly rural and agrarian society. The country entered the twentieth century as one of the poorest countries in the world: Colombian per capita exports were, together with those of Haiti and Honduras, the lowest in Latin America (Bulmer-Thomas, V. 1994). In addition, sanitary conditions at the beginning of the century were deplorable. For example, in Bogotá, the capital city of the country, the streets were littered with waste and rubbish, and public utilities were almost non-existent. Garbage invaded the streets, and citizens mostly lived in unhygienic conditions causing epidemics and infections inside the city (López, 2011).

However, throughout the twentieth century, Colombia experienced a very rapid decline in mortality rates, which dropped from roughly 23.4 deaths per thousand inhabitants in 1905 to about 5.5 in 2000. In addition, the infant mortality rate fell from 186 deaths per thousand births at the beginning of the century to 27 by the end of the twentieth century. The percentage of deaths from tuberculosis, pneumonia, and gastrointestinal diseases, which were the main causes of infant deaths during the first decades, decreased significantly throughout the century. On the other hand, the fertility rate declined from about 6.4 children for every woman in reproductive age in 1905 to about 2.5 by the end of the twentieth century. These demographic and epidemiological transformations were accompanied by an important progress in the living standard of the Colombian population, as a result of improvements in public health and sanitary conditions, better nutrition, and higher per capita income. As a consequence, life expectancy at birth in the country increased from 35 years during the period 1905-1912 to 73 years in 2000-2005. Our central hypothesis is that, to a significant degree, the decline in mortality rates was caused by improvements in the provision of public goods, especially regarding sanitary conditions, i.e. sewerage systems and aqueducts.

This paper provides a comprehensive long-run perspective of well-being in Colombia, covering more than one hundred years, with special attention to the case of health. Particularly, we construct a historical index of human development (HIHDC) for Colombia by gender. We find that there were no major advances in the index during the nineteenth century due to the stagnation of Colombia's GDP per capita resulting from the lack of dynamism of per capita exports. On the contrary, all HIHDC components exhibited significant advances during the twentieth century, especially those for women.

Next, we focus on the analysis of health achievements that have taken place in the last one hundred years, since health is one of the components of the HIHDC that has been less studied by the Colombian economic history literature. To this end, we construct a new dataset using statistics reported by the Colombian government, which included annual information on the main diseases and causes of mortality during the period 1916-2014 disaggregated by departments (the main subnational territorial units). We analyze the contribution of the provision of public services to the reduction in mortality rates from different types of diseases. Econometric results show that the decline in mortality rates and the prevalence of some waterborne diseases was highly related with the expansion of aqueducts and sewerage services.

Colombia is a very interesting case of study, because during the nineteenth century the country presented a very poor progress in terms of improvements in quality of life and economic growth. However, during the first half of the twentieth century, the country exhibited a rapid pace of economic growth, that was explained mainly by four factors: coffee exports growth, foreign loans, advances in transport infrastructure, and import substitution industrialization. In addition, during the second half of the century, Colombia presented substantial gains particularly in education and life expectancy, achieving rapid convergence to international standards. These achievements are mainly explained by the role of public policies throughout the twentieth century aimed to improve education and health.

The rest of the paper is organized as follows: first, we discuss related literature, and then we calculate and explain the evolution of the Colombian historical index of human development. Next, we present the data, the empirical strategy, and the results of the estimation of the relation between the advances in sewerage systems and aqueducts and the decline in waterborne diseases and total mortality. Finally, in the last section we present some conclusions.

II. Related Literature

During recent years, economic literature has placed much emphasis in understanding long run trends in economic growth and in the standard of living (Maddison, 2001; Allen, Bengtsson and Dribe, 2005; Deaton, 2013; van Zanden, J. L., *et al.* 2014; Gordon, 2016; Lindert and Williamson, 2016; and Sala i Martin, 2016). One of the most important achievements in human well-being is the unprecedented decline in mortality rates, which led to an exceptional increase in life expectancy during the twentieth century. The reasons for the remarkable decline in mortality that started in Europe in the eighteenth century and continued during the nineteenth century have been studied extensively by the economic history literature.[2] Nevertheless, the decline in mortality in Latin America started later on, around the 1940s, and has been less studied.

There is a long-standing debate in the literature about the determinants of health achievements (Cutler, Deaton, and Lleras-Muney, 2006). For example, Preston (1975) argues that the reduction of mortality was not related to income increase, but to improvements in technology, such as medical knowledge. More recently, Easterlin (1999) claims that new disease control techniques (based on advancements in the knowledge about diseases) were the main source of improved life expectancy, rather than economic growth. In this case, public intervention was crucial for implementing these new methods. On the other hand, McKeown (1976) and Fogel (1986) argue that health improvements were due to economic growth, mainly through access to better nutrition. However, Soares (2007) concludes for a sample of both developed and developing countries that between 1960 and 2000 the gains in life expectancy were largely independent from improvements in income and nutrition.

Recent contributions have highlighted other key factors such as the provision of public goods (e.g. expansion of public water and sewerage provision, and water chlorination) and adoption of health technology. For example, Cutler and Miller (2005) find that there is a causal influence of clean-water technologies on mortality in 13 cities in the United States during the early twentieth century. In particular, they found that in major American cities almost 50% of total mortality reductions, 75% of infant mortality declines, and nearly 66% of child mortality decreases were due to clean water technologies. Similarly, Ferrie and Troesken (2008) estimate that 30%-50% of the reduction in the crude death rate in Chicago between 1850 and 1925 can be attributed to water purification measures. Alsan and Goldin (2015) analyze the decline in child mortality in the Greater Boston area during 1880-1920, period in which the authorities developed a sewerage and water district in the area. They find that the two implementations were complementary and together accounted for nearly 33% of the reduction on child mortality during this period.

For the case of Swedish cities, Önnerfors (2015) examines if the implementation of clean-water technologies affected mortality between 1885 and 1925. The author concludes that the decline in mortality in the cities was influenced by many omitted variables besides clean-water technology. Thus, it was not possible to provide a consistent estimate of the magnitude of the effect of clean-water

[2] For example, see Cutler, Deaton, and Lleras-Muney (2006).

technologies on mortality in Swedish cities during the period under analysis. Finally, Knutsson (2017) analyze how technologies for cleaning and distributing water affected urban mortality in Sweden. The author finds large benefits for the general population of having clean, in-house water, reducing mortality in Stockholm during the 1860s.

The present paper contributes to the literature first by calculating a HIHD for Colombia by gender, in order to examine the long run evolution of Colombian population well-being, and then by examining the factors that explain the reduction of mortality in Colombia, an emerging economy, where studies are scarcer. We analyze if public health intervention in the form of improvements in the provision of water and sewerage systems has had an effect on mortality in the Colombian departments in the twentieth century. Understanding this relationship in developing countries is crucial from a historical perspective because emerging economies tend to have worse health outcomes and to adapt to—rather than generate—new medical technology. We intend to explain that the improvements in sanitary conditions have led to mortality declines in Colombia, as the literature has found for the advanced economies.

III. Colombian's Historical Index of Human Development (HIHDC)

One of our purposes of this paper is to examine how the living standards of the Colombian population have evolved over time. A historical index of human development for Colombia (HIHDC) can provide a comprehensive long-run perspective of the population's well-being.[3] Following Prados de la Escosura (2014 and 2015), we calculate the HIHDC over more than one hundred fifty years.[4]

The index comprises three main dimensions: education, income, and health.[5] Regarding education, we use data on primary education coverage for men and women during the nineteenth and twentieth centuries. In addition, for the twentieth century we also consider information on higher education by gender. For income, we use GDP per capita Geary–Khamis (GK) international constant dollars, and for health we use data on life expectancy at birth by gender.[6]

[3] For a historical cross-country comparison of the Human Development Index, see the papers by Crafts (1997, 2002) and Prados de la Escosura (2014, 2015).

