The democratization of longevity: How the poor became old in Paris, 1870-1940.

Lionel Kesztenbaum
Jean-Laurent Rosenthal*

"Mais comme il y a deux sortes de richesse, la richesse qui ne produit rien, et la richesse qui produit, que l'industrie sait partager pour l'accroître, j'ai été curieux de savoir si elles ont une influence également heureuse sur la durée de vie."

Louis-René Villermé, « De la mortalité dans les divers quartiers de la ville de Paris », *Annales d'hygiène publique et de médecine légale*, 1830

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Abstract

At the end 19th century, industrialized countries experienced both a decline in urban mortality to the extent that rural-urban differentials, once vastly favorable to rural areas, reversed. The process can be linked with two broad phenomena: a rise in income and improved sanitation. Here we focus on the rich data available for Paris in the three decades preceding WWI. These allow us to assemble a longitudinal data set on mortality and income at a fine scale of Paris's 80 neighborhoods during the key period of the health transition. Life expectancy in Paris is not very different from the rest of the country –around 50 years at age 5– but the difference between best and worst neighborhoods is over 10 years. To explain such huge mortality differentials, we add to this dataset various information on income and wealth from fiscal records, especially both the average rents and its distribution within neighborhoods. We document that the disparities in mortality between neighborhoods are strongly related to a variety of income indicators. Over time, mortality fell because of income increases rather than because of a change of the mortality income relationship.

Keywords: differential mortality, wealth, urbanization, Paris

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* Respectively: INED, 133 bd Davout 75940 Paris Cedex 20. lionel.kesztenbaum@ined.fr and Caltech, 200 E California Blvd Pasadena CA 91031 USA jlr@hss.caltech.edu.

Introduction

In the early nineteenth century, Parisians had a life expectancy at age five of about 44, some five years less than other French people. The gap did not begin to narrow until the middle of the century and it did not close until the 1930s. In the 1890s, Parisians in the toniest neighborhoods could expect to live 12 years longer than those in the worst neighborhoods (a difference that was almost twice as large as that between the best and worst French departments). Similarly large differences are found in age at death between the bottom and the top part of the wealth distribution. In nineteenth century Paris life was both brutally short and massively unequal. Starting in the 1850s the city began to address some of its worst environmental problems, first with the general delivery of clean water (by a concessionary company) and in the 1870s by embarking on a vast and prolonged public program of sewer construction. By the 1930s nearly all buildings in Paris had running water, their waste water discharged directly in the sewers, and life expectancy was beginning to converge. While even today differences in life span based on wealth, or neighborhood remain, they have massively diminished. Increased longevity, it seems, has been one of the more widely distributed benefits of long term economic growth.

This synopsis of Paris' experience raises questions about the sources and evolution of differential mortality. Scholars have identified two opposed forces that weighed on life expectancy before WWII. Life span was caught between the downward pressure of the ever increasing share of the population living in crowded and adverse urban environments and the lift provided by increases in income and knowledge. In the long run the second force triumphed and offset the negative effects of urban living. In their pure form income and knowledge are quite distinct. Higher income allows individuals to purchase privately consumed goods and services that prolong life (e.g. better nutrition, clothing, and housing). Save for possible epidemiological effects, the better food or housing of one family has little effect on the life expectancy of another. At the other extreme we can place pure knowledge effects (like home cleanliness or boiling milk), once the survival value of such techniques are known they can be adopted by everyone because their costs are low.

Of course there is a range of other changes that lie in between: they are expensive but have economies of scale and, as a result, their benefits are greatest if they are adopted by the whole of a given population. In particular sanitation relies on expensive networks of pipes to distribute clean water and collect waste water.[1] As most of the decline in mortality during the so-called "epidemiological transition" is linked to infectious diseases (Omran, 1971), large scale public

[1] The same can be said for garbage collection, or urban heating schemes.

innovations should be expected to matter a lot in that period. Indeed, the adoption of clean water technologies has been proven to have an important role by itself in reducing mortality (Cutler and Miller, 2005). However, it is important not to reduce clean water or sanitation to a public good, because although they have externalities, both are an excludable service whose provision occurs under a variety of schemes. Sanitation for instance can of course be provided uniformly at public expense, it can also be mandated as part of rebuilding programs, or, as most often, it can be left to a fee-for-service public or private provider. Its diffusion thus makes it quite distinct from public goods.

Paris turns out to be a very good laboratory to study differential mortality because the municipal statistical office was dominated by individuals who were obsessed with collecting and publishing detailed demographic data. Beyond the contrast between Paris and France that we can estimate for two centuries, we can track the evolution of mortality on a fine scale (in each of Paris's 20 districts (*arrondissement*)) from 1870 to 1945 and, between 1880 and 1913, for each of the 80 neighborhoods (*quartier*) of the city. Data on the number of buildings connected to the sewers start in the 1880s with the same disaggregation as mortality data. Their purpose in producing these disaggregated reports was to spur public action to reduce both mortality and morbidity in the city. Yet during this period their efforts did not lead to major changes in policy. Additionally the treasury collected (even though it did not publish) information on direct taxation for the same 80 neighborhoods. These also served as the units for published tabulations of the censuses of housings. Finally Piketty et al.'s data sets enable us to produce estimates of average wealth levels for the same neighborhoods (Piketty, Postel-Vinay et al., 2006). As we will show there is extraordinary stability in the ranking of these neighborhoods in terms of their real estate stock, their average wealth levels and in their relative life expectancy.

This paper has three goals. The first is to document the long term evolution of life expectancy in Paris and its extraordinarily marked spatial variation. It is no great surprise that the poorest neighborhoods were also those where life was shortest, but the extent of this type of differential mortality is striking. Second we show that the advent of sanitation (direct connection of a building's waste water pipes to the sewers) did reduce mortality. The fee-for-service nature of the diffusion implies early adoption by rich neighborhoods and thus a temporary increase in differential mortality. Third, convergence to the low mortality regime was slow and although it did reduce the variation in life expectancy within Paris it did not eliminate it

I. Paris as a laboratory

Paris has many advantages for studying differential mortality. To begin, income, wealth, and life expectancy variations were extremely large within the city. There are some serious complications, however, the most obvious of these being that Parisians have never been a closed population. In fact, half or more of the individuals who died in Paris had not been born there. Migrants to Paris are also not a random sample of the world or of France's population.

To be sure, France as a whole would be an attractive setting for studying differential mortality. Indeed, France has the lowest levels of emigration and immigration among the countries on both sides of the North Atlantic. Hence if one were to estimate differential mortality rates in a cross-section, one would not need to worry about the extent to which the individuals observed were selected, something that comes up if one deals with other locations that have high migratory flows. However, scholars have long established that mortality rates varied by location (e.g. urban vs rural) and we know that location was correlated with income. Hence in cross section it is difficult to isolate the effect of income on life expectancy. Using time to help sort out these correlations reintroduces the thorny problem of endogeneity because even if French people rarely listened to the siren calls of North America they moved around within their country quite a bit. In particular, from the beginning of the nineteenth century migration fuelled city growth and the largest cities (including the capital) were the dominant destinations (Guérin-Pace, 1993). Choosing Paris forces us to deal with the endogeneity problem full square.

Paris is also obviously interesting in and of itself, but it presents a remarkable contrast with the country as a whole. In 1880 Parisians could expect to live four years (or nearly 10%) less than French people as a whole and their mortality was mainly driven by infectious diseases (Kuagbenou and Biraben, 1998). Over the next three and a half decade, life expectancy in France rose by four years but that of Paris by nearly seven years leading to a convergence that would turn to Paris' advantage in the interwar period (Figure 1). To this respect the Parisian and French experience is quite similar to the general epidemiological transition in Europe or the US with a strong decline in infectious disease that leads to a disappearance of the urban penalty (For the US, see Haines, 2001; for Paris: Meslé and Vallin, 2009). Thus the patterns of spatial differential demography went through a great reversal. Yet at the same time, within the city, the pattern of differential demography changed very little.

[Figure 1 about here]

To understand the increase of life expectancy in Paris we must confront two different selection effects, first, selection of migrants from France into Paris and, second, the sorting of Parisians into neighborhoods. Indeed, changes in the mortality of Parisians could thus be simply attributed to changes in rates of migration and migrants' characteristics. Yet in prior work we established that migrants from the countryside to cities were positively selected. Shortly after migrating, they had lower mortality than either those who stayed behind, or those whom they joined in cities. After a decade of urban residence, however migrants' mortality converged to that of individuals who were born and resided in cities (Kesztenbaum and Rosenthal, 2011). Our analysis will take advantage of these results by examining difference in mortality rates by age where older groups will not be so sensitive to migration rates. The second selection effect, residential sorting, complicates the analysis. Indeed, there are two reasons for a neighborhood to have high life expectancy: income buys a longer a life and some neighborhoods are healthier than others. These two effects need not be connected. Suppose that high income buys a longer life span and that high income individuals want to live near each other because they value similar cultural amenities or economic networking. By historical accident the high income neighborhoods have no attributes that affect life expectancy. At the other extreme one could imagine that income is irrelevant in itself but that some neighborhoods have attributes that make them healthier places to live. Households with high income might well seek to live in such better neighborhoods and thus bid up the rental price of housing. In both cases we would observe a positive relationship between income and life span and a positive association between rich neighborhoods and life span. In the first case, the neighborhoods are good because they are rich and in the second the neighborhoods are rich because they are good. Empirically, Paris seems to fit both phenomena. Paris's rich neighborhoods are in the west, upwind from the poorer east and thus enjoyed less polluted air. The rich hired many more female servants to clean and take care of the children.

