Public goods and health inequality;
Lessons from Paris, 1880-1914.

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Abstract

Around 1900, after centuries of disadvantage, urban life expectancy passed its rural counterparts. The process can be linked with two broad phenomena: rising incomes and improved sanitation. We focus on Paris during the key period of the health transition (1880-1914) and assemble a longitudinal data set on mortality and income for each of the city's 80 neighborhoods. We show that life expectancy in Paris was not very different from the rest of the country –around 50 years at age 5– but the difference between best and worst neighborhoods exceeded 10 years. These huge mortality differentials are strongly related to a variety of income indicators. Over time, mortality across neighborhoods first diverged and then converged. This pattern cannot be explained by variation in income or fixed neighborhood characteristics. It is due to the gradual diffusion of sewers that were adopted faster in rich neighborhoods than in poor ones.

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Introduction

In nineteenth century Paris life was both brutally short and massively unequal. In the 1820s, Parisians had a life expectancy at age five of about 44, some five years less than other French people. 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 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. The capital city's disadvantage did not begin to narrow until the 1860s and it did not close until the 1930s. Inequality in life span within Paris persisted stubbornly but, starting in the 1850s, the city began to address some of its worst environmental problems. The process began with the general delivery of clean water (by a concessionary company) and continued in the 1860s with 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 within the city. 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.

Paris' experience, which is similar to that of most large cities in the western world, raises questions about the sources and evolution of differential mortality. In this paper we examine two critical forces behind the closing of the rural urban mortality gap and of inequality in life span within cities: income and infrastructure. More specifically we chart how increases in income and the diffusion of sewers let to a significant decline in urban mortality. This work connects to a more general literature that emphasizes that life span in the western world before WWII was caught between the downward pressure of the ever increasing share of the population living in crowded and adverse urban and industrial 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 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 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. It is thus quite distinct from public goods.

The relative importance of these different factors in the mortality decrease is still debated. Earlier works emphasized the role of income gains (McKeown 1976) whereas more recent studies try 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). Finally, environmental effects are more and more often put forward. This can be a simple rural-urban opposition (the "urban disamenity" effect) (Cain and Hong 2009, Szreter and Mooney 1998, Woods 2003). Alternatively, scholars have looked at large scale improvements such as implementing clean water (Cutler and Miller 2005, Ferrie and Troesken 2008, Szreter 1988). As a rule these studies argue for a much weaker link between mortality and income that was assumed before, in favor of a strong environmental effect on mortality. 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 specific environment (one of the largest cities in Europe) where the range of economic circumstances was particularly broad.

To put things differently, there is a long lasting consensus of a positive correlation between income (or wealth) and health, both between (Preston 1975, Pritchett and Summers 1996) and within countries (Hummers, Rogers and Eberstein 1998). Such a relationships has been observed and commented since at least the early 19th century (Villermé 1828). But at the same time, there is little evidence that affluence *per se* contributes to a better health (Cutler, Deaton and Lleras-Muney 2006). In other words, the relationship between economic growth and life expectancy is not one way. There are advances and retreats in the evolution of both health and wealth that are unrelated to each other, whether from the historical record (Easterlin 1999) or in contemporary analyses (Deaton and Paxson 2004). In fact, it seems clear that "there is no presumption that

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

economic growth will improve health without deliberate public action" (Cutler, Deaton and Lleras-Muney 2006, Drèze and Sen 2002).

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. 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.[2] Thus, it appears essential to explore how large scale health improvement diffuses in a given society. This will allow us to better understand health inequalities, 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 because the municipal statistical office was dominated by individuals 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 between 1880 and 1913 for each of the 80 neighborhoods (*quartier*) of the city.[3] Data on the number of buildings connected to the sewers start in the 1880s with the same disaggregation level as mortality data. Their purpose in producing these very detailed reports was 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 did so in ways that were largely revenue neutral in the case of sewers while clean water was a source of city income. There was no real consideration of subsidizing such improvements out of general revenues.

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 and Rosenthal 2006). As we will show there is extraordinary stability in the ranking of these neighborhoods in terms of their real estate stock and their average wealth levels.

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

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

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

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. The fee-for-service nature of the diffusion process implies early adoption by rich neighborhoods and thus a temporary increase in differential mortality. Third, the take up of sewers in poorer neighborhoods was slow and although it did reduce the variation in life expectancy within Paris it did not eliminate it. Throughout the paper we focus on life expectancy and mortality risk from age five or older because Parisian records do not allow the reconstruction of mortality at earlier age. It is commonly accepted that in this period 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 a very equally large benefit of sewer adoption are thus likely to be downward biased relative to what the population actually experience.

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. Paris is obviously interesting in and of itself, but it also presents a remarkable contrast with France taken as a whole. In 1880 Parisians could expect to live 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). In this respect the Parisian and French experiences are quite similar to the general epidemiological transition in the North Atlantic where the decline in infectious diseases erased the urban penalty (For the US, see Haines 2001, for Paris: Meslé and Vallin 2009). Yet it raises a conundrum: how could it be that at the same time that the urban rural mortality was being erased, within the city, the pattern of differential demography changed very little?