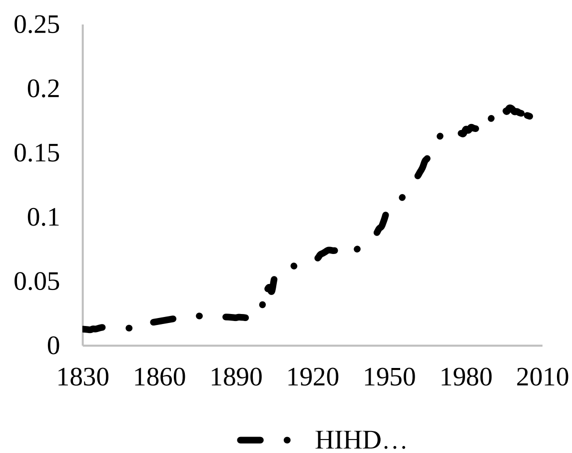
[4] Prados de la Escosura (2015) calculates a new historical index of human development for 12 Latin-American countries, including Colombia, by decades, for the period 1870-2007. However, the indices are not discriminated by gender.

[5] Appendix 1 provides details of the HIHDC methodology.

[6] See Graph 2 for the evolution of the HIHDC components and their sources.

Graph 1 depicts the evolution of the HIHDC over more than one hundred fifty years. There were no major advances in the index during the nineteenth century, which was due to very low income growth. According to Kalmanovitz (2008), GDP per capita only grew 0.1% per year during the nineteenth century, and life expectancy was also stagnant: 32 years at the end of that century (Flórez and Romero, 2010). Regarding education, Colombia was one of the most backward countries in the world. For example, at the end of the nineteenth century, Colombia's illiteracy rate (66%) was above that of Argentina (48.7%), Brazil (65%), Chile (56.5%), and Uruguay (40.6%). In addition, education in the country was not only lagging, but also its expansion was very slow: the ratio for children enrolled in primary education to the total population rose only from 1.5 per cent in 1827 to 2.6 per cent in 1898 (Ramírez and Salazar, 2010).

Graph 1
Colombia's HIHDC for 1830-2010



Source: Author's calculations. For a detailed explanation see Appendix 1.

On the other hand, all components of the HIHDC presented significant advances in the twentieth century (Graph 2), which led to considerable improvements in the living standards of the Colombian population. In particular, per capita GDP started to grow faster during the first half of the twentieth century, while major improvements in life expectancy and education were seen during the second half of the century. In fact, GDP per capita grew on average 2.7% during the period 1905-50.[7] As Meisel, Ramírez and Jaramillo (2016) point out, the period from 1920 to 1950 was one of the most successful for the Colombian economy. The rapid pace of economic growth during the first half of the twentieth century was explained mainly by export growth, especially coffee exports, foreign loans, advances in transport infrastructure, and import substitution industrialization However, during the first three decades of the century, Colombia

[7] See GRECO (2002) for a complete analysis of Colombian economic growth in the twentieth century.

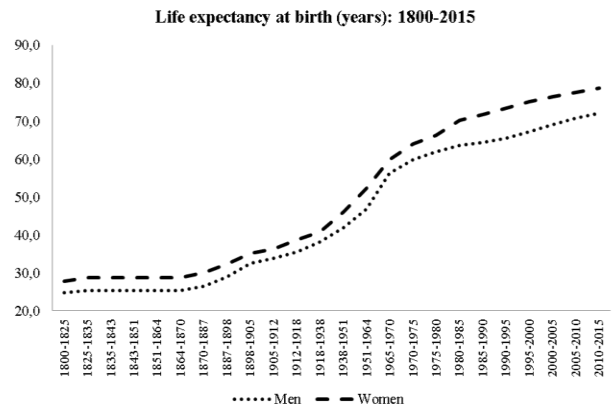
continued to exhibit a very low life expectancy (40 years) and few educational achievements. Therefore, at the beginning of the twentieth century, improvements in well-being were driven mainly by increases in per capita income.

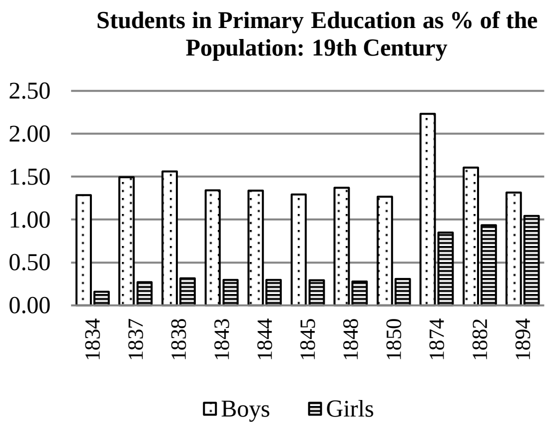
The decline in the mortality rate produced an increase in life expectancy at birth. Mortality rates in Colombia declined from roughly 30 deaths per thousand inhabitants in 1905 to about 13.2 in 1951, and about 5.5 in 2000. Life expectancy at birth improved considerably, from 40.2 years in 1937 to 56 years in 1965, and to 73 years in 2000-2005 (Flórez and Romero, 2010 and DANE). Regarding education, it was only at the beginning of 1950s that the takeoff began. Improvements in education were a consequence of the role of public policies that promoted the expansion of coverage at all levels of education and the increase fiscal revenue allocated to this sector, which was possible due to the favorable economic conditions during those years (Ramírez and Téllez, 2007). Consequently, from the late 1950s until the late 1970s, the number of students, teachers and schools grew at an unprecedented rate for all levels of education.

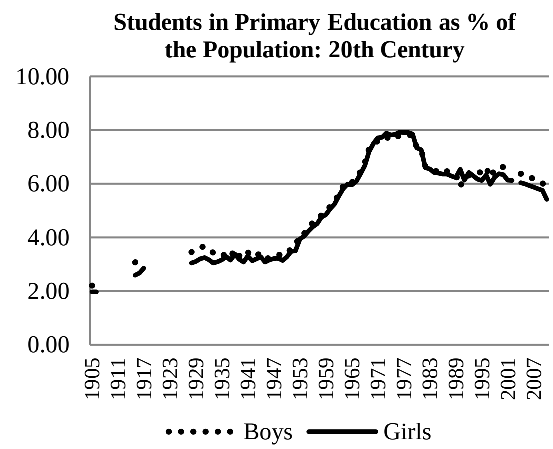
In addition, GDP per capita grew on average 2.0% during the period 1951-2010. In particular, since the mid-1960s, Colombia has experienced significant transformations in its economic structure, which passed from agricultural to industrial, communication, and services activities. This transformation significantly increased rural migration to the cities and contributed to the rise of urbanization. This process also implied a labor-force movement from low productivity to higher productivity activities, which increased the demand for more educated workers and induced investment in human capital (Mejía, Ramírez, and Tamayo, 2008).

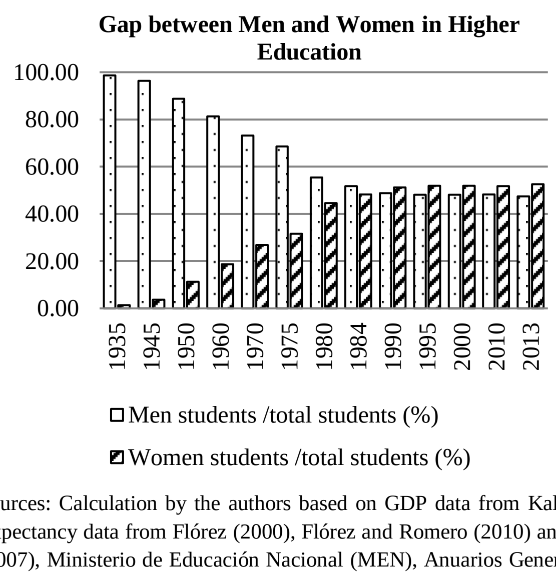
As mentioned, all these achievements led to large improvements on Colombian living standards, especially during the period 1950 to the end of the 1970s, where education was the leading dimension (Graph 1). Although the achievements reached by Colombia were significant and the country catch-up, especially in education coverage, these were accomplished later in time if compared to developed countries. For example, Prados de la Escosura (2014) finds that substantial gains in world human development are observed early, especially between 1920-1950. In particular, for the Latin American case, Prados de la Escosura finds that Latin America caught up to the OECD until 1980, but this process started during the first half of the twentieth century.

Graph 2
Components of the Colombian's HIHD









Sources: Calculation by the authors based on GDP data from Kalmanovitz (2010), Maddison (2014) and Bértola and Ocampo (2012); Life Expectancy data from Flórez (2000), Flórez and Romero (2010) and DANE; Education from Ramírez and Salazar (2010), Ramírez and Téllez (2007), Ministerio de Educación Nacional (MEN), Anuarios Generales de Estadistica, Departamento Nacional de Planeación (Umacro), Icfes and Dane; Population from Flórez and Romero (2010), Flórez (2000) and DANE.