As noted above and as we discuss below at age five, life expectancy differences between the worst and best decile of neighborhoods neared an enormous 15 years. Furthermore, this difference was relatively stable over time and endured even after the city had provided broad access to clean water. Building owners could provide running water to each dwelling, a faucet at every floor, or simply one on the ground floor (Bocquet, Chatzis et al., 2008), and there were also public fountains, most of them equipped with filters (Goubert, 1986: 90-92). Although, as elsewhere in Europe or the US, clean water did play a role in decreasing mortality, especially infant mortality (Preston and Walle, 1978), we lack the data to analyze its impact on Paris.

Beyond water an important health enhancing service involve the disposal of waste water. We thus track the diffusion of how dwellings in different neighborhoods connected to sewers. While major sewers were installed in most of Paris by the 1860s they could only accommodate liquid waste. Buildings were then equipped with a variety of systems. In their most basic type, buildings residents had to empty their waste water in pits, or tanks that would later be taken away by night soil companies. More often buildings were equipped with waste pipes (these were often installed at the same time as running water) but these emptied either into aforementioned tanks or into filtering systems (akin to septic tanks that captured solids and let the liquids drain to sewers or the street) and had to be emptied periodically as well. In either case the residents of buildings were never far from the contaminants of waste water. In 1886 the city allowed landlords to connect their buildings' waste water pipes directly to the sewer and thus they had to decide whether to retrofit their buildings and pay an annual fee of 60 francs per downpipe that was connected to the sewer. In a gesture designed to encourage owners of buildings in poor neighborhood to connect, those that rented for less than 500 francs faced fees of 30 francs (still substantial if rents did not respond to this improvement). Then in 1894 the city made connection mandatory, but it seems that the law was selectively enforced and that it only bound on new construction. Ten years after the ordinance had been passed only 37,342 buildings had direct connection, less than 54% of the buildings extant in 1894, and 51% of those extant in 1903. Indeed, it seems that most buildings built after 1894 were directly connected to the sewer; but connections in the central arrondissement where there was nearly no new construction show no sharp jump after 1894. By 1913 not quite 70% of the buildings were connected though the 20th, 13th and 12th arrondissement (district) on the eastern edge of the city had yet to pass 60%. Beyond its own efforts at improving the worst areas of Paris (Ilots insalubres), and a form of price discrimination, the city was relatively passive in promoting sewer, and the trend in sewer adoption as two inflections, an early acceleration in the mid 1890s and then a slowdown in the mid 1900. In fact, by 1906 the rate of growth of sewer adoption seems to have settled into some long term process (slightly faster in the poorer, less connected neighborhoods slightly slower in the richer ones). As a result there were steady gains and by 1928 when the detailed reports end, the connection rate toped 85% in the quartile of most favored arrondissements and ranged between 67 and 77% in the bottom quartile. Hence sewers represent a technological change whose endogenous adoption favors rich neighborhoods over poor ones and thus actually furthered the spatial inequality within the city well past World War I.

As noted in the introduction, we can carry out this analysis at three levels of aggregation: the city, its 20 districts, and its 80 neighborhoods from 1880 to 1913. We can extend the analysis forward to 1930 if we limit ourselves to arrondissement level data and backwards to 1820 if we limit ourselves to the city level. We can do so because the statistical department of the Paris municipality under the lead of Louis-Adolphe and Jacques Bertillon produced a regular flow of statistics about mortality. Jacques Bertillon himself was concerned with reducing the impact of communicable diseases in the city and with establishing the causes behind the dramatic differences in life expectancy. In fact, Paris was one of the birth places of studies of the relationship between mortality and wealth, with the work of Louis-René Villermé at the beginning of the 19th century (Villermé, 1823; Villermé, 1830). Indeed, Villermé was certainly one of earliest – if not the first – explorers of the link between affluence and life expectancy. His work broke a long established belief that all were equally at risk of death (Villermé, 1828; Lécuyer and Brian, 2000). Since then, scholars have taken for granted that social disparities in wealth, income, social status, and so on produce inequality in health and these inequalities have become policy matters.

The literature has since explored the income gradient in mortality and its evolution over time –not to mention a wide range of works that focus on this gradient today (among others: Williams, 1990; Hummers, Rogers et al., 1998; Cambois, Robine et al., 2001). Some scholars look at the income-mortality relationship from a macro perspective as an important element in "the mortality transition" (McKeown, 1976). Most of the research, however, has focused on measuring income-mortality relationship in specific times and places. All these studies try to understand how socio-economic gradient in life expectancy can come about. The factors that have been invoked include nutrition (Fogel, 1986; Harris, 2004), better housing, better hygiene, or better access to medical resources, among others. Some scholars argue that the social gradient is a long standing constant. In this view, the mechanisms that tie wealth to mortality may change over time (for instance lack of sanitation and bad housing in the 19th century, smoking and bad habits in the 20th century). This association, however, stays the same and is reproduced at each period because innovations in health technologies systematically diffuse down the social spectrum. Others, however, have tried to pin down a birth date for health inequality, because they believe that the past three centuries witnessed a divergence-convergence pattern with the gradient rising and then declining (Haines and Ferrie, 2011). This second argument mirrors the Kuznets hypothesis for income inequality. It postulates that mortality inequality was small before the industrial revolution because income inequality and medical knowledge were limited. Then it rose with income inequality and access to better quality medicine for the wealthiest before diminishing again as public infrastructures with massive benefit for the poorest part of the society were developed on a large scale.

Empirically, scholars have established that the income gradient in mortality is probably far older than the industrial revolution and that it did not disappear with the large-scale development of public goods. Scholars have often taken these findings to imply a small socio-economic gradient in mortality, and moved on to examine the impact of locality. Environmental effects were put forward often as a simple rural-urban opposition (the "urban disamenity" effect) (Szreter and Mooney, 1998; Woods, 2003; Cain and Hong, 2009). A second approach has produced a more detailed account of living conditions (Brown, 1989; Cain and Rotella, 2001; Ferrie and Troesken, 2008). As a rule these studies argue for a much weaker link between mortality and wealth that was assumed before, in favor of a strong environmental effect on mortality. In fact, some recent research challenges the very existence of any causal relationship between income and mortality based on the huge diversity of local experiences: in some places the social gradient appears before industrialization, in other only long after its start (Bengtsson and van Poppel, 2011). Overall, they argue that higher social class, income, or wealth do not *per se* give a decisive edge in mortality. They argue the effect of wealth is contingent on the environment. Such studies, however, focus on settings where the variance in income is relatively small and the variance in the environment is relatively large. Our contribution focuses on a very specific environment (one of the largest cities in Europe) where the range of economic circumstances was particularly broad.

A long view of the issue reveals a remarkable pattern: before the 19th century, no one thought mortality and health were linked to income. For Catholics, for instance, one died when called by god and not merely because of material matters such as wealth or even living conditions. Then, for two centuries, it was taken for granted that income was one of the major determinants of mortality inequalities even though the precise mechanisms that made the poor live short lives were still unknown. And, again, in the last twenty or thirty years, social scientists, have repeatedly reduced the role of affluence on health and mortality to the point that it almost disappears. To be more precise, the gradient is still there, but the environment is now the leading explanation. Hence, scholarship has undergone a slow but full revolution starting with no wealth effect wealth on mortality then moving towards a strong effect only to arrive at no effect again. How can research escape these convolutions?

Our approach changes the point of observation. To begin it is important to acknowledge that the perception of mortality inequality is by itself an important social issue. Moreover the issue goes well beyond any problem of measurement, in particular, because it has consequences for sanitary policies. Hence the case of Paris: we have an excellent mortality data because social scientists, politics, urban planners, etc. were all concerned by the dramatic differences in mortality they observed (Chevallier, 2010). One issue that had more to do with perception than reality was the common belief that that the massive influx of immigrants made Paris worse off in particular because of the poor health status of the new arrivers (Chevalier, 1958). This idea has since been challenged (Ratcliffe and Piette, 2007).

Second, it should be acknowledged that there is no such thing as an unambiguous link between affluence (be it wealth or income or social status) and life expectancy. Public goods such as sanitation or water improvement do improve life expectancy. But the wealthiest most often benefit from health promoting innovation earlier than anyone else. In that case, it is somehow contradictory to explore socioeconomic inequalities in death as if causality only runs one way. It is better to admit that this relationship must be put in a broader context.

Life and death in Paris: the data

This article relies centrally upon data published by the statistical office of the city of Paris from 1880 to 1913. The city's administrative structure included twenty arrondissements that were each further subdivided into four *quartiers*--neighborhoods. The office's publication, the *Annuaire statistique de la ville de Paris,* provides a variety of relevant information for each of the eighty different 'quartier' of the city. Before 1880 the same data are available for city wide aggregates, after 1913, the reports are the district--*arrondissement* level. The city level data are useful only in so far as they allow us to place the capital in its long run and French context. The arrondissement data are crucial because they will allow us to study how life expectancy inequalities of the late 19^{th} century evolved during the interwar period.

Starting in 1817 the city began to publish death by age totals broken down by sex and by five year age intervals. Then in 1880 the *Annuaire* reports death totals for each sex, broken down into six age categories for each neighborhood.[2] The statistical office also published a series of detailed abstracts for the city drawn from the national censuses from 1882 to 1911 that give us the age distribution of the living for the same neighborhoods.[3] Taking these two data together allows us to compute life expectancy at the *quartier* level, which is an excellent measure of differential mortality.