[Figure I about here]

Paris is also attractive because of its long connection with statistical research on mortality. At the beginning of the 19th century, Paris was one of the birth places of studies of the relationship between mortality and wealth, with the work of Louis-René Villermé (Villermé 1823, Villermé 1830) who was an early explorer of the link between affluence and life expectancy. His research broke a long established belief that all were equally at risk of death (Lécuyer and Brian 2000, Villermé 1828). Later Louis-Adolphe and Jacques Bertillon, who headed the city's statistical office of the city from 1880 to 1913, were concerned with reducing the impact of communicable diseases in the city and with establishing the causes behind the dramatic differences in life expectancy. The statistical office's main publication, the *Annuaire statistique de la ville de Paris* provides a variety of relevant information for each of the eighty different neighborhoods of the city. Before 1880 the same data are available as city wide totals; after 1913, the reports are available for each of the twenty districts.

Starting in 1817 the city began to publish death by age totals broken down by sex and by five year age intervals. These city level data are useful only in so far as they allow us to place the capital in its long run and French context. More importantly, in 1880 the *Annuaire* reports death totals for each sex, broken down into six age categories for each neighborhood.[4] The statistical office also published a series of detailed abstracts for the city drawn from the national population censuses from 1882 to 1911. These give us the age distribution of the living for the same neighborhoods.[5] Taking these two data together allows us to compute mortality rate and life expectancy at the neighborhoods level (see appendix A. for details). Unfortunately we cannot compute life expectancy at birth 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 risks to suffer severe bias (Preston and van de Walle 1974). Thus we prefer life expectancy at age five.

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.[6] 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 (average 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 at each census); the rich paid more than 1000 francs.

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[4] 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).

[5] 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.

[6] 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.

At the archives of the treasury we collected neighborhood level fiscal data for every five years from 1876 to 1911. These data include the number of households who paid a rent above the fiscal threshold (rich and middle class) and the total rent they paid. We can thus compute the average rent paid by households above the threshold. As we will see this rent is very highly correlated with average rent reported by the census.

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 the detailed reports on the demography of its inhabitants. 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.

Studying mortality within Paris poses serious complications, the most obvious of these being that Parisians have never been a closed population. 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 1886 to 1901) and this proportion varies only little between districts.[7] Migrants to Paris are also not a random sample of the world or of France's population. 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 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 older groups will not be so sensitive to migration rates.

The second selection effect, residential sorting, also 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.

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[7] 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.

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 with less polluted air. The rich hired many more female servants to clean and take care of the children. While we cannot disentangle these two chains of causation, it seems the characteristics of the neighborhoods were far less important than either their infrastructure or the incomes of their denizen. Indeed Paris was a small city with limited variation in its environment. Rich neighborhoods included both the 7th and 1st arrondissement along the Seine and the higher altitude 16th and 8th arrondissement. The poor 5th was actually upstream from the rich 7th. Save for air quality, the rich did not congregate in 'naturally' healthy environments, though, as we shall see, they did congregate.[8]

Yet such intuition is insufficient 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. An important feature of our empirical strategy is indeed to estimate our regressions with neighborhoods fixed effects: unless otherwise noted, we always consider differences over time within a given neighborhood. Such an approach helps resolve both migration issues. First, the structure of migration across Paris was very stable which means that 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.[9] 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 (Faure and Farcy: 370). If males' migrations aged 20 to 45 are any indication, 30% of the moves within Paris occur within the same neighborhood, 40% within the same district and 78% within the same area –center or periphery

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

[9] 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 it should be noted that such a variation should be huge to modify the differences in life expectancy between neighborhoods we observe.

(Faure et Farcy: 345-346). Overall, the ranking of neighborhoods change only little over time in term of both wealth and 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.

Let's start by describing the general evolution of health in Paris over time. As noted above, and as we discuss further below, at age five life expectancy differences between the worst and best decile of neighborhoods neared an enormous 15 years in 1880. 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 and Sander 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 van de Walle 1978), we lack the data to analyze its impact within Paris.

Beyond clean water, sewers are an important health enhancing service. The *Annuaire* provides a good deal of detail on the disposal of waste water. 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, those 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. 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 II). 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 II about here]

II. Mortality and wealth inequality in time and space

Figure III presents the average life expectancy for the city (the black line) and for France (the dotted line).[10] The figure also shows the life expectancy for the worst eight (the red line) and the best eight (the dotted red line) neighborhoods in Paris. 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 four years shorter than the average for the city and five to seven 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 seven year advantage over the rest of the city and a four year advantage over the rest of France. Over the next two decades life expectancy in the best districts rose quickly and neared 64 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 III about here]

The inequality in life expectancy within Paris is particularly striking because it is in fact much larger than the difference observed across deciles for departments (these 90 administrative districts are roughly equivalent to US counties). As Figure IV shows, the gap between the nine

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[10] Paris accounted for 4.5% at the beginning of our period and 7% at the end of the French population.

departments with the highest and lowest life expectancy was about twelve years in the 1880s; by 1905 it had shrunk to seven. This improvement is comparable to what has been documented for the US over the course of the 20th century (Peltzman 2009). In France, most of the gain came from the worst departments where life expectancy grew by six years while in the best departments it only eked out an additional year. During the same period, Paris had a reverse experience: the bottom eight neighborhoods managed at best a three year gain in life expectancy when the best ones 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 their residents became the longest lived French people. 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. In contrast to France as a whole, economic growth did not readily translate into a reduction of life expectancy inequality in Paris.

