Income versus sanitation.
Mortality Decline in Paris, 1880-1914.

Lionel Kesztenbaum
Jean-Laurent Rosenthal*

Abstract

After 1850, mortality began its long term fall in most industrialized countries; at the same time urban life expectancy improved beyond its rural counterparts. Both processes have been linked to rising incomes and improved water infrastructure. In this paper we estimate the impact of these two factors jointly. To do so, we assemble a longitudinal data set on mortality and income for each of Paris' 80 neighborhoods during the health transition (1880-1914). We show that, unsurprisingly, building owners in rich neighborhoods adopted improved sanitation (direct connection to sewers) fastest. We then instrument sewer adoption by taking advantage of the fact all new buildings had to be connected and show that sanitation did reduce mortality. Overall, income and sanitation both contributed to the decrease in mortality, the effect of a standard deviation change of either variable being about the same about two years gain in life expectancy. We argue that these results give insights on the determinants of the health transition but also on the long-term evolution of health inequality.

Keywords: differential mortality, wealth, urbanization, Paris

JEL codes: N33, N34

The authors would like to thank Leah Brooks, Tracy Dennison, Edward Glaeser, Timothy Guinnane, Philip Hoffman, Samantha Myers, Jim Oeppen, and William Summerhill and the participants at seminars at PSE, Stanford, UCLA, and Yale for helpful comments.

Introduction

The decline of mortality between 1870 and 1914 was widespread in large cities across the North Atlantic economies. The drop in mortality can be found in the US (Troesken, 1999 ; Cutler and Miller, 2005), in Germany (Brown, 1989), and in the U. K. (Szreter, 1988) among other countries. This decline first led urban mortality to converge on that of rural areas. Then it continued, finally giving cities the life expectancy advantage they currently enjoy. Time and again scholars have pointed to income growth and to the diffusion of water infrastructure (piped, filtered, and chlorinated water on the one side, sewers on the other) to explain why mortality fell so sharply and so quickly throughout the North Atlantic region. The central issue is thus to measure the impact of these different factors on mortality decline. Scholars have tried to evaluate the role of income or wealth by charting the differential adoption of new water infrastructure across cities (Brown, 1988). To evaluate the value of clean water they have looked at specific improvements that diffused quickly (e.g. chlorination) after the infrastructure has been put in place (Cutler and Miller, 2005). In each case they look at the impact of these measures city-wide—in effect treating it as a public good. These are informative approaches but they also have some limitations, the first being the elision of the huge variations *within* cities. Indeed in each of the major cities (New York, London, or Paris) mortality was both high and uneven (the inter-quartile range among districts ranges between 25 and 30% of the mean).[1] As a result, one might want to look at the impact of changes in mortality within cities.

We focus on Paris because it has a wealth of neighborhood level data that is unmatched in other cities. These data allow us to explain both the cross-sectional variation in death rates and its evolution over time. They also allow us to show that both changes in wealth or income and large-scale public investment were driving forces behind the reduction of mortality. Moreover once we consider the *endogenous* diffusion of infrastructure, income, clean water, and sewers become interrelated. Indeed, most investments that prolong life are goods that involve some user charges that only the wealthiest part of the population is willing to pay. Health innovation thus first brings benefits to the rich.

In their pure form income and knowledge are quite distinct. Higher income allows individuals to purchase 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

---

[1] London, New York and Paris all reported aggregate death rates by neighbourhood. Only in Paris are neighbourhood boundaries fixed in space. Death rates of course do not correct for differences in age (sources: Reports of the registrar general, 1881-1901; Vital Statistics of New York City and Brooklyn: Covering a Period of Six years preceding 1890, United States Census Office. 11th census, 1890; 1894).

known they can be adopted by everyone because their costs are low. Of course other innovations lie in between: they are expensive but have economies of scale and, as a result, their benefits are greatest if they are adopted by everyone. In particular, sanitation relies on expensive networks of pipes to distribute clean water and collect waste water.[2] Although expensive, large scale public investments are likely to have been important around 1900, since most of the mortality decline seems to have come from reducing the impact of infectious diseases (Omran, 1971). However, it is important not to reduce clean water or sanitation to a public good because, although they have externalities, they are excludable services 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. In few of these cases can water infrastructure be approximated as a public good.

Scholars have long known that the correlation between income (or wealth) and health is positive, both between (Preston, 1975 ; Pritchett and Summers, 1996) and within countries ((McKeown, 1976), (Hummers, Rogers et al., 1998). Such a relationships has been observed and commented upon for two centuries at least (Villermé, 1828). More recent studies have tried to break down the impact of higher income into the kinds of consumption that it enables: better nutrition, housing, hygiene, or access to medical resources (Fogel, 1986 ; Harris, 2004). But at the same time, there is little evidence that affluence *per se* contributes to a better health (Cutler, Deaton et al., 2006). In fact the relationship between economic growth and life expectancy is not one way. There are advances and retreats in the evolution of both health and income that are unrelated to each other, whether from the historical record (Easterlin, 1999) or in contemporary analyses (Deaton and Paxson, 2004). It seems clear that "there is no presumption that economic growth will improve health without deliberate public action" (Drèze and Sen, 2002 ; Cutler, Deaton et al., 2006).

On the other side, many scholars favor an important role of infrastructure and local conditions. These can simply be urban disamenities (Szreter and Mooney, 1998 ; Woods, 2003 ; Cain and Hong, 2009). Alternatively, scholars have looked at large scale improvements such as clean water (Szreter, 1988 ; Cutler and Miller, 2005 ; Ferrie and Troesken, 2008). As a rule these studies argue that the link between mortality improvements and income is weak and instead favor changes in local conditions due to infrastructure investments. Such studies, however, focus on settings where the variance in income is relatively small and the variance in the environment is relatively large (for instance looking across UK or US cities). Our contribution focuses on a very

---

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

specific environment (one of the largest cities in Europe) where the range of economic circumstances was particularly broad.

The elusiveness of the impact of income is to a large extent the result of the unequal pace of adoption of health innovations. Economic growth drives the development of health-improving new ideas and new technologies as rich people are willing to pay more for longer life. But precisely for that reason, the wealthy are early adopters of most innovations. This is pretty obvious when thinking of better drugs but, as we will show, this is also the case for infrastructure within a city. As a result, the evolution of health inequality may be –and certainly is most of the time– quite disconnected from the evolution of health itself: as with economic growth, a few may take most of the actual growth.[3] Thus, it appears essential to explore how large scale health improvements diffuse in a given society. This will allow us to better understand the mortality transition and the process underlying the relationship between affluence and health.

Paris turns out to be a very good laboratory to study differential mortality: first, because administrative boundaries within the city have not changed since 1860; second, because the municipal statistical office was staffed by individuals obsessed with collecting and publishing detailed demographic data. Their efforts allow us to track the evolution of mortality between 1880 and 1913 for each of the 80 neighborhoods (*quartier*) of the city.[4] Data on the number of buildings connected to the sewers start in the 1880s with the same disaggregation level as mortality data. They produced these very detailed reports to spur public action to reduce both mortality and morbidity in the city. Their impact was in many ways limited: although the city did build new infrastructure it financed it through user fees that covered the cost of sewers while more than covered the cost of clean water. There was no real consideration of subsidizing such improvements out of general revenues.

This paper has three goals. The first is to document the long term evolution of life expectancy in Paris and its extraordinarily marked spatial temporal variation–something it shares with every other large city. It is no great surprise that the poorest neighborhoods were also those where life was shortest, but both the extent of the mortality gradient and its evolution over time are striking. Second we show that the advent of sanitation (direct connection of a building's waste water pipes to the sewers) did reduce mortality. However, the fee-for-service nature of the diffusion process implies early adoption by rich neighborhoods and thus a temporary increase in differential mortality. Third, we instrument connection to sewer so as to separate the positive

---

[3] Some authors even suggest economic inequalities by themselves contribute to increased mortality (Wilkinson, 1996) but this view has been challenged (Deaton, 2003).

[4] The city's administrative structure included twenty *arrondissements* –districts– that were each further subdivided into four *quartiers* –neighborhoods.

effect of income and that of sanitation on health. We conclude that both were equally beneficial. Throughout the paper we focus on life expectancy and mortality risk from age one or older because Parisian records do not allow the reconstruction of infant mortality. It is commonly accepted that much of the benefits of income gains or public infrastructure are to be found in reduced infant mortality. Our findings of very steep life expectancy-income profile and an equally very large benefit of sewer adoption are thus likely to be downward biased relative to what the population actually experienced.

I. Paris as a laboratory

In nineteenth century Paris life was massively unequal. As late as the 1890s, Parisians in the toniest neighborhoods could expect to live 12 years longer than those in the poorest ones (a difference that is echoed in age at death differentials across the wealth distribution (See Piketty, Postel-Vinay et al., 2006). Life in the capital was also brutally short: in 1880 Parisians lived four years (or nearly 10%) less than French people as a whole and their excess mortality was mainly driven by infectious diseases (Kuagbenou and Biraben, 1998). Over the next three and a half decades, 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 I). The common account for this turn around is that starting in the 1850s the city began to tackle the source of infectious diseases. The process began with the general delivery of water and continued in the 1860s with a vast and prolonged public program of sewer construction. By the 1930s nearly all buildings in Paris had clean running water, their waste water discharged directly into sewers, and differences in life expectancy across the city had shrunk. While even today differences in life span based on wealth or neighborhood remain, they are tiny relative to a century ago. Increased longevity, it seems, has been one of the more widely distributed benefits of long-term economic growth (Peltzman, 2009). As noted above, while its timing is specific, Paris' mortality decline is part of the general epidemiological transition in the North Atlantic where the fall in infectious diseases erased the urban penalty (For the US, see Haines, 2001).

[Figure I about here]

What is also specific to Paris is the quality of the data that we can use to study the process of change. Starting in 1880 the statistical office's main publication, the *Annuaire statistique de la ville de Paris* reports death totals for each sex, broken down into six age categories for each neighborhood.[5] The statistical office also published a series of detailed abstracts for the city

---

[5] These reports are drawn from the national system of death registration, so in principle one could run the data series backwards to 1870 (older registers suffered devastation and fires during the *Commune de Paris* episode).

drawn from the national population censuses from 1881 to 1911. These give us the age distribution of the living for the same neighborhoods.[6] Taking these two datasets together allows us to compute mortality rate and life expectancy at the neighborhoods level (see appendix A. for details). Unfortunately we cannot compute infant mortality because middle and lower class Parisians had 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 city. Any computation of life expectancy in the first year of life would be biased (Preston and van de Walle, 1974). Thus we limit ourselves to studying mortality after age one.