One might want to compute life expectancy at birth. For Paris, at least, this would, however, present insurmountable problems because of underestimation of both deaths and population. One problem was Parisians' massive recourse to wet nurses who lived some distance from the capital until very late in the nineteenth century (Rollet-Echalier, 1982). Such wet nursing was associated with very severe mortality, but the deaths were not recorded in the capital, thus any computation of life expectancy in early years would suffer from massive undercounting

[2] These reports are drawn from the national system of death registration, so in principle one good run the data series backwards to 1860, the earlier Parisian records all burned in 1870.

[3] Since the French Revolution, censuses were performed every five years; they have been kept in the archives from 1836 on in most cases. Here we use data on censuses from 1881, 1886, 1891 and so on.

(Preston and Walle, 1974). Thus we prefer life expectancy at age five.[4] Even then because the age categories reports at the *quartier* level are not stable over time and do not necessarily accord between the *Annuaires* and the Censuses, we must make corrections. We proceed in three steps.

First, we adjust both mortality and population reports in order to obtain the number of deaths and the number of living for the same six age intervals: less than one year old; from one to four; five to nineteen; twenty to thirty-nine; forty to fifty-nine; and finally sixty or more years old. For each year we also have the report that breaks down death by gender and five year age groups for Paris as a whole. We use it to correct the coarser *quartier* level reports. Take for instance the death reports before 1893: instead of giving total deaths for 5-19; 20-39 and 40-59, the *Annuaire's* table uses the age intervals 5-14; 15-34; 35-59. So we estimate, from the detailed data for Paris as a whole, the share of deceased aged 15-19 among those aged 15-34. We apply this share to the groups defined at the *quartier* level to get the number of death between 15 and 19 years old. We add this number to total deaths in the age group 5-14 and subtract it from those in the age group 15-34. We proceed in the same way for the age groups 15-34 and 35-59.

Second, we estimate inter-census population for every year. The standard way to do so is to evaluate the change in population between census year by combining the effect of aging and net migration. If the population were closed, then a cohort based analysis would do (a new cohort is born each year, all other cohorts age by a year and lose some members to death). At the other extreme if migration rates are very high then it is the flow of new people in the city that matters. This is the case for Paris and we estimate the size of an age group between census years from the variation between census years at age (a). In other words the size of the population of age a in year t is an interpolation of the size of that group in the two adjoining censuses. Such a procedure neglect mortality shocks that in a given year might affect one age group rather than another more severely. Given the rather coarse nature of our data we could not try to capture the localization of such shocks without making heroic assumptions.

Third, we compute a life table for each year and neighborhood: to do so we calculate mortality rate (m) for each age group by dividing the number of death in the age group by the number of individuals living in that age group for each year and neighborhood. We can then produce death probabilities (q) where $q=n*m/(1+(n-a)*m)$ where n is the length of the age group and a is the time lived by deaths within this age group. This last value is taken from Keyfitz and Fliegler (1968:491) for individuals older than 5 and Coale and Demeny (1983) for ages 0-5 (but

[4] For comparability with the estate tax data (Piketty et al.'s data sets are censored to include only decedents twenty or older) we also compute life expectancy at 20. We also examine latter ages to limit the impact of migration.

we focus here on life expectancy after 5 years old). The step from death probabilities to mortality tables and life expectancy at each age is straightforward (Preston, Heuveline et al., 2001: 42-50).

Overall, we have tried to make the simplest assumptions in these computations to avoid biasing our results. When these assumptions matter, they do so in ways that tend to understate differential mortality. In particular, the time lived by those in the oldest group who die in a given year comes out to just under eight years which is perhaps too optimistic. More importantly it seems likely that this number varied across neighborhood: even among the old, mortality was probably more severe for the poor than for the rich. In this case we would be underestimating mortality in the poorer neighborhoods and as a consequence understating the actual mortality differential. The same goes for the way we calculate inter-census population: it is probably not true that migration affects all ages and neighborhoods in the same way. It is more likely that migration is more intense in the poorest neighborhood and that we underestimate the inter-census population of rich neighborhoods and increase their mortality. Yet it seems logical, at least to start, to make the same assumptions for all the neighborhoods so as to insure we do not produce differential mortality by construction. In the end, our computations probably understate mortality differences across neighborhoods, but the extent of the bias is limited. After all the life expectancies we compute for the census years (when we have the exact population) are very similar to those for inter-census years. Varying the average life span per interval or the maximal age in the life table has some impact on life expectancy but very little on differences among neighborhoods in the city.

Beyond these published data we have access to a series of cross section drawn from estate tax records that provide wealth, gender, and age for the entire population of decedents roughly once every five years from 1807 to 1937. To match the life expectancy by neighborhood one would want to have life expectancy by wealth fractile. We cannot, however compute such measures. Indeed we do not have an age distribution for the living that are in a given wealth fractile. In particular at the top end of the wealth distribution, one has to worry about endogeneity. Indeed the empirical age-wealth at death relationship is the result of both the impact of age on wealth (e.g passive capital gains on housing or inheritance), and of the impact of wealth on age (e.g. rich people can afford the resources to livelong). To be sure it is likely that wealth helps prolong life (thus distribution of ages for the top fractile is likely to be to the left of the age distribution of lower fractiles), that is the phenomenon we would like to capture. It is also true that at high levels of wealth, the older an individual lives, the larger the estate that person will leave behind, because of unrealized capital gains, because at high levels of wealth individuals have positive net savings rates, and because the likelihood that he or she will inherit from collateral lines increases with age. Because of the latter channel we cannot compute life expectancy by wealth fractile without more information that would allow us to estimate the joint distribution of wealth and age among the living. Thus we will simply present age at death by fractile.

Finally four real estate censuses (1876, 1890, 1900, and 1910) provide number of housing units as well as breakdowns of these units by their fiscal assessment. The data are reported by household (*ménage*) and break down rents into two dozen categories including two for those dwellings below the threshold of the *taxe mobilière* (a direct tax assessed on the basis of occupation and of the rental value of the household's dwelling). The largest category in 1890 included those 521 dwellings assessed at more than 16,000 francs in rent.[5] We define three categories of households: the poor are those who paid less than 300 francs a year in rent, the middle class paid between 300 and 1000 francs (per capita income in the 1890s for France was 600 francs, which puts the average income of households near 1,800 francs since there were about 3 Parisians per dwelling in each census), the rich paid more than a 1000 francs.

The halcyon days of the statistical office ended abruptly in 1913. Afterwards, and despite a massive increase in the city involvement in sanitation and other life preserving activities, it curtailed the details with which it reported the life outcomes of its inhabitants. After WWI the demographic data are only given by arrondissement, detailed reports from the census were no longer published, and all traces of further real estate censuses have vanished. Let us we focus on the period for which the more detailed data are available: 1880-1913.

Inequalities in time and space

Figure 2 below presents mortality trends across neighborhoods (*quartiers*) within Paris compared with the average life expectancy for Paris (the black line) and for France (in red). The figure also shows the life expectancy for the best eight (in orange) and worst eight neighborhoods (in green) in Paris. In the light of the variation within Paris the difference between the average life expectancy in Paris and France no longer seems so large. In fact life expectancy in the worst neighborhoods in Paris was always about eight year less than the average in the city and 10 to 12 years less than France as a whole. In the twentieth arrondissement, for example, life expectancy did increase but the change barely matched that of France and its relative gap did not change. At the other end of the spectrum, in the early 1880s the best neighborhoods in Paris had a seven year advantage over the rest of the city and a four year advantage over the rest of France. Over

[5] With per capita income below 600 francs in that year (Bourguignon and Levy Leboyer 1990), such rents would correspond to housing units with rentals values of 1 million dollars or more in the U.S. and 650,000 Euros or more in France.

the next three decades life expectancy in the best *quartiers* rose quickly and neared 64 years; over that time these neighborhoods saw their differences with all other benchmarks increase

[Figure 2 about here]

The inequality in life expectancy within Paris is particularly striking because it is in fact much larger than the difference observed across departments.[6] As Figure 3 shows, the gap between the nine departments with the highest and lowest life expectancy was about 12 years in the 1880s; by 1910 it had shrunk to seven. Most of the gain came from the worst departments who experienced large (6 years) gains in life expectancy while the best departments only eked out a gain of about 1 year. The pattern of rough stability at the top and big gains at the bottom is the reverse of Paris, where the bottom managed at best a three year gain in life expectancy when the top gained six. As a result, the worst departments, which started out with higher life expectancy than the worst neighborhoods in Paris pulled away with a difference that jumped from about two years to almost seven. At the top the Parisian neighborhoods with the lowest mortality experienced enough gains that they become the healthiest areas of France. The relatively poor performance of Paris's worst neighborhoods is not for lack of economic or urban growth. Indeed France, despite a difficult decade in the 1880s due to low agricultural prices, grew steadily up to World War I and Paris was a major beneficiary. The capital's share of France's population and wealth was at an all time high in 1913. Unlike for France as a whole, economic growth did not readily translate into a reduction of life expectancy inequality in Paris.

[Figure 3 about here]

This is not simply an effect of picking tiny populations with unusual life circumstances. Even as early as the 1870s each rich neighborhood had at least 20,000 inhabitants and the denizens of largest of the poor ones numbered above 35,000. The massive range of life expectancy instead comes from deep difference in the material circumstances of the residents of these neighborhoods.