[Figure IV 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 (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 instead comes from deep difference in the material circumstances of the residents of these neighborhoods.

We do not have direct evidence of incomes or consumption in the different neighborhoods of the city but we have access to excellent data on the distribution of rents across the city. To interpret rents, we assume that households devote a fixed fraction of their consumption to housing –which is not an unreasonable approximation. Furthermore we assume that the individual household heterogeneity averages out within neighborhoods so that the budget-share of housing can be taken as constant across neighborhoods. There are a couple of 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 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 V). 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 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 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 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 (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 V 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 time periods for each neighborhood that link each 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 I). Throughout this paper we only report simple linear coefficients, we did try to see if there were non-linear effects (in particular one might expect that the income effect would be concave) but the estimate were neither robust nor stable. 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's 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[11] (we ran the same regressions with average rents and got similar results). Increases in the share of the 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 I 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 VI 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 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 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 the increase in differential mortality suggested by Figure III. We can reproduce these results with the average rent paid in each neighborhood so as to extend the data to seven cross sections (Table II). 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). While the differences between coefficients from one cross section to the next are not statistically significant, we can reject the hypotheses that the coefficient of rents estimated for 1896 is the same as that for 1881 or 1910. At the same time the constant term increases steadily over time from 49 to 53.4 years in 1910, a gain of almost 10%. We estimated the same cross section for mortality by age group and by sex in regressions we do not report. The regressions show the same pattern of an increase in the impact of income on mortality to 1896 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

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[11] Both share of poor and share of rich are standardized and thus the coefficients can be directly expressed as the variation in life expectancy for one standard deviation of share of poor (rich respectively), the constant measuring the life expectancy at the average value of the share of poor (rich respectively).

is increasing in age, the proportional impact is similar across ages. Finally we found no statistical differences between sexes: more income reduced mortality risk in quite similar ways for men and women.

Clearly then, the relationship between income and life expectancy had changed over time. In the aggregate, we can reject first 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. Hence although it is tempting to interpret the divergence that we see from 1880 to 1896 as caused by increasing inequality (Piketty, Postel-Vinay and Rosenthal 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 diffusion of sanitation was responsible for the convergence, and part of the divergence as well.

[Table II about here]

[Figure VI about here]

To net out the effect of the long term decline in the share households below the fiscal threshold we re-ran the regression from Figure VI but instead of using the contemporaneous survey, we used only the first census for the explanatory variable (see Figure VII). Again, the 1881 share of poor implies a life expectancy range from 45 to 54 years old in 1881. The 1891 curve shows both an increase in life span 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' rose from 1881 to 1901 but did not change much from 1901 to 1911. In the poorest ones the gain came almost completely after 1901.

[Figure VII about here]

Life expectancy in Paris was thus very unequal, with differences between neighborhoods being both strong (and stronger than in France as a whole) and closely related to income.

Further, the evolution of mortality up to WWI sees 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: 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 reside 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 and Rosenthal 2006, Piketty, Postel-Vinay and Rosenthal 2011) based on a series of cross sections 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. 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 6,000 francs, enabling them to afford the housing of the rich). These data allow us to examine the extent of residential sorting. If wealthy people can be found all over Paris, then large neighborhood differences 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 III). 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 III about here]

The same data allow us to study mortality at the individual level. To match the life expectancy by neighborhood one would want to have life expectancy by wealth fractile. We cannot, however compute such measures: we do not have age distributions for the living by wealth fractile. In particular at the top end of the wealth distribution, one has to worry about endogeneity: 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 live long). To be sure, it is likely that wealth helps prolong life (thus distribution of ages for the top fractile is likely to statistically dominate 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. Indeed, at high levels of wealth individuals have positive net savings rates. 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 simply present age at death by fractile restricted to only include decedents aged 20 or more (see Table IV). 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 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 does not equal life expectancy data because it does not control for changes in the at risk population.

[Table IV about here]

III. Do public goods make things better… or worse?

Clearly then income first became more valuable over time to prolonging life, with a peak around 1896, and then 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. In 1901 the same 5 rich (high rent) districts we mentioned above had a connection rate of at least 54% (and 62% on average) while the 12 poorest districts had at most 39% of their buildings hooked up to the sewers (and 27% on average). A little theory seems in order 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.