On the income side we have access to four real estate censuses (1876, 1890, 1900, and 1910) that 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 top category in 1890 comprised 521 dwellings assessed at more than 16,000 francs in rent.[7] Although, as we shall see these data provide ample evidence of the correlation between income and life expectancy, they are unfortunately too infrequent to be of much help to study the impact of the diffusion of the sewers. So at the archives of the treasury we collected neighborhood level fiscal data for every five years from 1876 to 1911 from the summary registers of the *taxe mobilière*. These data include the number of households who paid a rent above the fiscal threshold and the total rent they paid. We can thus compute the average rent paid by households above the threshold, this average rent was extremely correlated with the average rent reported by the fiscal census (the correlation between the two measures in the same year is never less than 0.97). Though truncated, the fiscal rent data are an effective statistic for average rents.

We also have information on access to clean water and how soiled water was dealt with. Although, as elsewhere in Europe or the US, clean water did play a role in decreasing mortality, especially infant mortality (Preston and van de Walle, 1978), we lack the data to analyze its impact within Paris. Indeed, the city water service reached two-thirds of the buildings by 1885 (Cebron de Lisle, 1991: 547). However we lack the finer details to know whether building owners provided running water to each dwelling, a faucet at every floor, or simply one on the ground floor , (Goubert, 1986: 90-92; Bocquet, Chatzis et al., 2008). The *Annuaire* also reported the

---

[6] Since the French Revolution, censuses were performed every five years ending in '1' or '6'; 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.

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

fraction of buildings that had a direct connection to the sewer by neighborhood. But the diffusion of clean water (for whatever purpose) raised the problem of removing it once it had been used.

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 collective activities, it curtailed its detailed reports. After WWI some data are only given by district, and the city no longer published its abstracts from the population censuses, all traces of further real estate censuses have vanished, and even the treasury's internal reports lose most of their useful information. So we limit our analysis to the period before 1914, when the most important improvements had already occurred.

Studying mortality within Paris poses serious complications. The most obvious of these is that, like other large cities, its population is not closed. In fact, at the end of the 19th century, six out of ten people living in Paris had not been born there or in the suburbs (census results from 1886 to 1901) and this proportion varies little between districts.[8] Migrants to Paris are also not a random sample of the world or of France's population, in fact migrants choose to move to Paris, and Parisians sort themselves into neighborhoods. Indeed, changes in the mortality of Parisians could be simply attributed to changes in rates of migration or in 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 both youth and older groups will not be so sensitive to in-migration rates.

The second selection effect, residential sorting, also complicates the analysis. Indeed, there are two reasons for a neighborhood to have higher 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

---

[8] The information is available only at the district level: all districts except for three have between 57 and 70% of their population not born in Paris or the Seine department. The three remaining have 50, 51 and 74% respectively at both extremes of the distribution.

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. On the one side, Paris's rich neighborhoods are in the west, upwind from the poorer east and thus with less polluted air. On the other, the rich also hired many female servants, whose work (cleaning the home, washing clothe and linens, preparing food) reduced mortality**.** While we cannot precisely disentangle these two chains of causation, it seems that the characteristics of the neighborhoods were far less important than either their infrastructure or the income of their denizen. Indeed Paris was a small city with limited variation in its environment. Rich neighborhoods included both the 7th and 1st districts along the Seine and the higher altitude 16th and 8th districts. The poor 5th was actually upstream from the rich 7th. Save for air quality, the rich did not congregate in 'naturally' healthy environments, though they did congregate a lot.[9]

Intuition is not proof and our general approach is to use time to net out the neighborhood's fixed characteristics and estimate the effects of income and infrastructure from changes in mortality over time within neighborhood. Additionally we deploy year fixed effect to net out any common demographic shocks (as well as the general trend of improvement in mortality). Our regressions will thus include neighborhoods and year fixed effects. Such an approach helps resolve both migration issues because the structure of migration across Paris was very stable. As a result the contribution of migrants to the health status of a given neighborhood is likely to be absorbed by our fixed effects. Overall, the share of Parisian residents born elsewhere was 62, 59, and 61% respectively in 1886, 1896, and 1901. More importantly, the share of migrants by district is very persistent. Indeed, the ranking of districts in term of the share of non-Parisian residents does not vary at all over time.[10] Second, fixed effects eliminate most natural variations between neighborhoods to allow us to focus on what changes over time, like the diffusions of sanitation. Migration within Paris is not rare but it was both very local and much less frequent than one might have expected (Farcy and Faure, 2003: 370). If males' migrations aged 20 to 45 are any indication, 30% of within Paris moves occur within the same neighborhood, 40% within the same district and 78% within the same area –center or periphery

---

[9] The case of London is slightly different because the rich West End is both upstream and upwind of the poor East End.

[10] Of course, they may be variations over time in the characteristics of the migrants (e.g. their health advantage towards living conditions in Paris). But such a variation would have to be very large to modify the differences in life expectancy between neighborhoods we observe.

(Farcy and Faure, 2003: 345-346). Overall, the ranking of neighborhoods changes little over time for either wealth or life expectancy (see Appendix B.). So most of the changes occur within neighborhoods (and over time), which is the part of the variation we intend to exploit.

II. Mortality and wealth inequality in time and space

Figure II presents the average life expectancy for Paris (the black line) and for France (the dotted line).[11] The figure also shows the life expectancy for the worst eight (the red line) and the best eight (the dotted red line) neighborhoods in the capital. The variation within Paris dwarfs the difference between in Paris and France. In fact individuals in the worst neighborhoods in Paris always had a life span about seven years shorter than the average for the city and ten to fiveteen years less than French people as a whole. At the other end of the spectrum, in the early 1880s the best neighborhoods in Paris had a thirteen year advantage over the rest of the city and a four year advantage over the rest of France. Over the next three decades life expectancy in the best districts rose quickly and neared 65 years extending their lead over the rest of France and Paris. The last decade before WWI saw somewhat more rapid gains at the bottom than at the top.

[Figure II about here]

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 city's share of France's population and wealth was at an all time high in 1913. In contrast to France as a whole (Bonneuil, 1997), economic growth did not readily translate into a reduction of life expectancy inequality in Paris. The huge heterogeneity in life expectancy within Paris can not be explained by a size effect: neighborhoods having 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 almost 50,000 (an average Paris neighborhood would have had around 23,000 inhabitants in the 1870's and 35,000 in the 1900's). The massive range of life expectancy comes instead from deep difference in the material circumstances of the residents of these neighborhoods.

We do not have direct evidence of income or consumption but we have access to excellent data on the distribution of rents across the city. To interpret rents, let us start by assuming that households devote a fixed fraction of their consumption to housing and that the individual household heterogeneity averages out within neighborhoods so that the budget-share

---

[11] The share of Paris in the French population was 4.5% at the beginning of our period and 7% at the end.

of housing can be taken as constant across neighborhoods. To be sure there are some worries with this framework. The most notable is that the budget-share of housing might well be increasing with total consumption (housing being in effect a luxury good). In this case using rents as a proxy for consumption would overstate the rate of growth of consumption. The second is that household structure is likely to be directly related to budget share of housing (with larger households devoting relatively more of the budget to housing for a given total consumption). Moreover if household structure is related to aggregate consumption there are likely to be systematic differences in the budget share of housing across neighborhoods. In the absence of finer-grain data, however, we cannot address these issues in the statistical analysis. Yet measurement error due to household heterogeneity is likely to create attenuation bias. Increasing budget shares for housing will also tend to understate the income effect (because a doubling of rent expenditures is associated with a less than doubling of income). Thus both biases work against rather than in favor of the argument that income improves life expectancy. It seems reasonable to take rents to proxy consumption (leaving aside the issue of whether this consumption was funded out of current or future income or out of savings).

What do rents tell us about the variation in consumption? The real estate census of 1876 provides a striking image of the city's inequality (Figure III). The wealthy (paying annual rents over 1000 francs) comprised less than 10% of households. The poor (who paid little or no direct taxes, that is less than 300 francs rents) 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 households were rich. In contrast five neighborhoods (all in the northwest) 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 Élysées 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 higher 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 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 Élysée). 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 III about here]

Let us start with the cross sectional variation. We estimate a simple linear relationship between average fiscal rent and life expectancy at age 1 for each census year (1881, 1886, …, 1911). The first regression for 1881 shows a strong association between life expectancy and average fiscal rent, then with each decade the relationship increases, in part because of an increase in life expectancy in those neighborhoods where the poor were relatively rare. The second cause of the growing sensitivity of life expectancy to fiscal rent is that the fraction of poor tended to decline everywhere even though their mortality patterns did not change much. The coefficient for fiscal rent is largest for 1891. Surprisingly, the role of income then declines and the coefficient we estimate for 1911 is in fact lower than that of 1881 (and statistically different from that of 1891). The constant term (which estimates the mean life expectancy for each year) is increasing throughout, evidence of large city-wide gains in life expectancy (it grows from 44 years to just under 53). We estimated the same cross section regressions for mortality by age group and by sex in regressions we do not report. They show a similar pattern of increase in the impact of income on mortality to 1891 followed by a decline (the pattern is particularly well marked for the 20-39 age group). Across age groups the magnitude of the coefficients increases but because mortality risk is increasing in age, the proportional impact is similar across ages (these results should allay fears that changes over time were driven by changes in selective migration). Finally we found no statistical differences between sexes: living in a wealthier neighborhood reduced mortality risk in quite similar ways for men and women.

[Table I about here]

This general improvement suggests something other than simple income growth was at work in improving life expectancy. Given the steep life-expectancy to rent profile in 1881 we might imagine that even limited changes in income would have had a large effect on life expectancy. To evaluate the hypothesis that all the changes that follow 1881 are simply income effects we 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 1881 regression to the rent distribution in later years (see Figure IV). 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 by the effects of income growth alone 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 IV about here]

Clearly then, the relationship between income and life expectancy had changed over time. In the aggregate, we can first reject the idea that the relationship between consumption and life expectancy was fixed (the coefficients change over time in important and systematic ways). Second for Paris in particular, both the evolution of aggregate rents and of business taxes are consistent with steady growth from 1880 to 1914. As others have shown, wealth accumulation was not very sensitive to the economic cycles, either the one that followed the Franco-Prussian war or the agricultural crisis of the 1880s (Lévy-Leboyer and Bourguignon, 1990). Hence although it is tempting to interpret the divergence that we see from 1880 to 1896 as caused by increasing inequality (Piketty, Postel-Vinay et al., 2004), the convergence that follows occurs under the same regime of increasing inequality (it seems to have peaked on the eve of WWI). The convergence, therefore, can only be explained by factors that would have reduced the impact of income on life span. In the next section, we argue that the development of water infrastructure was responsible for the convergence, and part of the divergence as well. Overall, life expectancy in Paris was very unequal, with differences between neighborhoods being both strong (and much stronger than in France as a whole) and closely related to income.