Mortality and wealth

The real estate census of 1876 provides a striking image of the city's inequality (Figure 4). The rich comprised less than 10% of households. The poor (who paid little or no direct taxes) made up 68% of households. These different classes lived in different places. Twelve neighborhoods (principally in the eastern edge of the city) had more than 90% of their households paying less than 300 francs in rent, and in these neighborhoods less than 0.7% of

[6] Life expectancy by départements are taken from (Bonneuil, 1997).

households were rich. In contrast five neighborhoods (all in the northeast) had more than 40% of households that were rich, and in most of those the share poor was less than half that of the city. Average rents reflected these contrasts and had been noted at the time. Rents in the Champs Elysées neighborhood averaged 3,200 francs nearly twenty times the 179 francs of the rents in Charonne. In our twelve poor neighborhoods rents average 186 francs while in the five rich ones it was 2,204 francs. This better than ten to one difference in rents in part reflects the massive differences in the quality of the housing units from the size of apartments (the census provides the distribution of apartments by number of rooms) to amenities like running water, toilets within the apartment rather than in the hallway or on the ground floor, in air quality (prevailing winds being from the west, the east end of Paris was more polluted than the west) but it is also likely that there were pure location rents, indeed the high rent districts are clustered around the financial center (the Bourse) and its political counterpart (the Elysée). It is also not surprising that life expectancy for the happy few in the west was almost 8 years longer than in the poor neighborhoods in the east.

[Figure 4 about here]

To evaluate the role of wealth or income we proceed in two steps. First we explore links between mortality and wealth within neighborhood. To do so we use a panel regression with four observations that link housing census with its nearest mortality year (1876 wealth with 1880 mortality, 1890 wealth with 1890 mortality and so on). Because we only have four housing surveys our panel has four cross sections for a total of 320 observations (see Table 1). The advantage of this approach is that it allows us to include fixed effects that absorb any constant characteristics of the neighborhood (hence the estimates are based on the within neighborhood change over time). Those regressions show that changes in a neighborhood' share of poor were strongly associated with changes in mortality: a decrease of one standard deviation of the share of poor increases life expectancy by about three years (both share of poor and share of rich are standardized and thus the coefficients can be directly expressed as variations in life expectancy, the constant measuring the life expectancy at the average value of the share of poor). Increases in the share of rich were also good for life expectancy and the implied elasticity is actually slightly larger, with a one standard deviation change leading to more than four years of additional life expectancy. If we include both variables the coefficient of the share of rich declines dramatically and becomes statistically insignificant, but the coefficient on share poor is essentially unchanged.

[Table 1 about here]

An alternative approach is to focus on the cross sectional variation and estimate the impact of the share of poor across neighborhoods at each census date. Figure 5 shows the fitted values for regressions we do not report. The first set for 1881 shows a negative association between life expectancy and the share of poor, then with each decade the relationship steepens, in part because of increased in life expectancy in those neighborhoods where the poor were relatively rare. The second cause of the growing sensitivity of life expectancy to the share of poor is that the fraction of poor tended to decline everywhere even though their mortality patterns did not change much. The curve for 1911 is in fact the steepest, consistent with an increase in differential mortality as was suggested by Figure 2. We can reproduce these results with the average rent paid in each neighborhood but extend the data to 7 cross sections (Table 1 B). Again the coefficient on rents paid increase from 1881 to 1896 and then declines so that in 1910 it is the same as it was in 1880 (2.5). At the same time the constant term increases steadily over time from 49 to 53.4 years in 1910 a gain of almost 10%. It is as if the relationship between income and life expectancy had changed over time. As we shall see in the next section, this change is connected with the diffusion of sanitation.

[Table 1B about here]

[Figure 5 about here]

To net out the effect of a decline in the share poor we re-ran the regression from Figure 5 but instead of using the contemporaneous survey, we used only the first census for the explanatory variable (see Figure 6). Again, the 1881 share of poor implies a life expectancy ranges from 45 to 54 years old in 1881. The 1891 curve shows both an increase in life expectancy everywhere and a steeper slope suggesting that part of the increase in life expectancy in 1891 was associated with a decline in the share of poor. The 1901 data is even steeper suggesting that while things continued to improve in the richer neighborhoods, they had deteriorated in the poorer ones. 1911 is then flatter and higher with the richest neighborhoods (as defined in 1876) having gained almost 7 years in life span since 1881 while the poorest ones had a gain of about 3 years or less than half. The timing of both increases is very different though: life expectancy in the wealthiest neighborhoods' rises from 1881 to 1901 but does not change much from 1901 to 1911. In the poorest ones the gain comes almost completely after 1901.

[Figure 6 about here]

Life expectancy in Paris was very unequal, differences between neighborhood being both strong (and stronger than in France as a whole) and closely related to income. Further the evolution of mortality up to WWI involves an increase –and not a decrease– in inequality despite the general rise in incomes. This is not because the poor were dying younger (as seems to have been the case in the first half of the nineteenth century) but because the rich were making much more rapid gains in life span than the poor. The analysis has one clear limitation however, which is that it does stay at the neighborhood level. This may be a problem because people move between neighborhoods and thus experience different mortality patterns (and people chose where to stay at least in part because of the living conditions in a given neighborhood). And at the same time this analysis does not try to link individual's wealth to their mortality.

A way to overcome this limitation is to use individual data. We do have an exceptional dataset that gives wealth at death (Piketty, Postel-Vinay et al., 2006; Piketty, Postel-Vinay et al., 2011). These estate tax data give both demographic and wealth information for all wealthy Parisian decedents every five years. A first piece of information they provide is the address of wealthy individuals. We have extracted all individuals who died with at least 125,000 francs (which would have produced an income of about 6000 francs, enabling them to afford the housing of the rich). This is an important point because if wealthy people can be found all over Paris, then big neighborhood difference in rents would present a puzzle. In fact, the residential patterns of the wealthiest Parisians are very similar to the wealth pattern given by tax records and the real estate census (see Table 2). And it reveals very high residential sorting: between a quarter and half of the wealthiest lived in the 8th arrondissement alone. More surprisingly, even among the wealthiest, sorting is most intense at the top of the distribution, as the less wealthy people tended to live in adjacent neighborhoods.

[Table 2 about here]

The same data allow us to study mortality at the individual level. Unfortunately no source gives us the same data for the living and, as a result, we can only present age at death by fractile (see table 3). Again, it should be noted that this indicator is certainly biased because we observe wealth only at death; it nonetheless confirms the results we have seen in the previous section, age at death being inversely related to wealth. And again the cross-sectional patterns are incredibly strong, with the differences in age at death between the wealthiest (the top 2% among the deceased of a given year) and the poorest (the 92% poorest among Parisians) being over 17 years. Unlike in the previous data, however we do not see a process of divergence and convergence. Instead the pattern is stable over time, the difference being roughly the same in 1872 and forty years later on the eve of WWI. As we noted, however, age at death data is not life expectancy because it does not control for changes in the at risk population.

[Table 3 about here]

Do public goods make things better… or worse?

Clearly then, the relationship between income and life expectancy changed over time in ways that suggest income became more valuable with a peak around 1896. Our hypothesis is that difference is driven by the spatial diffusion of sanitation and in this period by the more rapid adoption of direction to sewers in rich neighborhoods. In 1901 the same 5 rich (high rent) *quartiers* has a connection rate of at least 54% (and 62% on average) while the 12 poorest *quartiers* had at most 39% of their buildings hooked up to the sewers (and 27% on average). Because sewer connection is a decision made by building owners only when a sewer runs down their street, and only when the residents are willing to pay an additional rent that is sufficient to cover the cost of installation, a little theory seems in order.

Consider Parisian households to have Cobb-Douglas utility functions with housing having a coefficient α. Thus each household devotes αY of its income to housing, a differentiated product (some apartments are large, some small, some have running water…). In each period one can imagine that the city's landowners run a sequence of second price auctions to determine the rent and tenant for each home. The highest income household gets the best apartment (at the second richest person's willingness to pay) and the poorest one gets the worst one for free (or at what an immigrant would pay for it). Now suppose sewers become available, and assume that they are just taken as another, positive, characteristic of housing. Those housing units which are connected to the sewers are more desirable than those without and thus the ranking of housing will be rearranged holding everything else constant such that a unit of housing commands a higher price than a unit without it *even* if sewers did not increase the budget share going to housing. A variant of this model would allow sewers to increase housing's budget share. In this case, sewers will appear to be a luxury good with the rich willing to pay more for having their apartments connected to sewers.

Now let us turn to building owners, and we must do so because of the way real estate was owned prior to WWI. Indeed the 757,000 housing units in Paris were divided among 137,000 buildings. Since each building had at most one owner, at the very least 82% of the households were renters, and the proportion was no doubt higher given that some of the buildings in poor neighborhoods were owned by individuals who were renters in nicer ones and that, if the estate tax data are any indication, the very rich owned multiple buildings. Thus the decision to connect to the sewer had to be made by landlords who wanted to maximize rental income. At 30 or 60 francs per connected pipe, it was quite a costly investment—by some account doubling the costs to owners relative to the traditional septic devices. Consider first the reaction of building owners if the budget share that household devote to housing does not change with the advent of sewers. In this case, competition will drive adoption but only for those building that can attract individuals who value the improvement enough. The improvement has to allow the owner to attract sufficiently better bidders, and thus the incentive to adopt had to be low for the owners of 68% of the housing that was below the taxable threshold. Moreover with fixed budget shares aggregate rental payments do not change (so what is gained by one apartment must be lost by another). On the other hand, if housing's budget share expands when sewers are available, then building owners have an aggregate surplus to capture. Yet, even in this case, sewers would be in higher demand in rich than in poor neighborhoods. Thus, real estate owners would be quite likely to resist any mandatory program in either case. An indeed, landlords were publicly opposed to any legal requirement that they connect their buildings to the sewer. They waged a long judicial and political battle to delay the passage and implementation of the 1894 ordinance (Jacquemet, 1979). Owners of buildings in the Champs Elysées neighborhood did adopt the new technology with great alacrity, because doing so would lead tenants to bid up the value of their rents by more than the cost of doing so. In poorer neighborhoods, tenants would still desire the improvements but, with a smaller budget, they could only offer much smaller increases in rent to landlords—not enough to induce them to retrofit buildings.