Consistent with our assumption that rents can stand as a good proxy for consumption, assume that Parisian households have Cobb-Douglas utility functions with housing having a coefficient α. Thus each household devotes α 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 (at what an immigrant would pay for it). Now suppose sewers become available, and that tenants' housing budget share increases from α to α' for homes connected to sewers. Each tenant is in effect willing to pay (α'-α) of his or her total consumption to live in a building that is connected to the sewer. In effect sewers appear to be a luxury good with the rich willing to pay more for the service than the poor. Suppose the provider charges a connection fee; then for rich enough tenants, the building owner will receive more in extra rent than the fee while for poor enough tenants most of the connection fee will come out of the owners' pocket.[12]

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. 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 tanks. Because housing's budget share expands (from α to α') when sewers are available, building owners have an aggregate surplus to capture. One might speculate that it would be efficient from both a social welfare and an engineering point of view to socialize sewers (if $(\alpha'-\alpha)$ times aggregate city income is larger than the flow cost of sewers). The city would levy a tax (on buildings or consumption) and connect 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 (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.

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[12] In a simpler model, the coefficient of expenditures going to housing does not change with sewers. In this case, total rents in the city are insensitive to sewers (total rents are just α of total consumption); thus sewer connections fees will come out entirely of building owners' pockets.

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 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, as connection was voluntary, owners faced 30 or 60 franc fee 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, 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 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 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).

The rational and systematic approach used to connect dwellings to sewers in 19th century Paris complicates the analysis. Indeed, sanitation is related to income in ways that force us to consider several alternative hypotheses. The first one is that the diffusion of sewers simply reflects income gains. In other words such forms of sanitation have no or only limited direct benefits. The second one is more subtle and has to do with migrants' selection: the diffusion of sewers actually increases residential sorting, with the richer neighborhoods attracting even more of the city's relatively healthy middle class. Finally, a more historical approach might well suggest that there were a host of other life improving new technologies, and so a naïve regression will overstate the impact of sewers on life expectancy.

We can reject the first two hypotheses with simple tests while maintaining that income does improve life expectancy. Given the steep life-expectancy to rent profile in 1880 –before any buildings were connected directly to the sewers–, we would imagine that even limited changes in income would have a large effect on life expectancy. So in that case connection to sewers would only be a by-product of rising income: as income increases the distribution of life expectancy improves and, at the same time, individuals want to remove themselves from the less pleasant aspects of waste water. Thus they prefer to live in buildings connected to the sewer even if sanitation does not improve life expectancy. To evaluate the hypothesis that all of the changes that follow 1880 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 1880 regression to the rent distribution in late years (see Figure VIII). 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 VIII about here]

The second hypothesis relies on increasing residential sorting to explain the rise in the life expectancy of the rich neighborhoods.[13] Practically, 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 were not available. If this effect was large we would expect to see rent and life expectancy decline in neighborhoods that were not served due to adverse selection. But, on the contrary, there is no evidence that any neighborhood experienced important mortality increases –due to adverse residential sorting or any other cause. It seems the diffusion of sewers was Pareto optimal: although some neighborhoods were better off early on, none were worse off.

Let us now look at sewers directly and start with some naïve estimations. These are only intended to show that the diffusion of sewers coincided with both the increase in life expectancy in rich neighborhoods and the catch up of poorer ones. Table V below reports simple regressions of life expectancy on the fraction of buildings connected to the sewers. The dataset includes one observation per neighborhood per census year (1881, 1886, …, 1911). Sewers seem to have significant benefits, between 1890 and 1910 they added about two years to Parisians' 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 neighborhood fixed effects. 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

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[13] More broadly, the same argument can be used to argue that Paris attracted better immigrants after sewers had been put in place.

connection is thus consistent with a widening of the gap in life expectancy. Then by 1910 while the richer districts powered to a 77% connection rate, the 19th and 20th reached 54%: the poorest districts had begun to close the gap. Finally, by 1928 the 8th and 9th were above 90% but the 19th and 20th were not so far away, at 81% or above.

[Table V about here]

One can also examine the impact of sewers on mortality by age group and by sex (Table VI). 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. 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 neighborhood fixed effects. If we include both year and neighborhood fixed effects, then we can only identify four of 8 coefficients at the 5% level, but given the small number of cross sections, this is hardly surprising. Overall, however, sewers always seem to offer substantial declines in mortality risk.

[Table VI about here]

That sewer diffusion was correlated with low mortality may be simply linked to the fact that affluent neighborhoods adopted sewers first. Indeed, 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 sewer adoption but not with a neighborhood's income. 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 starting in 1880 interacted with location. We divide Paris into two parts its old 'center' and the newer '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 to the stock of buildings in 1906 is 0.16; and the stock of building in 1889 represented 85% of the stock of 1906. In contrast in periphery (districts 12 to 20), population grew by 50% from 1881 to 1906 and much of the construction occurred after buildings started to be connected to sewers. The ratio of building permits issued between 1882 and 1906 to the stock of buildings in 1906 is 0.31; and the stock of building in 1889 was only 67% of the stock of 1906. 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.

In the periphery, building permits have the advantage that they are related to sewer connection but not to the distribution of rents. 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. The question is to what extent sewers versus these other attributes contributed to improvements in life expectancy. Table VII shows that overall, the cumulative number of building permits has a strong positive effect on life expectancy which, as we just argued, seems related to the better quality of new buildings, which probably refer to many improvements, and not only connection to sewer.