III. Sanitation and wealth: How much public are public goods?

Clearly then income first became more valuable over time to prolonging life, with a peak around 1891, and then a bit less valuable over time. Our hypothesis is that this evolution is driven by the spatial diffusion of sanitation and by the more rapid implementation of direct connection to sewers in rich neighborhoods. Sanitation is generally view as a major public health improvement, something that requires huge investment but benefit the whole population. It is thus a standard example of a public good in both the usual sense and the economic acceptance of it. A closer look however, reveals what a more precise analysis would immediately conclude: sanitation, as in fact most, if not all, public health improvements (and, to be sure, like all health improvements) have to be paid for and, as a result, benefit first (and sometimes only) to the wealthiest part of the population. In Paris, for instance, the same 5 rich (high rent) districts we mentioned above had, in 1901, a connection rate to sewers of at least 54% (and 62% on average) of buildings while the 12 poorest districts had at most 39% of their buildings hooked up to the sewers (and 27% on average).

Before addressing the issue of the relationship between wealth and access to sanitation, a brief review of the history of sanitation in Paris is necessary. While major sewers were installed in most of Paris by the 1860s they could only accommodate liquid waste (Chevallier, 2010: 244-246). Buildings were then equipped with a variety of waste disposal systems. In the most basic type, 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 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 (Jacquemet, 1979: 517). Thus landlords had to decide whether to retrofit their buildings and pay an annual fee of 60 francs per downpipe that was connected to the sewer. Given an average rent of 300 francs per apartment in 1876 this fee was sizeable and to encourage owners of buildings in poor neighborhood to connect, buildings that rented for less than 500 francs could connect at a reduced fee of 30 francs. The fee remained substantial if rents did not respond to this improvement: in the poorest neighborhoods, more than 90% of the household paid less than 300 francs in rent. Then in 1894 the city made connection mandatory, but the law was selectively enforced. Older buildings were in effect grand-fathered and their owners decided whether or not to connect. For new construction, however, the law was binding. In fact, ten years after the ordinance had been passed only 37,342 buildings had direct connection to sewer, a little more than half the total number of buildings. Nearly all structures 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.

However, beyond its own efforts at improving the worst areas of Paris (*Ilots insalubres*), and the price discrimination detailed above, the city was relatively passive in promoting sewers (Jacquemet, 1979). Nevertheless more and more buildings came to be connected. The trend in sewer adoption has two inflections, an early acceleration in the mid 1890s and then a slowdown in the mid 1900's (Figure V). 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. By 1913 almost 70% of the buildings were connected, although the 20th, 13th and 12th districts on the eastern edge of the city had yet to pass 60%. By 1928 when the detailed reports end, the connection rate topped 85% in the quartile of most favored districts 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.

[Figure V about here]

The Figure above makes it pretty clear that sewer connection is linked to wealth with the most affluent neighborhoods in the city having a higher rate of connection at any point in time as well as a much faster growing connection rate. A simple linear regression confirms that wealth is a strong determinant of the rate of buildings connected to sewer (Table II).[12] Whatever the wealth indicators we use, there is a significant, strong, and positive relation between the affluence of a neighborhood and the share of its buildings connected to sewer.

[Table II about here]

Beyond the obvious idea that those who pay for it will get it first, we need to be more specific about the mechanisms that explained why the wealthiest neighborhoods get access to sanitation much earlier. A little theory seems in order here to structure the decisions of three sets of actors. First, each renter must decide how much to bid up rents for an apartment in a building directly connected to the sewers. Second, each landlord must choose whether to provide a direct connection to the sewer. Third, the city's sanitation department has to prioritize the extension of the sewer-pipe system (though by 1894 each arrondissement had at least 65% of the sewers it would have in 1911 and for the city as a whole 80% of the sewers' extent at the end of the period had been put in place before connections became mandatory).

Consistent with our assumption that rents can stand as a good proxy for consumption, let us assume that the willingness of Parisian households to pay for a direct sewer connection is increasing in income. In effect direct connection to the sewers is a luxury good: the rich are willing to pay more for the service than the poor. Suppose there is a per dwelling charge for sewer connection, there will be a threshold income above which a household would be willing to connect.

Now let us turn to building owners and the way real estate was owned in Paris prior to WWI. The 757,000 housing units in the city were divided among 137,000 buildings. In this period, which antedates the rise of condominium associations, each building had at most one owner. Thus, at the very least 82% of the households were renters. That 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 was made by landlords who wanted to maximize rental income—but their decision depended on how much their tenants would bid up rents if units were directly connected to the sewer.

---

[12] Given the fast increase in sewer connection rates, it is clear that we need to use the full yearly sample from 1885 to 1913 if we are to understand the phenomenon. To do so, we linearly interpolate fiscal rents between census years (every five years). The data on the fiscal rents available yearly at the district level allow us to control that it is quite a good approximation.

As long as sewer connection is an increasing function of income, rent will increase more in absolute value for an expensive apartment than for a cheap one. Thus landlords of expensive apartment buildings will have a stronger incentive to provide the improvement than owners of poorer quality housing. At 30 or 60 francs per connected down pipe, it was quite a costly investment –by some account doubling the costs to owners relative to the traditional septic tanks. Thus it is not surprising that connections rose more quickly in richer than in poorer areas—and that income and infrastructure were correlated. As long as the connection decision was left within private hands, there was bound to be a delay in the take up of poor neighborhoods.

One might thought that the city could have levied a tax (on buildings or consumption) and connected all buildings in short order. Yet in a highly unequal society political economic considerations will get in the way of any such scheme. Because sewers are in higher demand in rich than in poor neighborhoods, the rich (including real estate owners) would be quite likely to resist any city-wide scheme. Indeed any such compulsory scheme would feature either a large subsidy from landlords to poor tenants or from the top part of the income distribution towards the bottom. Because the extent of the subsidy rises with inequality, the rich's opposition to any such scheme also grows with inequality. In any case, in late 19th century Paris 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 that made connection to sewer mandatory (Jacquemet, 1979). Owners of buildings in the Champs Élysées 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 implementing the new technology. 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. Let us assume that their goal is 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 as long as user charges cover interest and maintenance. In this case, it makes sense to equip richer neighborhoods faster than poorer ones, and indeed the correlation between rents and the ratio of street to sewer length per arrondissement is positive. It is largest early on (0.65 in 1880) and then declines over time as more and more neighborhoods become fully equipped (0.47 by 1906). It also 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, when connection was voluntary, owners faced 30 or 60 francs fees per connected pipe but by the end of the century, with mandatory connection, a more complex schedule was in place: the charge was still proportionate to property taxes but it varied from 10 to 1500 francs annually per building, 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 sanitation for the poor, it was efficient to start with those pauper neighborhoods that were closest to the main sewer line (the *collecteur d'Asnieres*) simply because they were cheapest to serve. Overall, however, it did have drawbacks: 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 less than 300 francs outnumbered those with rents at or above 1000 francs by 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: 535-545).

IV. Sanitation, income and mortality

Let us now look at sewers and income directly, temporarily leaving side the sewer-rent relationship. These are only intended to show that the diffusion of direct connection sewers coincided with both the increase in life expectancy in rich neighborhoods and the catch up of poorer ones. Table III below reports regressions of life expectancy on, first, the fraction of buildings connected to the sewers and, second, the average rents by neighborhood; both with and without fixed effects. The dataset includes one observation per neighborhood per year. We begin with a straightforward correlation taking in all neighborhoods and without fixed effects. Sewers seem to have significant positive benefits, adding nearly four years to Parisians' life expectancy. The impact of increasing sewers by one standard deviation (28%) is a bit less that doing the same for rents, and it is robust to including rents. In this model, neighborhoods that are one standard deviation below the mean in either rents or sewers have a life expectancy three years lower than those at the mean. 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 although the size of both coefficients falls markedly. In any case they remain statistically significant even with fixed effects. This is clearly linked to the fact that all three phenomena we observe (decline of mortality, sewer connection, and increase in income) evolve relatively linearly with time so much of their variance is absorbed by the fixed-effects. But at the same time we also net out local characteristics, annual demographic shocks and trends and so, in these conditions, it is all the more remarkable that the coefficients on sewers and rents remain well identified, for both Paris as a whole and for the periphery. For the center of Paris, where the built environment is much older, time fixed effects are too demanding, the process of change is not differentiated enough over time and space. More importantly the explanatory power of the regression that includes both variables is significantly higher than with either one variable, which suggests each has an independent effect (in the models without fixed-effects). Similarly, in the models that include fixed-effects the coefficient of sewer changes little when the rent variable is included (and the same is true for the coefficient of rents when we include sewers) and remains statistically significant. Overall, the results show that sewers seem to have had an important and significant impact in prolonging life.

[Table III about here]

One can also examine the impact of sewers and rents on mortality by age group and by sex. There are two reasons to do so. First, one might imagine that women who bore the burden of the washing, cooking, cleaning, and childrearing would be more likely to benefit than men from sewers because they came in closer contact with soiled water. Second, if one were worried about the results being driven by migration looking at older ages provides a robustness check since these groups were relatively less affected by in migration. To do so we look at age specific mortality risk as dependent variables, thus negative coefficient imply lower risk and higher life expectancy. Table IV mirrors Table III for mortality risks, presenting first sewers alone, then rents alone and finally both variables in the same regression. The first striking finding is that there are no statistical differences by sex, men seem to have slightly larger gross benefits but because their mortality risk is on average higher, the proportional reductions are very similar. The mortality risk reduction from sewers is highest at younger ages. What is surprising, though, is that the effect persists even past age 60: it remains statistically significant even if we include fixed effects. Again, sewers always seem to offer substantial declines in mortality risk.

[Table IV about here]

Overall, however, it is clear both from principles and from the spatial pattern of diffusion that sewer adoption is related to income. In that case, our direct regressions would clearly overstate the effect of sanitation which in part results from the fact that wealthy neighborhoods get sewers first. Similarly any regression of life expectancy on income would overstate the impact of income gains over time. As a first pass, we included both rent and sewer in the regressions and although the coefficients for both variables decline by about one third than if they are included alone, they are both still large and statistically significant, and of similar magnitude.