Graph 3 presents the disaggregated index for men and women in order to observe possible differences in achievements by gender.[8] During the nineteenth century, both index were similar, with the men's index being slightly higher. This result may be due to the fact that during the nineteenth century education showed a high gender disparity: the number of girls attending primary school did not exceed 1% of the population. However, during the twentieth century, women's HIHDC has also improved substantially, especially since the 1950s, when women's index surpasses that of men. This result is interesting when compared to the case of Britain. According to Horrell (2000), women's development index in Britain has improved considerably throughout the twentieth century, but little progress has been made in closing the gap between women's positions relative to men's.[9]

In particular, the Colombian women's index improved mainly due to large gains in life expectancy and to large educational achievements. Between the period 1905/1912 and 2000/2005, women's life expectancy grew over 40 years, from 36.3 years to 76.3 years, while life expectancy for men grew 35 years, from 33.7 years in 1905/1912 to 69 years at the end of the century. Concerning education, when we calculate the HIHDC including higher education instead of primary education as one of its components, we observe that women's HIHDC is greater than the one for men since the end of 1970s, when the gap between men and women enrolled in higher education began to close. By the end of the century, 52% of total students enrolled in higher education were women (Graph 2).

It is important to mention, that as Mejia, Ramirez and Tamayo (2008) state, in the 1960s the reduction in the infant mortality rates, the introduction of birth control planning and the increasing opportunity cost for women with their greater participation in the labor force, led to a significant reduction in the fertility rates. This decline was preceded by a rise in women human capital investments and their corresponding increase rate of returns. In short, we observed significant advances in women's well-being during the whole twentieth century.

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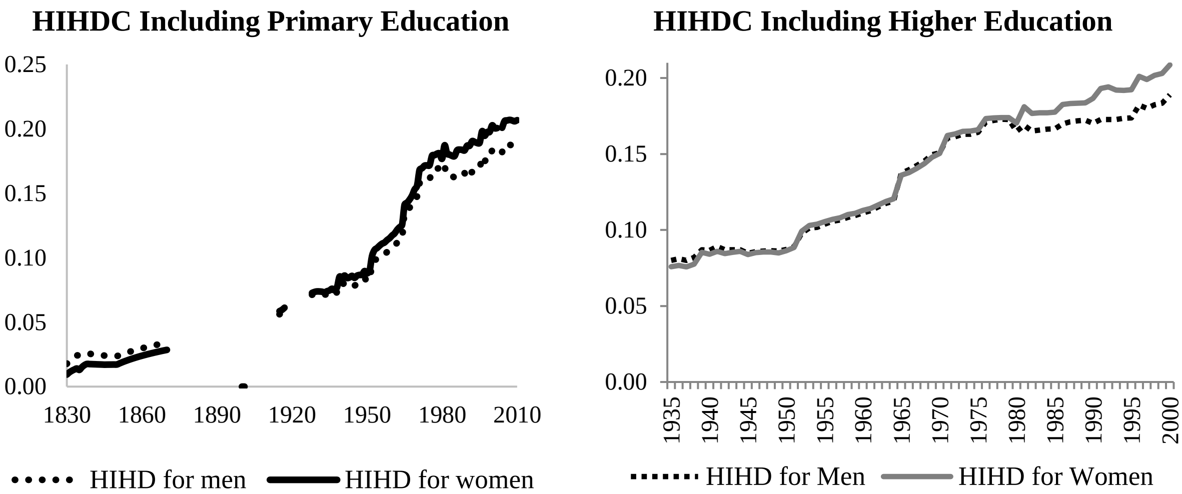
[8] The HIHDC by gender that we calculate can be considered as a proxy, since information of income by gender is not available for such long period of time. Therefore, our calculation of HIHDC by gender depicts only the differences in education and health achievements between women and men throughout the century. It is important to mention that recently, United Nations Development Programme (UNDP) has calculated the Human Development Index (HDI) by gender, which includes life expectancy, education attainment and per capita gross national income corresponding to women and men. The 2015 HDI value for women in Colombia is 0.731 and for men it is 0.728, which results in a Gender Development Index (ratio of female to male HDI) of 1.004, indicating that when income differences by gender are included in the calculation of the index, the gap between women and men also closes (UNDP, 2016).

[9] Horrell (2000) calculated a comprehensive gendered version of the human development index for the twentieth century in Britain, including indicators for income, leisure, inequality, wealth, health, education, and political rights.

Graph 3
Colombia's HIHDC by Gender



Sources: Authors' calculations based on data from Graph 2.

IV. The Case of Health: 1916-2014

A. Data and Health Achievements

In this section, we analyze achievements in health over the last 100 years in Colombia and the relationship between health outcomes and the provision of public goods (e.g. public water and sewerage provision). We examine health because it is one of the least studied components of the HIHDC by the economic history literature on Colombia.[10] Our hypothesis is that the significant decline in mortality rates, which led to a rise in life expectancy and to improvements in the HIHDC for both men and women, was partly caused by improvements in the provision of public goods, especially regarding sanitary conditions.

For this paper, we construct a database with the annual data on the main diseases, mortality rates, and provision of sewerage and aqueduct services for fourteen Colombian departments (Map 1) for which we were able to collect consistent information for the period 1916-2014.[11] In particular, data by gender on tuberculosis, pneumonia, gastrointestinal illness, cancer, and heart diseases were obtained from statistical yearbooks published by the Colombian government: for 1916-1948, *Anuarios Generales de Estadistica*

[10] For a comprehensive analysis on the evolution of education in Colombia, see (among others) Ramírez and Salazar (2010), and Ramírez and Téllez (2007). For a complete analysis of Colombian historical series on income trends and economic growth, see for instance Kalmanovitz (2008), Kalmanovitz and López (2010), and GRECO (2002). For the evolution of demographic indicators see Flórez (2000) and Flórez and Romero (2010)
[11] These departments accounted, on average, for 94% of the total population during the period 1916-2014.

de la Contraloria; for 1945-1969, *Anuarios Generales de Estadistica;* for 1970-1978, *Registro de Defunciones en Colombia;* and for 1979-2014, DANE database on Vital Statistics of Births and Deaths (*Estadísticas Vitales Nacimientos y Defunciones).*[12] On the other hand, the Colombian censuses provided information on the coverage of aqueduct, sewerage services, and some demographic characteristics.[13]

Map 1
Colombian Sub-national Territorial Units (departments), 1928

Sources: Authors' elaboration. Note: Shaded departments represent the ones used for the analysis.

Graph 4 presents the evolution of mortality rates and the causes of death in Colombia for some of the main diseases during the period 1916-2014.[14] The data shows the significant decline occurred in total and infant mortality rates and the profound changes in the causes of mortality for the Colombian population over the last 100 years.[15] As the graph shows, there is evidence of an epidemiological transition (the

[12] The values for the years for which we were not able to find information, were estimated by imputation.
[13] For the years between censuses, we estimated the values by interpolation.
[14] See Appendix 2 for the definition of the diseases groups used in this paper.
[15] The data on causes of death by type of disease for each Colombian department are not presented here due to space limitations, but are included in our database.

change from deaths caused by infectious diseases to deaths caused by chronic diseases).[16] For instance, the percentage of deaths from tuberculosis, pneumonia, and gastrointestinal diseases decreased significantly throughout the century, especially the latter. On the contrary, deaths due to cancer and heart diseases have increased considerably in recent decades. By gender, some differences are likely to exist in the prevalence of causes of deaths. For example, there are differences in chronic diseases such as cancer or cardiovascular diseases, where genetics plays a major role in contrast to infectious diseases.

The decline of mortality rates, especially at the middle of the century, was in part the result from public health policies, the introduction of good hygienic practices and the proper treatment of drinking water instead of the dissemination of treatments based on antibiotics, sulfa drugs and vaccination campaigns, since they arrived later and in many cases these treatments were more expensive. [17] For example, one of the main significant measures was, the issue of the Law 27 in 1946, in which the Ministry of Hygiene was created and assigned the responsibility for public assistance and for organizing a network of hospitals financed by public resources. Later on, in the 1970s other important reforms in the Colombian health system took place: in 1974 the National Health System was created, which was financed by the State, also an expanded immunization program, a family planning program and prenatal care were also established.[18] Finally, as we will see in the next section, public policies oriented to expand the provision of aqueducts and sewage also contributed considerably to the decline in mortality rates throughout the twentieth century.