But one should not yet conclude that we should reject the instrument because the statistical finding above is extremely coarse. A better way to examine this question is to estimate the impact of new building permits on life expectancy directly and compare its effect before and after 1894. If sewer connection is the dominant channel whereby new buildings improve life expectancy, we would expect the coefficient before 1894 to be smaller than the one after that date. If sewers are irrelevant then the coefficients should be identical. However, as the second panel of Table VII shows the effect of building permits before mandatory connection to sewers was implemented (1894) is negative, while the one for the period after mandatory connection is positive and statistically significant. The result for the period before 1894 may be linked to the fact that most construction occurred in bad neighborhoods –something that was also true later. Our interpretation, however, is that new buildings are not life prolonging if they do not embody life prolonging sanitation. More importantly, the effects are opposite in the center and the periphery. In the former, where only few new building went up, the effect is small and even insignificant in the second period. In the periphery, on the other side, the effect is negative before 1894 and large and positive after that date. This clearly means that, at least in the periphery, building permits have a positive influence on life expectancy only after sewer connections became available.

[Table VII about here]

Building permits do seem to be an acceptable instrument and we now estimate both income and sewers effects on life expectancy. As discussed before, we use rent as an income proxy and we can take advantage of two different measures, either average rents from the rent censuses or rent per fiscal household from the tax data. The former have the advantages that they cover every household but they are limited to two cross sections during the mandatory connection to sewers period (1901 and 1910). The latter are more frequently available (every five years) but they are censored because households who paid less than 500 francs 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. Nevertheless we estimated 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 Tables VIII and IX).

Table VIII reports regressions based on the housing censuses and uses building permits as an instrument. Interestingly, and consistent with what we suggested just above, the instrument has power only in the periphery of Paris. While the first stage F tests are high in all specifications of Table VIII, the adjusted R-square of the center regression is dismal. Furthermore, in the center the second stage regression provides a negative income effect that seems hard to believe and a very large effect to the sewer connection rate. On the periphery the magnitude of the estimated effect is reasonable, with a gain in life expectancy of almost 2 years, which is substantial. One drawback from these regressions is that we cannot identify the rent index if we include neighborhood fixed effects. The lack of statistical significance of the income coefficients is not surprising since the correlation between rents in 1901 and 1910 is 0.99, but it does not seems sufficient evidence to dismiss the role of income on life expectancy.

[Table VIII about here]

Clearly we need more variation over time to disentangle the effects of income, sewers, and neighborhood; that is just what Table IX reports. Here we use a panel with five observations per neighborhood (1891, 1896, 1901, 1906, 1910) based on the rents reports in tax records. Again we instrument sewers with cumulative building permits and include fixed effects. For Paris as a whole, there is 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, which seems hardly plausible. Only in the periphery –again consistent with our expectations–, do we get a clean identification of both sewers and income effects. Sewers provide a modest additional year of life while income has a bigger impact. This is not surprising since the 'good' neighborhoods of the 16th and 17th districts were leaders in sewer connection, income gains and life expectancy gains. Overall, however, the periphery does allow us to show that opposing income to infrastructure is wrong headed, both contributed to the rise in life expectancy.

[Table IX 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. To control for this effect, we estimate two stage least square regressions as in Table IX but replace life expectancy with age specific mortality for different ages and sex and for the periphery only –thus variables that prolong life will have negative coefficients because they reduce mortality risk. We do not report the first stage again since it does not vary by age and is already reported in table IX (Column 3). Table X reports the results for ages 5-19, 20-39, 40-49 and 60-79. The first striking finding is that there are no statistical differences between men and women (nearly all the age specific coefficients for men always lie within the confidence interval of that for women and vice versa). If we accept a 10% confidence bound, sewers seem to reduce mortality both for youth (5-19) and later in life for adults between 40 and 79. If we place a higher threshold of 1% the oldest group drops out. Men and women ages 20-39 and 60-79 even have a negative coefficient but it is not statistically significant. Income is nearly always negative and is only statistically significant at the 10% level for men. It may be that women who came into contact with waste water much more frequently in their homemaking activities were more sensitive to sewers than income. It also appears that during the childrearing years the effects of infrastructure investments were small simply because other factors (varying fertility) really drove change over time. 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 (though that leaves internal residential sorting to be considered).

[Table X about here]

We can take the estimates from Table X 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 rich 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 1870 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 one s 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 5 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.