Now we can step back to the problem faced by city planners. Suppose for an instant that they want to maximize the diffusion of sewers because they know that water borne diseases are a major contributor to the city's mortality, and that mortality is particularly high in poor neighborhoods. On the financial side, they can borrow to finance the construction of the infrastructure but only at a rate that is consistent with the revenues from user charges –these must cover interest and maintenance. In this case, it makes sense to price discriminate and charge high rent buildings more than low rent buildings and use the proceeds to expand the network. This is precisely the mechanism used by the city with variations over time. In 1888 the scheme involved a 30 or 60 franc fee per connected pipe but by the end of the century, a more complexe scheme was in place: the charge was still proportionate to property taxes, but it varied from 10 to 1500 francs annually, in 12 groups (Préfecture de la Seine, 1899: 9). Capturing the rents available from expensive housing units would thus be a priority and the system would expand there first. Second when seeking to improve matters for the poor, it was efficient to serve those poor neighborhoods that were closer to the main sewer line (the *collecteur d'Asnieres*) simply because it would be cheaper to do so. Overall, however, it did have a drawback: diffusion was slow because there were relatively few rich housing units available to subsidize the vast number of housing units rented by the poor (in Paris as a whole, housing units with rents bellow 300 francs outnumber those with rents at 1000 francs or more almost five to one). It was also slow due to the hostility of building owners and the political obstacles the city encountered in enforcing the 1894 ordinance (Jacquemet, 1979).

The rational and systematic approach to connecting apartments to sewers used in 19th century Paris complicates the analysis, because it connects cleanliness to income in ways that force us to consider several alternative hypotheses. The first is that the diffusion of sewers is a statistic for income gains and in other words such forms of sanitation have few direct benefits. The second is more subtle, it proposes that the diffusion of sewers actually increase residential sorting, with the richer neighborhoods attracting even more of the city relatively healthy middle class. Finally, a more historical approach might well suggest that there were a host of other life improving new technologies, and that a naïve regression will overstate the impact of sewers on life expectancy.

We can dispense with the first two with relatively simple tests. Given the steep life-expectancy rent profile in evidence in 1880, before any buildings were connected directly to the sewers, one might imagine that even limited changes in income might have big effects on life expectancy. To our mind, hypothesis 1 is simply that the relationship between income and mortality risk is constant. This allows us to ask, what would life expectancy have been in 1900 and 1910 if the rent to life expectancy link had been constant? We simply apply the coefficients of the 1880 regression to the rent distribution in late years (see Figure 7). When we do so, we find systematic errors across the range of rents in 1900 and 1910. And the errors are nearly all one way, realized life expectancy was significantly higher than what was predicted and the gap is increasing in rent. One cannot blame inflation or other shocks since this was a period of limited price changes and of increasing prosperity –it seems longer life had become cheaper to buy.

[Figure 7 about here]

The second hypothesis which would explain the rise in the life expectancy of the rich neighborhoods by increasing residential sorting (and then we might conceivably extend the argument to consider that Paris attracted better immigrants after sewers had been put in place). Operationally, the hypothesis suggests that the early adopting neighborhoods had small life expectancy advantages from sewers and huge gains from replacing their less healthy poorer inhabitants with healthier and more productive in-migrants from neighborhoods where the sewers are not available. If this effect was large we would expect to see rent and life expectancy declines in neighborhoods that were not served due to adverse selection. But, there is no evidence that any neighborhood experienced important mortality increases—due to adverse residential sorting or any other cause. Instead it seems the diffusion of sewers was Pareto optimal, although it made only some neighborhoods better off, none were worse off.

Let us now look at sewers directly and start with some naïve estimations that only intend to document that the diffusion of sewers is nicely coincident with, first, the increase in life expectancy in rich neighborhoods and, second, the catch up of poorer ones. Table 5 below reports simple regressions of the life expectancy on the fraction of buildings connected to the sewers. The data set includes one observation per neighborhood per census year (1881, 1886,…1911). Sewers seem to have a significant benefits contributing about 2 years of life expectancy. The result is robust to both splitting the sample between the center (where relatively little new construction took place and thus connection involved retrofitting buildings) and the periphery (where new construction drove connection) and to including fixed effects for each neighborhood. In 1891 and in 1901, the 8th and 9th districts had twice as many of their buildings connected (13% and then 55%) to the sewers than the 19th and 20th. The timing of sewer connection is thus consistent with a widening of the gap in life expectancy. Then by 1910 while the richer arrondissements powered to a 77% connection rate, the 19th and 20th reached 54%; they had begun to close the gap; by 1928 the 8 and 9th were above 90% but the 19th and 20th were close at 81% or more.

These results might cause concern because it is clear both from principles and from the spatial pattern of diffusion that sewer adoption is related to income. Moreover even if sewer adoption is not a proxy for income growth, there is a real endogeneity issue. To disentangle income from sewers we need instruments, something that would be correlated with a neighborhood's income but not its sewer adoption rate or vice versa. We propose two instruments. First the fraction of buildings with running water in 1891—just before the passage of mandatory connection. This might be a plausible instrument since buildings with running water were likely to have installed waste water pipes and thus the cost of connecting to the sewer (and complying with the 1894 ordinance) was lower than were a complete retrofit was required. Whatever the building's residents' income, landlords should have been more willing to connect to the sewer if they had provided running water. Of course, this instrument raises the question of why building owners invested in providing running water and it is not time varying, which implies it is likely correlated with the 'permanent' income of the neighborhood.

Our second instrument involves the cumulated building permits starting in 1880 and interacted with location. We divide Paris into two parts the old 'center' and new 'periphery. By 1880 the center, composed of districts 1 to 11, had a very stable population (about 1.2 million in

1881 and 1906) and an equally stable stock of buildings. In the center the ratio of building permits issued between 1882 and 1906 and the stock of buildings in 1906 is 0.16 and the stock of building in 1889 was 85% of the stock of 1906. In contrast in periphery (arrondissements 12 to 20), above population grew by 50% from 1881 to 1906 and much of the construction occurred after the sewers were put in. The ratio of building permits issued between 1882 and 1906 and the stock of buildings in 1906 is 0.31 and the stock of building in 1889 was 67% of the stock of 1906. While that construction was of much better quality than was there before (rents increased much more on the periphery than in the center) the growth of the stock is clearly related to the growth of the city overall and not nearly so much to rents. In fact the correlation between rents in 1876 and 1900 with the ration of building permits to total buildings is negative overall. More importantly it is very close to zero (-0.03, and 0.06) for the exterior arrondissements. Because building permits vary over time we can afford to include fixed effects in the regression when we use it as an instrument.

We present two sets of regression results that vary because of difference in sample size implied by our rent proxy. We can use average rents as detailed in the rent censuses, these have the advantages that they cover every household, but the disadvantage that they are limited to two cross sections (1901 and 1910). The alternative is to use the rent per fiscal household, as reported in the tax data. These data are censored because households who paid less than 500 were not subject to the tax and are thus not counted in either total rent or households. Nevertheless the correlation between average rent computed from the censuses of housing ranges between 0.93 and 0.97. At our level of precision both sources are equivalent, thus we prefer the larger sample. The two stage least square regressions are reported in tables 8 and 9.

The first regression in Table 8, which is based on real estate census rents and uses running water as an instrument, produces a very large effect from the sewers and nearly no effect from income. What makes this regression suspect is that in the absence of fixed effects one would expect income to matter. Indeed neighborhoods had been different in terms of their incomes long before either running water or sewers diffused. It also produces an effect of the sewer connection rate on life expectancy of six years that is larger than even the naïve regressions. This leads us to have serious concerns about the instrument despite its apparent plausibility. The second regression using building permits, produces more sensible results, and it seems that the rent index is absorbed by the fixed effects (this is not surprising since the correlation between rents in 1901 and 1910 is 0.99). What is more interesting, is that just as our discussion of our instrument had suggested, it has power only in the periphery of Paris (the first stage regression is meaningful) and the magnitude of the estimated effect is reasonable. When we include both instruments and loose the fixed effects, rent becomes statistically significant again.

[TABLE 8 ABOUT HERE]

Clearly we need more variation over time to disentangle these effects, and that is just what Table 9, reports where we use a panel with five observations per neighborhood (1891, 1896, 1901, 1906, 1910). Here it is clear that the share of buildings with running water in 1891 is a poor instrument. Hence our preferred specification involves using cumulative building permits and fixed effect (the middle columns of the table). If we take in all of Paris we get a sensible impact of an additional year's life from connecting to the sewer but we cannot identify income. We then break Paris into its two components. In the center the sewer connection rate continues to offer about a year's life but income becomes utterly irrelevant—something that we find implausible. Only in the periphery, as we had hoped, do we get a clean identification of both sewer and income effects.