Concerning the provision of aqueducts and sewerage services, Graph 5 presents the coverage rate for the country and by departments. As observed, throughout the century there is a great heterogeneity in the coverage of these services by departments, and for urban and rural areas. For example, in cities like Bogotá, and departments such as Atlántico, Antioquia and Valle, where aqueduct systems were implemented at the end of the nineteenth century, more than 90% of their household had aqueducts in 2005.[19] On the other hand, in departments such as Choco, Guainía, Guaviare, Vichada and Putumayo less

[16] For a complete and detailed study on the epidemiological and demographic transition in Colombia for the period 1946-2001 see Jimenez (2014). For an analysis on health transitions around the world see Riley (2005).

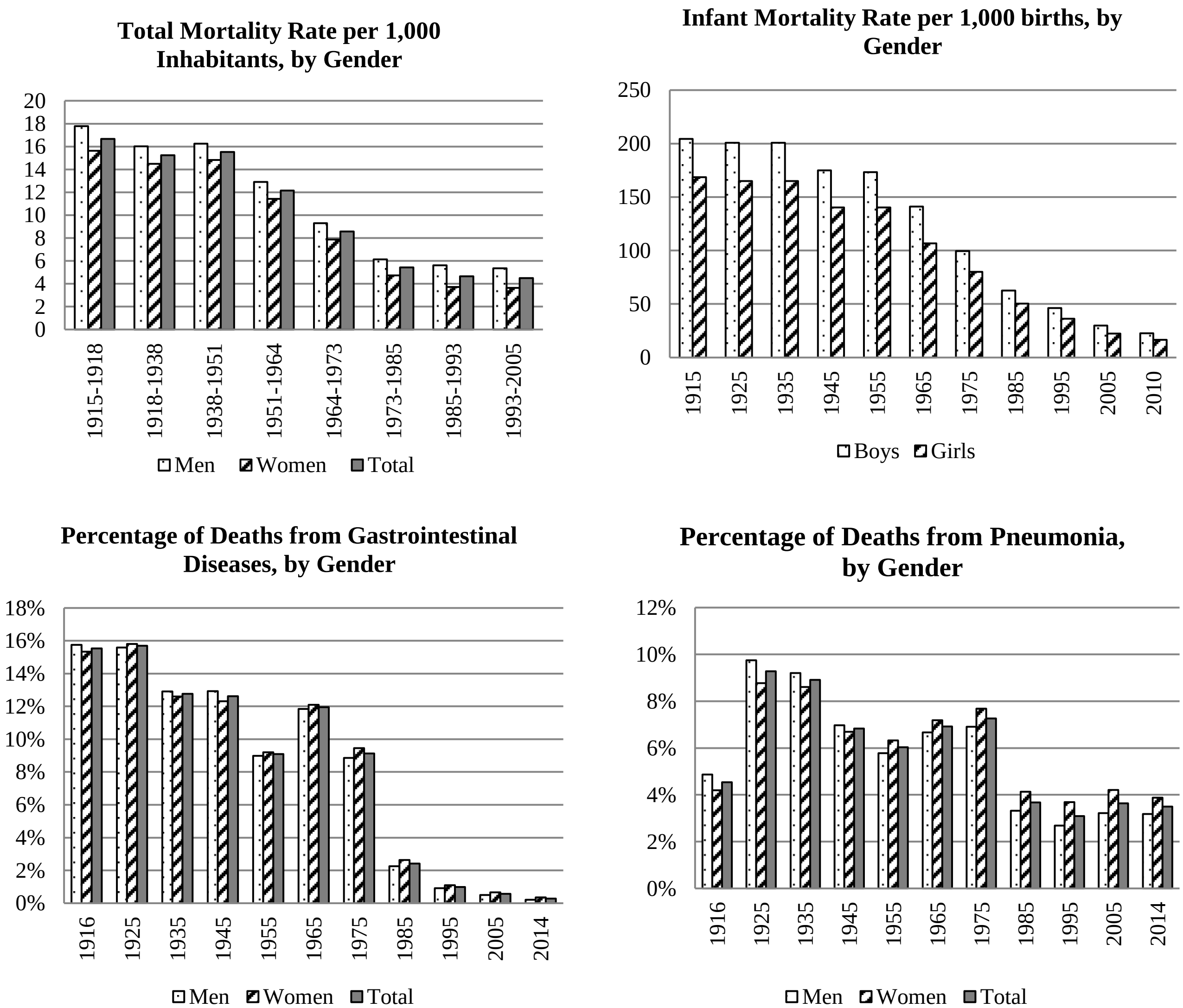
[17] In general, public policies were also important in reducing mortality rates in Latin American countries, see for example, Prados de la Escosura (2014).

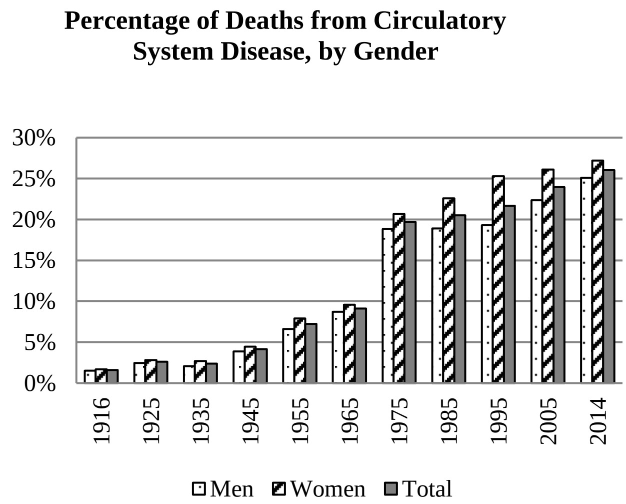
[18] For details on public health policies see for example Ministerio de Protección Social (2010).

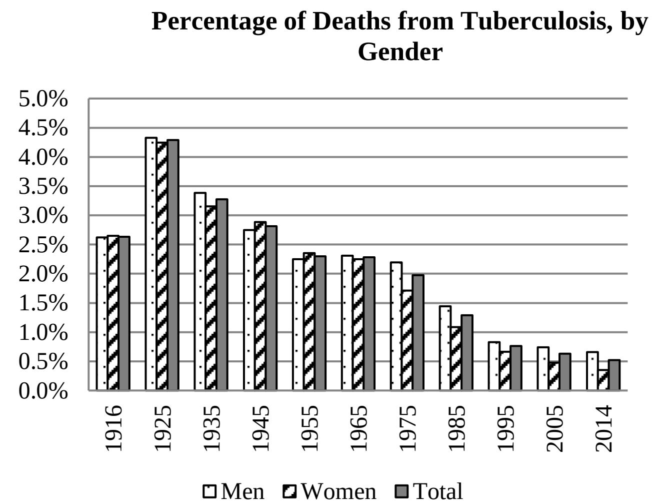
[19] The aqueduct systems started to appear in the urban centers of greater economic dynamisms and population growth, under the modality and concession contract granted to private entrepreneurs.by the municipality. For example, in 1880 the aqueduct of Barranquilla (Atlántico) was inaugurated, in 1886 was the aqueduct of Bogotá, in 1891 was the aqueduct of Medellin (Antioquia). At the beginning of the 20th century, a process of nationalization of public services began, and in 1928 the Congress declared the public utility of the aqueduct and sewerage services, for which the State should be in charge of their provision (for details see Comisión de Regulación de Agua Potable y Saneamiento Básico, 2001).

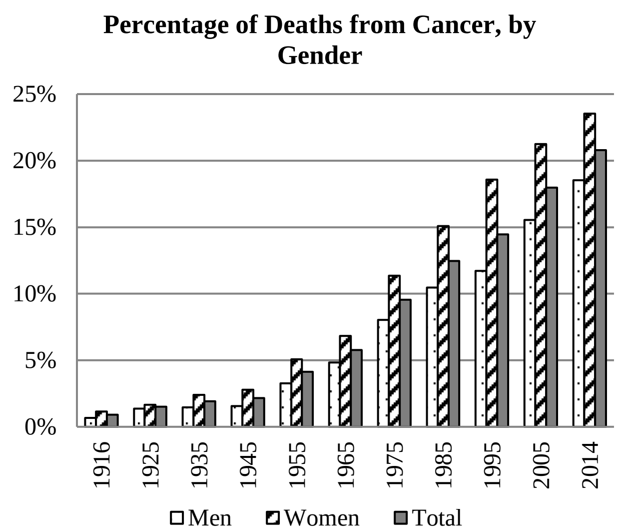
than 50% of their household had aqueducts in 2005. A similar pattern is observed in the provision of sewerage service.