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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 and Guillot 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 5 (years)	2640	1881-1913	51.82	4.78	4.02	2.62	0.65
Share of poor household (%)	320	1878, 1890, 1900, and 1910	49.44	20.06	19.99	10.80	0.88
Average rents -- complete (francs)	320	1878, 1890, 1900, and 1910	656.42	606.81	595.09	131.97	0.93
Average rents – fiscal (francs)	560	1881, 1886, 1891, …, 1911	890.69	792.31	782.31	149.37	0.94
Sewer connection rate (SCR) (%)	2000	1889-1913	37.09	26.94	8.12	25.70	
Building permits (cumulated number)	2560	1882-1913	277.69	316.43	233.26	215.36	

Panel B. Centre (44 neighborhoods)

Life expectancy at age 5 (years)	1452	1881-1913	53.43	4.44	3.65	2.59	0.74
Share of poor household (%)	176	1878, 1890, 1900, and 1910	40.28	14.04	12.66	8.28	0.90
Average rents -- complete (francs)	176	1878, 1890, 1900, and 1910	843.64	674.51	672.23	104.00	0.90
Average rents – fiscal (francs)	308	1881, 1886, 1891, …, 1911	1127.33	851.15	848.93	133.70	0.83
Sewer connection rate (SCR) (%)	1100	1889-1913	39.83	27.71	6.50	26.95	
Building permits (cumulated number)	1408	1882-1913	112.95	124.45	91.82	85.11	

Panel C. Periphery (36 neighborhoods)

Life expectancy at 5 (years)	1188	1881-1913	49.85	4.43	3.58	2.67	0.34
Share of poor household (%)	144	1878, 1890, 1900, and 1910	60.65	16.14	14.83	13.27	0.89
Average rents -- complete (francs)	144	1878, 1890, 1900, and 1910	427.61	410.84	382.42	160.04	0.81
Average rents – fiscal (francs)	252	1881, 1886, 1891, …, 1911	601.45	599.38	582.70	166.82	0.89
Sewer connection rate (SCR) (%)	900	1889-1913	33.74	25.59	8.72	24.09	
Building permits (cumulated number)	1152	1882-1913	479.04	360.43	191.40	307.03	

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).

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Table I 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.)		0.71	0.671
Constant	51.51	51.51	51.51
(S.E.)	0.130	0.157	0.157
R^2	0.59	0.53	0.64
Fixed effects for Quartier	Yes	Yes	Yes
N	320	320	320

Table II 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 R2 varies between 0.33 and 0.61.

Table III : 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				
	1876		1910		W > 4M	4M>W >1M	1>W> 0.5	0.5>W> 0.25	0.25>W >0.125
District	1000>R >5999	R> 6000	1300> R> 6999	R> 7000 F					
1	6.8	6.9	3.2	2.7	3.1	2.8	4.3	2.7	2.8
2	6.7	3.2	1.9	1.1	0	3.2	1.8	1.7	2.2
3	4.9	0.3	2.0	0.2	0	0.9	1.8	1.9	2.3
4	4.0	0.4	3.3	0.3	0	2.8	3.3	4.1	4.7
5	3.8	0.3	3.5	0.4	0	1.8	2.5	4.9	4.6
6	7.6	2.2	6.8	1.6	0	4	7.9	7	6.6
7	5.6	12.1	7.9	12.6	13.5	11.3	8.7	6.8	7.2
8	14.2	45.7	14.9	37.8	52.1	36.5	22.7	19.3	12.5
9	20.0	16.4	12.0	4.6	12.5	13.4	15.6	14.7	12.3
10	10.0	1.2	5.0	0.3	0	3.2	5.8	6.7	6.1
11	3.5	0.1	2.5	0.1	1.1	1.9	3.2	5.5	6.4
12	0.9	0.1	1.8	0.1	0	0.9	0.8	1.7	3.2
13	0.4	0.1	0.3	0.1	1.1	0.6	0.6	0.9	1.1
14	0.5	0.1	2.0	0.3	0	0.2	0.7	1.4	2.5
15	0.5	0.1	2.1	0.2	0	0.5	1.4	1.3	2.6
16	4.9	8.5	16.2	29.1	13.5	11.9	11.1	10.3	9.6
17	4.1	2.1	12.6	8.2	2.1	2.6	5.2	5.1	6.2
18	0.9	0.0	1.3	0.1	1	1	1.4	2	2.4
19	0.4	0.0	0.3	0.1	0	0.4	0.5	1.1	2.5
20	0.2	0.1	0.2	0.0	0	0.1	0.7	0.9	2.2
N	58053	5532	76779	6924	97	850	1040	1455	2091

Table IV 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
Average 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 month of January 1th 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 V 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 VI Life Expectancy and the Diffusion of Sewers, by Age