[TABLE 9 ABOUT HERE]

Table 10 reports the second stage of regressions using building permits as instruments for sewers with the dependent variable being life expectancy at age 5 (as in Table 9), 20, 40 and 60. We do not report the first stage again since it does not vary by age and is already reported in table 9. Again the most useful regressions involve the periphery and they gives about a one year increase in life expectancy irrespective of age except for the oldest group. For life expectancy at age 60 the periphery produces no statistically significant results. On the one hand the stability of the results across different definitions of life expectancy suggests that the gains are unlikely to be driven by migration into Paris, since this was largely a phenomenon of early adulthood (though that leaves internal residential sorting to be considered). On the other hand we do not get the kind of decline in pay-off as groups get older that we did in Table 6.

[TABLE 10 ABOUT HERE]

If we take the estimates from Table 10 and then apply them to Paris they offer an explanation of the divergence followed by convergence of life expectancy in the city. The residents of five high income neighborhoods we began with had long benefited from that status but in the in the 1890s and early 1900s they got an additional boost by their early adoption of sewers. In contrast our twelve poor neighborhoods had to wait until 1927 to reach the level of sewer connection that the rich eight had achieved by 1906.

Conclusion

To disentangle the effect of income and infrastructure on life expectancy we have examined the pace at which the built environment changed in Paris between 1870 and 1913. Building permits on the periphery provide a good instrument for the rate at which buildings connected to the sewers that is not correlated to income or rents. Yet more remains to be done by exploiting variation in the impact of sewers on different diseases or groups of individuals. Paris offers more opportunities for research because the civil death registration data are now on line.

In thinking about differential mortality, scholars tend to privilege one or two elements: income and location. For instance the rich individuals live longer because they can afford to devote significant resources to life enhancing activities –better and more food, private health care, cleaner clothes, isolation from the sick and so on. Similarly, tropical areas have high mortality because the disease environment is severe. When thinking about increasing life span, one tends to contrast private consumption (of food or medicine) with public goods like sanitation and cleanliness which are assumed to benefit everyone.

Historically, however, it is important to take sanitation and many other investments that prolong life, for what they are network goods that involve some use charge. Doing so in the case of Paris shows that despite both high income growth and a rapid diffusion of infrastructure life span remained massively unequal on the eve of World War One. There were two reasons: first the gains in income were concentrated at the top, second the non-trivial user charges on sanitation also concentrated benefits towards the top. In sewers, as in many other things, the trickle down is slow.

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Figure 1 Life expectancy at age 5, Paris and France, 1860-1939.