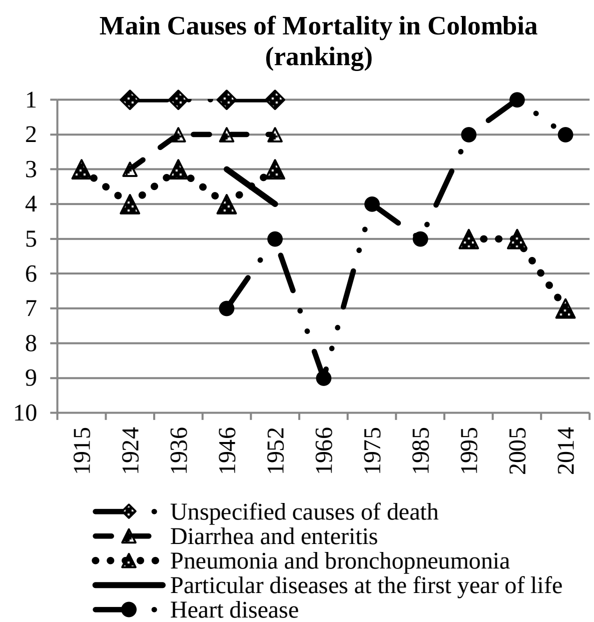
Graph 4
Mortality Rates and Causes of Death by Type of Disease in Colombia: 1916-2014







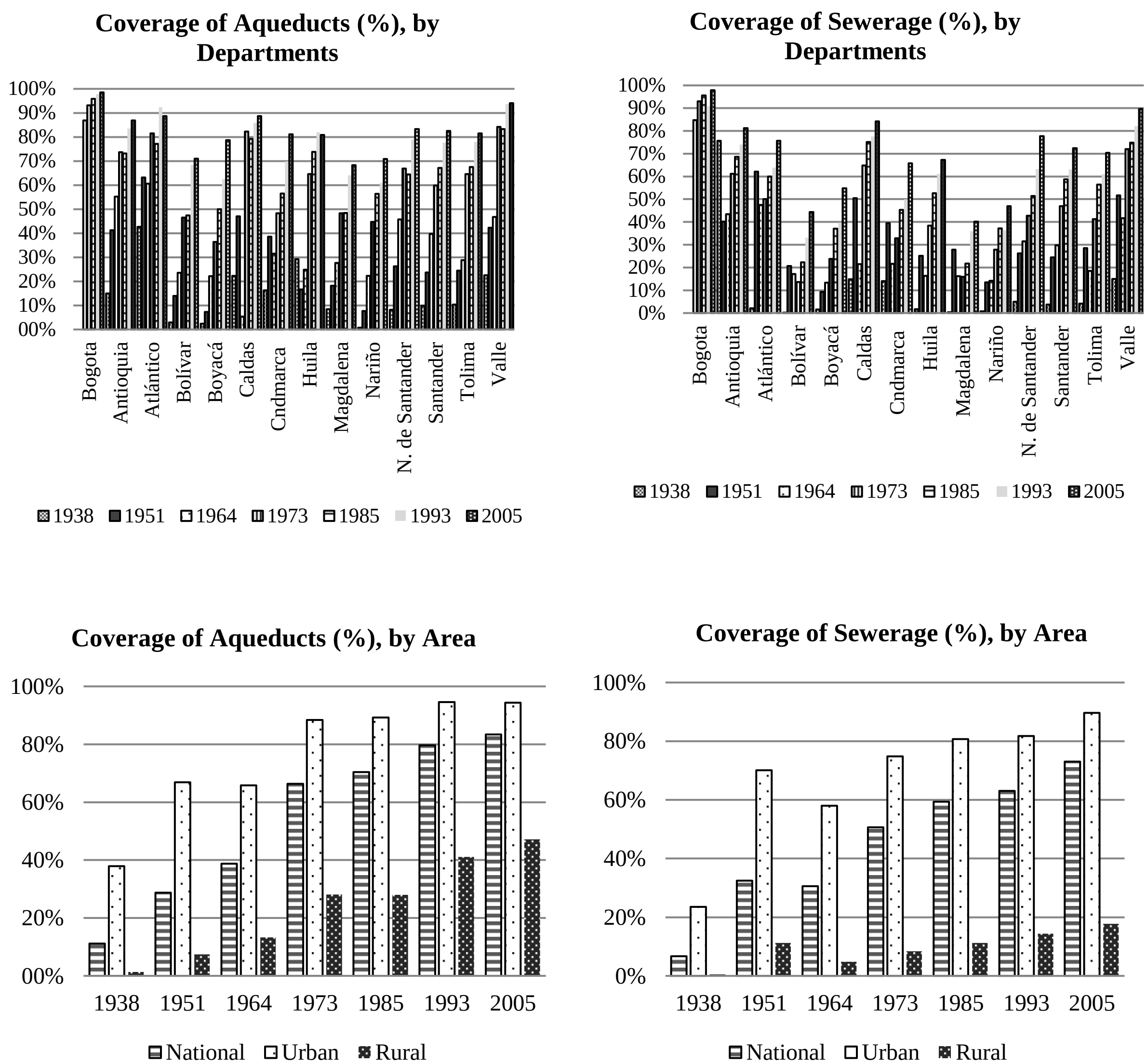




Sources: Database constructed by the authors based on *Anuarios Generales de Estadística de la Contraloría*, *Anuarios Generales de Estadística*, *Estadísticas Vitales Nacimientos y Defunciones* (several years).

In addition, the differences in the provision of the two services between urban and rural areas are enormous. In 2005, the percentage of households covered by aqueducts was near 90% in urban areas while in rural areas this percentage was less than 50%. Regarding the sewage service, these percentages were on average 77% and near 20%, respectively.

Graph 5
Aqueducts and Sewerage Coverage by Households (%): National and by Departments



Source: Database constructed by the authors based on the Colombian censuses, several years.

B. Empirical Strategy and Results:

1. Empirical Strategy

Our empirical strategy is to use the timing and regional variation of sewerage and aqueduct provision to assess the impact of the provision of these public utilities on mortality rates. First, we use the annual percentage of households in departments covered by public services during the period 1916-2014. Specifically, we estimate the following equation:

$$log(MRI)_{i,t} = \alpha + \beta_1 log(W_{i,t}) + \beta_2 log(S_{i,t}) + \gamma X_{i,t} + \delta FE_i + \lambda_1 log(MRI)_{i,t-n} + \varepsilon_{i,t} \quad (1)$$

where each observation is a departmental-year cell with *i* indexing the department, *t* the year, and *n*=1, 2,..n. $log(MRI)_{i,t}$ corresponds to the natural logarithm of a mortality rate indicator.[20] In particular, we use three different mortality measures.[21] In the first one, the mortality rate indicator corresponds to deaths from gastrointestinal infections (*GDMR*); the second one, to deaths from respiratory diseases (*RDMR*); and the third one, to the total mortality rate (*TMR*).[22] *W* and *S* are the provision of public services, which corresponds to the annual percentage of households in departments covered by aqueducts (*W*) and sewerage (*S*) services. The coefficients β_1 and β_2 indicate the impact of this infrastructure provision on the different mortality measures.

X includes demographic variables such as education.[23] In this paper, we are interested in exploring whether education has had an effect on reducing mortality rates in Colombia throughout the 20th century.[24] *FE* is a department-fixed effect and ε is the error term. We also include lagged dependent variables to account for the noisy nature of year-to-year mortality, as Cutler and Miller (2005) did.

[20] We use logarithms to smooth out the series. All rates are per 1,000 inhabitants.

[21] For a definition of the mortality measures used in this paper, see Appendix 2.