Yet despite these strong results one might be concerned that even if sewer adoption is not a proxy for income growth, it is endogenous. Thus we face both an identification and an endogeneity challenge. The identification challenge is to insure that we are not mistakenly attributing to sewers some of the benefits from income gains. The endogeneity challenge is to avoid attributing to sewer the impact of omitted variables that influence mortality and would be correlated with sewers connection and the part of income that is not captured by rents. It should be noted that such a variable need to be something that varies over time within a neighborhood (since either spacial or time invariant factors would be neutralized by our space and time fixed-effects). Among those possible factors we might think that the wealthy may be more prone to adopting sewers, increasing their cleanliness and using new medical knowledge.

We thus want a variable that is correlated to sewer adoption but not a neighborhood's income and unlikely to influence or be driven by life expectancy. We also need that variable to pass the exclusion restriction, namely that it does not act on its own to improve life expectancy. Although there are potentially many candidates instruments for sewer adoption, most fall by the wayside because there are either correlated with income or with mortality directly. We propose to use the cumulated building permits interacted with location. The ordonnance of July 1894 makes connection to sewer mandatory. We can expect that it was applied to the building permits starting in 1895 but those buildings would not be occupied until 1896. Additionally, we divide Paris into two parts its old 'center' and the newer 'periphery'. The center, composed of districts 1 to 11, had a very stable population (about 1.2 million between 1881 and 1911) and an equally stable stock of buildings. In the center the ratio of building permits issued between 1882 (respectively 1896) and 1913 to the stock of buildings in 1913 is 0.32 (resp. 0.18); and the stock of building in 1896 represented 97% of the stock of 1913. In contrast in periphery (districts 12 to 20), population grew by more than 60% from 1881 to 1913 and much of the construction occurred after buildings started to be connected to sewers. The ratio of building permits issued between 1882 (resp. 1896) and 1913 to the stock of buildings in 1913 is 0.77 (resp. 0.47); and the stock of building in 1889 was only 79% of the stock of 1913. All the new buildings were covered by the mandate that they connect to the sewer as part of the permitting process. While new constructions were of much better quality than the initial buildings (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 and the ratio 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 districts. Because building permits vary over time we can afford to include fixed effects in the regression when we use it as an instrument.

Clearly then for the periphery, building permits have the advantage that they are related to sewer connection but not to the distribution of rents–identification of an effect other than income is possible. Yet they have a serious potential disadvantage: new buildings are typically better than old ones, and thus building permits might fail the exclusion restriction. More precisely, because the city enforced the rule that new buildings be connected to sewers, the increase in sewer connection rate is strongly linked to building permits, but the building themselves are likely to have had other life-prolonging attributes. There is an alternative view that suggests that new construction was good in rich neighborhood and not very good in poor ones and that the mandate for direct connection was the most important element in improving buildings. Hence new constructions would have improved life expectancy much more after 1896 (the earliest date when buildings covered by the mandate were completed and occupied). Because our data run for 15 years before and after that date, we can test this hypothesis. Table V shows that, overall, the cumulative number of building permits has a strong positive effect on life expectancy–a necessary condition if we are to have a useful instrument. When we break the data down into two sub periods (one before 1896 and one after), the difference in impact is striking. As the second panel of Table V shows we cannot identify any direct effect of building permits before mandatory connection to sewers was implemented (1896), both overall and in the periphery. After 1896, however, both the whole of Paris and show a positive effect on the share of buildings that were built after the city required them to be connected to sewers. For the center where the number of new buildings was tiny, the regressions give huge coefficients that are clearly not credible. But we had no anticipation that the small number of buildings there would produce any useful results. In sum, confronting building permits before and after sewer connections were mandatory suggests that the exclusion restriction is satisfied for the periphery.

[Table V about here]

We now estimate the effects of both income and sewers on life expectancy using building permits after 1896 as instruments. We report results for Paris as a whole, and for the two groups of neighborhoods for completeness sake, but the key results come from the peripheral neighborhoods. We estimate the impact of sewers based on both samples and using both the two stage least squares and generalized method of moments (GMM) regressions. The two methods produce startlingly close results with a number of coefficients of interest identical to the third digit. Accordingly we only report the two stage least squares results (see Table VI and VII). In all cases we cluster the standard errors at the district (arrondissement level).

The first half of Table VI reports regression results without fixed effects. These can be compared with the results in Table III where we did not instrument. For Paris and as a whole the variables have the same sign but only income is significant. For the periphery where we think the instrument is valid the impact of sewer is smaller with 2SLS than if estimated directly but it remains well identified and socially significant (one standard deviation increase in sewer connections increases life expectancy by two years). The income coefficient remains almost unchanged. When we add fixed effects the instruments no longer have power for the center neighborhoods and the regression for Paris as a whole is contaminated. In the periphery however, the 2SLS estimate coefficient is not very different from what we estimated without instruments and fixed effects or with fixed effects and without instruments: one standard deviation increase in sewers would add between two and three years of life. Interestingly, the coefficient of rents suggest a roughly similar effect: a standard deviation increase in income also increases life expectancy by two to three years.

Again focusing solely on the periphery, it seems that income gains were equally important for reducing the mortality of women and men (the estimated coefficients at 1.52 and 1.88 are statistically very close). Sewers however have the startling effect of being very important to women (a standard deviation increase in sewer connection raises women's life expectancy by nearly five years) while it is irrelevant for men.

[Table VI about here]

One last concern remains, however, that is the extension of migration, both immigration and residential mobility within Paris, and the selection it may induce. As a robustness test, we estimate two stage least square regressions as in Table VI but replacing life expectancy with age specific mortality for different ages and sex (for simplicity we present only result for the periphery). We do not report the first stage again since it does not vary by age and is already reported in the previous table. Table VII reports the results for ages 1-4, 5-19, 20-39, 40-49 and 60-79 and includes on the peripheral neighborhoods and each regression includes the full set of location and year fixed effects. Repeating the finding of Table VI, females from age 1 to age 40 seem to receive significant benefits from the extension of sewers. Male infants seem to have very large benefits, but sewers seem not to matter at all for other ages (and in fact for men over 60 the coefficient suggests sewers are a bad thing). Rent always has a negative coefficient and its magnitude is the same for both men and women. These results suggest that women who came into contact with waste water much more frequently in their homemaking activities were more sensitive to sewers than income. Nevertheless, the ubiquity of a negative impact on mortality risk of both income and sewers suggests that these effects are unlikely to be driven by migration into Paris, since the large majority of migrants were young adults.

[Table VII about here]

We can take the estimates from Table VII and consider what they imply for Paris. To begin they offer an explanation of the divergence followed by convergence of life expectancy in the city. The residents of the eight high income neighborhoods we began with had long benefited from that status: they had low mortality and it was declining as they were gaining income. Then in the 1890s and early 1900s they got an additional boost by their early adoption of sewers. In contrast our twelve poor neighborhoods likely experienced smaller income gains (since this was a period of increasing wealth inequality) and they had to wait until 1927 to reach the level of sewer connection that the wealthy eight had achieved by 1906. It is not surprising then that life expectancy diverged in the early days of infrastructure investment.

IV. Conclusion

On a first level, this paper documents a very close connection between life expectancy inequality and economic inequality (be it wealth inequality, the quality of housing, or income). In Paris in the 1880s to be poor was to die young, and on average mortality risk was higher in the capital city than elsewhere in the country. On the eve of World War One, Paris' disadvantage compared with France as a whole had all but disappeared. The improvement came, first, from a massive increase in the life expectancy of those who lived in the city's best neighborhoods, and then, after 1900, with a catch up from the poorer ones. One could attribute these changes either to income effects or to the consequences of improvement in infrastructure.

To disentangle the effect of income and infrastructure on life expectancy we examine the pace at which sewers were adopted across Parisian neighborhoods between 1882 and 1913. Building permits in the periphery give us an instrument for the rate at which buildings were connected to the sewers that is not correlated with income or rents. To validate this instrument we examine its impact on life expectancy *before* sewers were adopted and show that although new buildings were probably better than older ones they did not contribute directly to improvements in life expectancy in the peripheral part of Paris. It is only after sewer connection became mandatory that life expectancy gains became substantial in the poorer neighborhoods of Paris. Yet more remains to be done by exploiting variation in the impact of sewers on different diseases or groups of individuals –though computing mortality risks for finer and finer subgroups of the population raises even greater problems of endogeneity.

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 user charges. In highly unequal societies such as 19th century Paris, these user charges tend to be substantial and they have a significant impact on the take up rate of infrastructure improvements.

The long delay between the initially availability of sewers and their adoption in the poorer districts of the periphery brings up the question of the social cost of the high user fees charged by the city to building owners. To do so, we estimate a counterfactual: what would the life expectancy of these districts have been had they achieved in 1900 the sewer connection rate that they experienced in 1928. This would have tripled their connection rates from just about a quarter of buildings connected to more than three quarters. Our estimates suggest that this would have raised life expectancy by four years. There are three ways to consider how substantial this gain might have been. First, this jump would have been enough to propel life expectancy in the worst decile of neighborhoods all the way to the level experienced by the median neighborhoods for Paris as a whole. Second, had one wanted to achieve the same effect by increasing income (or rents) one would have had to double them; at 2% growth (which is twice the rate of growth of rents and likely exceeds the growth of wages in Paris) that would have taken 35 years. Finally, since the life expectancy at age 1 was about 47, the increased life span coming from sewers would have mostly involved extra years of work. Nevertheless, in Paris, 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.

Lionel Kesztenbaum (INED)
Jean-Laurent Rosenthal (Caltech)

Appendix A. Computing Mortality risk and Life expectancy

Our goal is to compute life expectancy at age five. Implicitly this is a simple procedure that integrates age specific mortality risk. Yet because the age categories reported at the neighborhood (*quartier*) level are not stable over time and do not necessarily accord between the *Annuaires* –that give the deaths– and the Censuses –that report the number of living–, we must make corrections. We proceed in three steps.

First, we adjust both the mortality and population reports in order to obtain the number of deaths and the number of living for the same four age intervals: five to nineteen; twenty to thirty-nine; forty to fifty-nine; and finally sixty or more years old (as noted in the text, we omit all information on those aged below 5 years old). For each year we also have the report that breaks down deaths 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 between 1881 and 1893: instead of giving total deaths for age groups 5-19; 20-39 and 40-59, the *Annuaires'* table uses the age intervals 5-14; 15-34; 35-59. So we estimate, from the 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 neighborhood level to get the number of deaths 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. Finally, we estimate smaller age-interval for the older ages using the distribution of death for Paris as a whole: we subdivide both 40-59, and 60 and over intervals into five-years age groups.