	Mortality Risk by neighborhood								
	Men					Women			
	No Fixed Effects								
	5-19	20-39	40-59	60-69		5-19	20-39	40-59	60-69
Sewer connection rate	**-0.011** **(0.001)**	**-0.015** **(0.001)**	**-0.042** **(0.002)**	**-0.033** **(0.002)**		**-0.010** **(0.001)**	**-0.013** **(0.001)**	**-0.035** **(0.002)**	**-0.037** **(0.003)**
Constant	**0.0688** **(0.001)**	**0.166** **(0.001)**	**0.398** **(0.002)**	**0.678** **(0.002)**		**0.067** **(.001)**	**0.137** **(0.001)**	**0.269** **(0.002)**	**0.604** **(0.003)**
	Location Fixed effect								
SCR	**-0.009** **(0.001)**	**-0.005** **(0.001)**	**-0.027** **(0.001)**	**-0.026** **(0.002)**		**-0.008** **(0.000)**	**-0.003** **(0.001)**	**-0.023** **(0.001)**	**-0.027** **(0.002)**
Constant	**0.065** **(0.005)**	**0.175** **(0.007)**	**0.405** **(0.012)**	**0.677** **(0.017)**		**0.068** **(0.004)**	**0.133** **(0.006)**	**0.243** **(0.009)**	**0.563** **(0.015)**
	Location and year Fixed Effects								
SCR	0.004 (0.002)	**-0.012** **(0.003)**	**-0.015** **(0.006)**	*-0.022* *(0.009)*		0.000 (0.002)	**-0.009** **(0.003)**	-0.001 (0.005)	-0.013 (0.008)
Constant	**0.069** **(0.005)**	**0.198** **(0.007)**	**0.419** **(0.012)**	**0.701** **(0.019)**		**0.071** **(0.005)**	**0.148** **(0.006)**	**0.239** **(0.010)**	**0.578** **(0.017)**

Note: The table reports two coefficients for 24 separate regressions of mortality risk by age group on the sewer connection rate. Each regression is based on 33 years X 80 districts or 660 observations. Bold coefficients are significant at the 1% level.

Table VII Life Expectancy and Building Permits

Dependant variable: life expectancy at age 5			
	Neighborhoods included		
	All	Center (1-11)	Periphery (12-20)
Cumulated building permits	**1.75** **(0.07)**	**5.11** **(0.21)**	**1.43** **(0.07)**
Constant	**53.00** **(0.41)**	**55.53** **(0.41)**	**45.35** **(0.43)**
Neighborhood F.E.	Yes	Yes	Yes
Adj R^2	0.77	0.77	0.73
N	2560	1408	1152
Cumulated building permits before 1895	**-0.37** **(0.07)**	**1.12** **(0.20)**	**-0.49** **(0.07)**
Cumulated building permits 1895 and after	**0.68** **(0.07)**	0.20 (0.23)	**0.71** **(0.07)**
Constant	**51.82** **(0.45)**	**51.86** **(0.45)**	**46.98** **(0.47)**
Neighborhood F.E.	Yes	Yes	Yes
Adj R^2	0.72	0.67	0.70
N	2560	1408	1152

Note: The table reports six separate regressions of life expectancy on cumulated building permits. Bold coefficients are significant at the 1% level.

Table VIII I.V. Regressions Panel A: pooled 1901 and 1910 Observations with Rent

First stage endogenous variable: Sewer Connection Rate (SCR)			
	Neighborhoods included		
	All	Center (1-11)	Periphery (12-20)
Rent index	0.21 (0.87)	-1.22 (1.53)	1.30 (0.93)
Cumulated building permits	**0.93** **(0.16)**	**2.36** **(0.52)**	**0.69** **(0.15)**
Constant	**1.66** **(0.52)**	**2.92** **(0.67)**	-0.78 (1.08)
Neighborhood F.E.	Yes	Yes	Yes
F-stat	30.57	20.72	19.12
Adj R^2	0.11	0.01	0.37
Second stage independent variable: Life expectancy at Age 5			
SCR	**2.68** **(0.41)**	**3.58** **(0.45)**	**1.86** **(0.72)**
Rent index	0.67 (2.4)	-4.96 (3.15)	5. 17 (3.51)
Constant	**48.93**	**48.37** **(1.14)**	**51.62** **(1.59)**
Neighborhood F.E.	Yes	Yes	Yes
N	160	88	72
R^2	0.89	0.88	0.84

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

Table IX I.V. Regressions Panel B: 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	Center (1-11)	Periphery (12-20)
Fiscal Rent	**0.88** **(0.25)**	**1.20** **(0.37)**	**0.36** **(0.25)**
Cumulated building permits	**1.20** **(0.09)**	**3.27** **(0.33)**	**1.04** **(0.07)**
Constant	**1.01** **(0.38)**	**2.50** **(0.46)**	**-1.82** **(0.42)**
Neighborhood F.E.	Yes	Yes	Yes
F-stat	169.81	95.39	216.77
Adj R^2	0.31	0.28	0.59
Second stage independent variable: Life expectancy at Age 5			
SCR	**1.05** **(0.14)**	**0.93** **(0.17)**	**1.02** **(0.18)**
Fiscal Rent	0.96 (0. 52)	-0.12 (0.69)	**2.31** **(0.99)**
Constant	**52.09** **(0.71)**	**52.02** **(0.71)**	**50.38** **(1.13)**
Neighborhood F.E.	Yes	Yes	Yes
N	400	220	180
R^2	0.88	0.87	0.85

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

Table X I.V. Regressions: pooled 1891, 1896, 1901, 1906 and 1910 Observations with Fiscal Rent as an Income Proxy (Periphery only).