[22] Despite the fact that Colombia is well-known as a violent county, the mortality rate caused by violent deaths is not as high as other causes of mortality. For example, in 1991, the year with the highest level of violent deaths (79.64 deaths/100,000 inhabitants), the mortality rate from circulatory diseases was (99.71 deaths/100,000 inhabitants).

[23] Income is another possible variable that could be included in the regressions. However, we do not include it due to the lack of consistent data of departmental income for such a long period of time, and due to the problems of reverse causality between income and health found in the literature (for a complete discussion on this issue see Deaton, 2006). As in the case of education, the economic literature has found an ambiguous relationship between income and some health measures (infant mortality or the decline in the mortality rate). For example, Acemoglu and Johnson (2007) find that that relative growth rate of GDP per capita show some decline in countries experiencing large increases in life expectancy. In contrast, Pritchett and Summers (1996) argue that child deaths in developing countries in 1990 could be attributed to the poor economic performance in the 1980s.

[24] The relationship between education and health has been extensively examined in the literature, for example by Lleras-Muney (2005), Cutler and Lleras-Muney (2010) and Cutler, Huang and Lleras-Muney (2015). These authors find that, in general, education is positively associated with health outcomes, but there are important differences across countries. Cutler, Huang and Lleras-Muney (2015), point out that recent studies that estimate the casual effect of education on reducing mortality rates are ambiguous. As these authors mention, some studies have found that for instance education, measured as compulsory schooling, reduces mortality in the United States, but not in England or France (see Cutler, Huang and Lleras-Muney (2015) and references therein). On the other hand, other studies such as Beach, Ferrie, Saavedra and Troesken (2016) examine how the declines of mortality rates due to new water purification technologies affected human capital formation.

Next, we consider that the effects of public services coverage on mortality rates have decreasing marginal returns. Therefore, we decided to analyze the effect of different thresholds in the provision of aqueducts and sewage systems on mortality rates. To this end, we use dummies variables indicating, in each specification, when at least 30%, 40% and 50% of the households in a department had access to aqueduct and/or sewerage services. We estimate the following equation:

$$log(MRI)_{i,t} = \alpha + \beta_1 dW_{i,t} + \beta_2 dS_{i,t} + \beta_3 Interac_{i,t} + \gamma X_{i,t} + \delta FE_i + \lambda_1 log(MRI)_{i,t-n} + \varepsilon_{i,t} \qquad (2)$$

where *dW* and *dS* are dummy variables indicating whether or not 30%, 40% or 50% of the households in a department had access to aqueduct (*W*) and/or sewerage (*S*) services at year *t*. That is, the dummy variable is 1 for the years when the coverage of *W* and/or *S* are equal or greater than 30%, 40% or 50%, and 0 otherwise. Also, following Cutler and Miller (2005) and Alsan and Goldin (2015), we include the interaction term (*Interac*) between water (*W*) and sewerage (*S*) to test if they are substitutes ($\beta_3 > 0$) or complements ($\beta_3 < 0$). The interaction term is a dummy variable that equals 1 in the first years that the provision of *W* and *S* reached a 30%, 40% or 50% coverage simultaneously in a department. The coefficients β_1, β_2 and β_3 indicate the impact of this infrastructure provision on the different mortality measures. The rest of the variables are defined as in equation 1.

All estimations are linear regressions with panel-corrected standard errors, by heteroskedastic and contemporaneous correlation across panels.

2. Results

Table 1 presents the results of the estimation of equation (1).[25] The results suggest that there is a negative and significant relationship between the provision of aqueduct and the different mortality rates. As expected the largest effects of the expansion of this type of public services are on gastrointestinal diseases, which are mainly waterborne diseases (see Appendix 2). However, sewerage provision only had significant effects on the decline of gastrointestinal diseases' mortality rates.

[25] We find similar results estimating equation (1) when the dependent variables (mortality measures) were specified by gender. Regressions by gender are available upon request.

It is important to mention that the effects of both aqueducts and sewerage provisions are small. This may be due to the fact that the effects of the coverage of these services on mortality rates have decreasing marginal returns. Therefore, we decided to estimate equation 2, which account for the effect of different thresholds in the provision of aqueducts and sewage systems on mortality rates.

Tables 2, 3 and 4 present the results for the estimations of equation 2, for each type of diseases and for total mortality rates, using dummy variables indicating, in each specification, when at least 30%, 40% and 50% of the households in a department had access to aqueduct and/or sewerage services. Specifically, Table 2 presents the results when we considered as the dependent variable the log of the mortality rate for gastrointestinal diseases. Each column corresponds to a different specification. In columns 1 and 2, we estimate the equation including dummy variables (*W* and *S*), which indicate whether or not a department reached 30% aqueduct (*W*) and/or sewerage (*S*) coverage at year *t;* an interaction term between aqueduct and sewerage provision, lagged variables of gastrointestinal disease mortality rates and education.

The result indicates that aqueduct and sewerage provisions have a significant negative effect on gastrointestinal disease mortality rates. On average, achieving 30% coverage in aqueduct provision reduces the mortality rate for gastrointestinal diseases between 5.5% and 7.3%, while sewerage provision reduced the mortality rate between 11% and 12%. When we considered that households achieved a 40% coverage for aqueduct and sewerage (columns 3 and 4), the results are lager: for the aqueduct provision that reduces the gastrointestinal mortality rate between 13% and 16%, while sewerage provision reduced it between 7% and 8%. Similar results are found when households achieved a 50% coverage for aqueduct and sewerage, the effects of water provision are between 13% and 16%, and the sewerage provision reduced gastrointestinal diseases mortality by near 11% (columns 5 and 6).

Tables 3 and 4 present regression results using the same specification with the log of respiratory disease mortality rates and the log of total mortality rates as the dependent variables, respectively. We expect to find a lesser effect of aqueduct and sewage provision on reducing respiratory diseases than on gastrointestinal disease mortality rates. As in Table 2, each column corresponds to a different specification. The results show that the effect of water and sewerage access on total mortality rate and respiratory disease mortality are indeed lower than on gastrointestinal disease mortality rates, especially in the case of sewerage services. The only exception is in the case when households achieved a 30% coverage for aqueduct, where the effect of aqueducts on reducing mortality rates is slightly higher than on gastrointestinal diseases mortality rates. In particular, the results show that the provision of water reduced total mortality rates by 5%, and deaths related to the respiratory system lowered between 6.6% and 8.5% in the case of aqueduct coverage to 30% of the households. In the case of sewerage provision the effects are between 4% and 5% for respiratory diseases mortality rates and 2.7% in the case of total mortality rate.

When we considered a coverage of 40% and 50%, the effects of sewerage provision on reducing respiratory disease mortality rates and total mortality rates were no longer significant (Tables 3 and 4, columns 3-6). Regarding aqueduct provision the effects of a 40% aqueduct coverage on both respiratory mortality rates and total mortality rates are larger than in the scenario of a coverage of 30% and 50%. Specifically, achieving 40% coverage in aqueduct provision reduces the respiratory diseases mortality rate between 7.5% and 10%, and total mortality rate between 4.6% and 6.3%.

In all estimations (Tables 2, 3 and 4), the coefficients of the interaction term between aqueduct and sewerage provision are positive but not significant. In addition, in all scenarios, the coefficients of the first and second lags of the dependent variables are positive and significant, which means that mortality rates for previous years still have an effect on current mortality. Regarding education, results suggest that this variable plays an important role in reducing mortality rates, in all scenarios.

Finally, for robustness, we estimated two more exercises that are presented in table 5: one when the departments reached 60% of aqueduct and sewerage coverage, and the other when they reached 65%. We find that the effects of aqueducts and sewerage provision on reducing respiratory diseases and total mortality rates are no longer significant. In the case of gastrointestinal diseases, although aqueducts and sewerage provision still have an effect in reducing mortality rates, its magnitude is less than that of the other scenarios. In addition, when the 65% of the households in a department had access to aqueduct sewerage services the effect on gastrointestinal diseases mortality rate is not significant. On the other hand, education continues to be an important factor in reducing mortality rates.