Second, we need the population at risk. We estimate inter-census populations for every year. The standard way to do so is to evaluate the change in population between census years by combining the effect of mortality and net migration. In the case of a closed population, such estimates are (almost) immediate given the population total by age in a census year and the number of deaths each year (one just needs to make hypotheses about the relationship between birth cohorts and calendar years). At the other extreme, if migration rates are very high, then the flow of new people in the city determines the size of a given age group. This is the case for Paris and we use a linear interpolation of the size of the population of a given age between the two adjoining censuses. Such a procedure neglects both mortality shocks and variation in migration patterns that might affect one age group more severely than another in a given inter-census year. Given the rather coarse nature of our data we could not try to capture the differentiated consequence of either effects at the neighborhood level without making heroic assumptions.

Third, we compute a life table for each year and neighborhood: to do so we compute a set of age-specific death rates (m) for each year and neighborhood by dividing the number of death in the age group by the number of individuals living in that age group. We can then produce probabilities of dying (q) using the standard formula $q=n*m/(1+(n-a)*m)$, n and a being the average number of person-years lived in the interval by, respectively, those who survived that age group and those dying in that age group. Given that we don't have the exact age at death, the value of a, the average number of person-years lived by the deceased, is borrowed from another population, e.g. Keyfitz and Fliegler (1968: 491). The step from death probabilities to mortality tables and life expectancy at each age is then 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 average number of person-years lived by those dying in the last age group (that is ${}_{\infty}a_{80}$) 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. 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.

Appendix B. Descriptive statistics of the longitudinal sample

Panel A. All

	N	Year	Mean	SD total	SD between	SD within	Rank
Life expectancy at age 1 (years)	2640	1881-1913	49.35	7.02	5.54	4.36	0.73
Average rents -- complete (francs)	320	1878, 1890, 1900, and 1910	656.42	606.81	595.09	131.97	0.93
Average rents – fiscal (francs)	2640	1881-1913	896.12	797.48	789.75	140.82	0.94
Sewer connection rate (SCR) (%)	2320	1885-1913	32.05	27.97	0.07	27.05	
Building permits (%)	1440	1896-1913	16.83	22.61	17.07	14.93	

Panel B. Centre (44 neighborhoods)

Life expectancy at age 1 (years)	1452	1881-1913	51.50	6.65	5.14	4.29	0.77
Average rents -- complete (francs)	176	1878, 1890, 1900, and 1910	843.64	674.51	672.23	104.00	0.89
Average rents – fiscal (francs)	1452	1881-1913	1132.39	854.82	855.33	123.60	0.90
Sewer connection rate (SCR) (%)	1276	1885-1913	34.46	29.00	5.74	28.44	
Building permits (%)	792	1896-1913	8.91	12.59	9.51	8.36	

Panel C. Periphery (36 neighborhoods)

Life expectancy at age 1 (years)	1188	1881-1913	46.72	6.56	4.88	4.45	0.63
Average rents -- complete (francs)	144	1878, 1890, 1900, and 1910	427.61	410.84	382.42	160.04	0.89
Average rents – fiscal (francs)	1188	1881-1913	607.36	60.39	594.16	159.43	0.81
Sewer connection rate (SCR) (%)	1044	1885-1913	29.11	26.38	7.71	25.26	
Building permits (%)	648	1896-1913	26.51	27.79	19.28	20.26	

Note: All data are for 80 neighborhoods. "Rank" gives the linear correlation between neighborhoods ranking in 1881 and in 1911 (1876 and 1910 for share of poor households and complete rents).

References

Bocquet, D., K. Chatzis and A. Sander (2008). "From free good to commodity : Universalizing the provision of water in Paris (1830-1940)." *Geoforum* 39: 1821-1832.

Bonneuil, N. (1997). *Transformation of the French demographic landscape 1806-1906*. Oxford, Clarendon Press.

Brown, J. C. (1988). "Coping with Crisis? The Diffusion of Waterworks in Late Nineteenth-Century German Towns." *The Journal of Economic History* 48(2): 307-318.

Brown, J. C. (1989). "Reforming the urban environment: sanitation, housing, and government intervention in Germany, 1870–1910." *Journal of Economic History* 49: 450-472.

Cain, L. and S. C. Hong (2009). "Survival in 19th Century Cities: The Larger the City, the Smaller Your Chances." *Explorations in Economic History* 46(4): 450-463.

Cebron de Lisle, P. (1991). *L'eau à Paris au 19ème siècle*. Paris, Association générale des hygiénistes et techniciens municipaux.

Chevallier, F. (2010). *Le Paris moderne. Histoire des politiques d'hygiène (1855-1898)*. Rennes, Presse universitaires de Rennes.

Cutler, D., A. Deaton and A. Lleras-Muney (2006). "The determinants of mortality." *Journal of Economic Perspectives* 20(3): 97-120.

Cutler, D. and G. Miller (2005). "The role of public health improvements in health advances: the twentieth-century united states." *Demography* 42(1): 1-22.

Deaton, A. (2003). "Health, Inequality, and Economic Development." *Journal of Economic Literature* 41(1): 113-158.

Deaton, A. and C. Paxson (2004). Mortality, Income, and Income Inequality over Time in Britain and the United States. *Perspectives on the Economics of Aging*. Boston, NBER: 247-286.

Drèze, J. and A. Sen (2002). *India: Development and Participation*. Delhi, Oxford university press.

Easterlin, R. A. (1999). "How beneficient is the market? A look at the modern history of mortality." *European Review of Economic History* 3(3): 257-294.

Farcy, J.-C. and A. Faure (2003). *La mobilité d'une génération de Français : recherche sur les migrations et les déménagements vers et dans Paris à la fin du XIXe siècle*. Paris, INED.

Ferrie, J. P. and W. Troesken (2008). "Water and Chicago's mortality transition, 1850–1925." *Explorations in Economic History* 45(1): 1-16.

Fogel, R. W. (1986). Nutrition and the Decline in Mortality since 1700: Some Preliminary Findings *Long-Term Factors in American Economic Growth*. S. L. Engerman. Chicago and London, University of Chicago Press: 439-527.

Goubert, J.-P. (1986). *La conquête de l'eau: L'avènement de la santé à l'âge industriel.* Paris, Robert Laffont.

Haines, M. R. (2001). "The urban mortality transition in the United States, 1800-1940." *Annales de démographie historique* 1: 33-64.

Harris, B. (2004). "Public Health, Nutrition, and the Decline of Mortality: The McKeown Thesis Revisited." *Social History of Medicine* 17(3): 379-407.

Hummers, R. A., R. G. Rogers and I. W. Eberstein (1998). "Sociodemographic differentials in adult mortality : A review of analytic approaches." *Population and Development Review* 24(3): 553-578.

Jacquemet, G. (1979). "Urbanisme parisien : la bataille du tout-à-l'égout à la fin du XIXe siècle." *Revue d'histoire moderne et contemporaine* XXVI(10): 505-548.

Kesztenbaum, L. and J.-L. Rosenthal (2011). "The health cost of living in a city: The case of France at the end of the 19th century." *Explorations in Economic History* 48(2): 207-225.

Keyfitz, N. and W. Flieger (1968). *World Population: An Analysis of Vital Data.* Chicago, The University of Chicago Press.

Kuagbenou, V. K. and J.-N. Biraben (1998). *Introduction à l'étude de la mortalité par causes de décès à Paris dans la première moitié du XIXe siècle : présentation de données inédites.* Paris, INED.

Lévy-Leboyer, M. and F. Bourguignon (1990). *The French economy in the Nineteenth century: an essay in econometric analysis.* Cambridge, Cambridge University Press.

McKeown, T. (1976). *The modern rise of population.* London, Academic Press.

Omran, A. (1971). "The Epidemiologic Transition: A Theory of the Epidemiology of Population Change." *The Milbank Memorial Fund Quarterly* 49(4): 509-38.

Peltzman, S. (2009). "Mortality Inequality." *Journal of Economic Perspectives* 23(4): 175-190.

Piketty, T., G. Postel-Vinay and J.-L. Rosenthal (2004). "Wealth Concentration in a Developing Economy: Paris and France, 1807-1994". CEPR Discussion Papers 4631, C.E.P.R. Discussion Papers.

Piketty, T., G. Postel-Vinay and J.-L. Rosenthal (2006). "Wealth concentration in a developing economy: Paris and France, 1807-1994." *American Economic Review* 96(1): 236-256.

Préfecture de la Seine (1899). *Travaux d'assainissement de la Seine. Lois & Décrets.* Paris, Paul Dupont.

Preston, S. H. (1975). "The Changing Relation between Mortality and Level of Economic Development." *Population Studies* 29(2): 231-248.

Preston, S. H., P. Heuveline and M. Guillot (2001). *Demography: measuring and modeling population processes.* Oxford, Blackwell Publishers.

Preston, S. H. and E. van de Walle (1974). "Mortalité de l'enfance au XIXe siècle à Paris et dans le département de la Seine." *Population* 29(1): 89-107.

Preston, S. H. and E. van de Walle (1978). "Urban French Mortality in the Nineteenth Century." *Population Studies* 32(2): 275-297.

Pritchett, L. and L. H. Summers (1996). "Wealthier is Healthier." *Journal of Human Ressources* 31(4): 841-868.

Rollet-Echalier, C. (1982). "Nourrices et nourrissons dans le département de la Seine et en France de 1880 à 1940." *Population* 3: 573-606.

Szreter, S. (1988). "The importance of social intervention in Britain's mortality decline c. 1850-1914 : a re-interpretation of the role of public health." *Social history of medicine*(1).

Szreter, S. and G. Mooney (1998). "Urbanization, mortality, and the standard of living debate: new estimates of the expectation of life at birth in nineteenth-century British cities." *Economic History Review* LI(1): 84-112.

Troesken, W. (1999). "Typhoid Rates and the Public Acquisition of Private Waterworks, 1880-1920." *The Journal of Economic History* 59(4): 927-948.

Villermé, L.-R. (1828). "Mémoire sur la mortalité en France dans la classe aisée et dans la classe indigente." *Mémoires de l'Académie Royale de médecine*: 51-98.

Wilkinson, R. G. (1996). *Unhealthy Societies: The Afflictions of Inequality*. London, Routledge.

Woods, R. (2003). "Urban-Rural Mortality Differentials: An Unresolved Debate." *Population and Development Review* 29(1): 29-46.