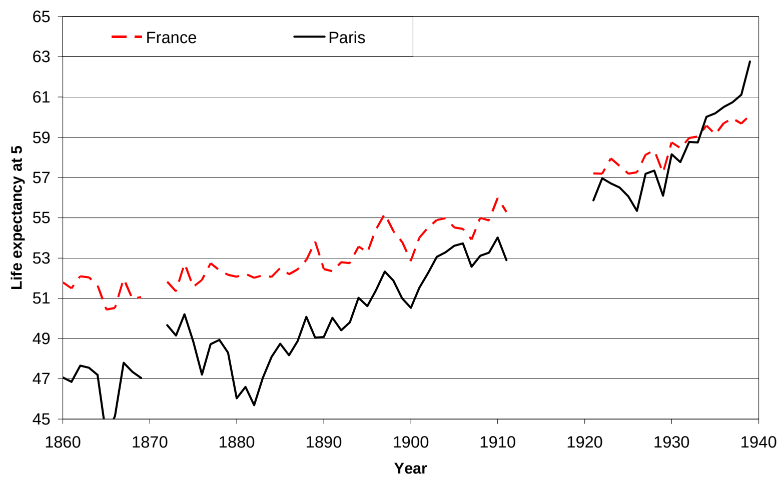


Figure 2 Life expectancy at age 5 within Paris, compared to France

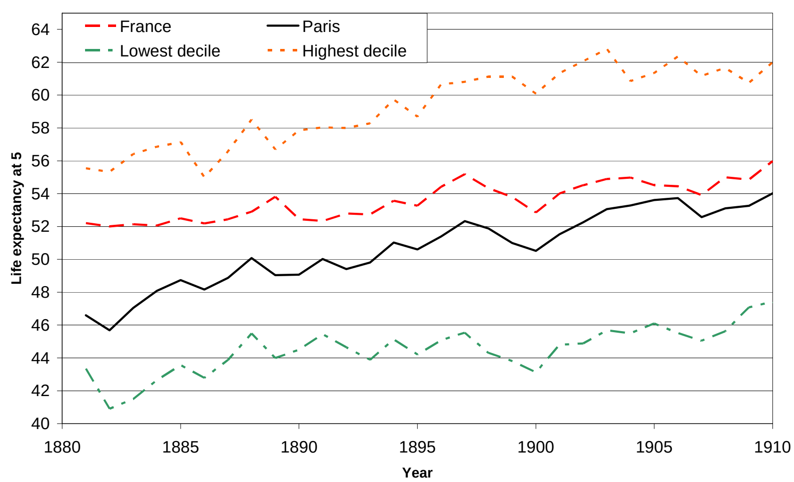


Figure 3 Life expectancy at age 5 within Paris and within France

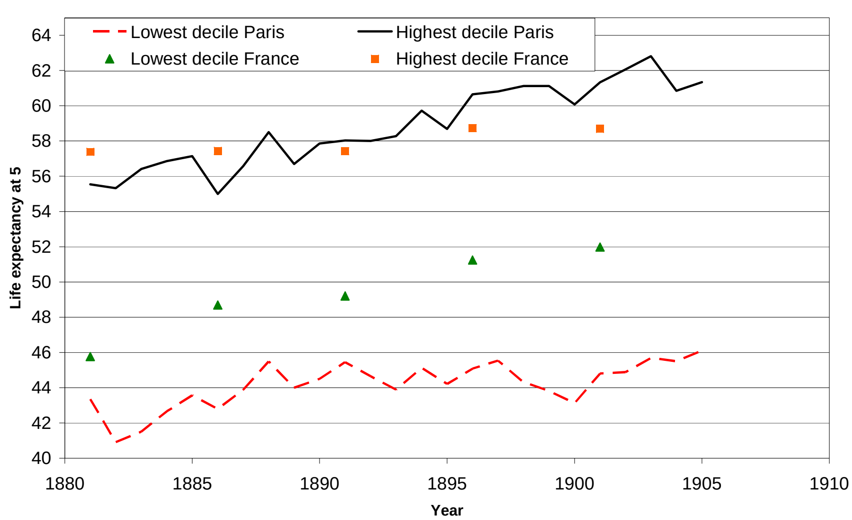


Figure 4 Average rents by quartier in Paris, 1876

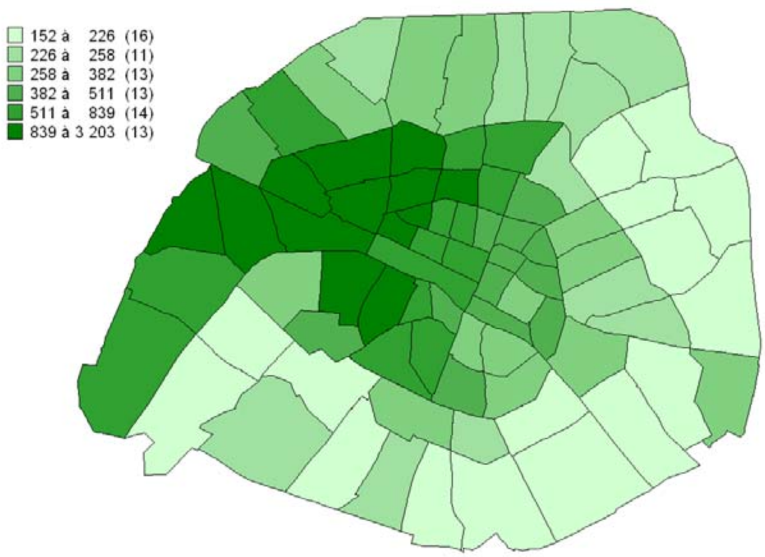


Figure 5 Life expectancy and the share of poor households

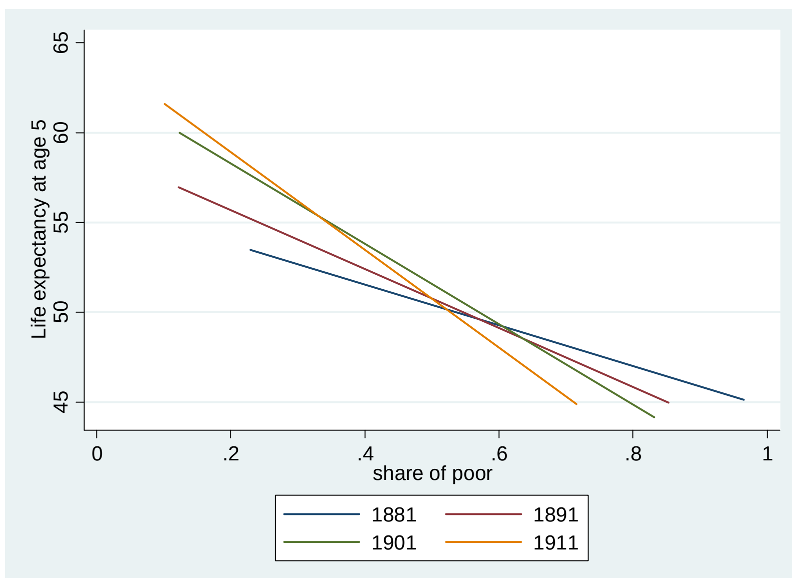


Figure 6 Life expectancy and the share of poor in 1876

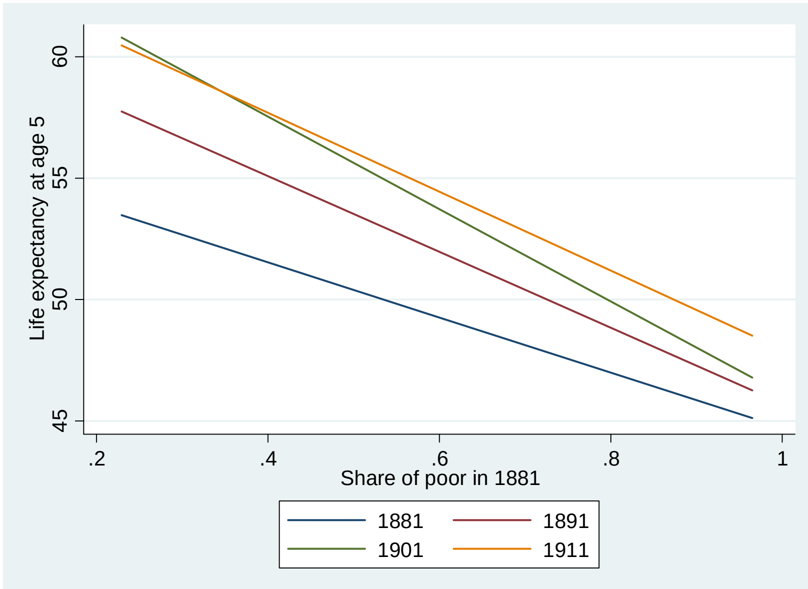
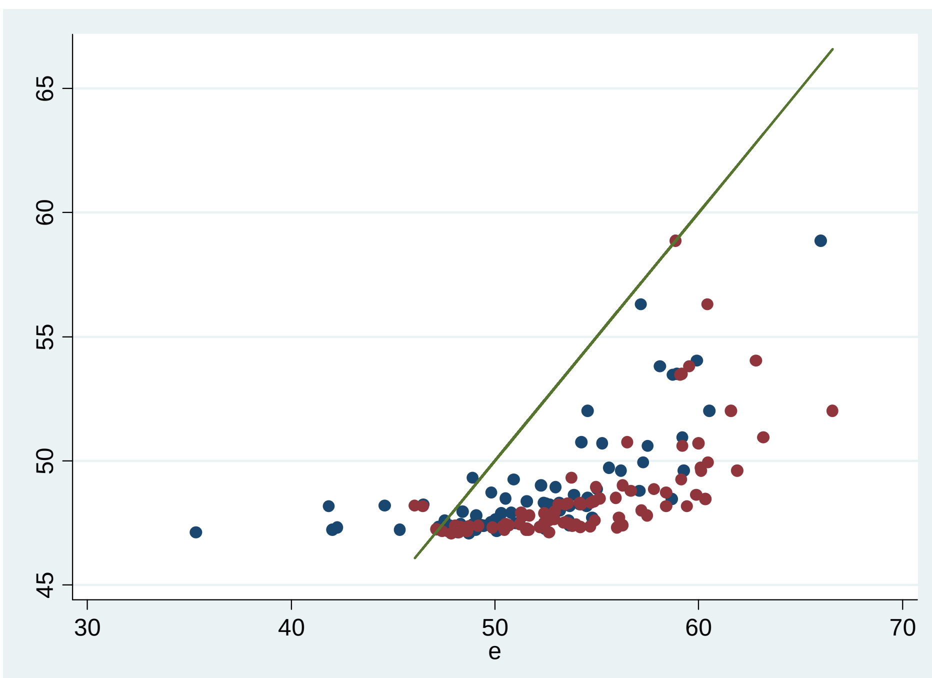


Figure 7: life expectancy in 1910 as predicted by the 1880 rent-life expectancy relationship



Life expectancy predicted by the coefficients from a regression of life expectancy in 1880 on rents in 1878 as applied to rents in 1900 (blue) and in 1910 (red) to obtain a predicted life expectancy in 1900 and 1910. The predicted values lie on the horizontal axis and the empirical values on the vertical axis. The green line is what we should see if the regression was perfect.

Table 1 Mortality, the Rich and the Poor

Dependent variable is life expectancy at age 5			
Share of poor	-3.08***		-2.94***
(S.E.)	0.24		0.27
Share of rich		4.15***	0.706
(S.E.)		0.714	0.671
Constant	51.51	51.51	51.51
(S.E.)	0.130	0.157	0.157
R^2	0.59	0.53	
Fixed effects for Quartier	Yes	Yes	Yes
N	320	320	320

Table 1B Cross section regressions of Life Expectancy on Rents

	Life Expectancy 1881			Life Expectancy 1886			Life Expectancy 1891
Rents 1881	2.44 (0.388)		Rents 1886	2.77 (0.320)		Rents 1891	3.53 (0.318)
Constant	49.0 (0.332)		Constant	48.2 (0.292)		Constant	51.3 (0.270)
	Life Expectancy 1896			Life Expectancy 1901			Life Expectancy 1906
Rents 1896	3.75 (0.409)		Rents 1901	3.22 (0.340)		Rents 1906	3.19 (0.348)
Constant	52.2 (0.366)		Constant	52.6 (0.387)		Constant	53.3 (0.389)
	Life Expectancy 1911						
Rents 1911	2.45 (0.331)						
Constant	53.4 (0.383)						
Note: the coefficients reported come from seven different linear regressions with 80 observations each. The R^2 varies between .33 and .61							

Table 2 : Place of residence of wealthy individuals according to their asset at death (1872-1912) compared with rental value of dwelling in 1876 and 1910

	Rental value of Properties (R) In Francs		Wealth from Estate tax (W) In Million Francs					Rental value of Properties (R) In Francs	
Arrondissment	R> 6000	R> 7000 F	W> 4	4>W> 1	1>W> 0.5	0.5>W> 0.25	0.25>W >0.125	1000>R >5999	1300>R > 6999
	1876	1910						1876	1910
1	7.7	0.6	3.1	2.8	4.3	2.7	2.8	7.7	3.7
2	3.6	1.1	0	3.2	1.8	1.7	2.2	7.5	1.9
3	0.3	0.2	0	0.9	1.7	1.9	2.3	5.6	2.0
4	0.4	0.3	0	2.8	3.3	4.1	4.7	4.5	2.3
5	0.3	0.4	0	1.8	2.5	4.9	4.6	4.3	3.3
6	2.5	1.6	0	4	7.9	7	6.6	8.6	6.9
7	13.6	12.3	13.5	11.3	8.6	6.8	7.2	6.3	8.7
8	51.3	37.7	52.1	36.5	22.7	19.3	12.5	16.1	16.0
9	18.4	5.1	12.5	13.4	15.6	14.7	12.3	22.6	12.0
10	1.3	0.7	0	3.2	5.8	6.7	6.1	11.3	4.6
11	0.2	0.1	0	1.9	3.2	5.5	6.4	4.0	2.2
12	0.1	0.1	0	0.9	0.8	1.7	3.2	1.0	1.6
13	0.1	0.2	1	0.6	0.6	0.9	1.1	0.4	0.3
14	0.1	0.3	0	0.2	0.7	4.4	2.5	0.6	1.7
15	0.1	0.2	0	0.5	1.4	1.3	2.6	0.6	1.8
16	8.6	29.0	13.5	11.9	11.1	10.3	9.6	5.5	17.1
17	2.3	8.2	2.1	2.6	5.2	5.1	6.2	4.6	12.6
18	0.0	0.1	1	1	1.4	2	2.4	1.0	1.0
19	0.0	0.1	0	0.4	0.5	1.2	2.5	0.5	0.3
20	0.1	0.0	0	0.1	0.7	0.9	2.2	0.2	0.2
N	4,929	6,935	97	850	1040	1455	2091	35,879	65,838

Table 3 Age at death according to wealth at death

	1872	1877	1882	1887	1902	1912
top 2%	65.0	66.2	66.1	67.3	67.3	68.4
next 4%	61.2	62.5	62.5	63.1	63.6	65.6
next 8%	56.4	57.1	55.3	58.0	58.0	58.3
Rest	48.0	49.8	47.9	49.6	52.0	52.9
Av age	49.5	51.2	49.5	51.2	53.2	54.2
Total deaths	24348	28777	36790	34410	36366	36681
N with age and wealth	15576	18597	24831	20860	26624	29323

Note: the estate tax sample are comprised of all the individuals who died in a given year (e.g. 1872) and filed a return within 30 months of January 1 of that year; not all individuals with tax data have an age, we accordingly trim the population of no wealth individuals by the same proportion