In short, we find that early expansions on aqueducts and sewerage services had larger effects on the decline of mortality rates in Colombia during the twentieth century

Table 1
Effects of the Provision of Aqueduct and Sewerage, 1916-2014, on the *Log of*:

	Gastrointestinal Diseases Mortality Rate, GDMR		***Respiratory Diseases Mortality Rate, RDMR***		***Total Mortality Rate, TMR***	
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Log Aqueduct provision (*W*)	-0.0812*	-0.0837*	-0.0741**	-0.0600**	-0.0472***	-0.0391***
	(0.048)	(0.049)	(0.031)	(0.029)	(0.014)	(0.013)
Log Sewerage provision (*S*)	-0.0870*	-0.1054*	0.0080	0.0135	-0.0066	-0.0040
	(0.053)	(0.064)	(0.024)	(0.026)	(0.015)	(0.015)
Log $(GDMR)_{-1}$	0.6336***	0.6305***				
	(0.081)	(0.084)				
Log $(GDMR)_{-2}$	0.3145***	0.3134***				
	(0.081)	(0.083)				
Log Education		0.0204		-0.0551**		-0.0321**
		(0.057)		(0.028)		(0.015)
Log $(RDMR)_{-1}$			0.8860***	0.8799***		
			(0.056)	(0.057)		
Log $(RDMR)_{-2}$			0.0445	0.0516		
			(0.055)	(0.056)		
Log $(TMR)_{-1}$					0.7250***	0.7177***
					(0.047)	(0.047)
Log $(TMR)_{-2}$					0.1964***	0.2033***
					(0.046)	(0.046)
Constant	-0.2380***	-0.3074*	-0.0674***	0.0841	0.1193***	0.2078***
	(0.042)	(0.170)	(0.022)	(0.079)	(0.030)	(0.052)
Department Fixed Effects	YES	YES	YES	YES	YES	YES
Number of Observation	896	879	924	921	924	921
R^2	0.954	0.953	0.974	0.974	0.979	0.980
Number of Departments	14	14	14	14	14	14

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' estimations.

Table 2

Effects of the Provision of Aqueduct and Sewerage, 1916-2014, on the *Log (Gastrointestinal Diseases Mortality Rate, GDMR)*

	(1)	(2)	(3)	(4)	(5)	(6)
Aqueduct provision (*dW*)$_{30\%}$	-0.0760**	-0.0566*				
	(0.038)	(0.034)				
Sewerage provision (*dS*)$_{30\%}$	-0.1279***	-0.1106***				
	(0.038)	(0.033)				
Interaction$_{30\%}$	0.0540	0.0448				
	(0.091)	(0.093)				
Aqueduct provision (*dW*)$_{40\%}$			-0.1743***	-0.1370***		
			(0.042)	(0.037)		
Sewerage provision (*dS*)$_{40\%}$			-0.0851**	-0.0728*		
			(0.043)	(0.043)		
Interaction$_{40\%}$			0.1435	0.0525		
			(0.147)	(0.119)		
Aqueduct provision (*dW*)$_{50\%}$					-0.1752***	-0.1346***
					(0.040)	(0.040)
Sewerage provision (*dS*)$_{50\%}$					-0.1214***	-0.1137***
					(0.043)	(0.040)
Interaction$_{50\%}$					0.1392	0.1223
					(0.140)	(0.116)
Log (*GDMR*)$_{-1}$	0.6657***	0.6664***	0.6578***	0.6555***	0.6657***	0.6579***
	(0.068)	(0.075)	(0.067)	(0.070)	(0.067)	(0.070)
Log (*GDMR*)$_{-2}$	0.2184**	0.2207**	0.2147**	0.2157**	0.2135**	0.215**
	(0.084)	(0.095)	(0.084)	(0.088)	(0.084)	(0.088)
Log (*GDMR*)$_{-3}$	0.0721	0.073	0.0706	0.0800	0.0602	0.0711
	(0.066)	(0.073)	(0.065)	(0.068)	(0.065)	(0.068)
Education		-0.0052		-0.0075*		-0.0113***
		(0.0039)		(0.004)		(0.004)
Constant	0.0456	0.0857	0.0680***	0.1258**	0.0310	0.1444***
	(0.035)	(0.053)	(0.033)	(0.053)	(0.025)	(0.051)
Department Fixed Effects	YES	YES	YES	YES	YES	YES
Number of Observation	1,141	1,141	1,141	1,141	1,141	1,141
R^2	0.949	0.952	0.950	0.960	0.949	0.960
Number of Clusters	14	14	14	14	14	14

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' estimations.

Table 3

Effects of the Provision of Aqueduct and Sewerage, 1916-2014, on the *Log (Respiratory Diseases Mortality Rate, RDMR)*

	(1)	(2)	(3)	(4)	(5)	(6)
Aqueduct provision (dW)$_{30\%}$	-0.0887***	-0.0684***				
	(0.022)	(0.020)				
Sewerage provision (dS)$_{30\%}$	-0.0715***	-0.0425**				
	(0.018)	(0.019)				
Interaction$_{30\%}$	0.0654	0.0473				
	(0.043)	(0.043)				
Aqueduct provision (dW)$_{40\%}$			-0.1082***	-0.0780***		
			(0.021)	(0.020)		
Sewerage provision (dS)$_{40\%}$			-0.0122	0.0013		
			(0.018)	(0.018)		
Interaction$_{40\%}$			0.0643	0.0286		
			(0.054)	(0.052)		
Aqueduct provision (dW)$_{50\%}$					-0.0405***	-0.0039
					(0.020)	(0.022)
Sewerage provision (dS)$_{50\%}$					0.0061	0.0065
					(0.019)	(0.019)
Interaction$_{50\%}$					0.0657	0.0793
					(0.068)	(0.067)
Log (*RDMR*)$_{-1}$	0.8532***	0.8069***	0.8736***	0.8114***	0.9050***	0.8395***
	(0.039)	(0.041)	(0.040)	(0.041)	(0.042)	(0.042)
Log (*RDMR*)$_{-2}$	0.1542***	0.1986***	0.1605***	0.2005***	0.1668***	0.1842***
	(0.046)	(0.047)	(0.046)	(0.047)	(0.048)	(0.049)
Log (*RDMR*)$_{-3}$	-0.0936***	-0.0870**	-0.1044***	-0.0893**	-0.1043***	-0.0675*
	(0.036)	(0.038)	(0.037)	(0.038)	(0.038)	(0.039)
Education		-0.0065**		-0.0100***		-0.0123***
		(0.003)		(0.003)		(0.003)
Constant	0.1018***	0.1479***	0.0677***	0.1636***	0.0028	0.1366***
	(0.022)	(0.036)	(0.020)	(0.038)	(0.016)	(0.037)
Department Fixed Effects	YES	YES	YES	YES	YES	YES
Number of Observation	1,119	1,119	1,119	1,119	1,119	1,119
R^2	0.970	0.973	0.970	0.973	0.969	0.972
Number of Clusters	14	14	14	14	14	14

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' estimations.

Table 4
Effects of the Provision of Aqueduct and Sewerage, 1916-2014, on the *Log (Total Mortality Rate, TMR)*

	(1)	(2)	(3)	(4)	(5)	(6)
Aqueduct provision $(dW)_{30\%}$	-0.0573***	-0.0423***				
	(0.013)	(0.011)				
Sewerage provision $(dS)_{30\%}$	-0.0273**	-0.0136				
	(0.012)	(0.011)				
$\text{Interaction}_{30\%}$	0.0304	0.0249				
	(0.028)	(0.026)				
Aqueduct provision $(dW)_{40\%}$			-0.0653***	-0.0475***		
			(0.013)	(0.011)		
Sewerage provision $(dS)_{40\%}$			-0.0016	0.0017		
			(0.010)	(0.009)		
$\text{Interaction}_{40\%}$			0.0405	0.0064		
			(0.033)	(0.029)		
Aqueduct provision $(dW)_{50\%}$					-0.0319***	-0.0102
					(0.012)	(0.011)
Sewerage provision $(dS)_{50\%}$					0.0091	0.0074
					(0.010)	(0.009)
$\text{Interaction}_{50\%}$					0.0198	0.0249
					(0.042)	(0.033)
Log $(TMR)_{-1}$	0.7469***	0.7086***	0.7640***	0.7089***	0.7927***	0.7260***
	(0.041)	(0.038)	(0.041)	(0.038)	(0.042)	(0.038)
Log $(TMR)_{-2}$	0.1737***	0.1872***	0.1768***	0.1876***	0.1814***	0.1928***
	(0.049)	(0.045)	(0.050)	(0.045)	(0.051)	(0.046)
Log $(TMR)_{-3}$	0.0153	0.0403	0.0044	0.0366	-0.0005	0.0399
	(0.040)	(0.037)	(0.040)	(0.037)	(0.041)	(0.038)
Education		-0.0051***		-0.0069***		-0.0076***
		(0.001)		(0.001)		(0.001)
Constant	0.1934***	0.2322***	0.1568***	0.2529***	0.0590	0.1742***
	(0.038)	(0.039)	(0.037)	(0.040)	(0.037)	(0.037)
Department Fixed Effects	YES	YES	YES	YES	YES	YES
Number of Observation	1,148	1,148	1,148	1,148	1,148	1,148
R^2	0.976	0.979	0.976	0.979	0.975	0.979
Number of Clusters	14	14	14	14	14	14

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' estimations.