Table I Cross section Regressions of Life Expectancy on Rents

	Life Expectancy 1881			Life Expectancy 1886			Life Expectancy 1891
Rents 1881	4.17 (0.572)		Rents 1886	4.53 (0.450)		Rents 1891	5.06 (0.412)
Constant	43.8 (0.488)		Constant	44.1 (0.409)		Constant	47.4 (0.399)
	Life Expectancy 1896			Life Expectancy 1901			Life Expectancy 1906
Rents 1896	4.77 (0.479)		Rents 1901	4.26 (0.393)		Rents 1906	4.07 (0.405)
Constant	50.22 (0.426)		Constant	51.5 (0.445)		Constant	52.9 (0.449)
	Life Expectancy 1911						
Rents 1911	3.55 (0.441)						
Constant	52.7 (0.508)						

Note: the coefficients reported come from seven different linear regressions with 80 observations each. The R2 varies between 0.33 and 0.61.
Dependant variable is standardized.

Table II Cross section Regressions of Sewer Connection Rate on Rents

	Sewer Connection Rate		**Sewer Connection Rate**
Rents	**0.07 (0.006)**		**0.11 (0.007)**
FE-Neighborhood			YES
FE-Year			YES
Constant	**0.32 (0.06)**		**0.41 (0.018)**
R^2	0.06		0.96
N	2320		2320

Dependant variable is standardized.

Table III Life Expectancy and the Diffusion of Sewers

Dependent Variable Life Expectancy-Age 1 All Parisian Neighborhoods						
SCR	**3.93** **(0.114)**	**1.33** **(0.225)**			**3.02** **(0.087)**	**1.01** **(0.23)**
Rent			**4.45** **(0.102)**	**1.69** **(0.281)**	**3.74** **(0.85)**	**1.31** **(0.29)**
Constant	**50.15** **(0.149)**	**51.96** **(0.473)**	**50.09** **(0.104)**	**52.43** **(0.468)**	**50.1** **(0.84)**	**52.11** **(0.47)**
FE-Neighborhood		YES		YES		YES
FE-Year		YES		YES		YES
N	2320	2320	2320	2320	2320	2320
Adj-R^2	0.34	0.90	0.44	0.89	0.63	0.89
Dependent Variable Life Expectancy-Age 1 Center (Arrondissements 1-11)						
SCR	**3.51** **(0.14)**	-0.67 (0.37)			**2.87** **(0.10)**	-0.13 (0.38)
Rent			**3.81** **(0.12)**	0.25 (0.42)	**3.30** **(0.10)**	0.29 (0.43)
Constant	**51.96** **(0.14)**	**51.95** **(0.47)**	**51.09** **(0.14)**	**52.58** **(0.51)**	**51.00** **(0.11)**	**52.64** **(0.53)**
FE-Neighborhood		YES		YES		YES
FE-Year		YES		YES		YES
N	1276	1276	1276	1276	1276	1276
Adj-R^2	0.32	0.89	0.41	0.88	0.62	0.88
Dependent Variable Life Expectancy-Age 1 Periphery (arrondissements 12-20)						
SCR	**4.07** **(0.16)**	**2.73** **(0.31)**			**3.14** **(0.13)**	**2.1** **(0.33)**
Rent			**4.93** **(0.19)**	**2.87** **(0.37)**	**3.83** **(0.16)**	**1.94** **(0.39)**
Constant	**47.99** **(0.15)**	**46.17** **(0.52)**	**49.27** **(0.16)**	**48.38** **(0.61)**	**49.23** **(0.13)**	**47.7** **(0.61)**
FE-Neighborhood		YES		YES		YES
FE-Year		YES		YES		YES
N	1044	1044	1044	1044	1044	1044
Adj-R^2	0.37	0.89	0.38	0.88	0.59	0.88

Note: the independent variables are the sewer connection rate (SCR). Bold coefficients are significant at the 1% level, italics at the 5% level. Dependant variable is standardized.

Table IV Life Expectancy and the Diffusion of Sewers, by Age (Men)

Men	Log Mortality Risk										
	No Fixed Effects						Time and Space Fixed Effects				
	1-4	5-19	20-39	40-59	60-69		1-4	5-19	20-39	40-59	60-69
Sewer connection rate	**-0.37** **(0.01)**	**-0.19** **(0.01)**	**-0.09** **(0.01)**	**-0.12** **(0.01)**	**-0.04** **(0.01)**		**-0.25** **(0.03)**	**-0.09** **(0.03)**	**-0.17** **(0.02)**	**-0.10** **(0.01)**	*-0.034* *(0.013)*
Constant	**4.81** **(0.01)**	**4.20** **(0.01)**	**5.04** **(0.01)**	**5.97** **(0.01)**	**6.51** **(0.01)**		**4.74** **(0.07)**	**4.18** **(0.07)**	**5.31** **(0.04)**	**6.03** **(0.03)**	**6.53** **(0.02)**
Adj-R2	**0.37**	**0.20**	**0.06**	**0.19**	**0.07**		**0.68**	**0.45**	**0.71**	**0.76**	**0.42**
	No Fixed Effects						Time and Space Fixed Effects				
Rent	**-0.34** **(0.01)**	**-0.17** **(0.01)**	**-0.23** **(0.01)**	**-0.17** **(0.01)**	**-0.04** **(0.01)**		**-0.38** **(0.04)**	**-0.13** **(0.04)**	**-0.28** **(0.02)**	**-0.14** **(0.02)**	-0.01 (0.015)
Constant	**4.86** **(0.01)**	**4.25** **(0.01)**	**5.05** **(0.01)**	**5.99** **(0.01)**	**6.51** **(0.01)**		**4.70** **(0.07)**	**4.1** **(0.07)**	**5.33** **(0.04)**	**6.03** **(0.03)**	**6.53** **(0.02)**
Adj-R2	**0.30**	**0.14**	**0.40**	**0.36**	**0.06**		**0.69**	**0.48**	**0.68**	**0.75**	**0.39**
	No Fixed Effects						Time and Space Fixed Effects				
Sewer connection rate	**-0.31** **(0.01)**	**-0.16** **(0.01)**	**-0.037** **(0.01)**	**-0.08** **(0.01)**	**-0.039** **(0.01)**		**-0.17** **(0.03)**	**-0.06** **(0.03)**	**-0.13** **(0.02)**	**-0.082** **(0.01)**	**-0.034** **(0.013)**
Rent	**-0.27** **(0.01)**	**-0.13** **(0.01)**	**-0.23** **(0.01)**	**-0.15** **(0.01)**	**-0.036** **(0.01)**		**-0.32** **(0.04)**	**-0.13** **(0.04)**	**-0.20** **(0.03)**	**-0.087** **(0.02)**	-0.02 (0.015)
Constant	**4.81** **(0.01)**	**4.20** **(0.01)**	**5.04** **(0.01)**	**5.97** **(0.01)**	**6.50** **(0.01)**		**4.73** **(0.07)**	**4.1** **(0.07)**	**5.30** **(0.04)**	**6.03** **(0.03)**	**6.53** **(0.03)**
Adj-R2	**0.56**	**0.29**	**0.43**	**0.47**	**0.11**		**0.69**	**0.48**	**0.72**	**0.77**	**0.42**

Note: The first panel reports two coefficients for 10 separate regressions of mortality risk by age group on the sewer connection rate. The second panel does the same for 10 separate regressions of mortality risk by age group on the average fiscal rent. The third reports regressions of mortality risk by age group on the sewer connection rate and rent. Each regression is based on 29 years X 80 districts or 2320 observations. Bold coefficients are significant at the 1% level, Italic at 5%.

Table IV continued (Women)

Women	Log Mortality Risk										
	No Fixed Effects						Time and Space Fixed Effects				
	1-4	5-19	20-39	40-59	60-69		1-4	5-19	20-39	40-59	60-69
Sewer connection rate	**-0.36** **(0.01)**	**-0.19** **(0.01)**	**-0.10** **(0.01)**	**-0.16** **(0.01)**	**-0.07** **(0.01)**		**-0.18** **(0.03)**	**-0.14** **(0.03)**	**-0.11** **(0.02)**	**-0.09** **(0.01)**	**-0.035** **(0.013)**
Constant	**4.75** **(0.01)**	**4.16** **(0.01)**	**4.83** **(0.01)**	**5.58** **(0.01)**	**6.39** **(0.01)**		**4.55** **(0.07)**	**4.14** **(0.07)**	**5.03** **(0.04)**	**5.51** **(0.03)**	**6.39** **(0.03)**
Adj-R2	**0.36**	**0.18**	**0.06**	**0.22**	**0.12**		**0.68**	**0.40**	**0.78**	**0.77**	**0.53**
	No Fixed Effects						Time and Space Fixed Effects				
Rent	**-0.33** **(0.01)**	**-0.19** **(0.01)**	**-0.30** **(0.01)**	**-0.20** **(0.01)**	**-0.07** **(0.01)**		**-0.38** **(0.04)**	**-0.18** **(0.04)**	**-0.27** **(0.02)**	**-0.14** **(0.02)**	-0.021 (0.015)
Constant	**4.82** **(0.01)**	**4.22** **(0.01)**	**4.85** **(0.01)**	**5.61** **(0.01)**	**6.40** **(0.01)**		**4.84** **(0.07)**	**4.10** **(0.07)**	**5.04** **(0.04)**	**5.51** **(0.03)**	**6.40** **(0.03)**
Adj-R2	**0.27**	**0.17**	**0.55**	**0.37**	**0.13**		**0.70**	**0.47**	**0.77**	**0.77**	**0.52**
	No Fixed Effects						Time and Space Fixed Effects				
Sewer connection rate	**-0.31** **(0.01)**	**-0.15** **(0.01)**	**-0.029** **(0.01)**	**-0.11** **(0.01)**	**-0.054** **(0.01)**		**-0.11** **(0.04)**	**-0.09** **(0.04)**	**-0.06** **(0.02)**	**-0.074** **(0.02)**	**-0.037** **(0.013)**
Rent	**-0.26** **(0.01)**	**-0.15** **(0.01)**	**-0.30** **(0.01)**	**-0.18** **(0.01)**	**-0.056** **(0.01)**		**-0.32** **(0.05)**	**-0.18** **(0.05)**	**-0.22** **(0.03)**	**-0.094** **(0.02)**	-0.09 (0.018)
Constant	**4.75** **(0.01)**	**4.17** **(0.01)**	**4.83** **(0.01)**	**5.58** **(0.01)**	**6.39** **(0.01)**		**4.54** **(0.07)**	**4.13** **(0.07)**	**5.02** **(0.04)**	**5.50** **(0.03)**	**6.39** **(0.03)**
Adj-R2	**0.54**	**0.30**	**0.57**	**0.50**	**0.20**		**0.68**	**0.40**	**0.78**	**0.77**	**0.53**

Note: The first panel reports two coefficients for 10 separate regressions of mortality risk by age group on the sewer connection rate. The second panel does the same for 10 separate regressions of mortality risk by age group on the average fiscal rent. The third reports regressions of mortality risk by age group on the sewer connection rate and rent. Each regression is based on 29 years X 80 districts or 2320 observations. Bold coefficients are significant at the 1% level.