Table 5 Life expectancy and the diffusion of sewers

	Dependent Variable Life Expectancy-Age 5											
	All	Center	Peri-phery	All	Center	Peri-phery	All	Center	Peri-phery	All	Center	Peri-phery
SCR	**2.047** **(0.10)**	**1.67** **(0.12)**	**2.15** **(0.15)**	**1.27** **(0.47)**	**1.67** **(0.12)**	**1.51** **(0.07)**	**3.45** **(0.38)**	**3.64** **(0.48)**	**2.68** **(0.52)**	**1.93** **(0.17)**	**1.85** **(0.24)**	**2.11** **(0.25)**
SCR (25<>50)							**-2.85** **(0.51)**	**-2.17** **(0.64)**	**-1.91** **(0.68)**	**-1.08** **(0.24)**	**-0.98** **(0.38)**	**-1.27** **(0.33)**
SCR (50<>75)							**-3.73** **(0.81)**	**-5.10** **(1.03)**	-1.59 (1.09)	**-1.33** **(0.37)**	**-1.58** **(0.51)**	*-1.06* *(0.53)*
SCR (>75)							-1.85 (1.17)	*-3.52* *(1.44)*	0.92 (0.56)	**-2.01** **(0.53)**	**-2.15** **(0.70)**	*-1.84* *(0.81)*
Constant	**52.46** **(0.10)**	**53.99** **(0.12)**	**50.64** **(0.14)**	**53.8** **(0.41)**	**53.9** **(0.12)**	**53.81** **(0.41)**	**54.07** **(0.37)**	**56.01** **(0.37)**	**51.43** **(0.5)**	**54.1** **(0.43)**	**54.49** **(0.44)**	**50.01** **(0.48)**
N	1680	924	756	1680	924	756	1680	924	756	1680	924	756
FE-Neighborhood				Y	Y	Y				Y	Y	Y
Adj-R^2	0.18	0.16	0.21	0.84	0.82	0.82	0.22	0.20	0.21	0.84	0.82	0.82

Note: the independent variables are the sewer connection rate (SCR) and then the same variables interacted with a dummy if SCR is within a given range. SCR (50<>75) is zero for any connection rate less than 50% and more than 75% and it takes on the value of SCR within that range. Thus the impact of the sewer connection rate comes from the sum the coefficient of SCR and the one for the relevant range. Bold coefficients are significant at the 1% level, italics at the 5% level.

Table 6

Life expectancy by arrondissement				
	Age 5	Age 20	Age 40	Age 60
SCR No FE	**3.17** **(0.11)**	**2.26** **(0.11)**	**1.90** **(0.07)**	**0.68** **(0.04)**
Constant	**52.9** **(0.11)**	**41.3** **(0.11)**	**26.3** **(0.07)**	**13.8** **(0.41)**
SCR Location FE	**2.77** **(0.058)**	**1.89** **(0.052)**	**1.65** **(0.041)**	**0.57** **(0.02)**
Constant	**54.32** **(0.26)**	**43.2** **(0.23)**	**27.35** **(0.18)**	**14.4** **(0.12)**
SCR Location FE Year FE	**1.70** **(0.30)**	**1.32** **(0.27)**	0.62 (3.02)	0.25 (0.17)
Constant	**52.6** **(0.42)**	**42.8** **(0.38)**	**25.9** **(0.29)**	**14.35** **(0.25)**

Note: The table reports 2 coeffcients for 12 separate regressions of life expectancy by age on the sewer connection rate. Each regression is based on 33 years X 20 arrondissement or 660 observations. Bold coefficients are significant at the 1% level.

Table 8 I.V. regressions Panel A: pooled 1901 and 1910 observations with rent

First stage endogenous variable: Sewer Connection Rate (SCR)							
	Neighborhoods included						
	All	**All**	Center (1-11)	Periphery (12-20)	All	Center	Periphery (12-20)
Rent index	**0.28 (0.05)**	0.21 (0.87)	-1.22 (1.53)	1.30 (0.93)	**0.28 (0.05)**	**0.24 (0.06)**	**0.33 (0.10)**
Running water in 1891	**0.14 (0.05)**				0.23 (0.06)	0.13 (0.15)	**0.19 (0.07)**
Cumulated building permits		**0.93 (0.16)**	**2.36 (0.52)**	**0.69 (0.15)**	**0.18 (0.06)**	**0.19 (0.19)**	**0.29 (0.07)**
Constant	**0.64 (0.05)**	**1.66 (0.52)**	**2.92 (0.67)**	-0.78 (1.08)	**0.61 (0.05)**	**0.74 (0.13)**	**0.43 (0.10)**
Adj R^2	0.23	0.11	0.01	0.37	0.27	0.14	0.38
Second stage independent variable: Life expectancy at Age 5							
SCR	**6.69 (2.41)**	**2.68 (0.41)**	**3.58 (0.45)**	**1.86 (0.72)**	**3.81 (1.24)**	9.28 (6.33)	1.52 (0.23)
Rent index	0.97 (0.90)	0.67 (2.4)	-4.96 (3.15)	5. 17 (3.51)	**1.97 (0.5)**	**-0.032 (1.74)**	**3.65 (3.51)**
Constant	**48.7 (1.59)**	**48.93**	**48.37 (1.14)**	**51.62 (1.59)**	**50.61 (0.84)**	**46.86 (4.59)**	**51.62 (1.59)**
Neighborhood F.E.	No	Yes	Yes	Yes	No	No	No
N	160	160	88	72	160	88	72
R^2	0.25	0.89	0.88	0.84	0.54	0.0	0.59

Bold coefficients are significant at the 1% level, italics at the 5% level.

Table 9 I.V. regressions Panel A: pooled 1891, 1896, 1901, 1906 and 1910 observations with Fiscal Rent as an income proxy

First stage endogenous variable: Sewer Connection Rate (SCR)							
	Neighborhoods included						
	All	**All**	Center (1-11)	Periphery (12-20)	All	Center (1-11)	Periphery (12-20)
Fiscal Rent	**0.21** **(0.05)**	**0.88** **(0.25)**	**1.20** **(0.37)**	**0.36** **(0.25)**	**0.21** **(0.05)**	**0.20** **(0.06)**	**0.15** **(0.07)**
Running water in 1891	*0.11* *(0.05)*				**0.28** **(0.05)**	0.02 (0.14)	**0.23** **(0.06)**
Cumulated building permits		**1.20** **(0.09)**	**3.27** **(0.33)**	**1.04** **(0.07)**	**0.45** **(0.05)**	**0.88** **(0.20)**	**0.61** **(0.07)**
Constant	**0.19** **(0.04)**	**1.01** **(0.38)**	**2.50** **(0.46)**	**-1.82** **(0.42)**	**0.19** **(0.05)**	**0.68** **(0.14)**	-0.11 (0.07)
Adj R^2	0.07	0.31	0.28	0.59	0.19	0.24	0.39
Second stage independent variable: Life expectancy at Age 5							
SCR	*8.54* *(3.54)*	**1.05** **(0.14)**	**0.93** **(0.17)**	**1.02** **(0.18)**	*1.14* *(0.44)*	*-0.07* *(0.72)*	**1.27** **(0.42)**
Fiscal Rent	0.93 (1.19)	0.96 (0. 52)	-0.12 (0.69)	**2.31** **(0.99)**	**2.86** **(0.19)**	**2. 64** **(0.24)**	**3.00** **(0.32)**
Constant	**50.9** **(1.66)**	**52.09** **(0.71)**	**52.02** **(0.71)**	**50.38** **(1.13)**	**52.34** **(0.43)**	**53.51** **(0.28)**	**51.51** **(0.26)**
Neighborhood F.E.	No	Yes	Yes	Yes	No	No	No
N	400	400	220	180	400	220	180
R^2	0	0.88	0.87	0.85	0.52	0.45	0.48

Coefficient in bold are statistically significant at the 1%,(italics at 10%) level.

Table 10 I.V. regressions: pooled 1891, 1896, 1901, 1906 and 1910 observations with Fiscal Rent as an income proxy

Second stage independent variable: Life expectancy												
	Age 5			Age 20			Age 40			Age 60		
	Neighborhoods included											
	All	Center (1-11)	Periphery (12-20)	**All**	Center (1-11)	Periphery (12-20)	**All**	Center (1-11)	Periphery (12-20)	**All**	Center (1-11)	Periphery (12-20)
SCR	**1.05 (0.14)**	**0.93 (0.17)**	**1.02 (0.18)**	**1.05 (0.14)**	**0.75 (0.16)**	**0.83 (0.17)**	**0.91 (0.12)**	**0.93 (0.16)**	**0.85 (0.15)**	**0.29 (0.10)**	**0.62 (0.15)**	0.17 (0.11)
Fiscal Rent	0.96 (0. 52)	-0.12 (0.69)	**2.31 (0.99)**	0.61 (0. 49)	-0.53 (0.63)	**2.01 (0.70)**	0.48 (0. 45)	-0.62 (0.63)	**1.63 (0.61)**	0.27 (0. 38)	-0.73 (0.60)	*0.86 (0.43)*
Constant	**52.09 (0.71)**	**52.02 (0.71)**	**50.38 (1.13)**	**40.16 (0.67)**	**40.08 (0.71)**	**38.06 (0.92)**	**25.84 (0.61)**	**25.76 (0.61)**	**24.14 (0.81)**	**13.80 (0.51)**	**13.70 (0.58)**	**12.98 (0.57)**
Neighborhood F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	400	220	180	400	220	180	400	220	180	400	220	180
R^2	0.88	0.87	0.85	0.88	0.87	0.85	0.81	0.87	0.79	0.63	0.48	0.68

Note: this table only reports the second stage because the first stage is identical across all age groups the coefficients can be found in Table 9, columns 3, 4 and 5. Coefficient in bold are statistically significant at the 1%,(italics at 10%) level.