Table 5
Effects of the Provision of Aqueduct and Sewerage, 1916-2014, on the *Log of*:

	Gastrointestinal Diseases Mortality Rate (GDMR)		*Respiratory Diseases Mortality Rate (RDMR)*		*Total Mortality Rate (TMR)*	
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Aqueduct provision (*dW*)$_{60\%}$	-0.0727*		-0.0012		-0.0003	
	(0.037)		(0.023)		(0.012)	
Sewerage provision (*dS*)$_{60\%}$	-0.0679*		0.0145		-0.0069	
	(0.038)		(0.019)		(0.013)	
Interaction$_{60\%}$	-0.0551		0.0085		-0.0293	
	(0.124)		(0.067)		(0.042)	
Aqueduct provision (*dW*)$_{65\%}$		-0.1033***		0.0067		0.0062
		(0.037)		(0.018)		(0.011)
Sewerage provision (*dS*)$_{65\%}$		-0.0328		0.0004		-0.0050
		(0.034)		(0.019)		(0.022)
Interaction$_{65\%}$		0.0861		0.0712		0.0190
		(0.093)		(0.079)		(0.078)
Log (*GDMR*)$_{-1}$	0.7127***	0.7105***	0.8306***	0.8306***	0.6948***	0.6941***
	(0.057)	(0.057)	(0.045)	(0.045)	(0.042)	(0.042)
Log (*GDMR*)$_{-2}$	0.2372***	0.2359***	0.1938***	0.1941***	0.2114***	0.2115***
	(0.072)	(0.072)	(0.050)	(0.050)	(0.049)	(0.049)
Log (*GDMR*)$_{-3}$	0.0235	0.0284	-0.0605	-0.0607	0.0604	0.0619
	(0.054)	(0.054)	(0.041)	(0.041)	(0.041)	(0.041)
Education	-0.0101**	-0.0114***	-0.0109***	-0.0110***	-0.0072***	-0.0073***
	(0.004)	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)
Constant	0.0926*	0.1002*	0.1142***	0.1165***	0.1492***	0.1483***
	(0.053)	(0.052)	(0.038)	(0.038)	(0.041)	(0.041)
Department Fixed Effects	YES	YES	YES	YES	YES	YES
Number of Observation	1,141	1,141	1,119	1,119	1,148	1,148
R^2	0.965	0.965	0.971	0.971	0.977	0.977
Number of Clusters	14	14	14	14	14	14

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Source: Authors' estimations

V. Conclusions

This paper shows that Colombia improved the living standard of its population remarkably during the twentieth century. Progress was made especially on income, education, and health. During the first half of the century, improvements in the quality of life were mainly driven by higher per capita income, while improvements after the 1950s were driven by greater public investments, as in the case of education and health.

The decline in mortality rates, which led to an important increase in life expectancy, was partly triggered by improvements in the provision of public goods, especially regarding sanitary conditions. We find large effects of the provision of aqueducts and sewerage services on mortality rate declines, especially on deaths from waterborne illnesses such as gastrointestinal diseases. However, the effect on mortality rates from water and sewerage access is low compared with the results from other studies such as those by Cutler and Miller (2005). This can be explained in several ways. For example, due to data availability, we use the coverage of water provision instead of a precise measure of water quality. Therefore, our results could be interpreted as a lower bound of the actual effects. Another possible explanation is that the expansion of the aqueduct and sewerage systems in Colombia was gradual, and came late in most of the departments. Also, other factors such as medicines and prevention campaigns may also explain the reduction in mortality rates.

There are some caveats to our paper. First, due to the availability of data, the analysis of the effects of the provision of safe water and sewerage services on some measure of mortality was performed at the departmental level rather than at the municipal level, where the results could be more conclusive. For future research, we intend to analyze some of the major cities of the country, for which we will assemble a consistent database. We also want to extend the estimates to other causes of death such as pneumonia and tuberculosis. In addition to aqueduct and sewerage, there are other factors which are not mutually exclusive that were responsible for the reduction of mortality in the country, and which should be taken into account in future analyses.

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Appendix 1

Human Development Index and Historical Index of Human Development: Methodology

1. **Variables:** The Colombian Human Index of Human Development (HIHDC) intends to understand the following dimensions of the standard of living, both at the general level and by gender:

   a. Education: we use the following proxy for coverage in primary education by gender:

$$Coverage = \frac{(Students\ in\ primary\ education)_{t,g}}{(Total\ Population)_{t,g}}$$
$$g = \{male, female, total\}$$

   b. Income: we use the GDP per capita in Geary–Khamis international dollars, at constant prices. A logarithmic transformation of income is necessary because, as Amand and Sen (2000) point out, the function of capabilities is probably concave:

$$Ln\_PIB_{pc_t} = \ln\left(PIB_{pc_t}\right)$$

   c. Health: We use the life expectancy at birth by gender.

2. **Construction of a continuous series:** The lack of data availability for several years compelled us to interpolate data for some years. The interpolation uses the nearest points (x_0, y_0) and(x_1, y_1), such that$x_0 < x$ and$x_1 > x$. While y_1 and y_0 are observable, the interpolation of the *y* value follows this formula:

$$y = \frac{y_1 - y_0}{x_1 - x_0}(x - x_0) + y_0$$

The interpolation is not done for the years 1870-1900, given that the period is too broad, and any interpolation would ignore all of the changes at the end of the century.

3. **HDI:** To calculate the HDI, it is necessary to transform the variables as follows:

$$I_{d,t,g} = \frac{x_{d,t,g} - Min_d}{Max_d - Min_d}$$
$$d = \{income, education, health\}$$
$$g = \{Male, Female, National\}$$

where $x_{d,t,g}$ represents the value of the dimension *d*, in period *t*, and gender, *g*. The maximum and minimum (goalposts) are historical worldwide observations for each dimension. However, no historical information is available on goalpost differentiated by gender, therefore we decide to adopt the same values used by Prados de la Escosura (2015).

Finally:

$$HDI_{t,g} = \sqrt[3]{\prod_{d} I_{d,t,g}}$$

4. **HIHD:** Following Prados de la Escosura's (2015) methodology, the construction of the HIHD results in a logarithmic transformation of $I_{\mathrm{d,t,g}}$ given that as country's development increases, it is more difficult to improve, so this indicator gives more points for growth at advanced levels of development. It is worth mentioning that the income dimension does not require this transformation, since it already has a logarithmic transformation.

$$HI_{d,t,g} = \frac{\ln(Max_d - Min_d) - \ln\left(Max_d - x_{d,t,g}\right)}{\ln(Max_d - Min_d)}$$

Finally, the calculation of the HIHD is similar to that of the HDI:

$$HIHD_{t,g} = \sqrt[3]{\prod_{d} HI_{d,t,g}}$$

Appendix 2

Definition of Disease Groups

Gastrointestinal Diseases	Cholera Typhoid and paratyphoid fevers Other infections due to salmonella Shigellosis Other bacterial intestinal infections Other bacterial food poisonings, not classified elsewhere Amoebiasis Other intestinal diseases due to protozoa Intestinal infections due to viruses and other specified organisms Other gastroenteritis and colitis of infectious and unspecified origin
Respiratory Diseases	Pneumonia Chronic diseases of the lower respiratory tract Lung diseases due to external agents All other diseases of the respiratory system
Circulatory System Diseases	Rheumatic fever and chronic rheumatic heart disease Hypertensive diseases Ischemic heart disease Cardiopulmonary disease and diseases of the pulmonary circulation All other forms of heart disease Heart failure Atherosclerosis Aortic aneurysm Diseases of blood vessels and other diseases of the circulatory system.¿

Source: Authors' elaboration.