Table V Life Expectancy and Building Permits

Dependant variable: life expectancy at age 1			
	Neighborhoods included		
	All	Center (1-11)	Periphery (12-20)
	All Years		
Cumulated building permits/1913 stock	**1.68** **(0.34)**	**4.52** **(0.78)**	0.56 (0.49)
Constant	**52.22** **(0.47)**	**52.13** **(0.50)**	**46.10** **(0.63)**
Adj R^2	0.90	0.89	0.88
N	2560	1408	1152
	Before 1896		
Cumulated building permits before 1896	1.7 (1.28)	**15.72** **(4.29)**	2.10 (3.17)
Constant	**50.46** **(0.66)**	49.63 **(0.74)**	**44.44** **(1.21)**
Location and Time F.E.	Y	Y	Y
Adj R^2	0.88	0.91	0.17
N	1120	616	1152
	1896 and after		
Cumulated building permits before 1896	**2.25** **(0.47)**	**3.69** **(1.06)**	***1.07*** ***(0.63)***
Constant	**51.60** **(0.52)**	**51.91** **(0.54)**	**44.36** **(0.65)**
Location and Time F.E.	Y	Y	Y
Adj R^2	0.89	0.88	0.87
N	1440	792	1152

Bold is statistically significant at 1% level, italic at 10%.

Table VI I.V. Regressions of Life Expectancy on Sewer Connection Rate

First stage endogenous variable: Sewer Connection Rate (SCR)								
	Sample							
	All	Center (1-11)	Periphery (12-20)	**All**	Center (1-11)	Periphery (12-20)	Periphery (12-20)	
	Women and Men together						Women	Men
Fiscal Rent	**0.296** **(0.02)**	**0.18** **(0.02)**	**0.34** **(0.03)**	0.04 (0.03)	**0.27** **(0.044)**	-0.12 (0.05)	-0.12 (0.05)	-0.12 (0.05)
Cumulated building permits	**0.293** **(0.02)**	**0.44** **(0.04)**	**0.35** **(0.02)**	**0.04** **(0.01)**	0.01 (0.02)	**0.08** **(0.01)**	**0.08** **(0.01)**	**0.08** **(0.01)**
Constant	**0.60** **(0.02)**	**0.83** **(0.03)**	**0.41** **(0.02)**	**0.33** **(0.04)**	**0.35** **(0.04)**	**-0.37** **(0.06)**	**-0.37** **(0.06)**	**-0.37** **(0.06)**
Location and Time F.E.	NO	NO	NO	YES	YES	YES	YES	YES
F-stat	268.9	103.6	386.5	15.91	0.24	67.3	67.3	67.3
Adj R^2	0.27	0.18	0.47	0.96	0.97	0.96	0.96	0.96
Second stage independent variable: Life expectancy at Age 5								
SCR	0.45 (0.38)	*0.99* *(0.57)*	**1.86** **(0.36)**	**10.27** **(2.67)**	104.1 (210.4)	*2.96* *(1.44)*	*4.7* *(2.05)*	-1.26 (2.01)
Fiscal Rent	**3.96** **(0.14)**	**3.21** **(0.14)**	**3.96** **(0.21)**	0.33 (0. 64)	-24.80 (49.3)	**1.77** **(0.72)**	*1.52* *(0.91)*	*1.88* *(0.91)*
Constant	**51.98** **(0.25)**	**52.70** **(0.41)**	**50.27** **(0.26)**	**48.641** **(0.99)**	14.76 (74.18)	**46.86** **(0.94)**	50.56 (1.19)	**44.39** **(1.19)**
Location and Time F.E.	NO	NO	NO	YES	YES	YES	Yes	Yes
N	1440	792	720	1440	792	648	648	648
R^2	0.53	0.52	0.54	0.84	0	0.89	0.85	0.96

Table VII I.V. Regressions of mortality risks by age and sex on Sewer Connection Rate

	Second stage dependent variable: log (probability of death /1000)										
	Men						Women				
	Age 1-4	Age 5-19	Age 20-39	Age 40-59	Age 60-79		Age 1-4	Age 5-19	Age 20-39	Age 40-59	Age 60-79
SCR	**-0.65** **(0.20)**	0.19 (0.20)	0.11 (0.13)	0.07 (0.09)	**0.26** **(0.10)**		*-0.32* *(0.19)*	*-0.37* *(0.22)*	*-0.25* *(0.12)*	-0.08 (0.11)	-0.01 (0.09)
Fiscal Rent	**-0.43** **(0.08)**	**-0.26** **(0.08)**	**-0.30** **(0.05)**	**-0.16** **(0.03)**	-0.03 (0.04)		**-0.22** **(0.07)**	**-0.21** **(0.08)**	**-0.32** **(0.04)**	**-0.12** **(0.04)**	-0.03 (0.03)
Constant	**4.61** **(0.10)**	**4.00** **(0.10)**	**5.25** **(0.06)**	**6.14** **(0.05)**	**6.69** **(0.05)**		**4.76** **(0.10)**	**4.18** **(0.11)**	**4.98** **(0.06)**	**5.72** **(0.06)**	**6.45** **(0.04)**
Neighborhood and Year F.E.	YES	YES	YES	YES	YES		YES	YES	YES	YES	YES
N	720	720	720	720	720		720	720	720	720	720
R^2	0.72	0.42	0.79	0.75	0.34		0.75	0.37	0.84	0.77	0.61

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.

Figure I Life Expectancy at Age 5, Paris and France, 1860-1939

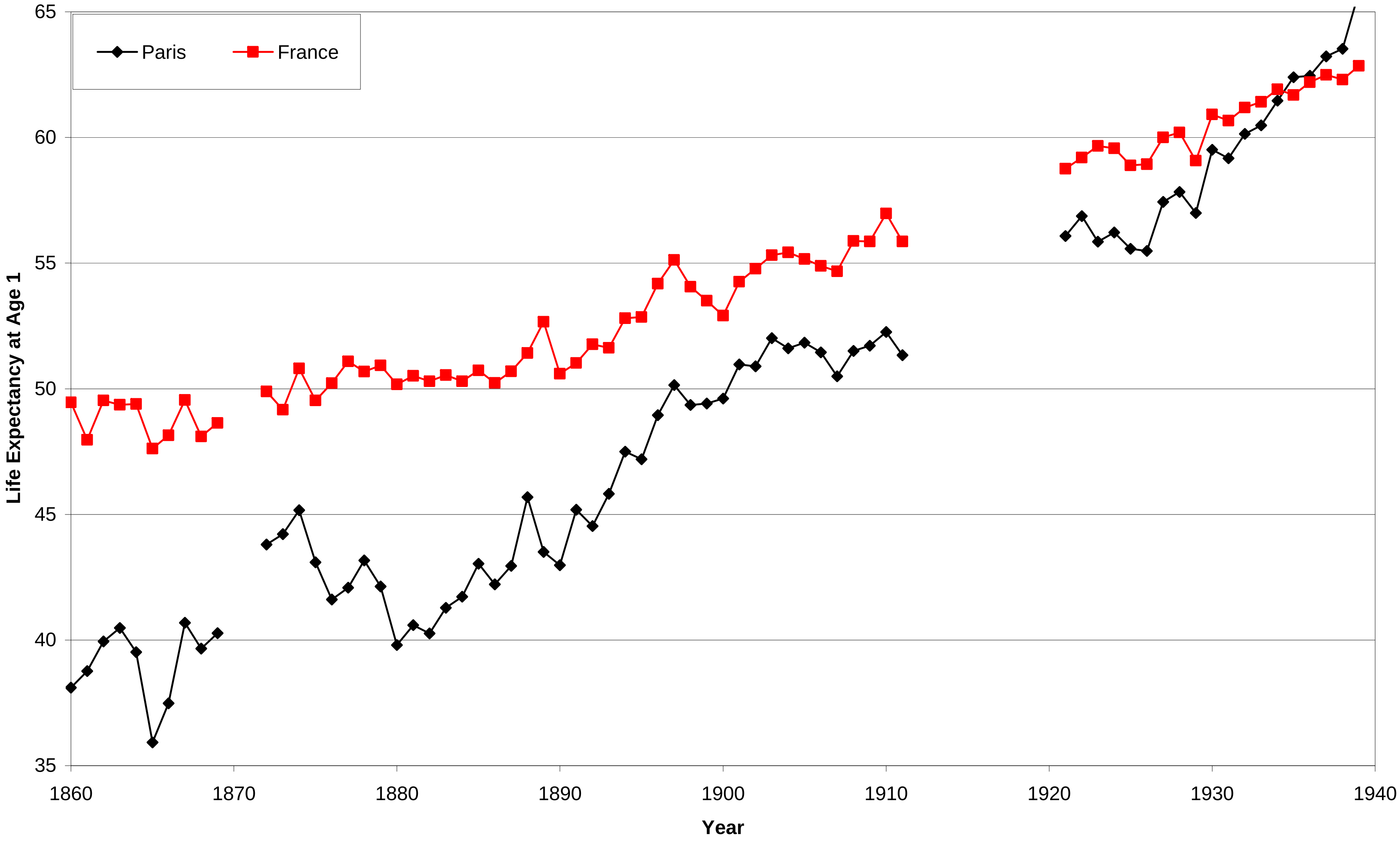

Figure II Life expectancy at age 5 within Paris, compared to France

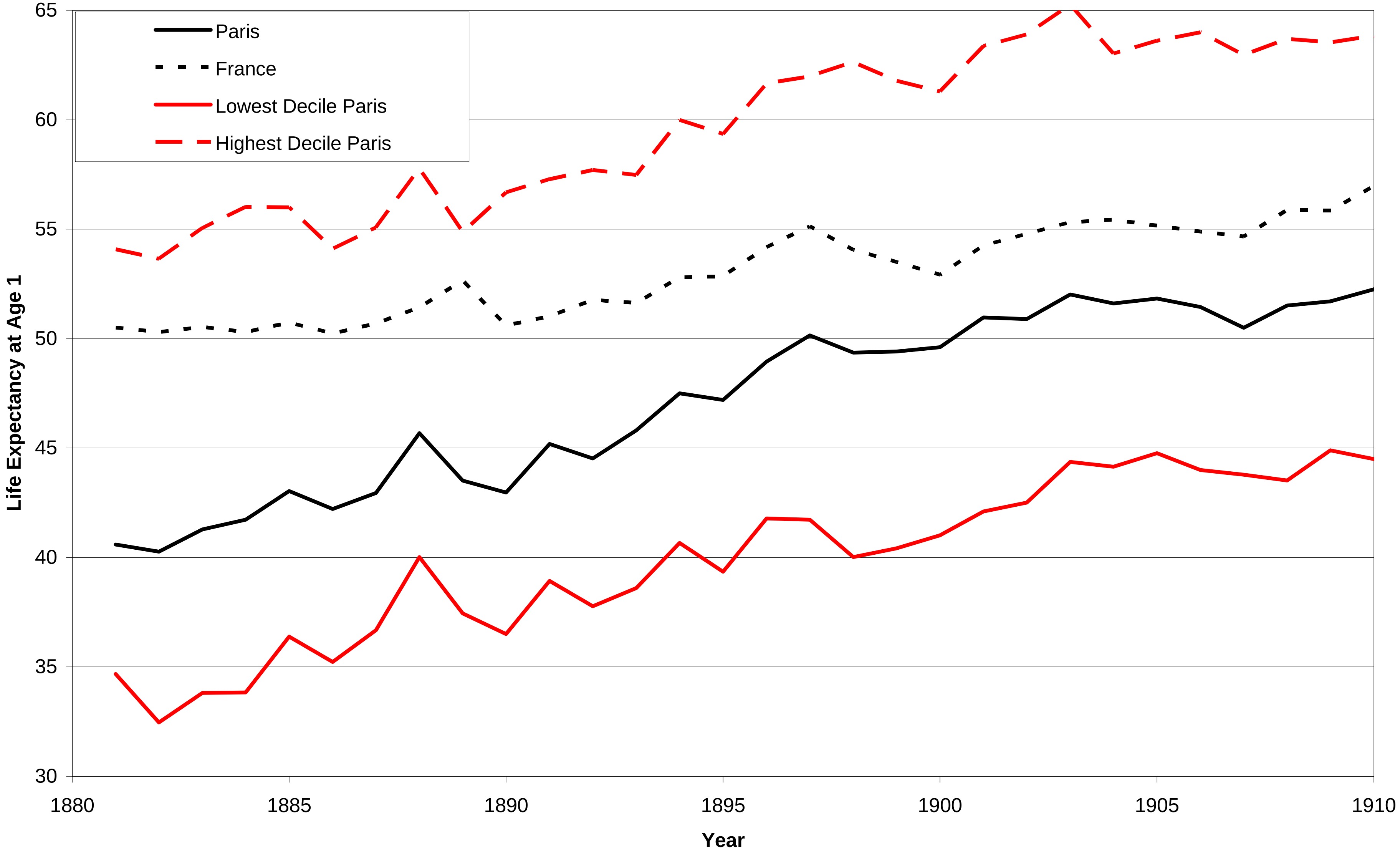

Figure III Average Rents by Neighborhoods in Paris, 1876

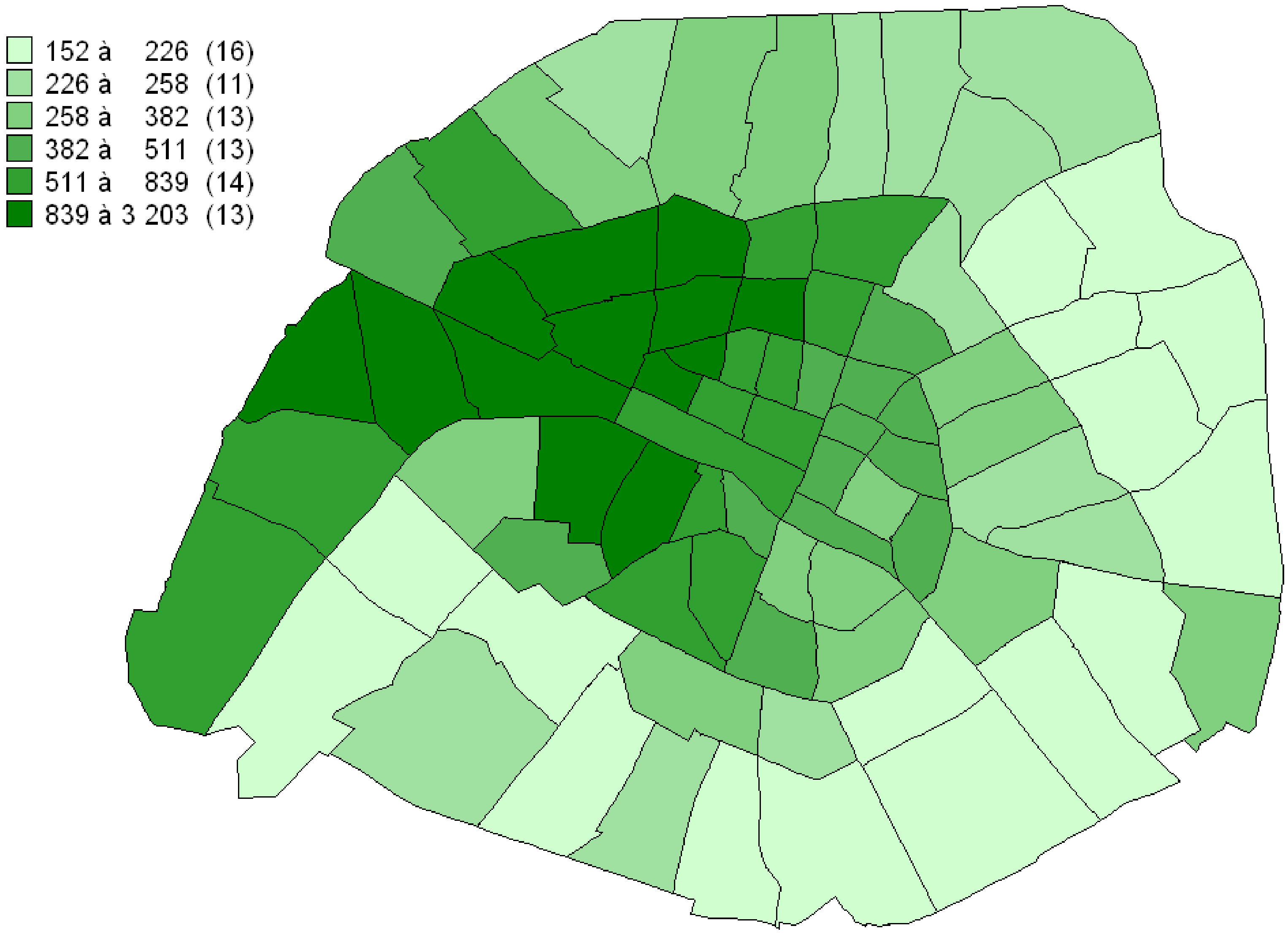

Figure IV Life Expectancy in 1910 as predicted by the 1880 Rent-Life Expectancy Relationship

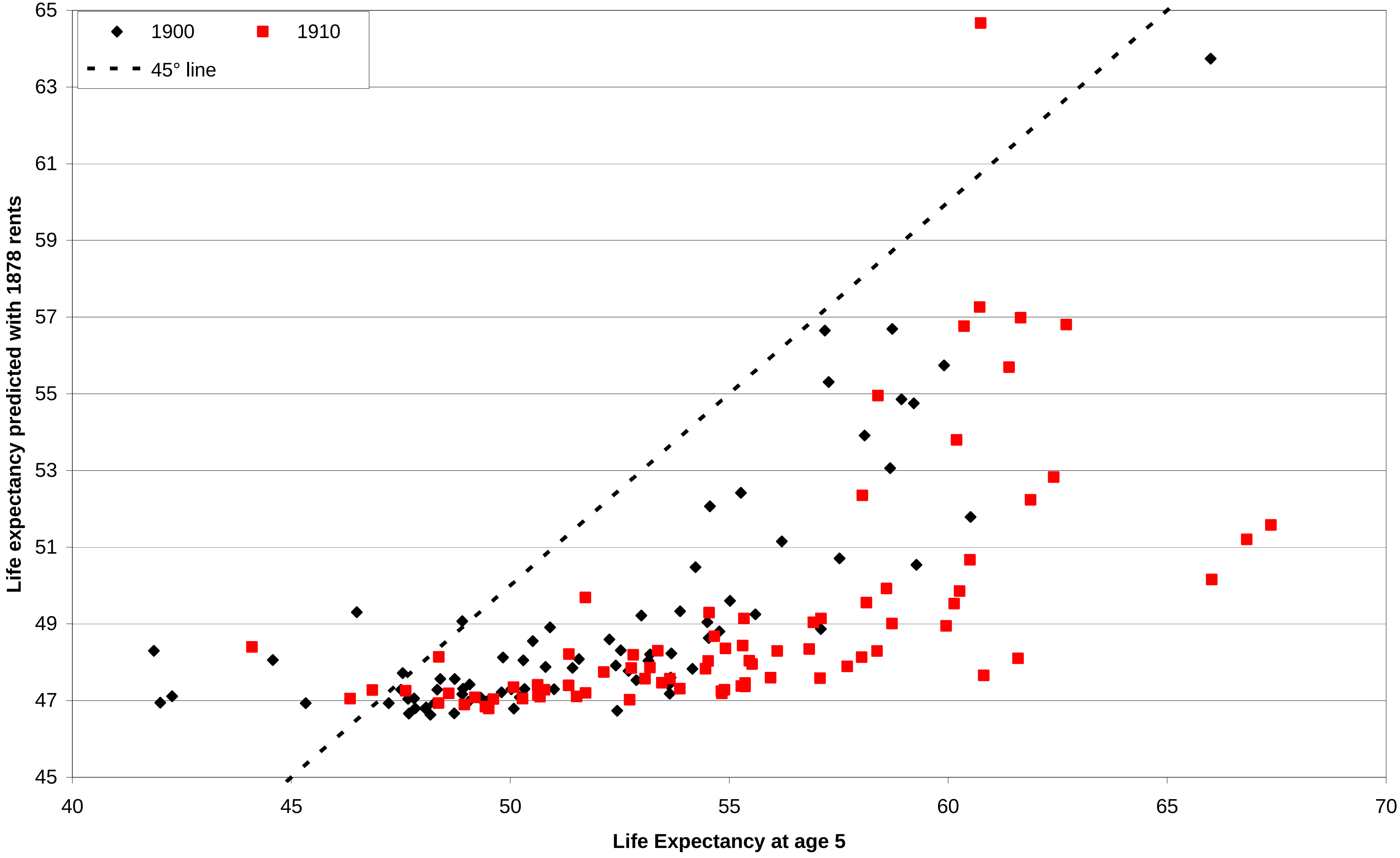

Figure V Share of Buildings connected to the Sewer by Districts