	Second stage dependent variable: probability of death /1000								
	Men					Women			
	Age 5-19	Age 20-39	Age 40-59	Age 60-79		Age 5-19	Age 20-39	Age 40-59	Age 60-79
SCR	**-5.29** **(1.82)**	-1.03 (4.18)	**-32.35** **(6.15)**	*-16.1* *(7.88)*		**-5.84** **(1.89)**	-5.01 (3.75)	**-34.51** **(5.58)**	*-16.41* *(7.52)*
Fiscal Rent	*-17.74* *(7.36)*	-16.81 (16.9)	*-44.76* *(24.96)*	*-53.36* *(32.0)*		4.99 (7.68)	-5.10 (15.21)	-31.32 (22.63)	-31.15 (30.48)
Constant	**57.1** **(9.66)**	**194.87** **(22.2)**	**459.86** **(28.51)**	**766.6** **(41.9)**		**68.9** **(10.1)**	**180.2** **(20.0)**	**340.17** **(29.68)**	**626.5** **(40.0)**
Neighborhood F.E.	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes
N	180	180	180	180		180	180	180	180
R^2	0.55	0.64	0.74	0.47		0.48	0.67	0.74	0.74

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.

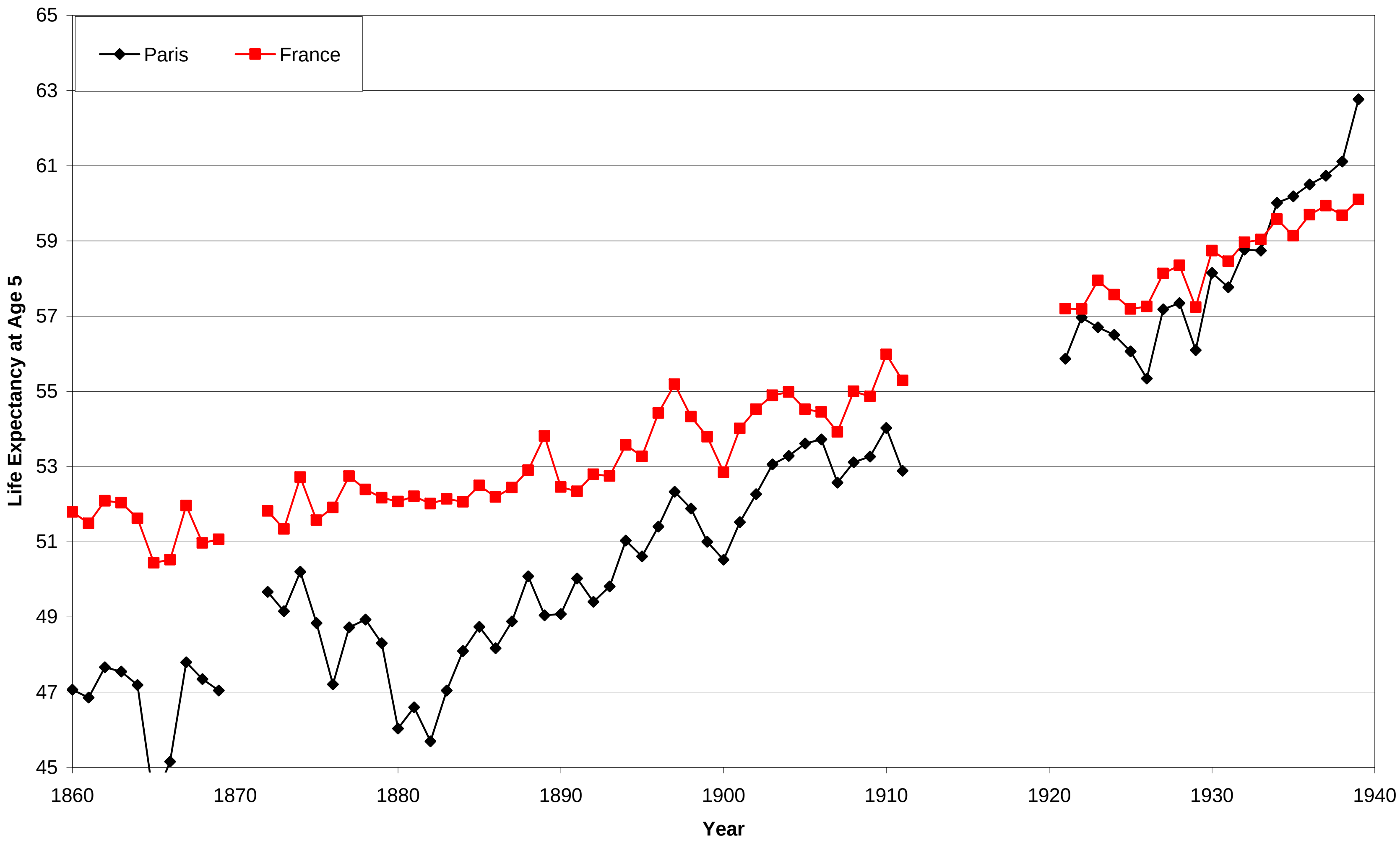


Figure II Share of Buildings connected to the Sewer by Districts

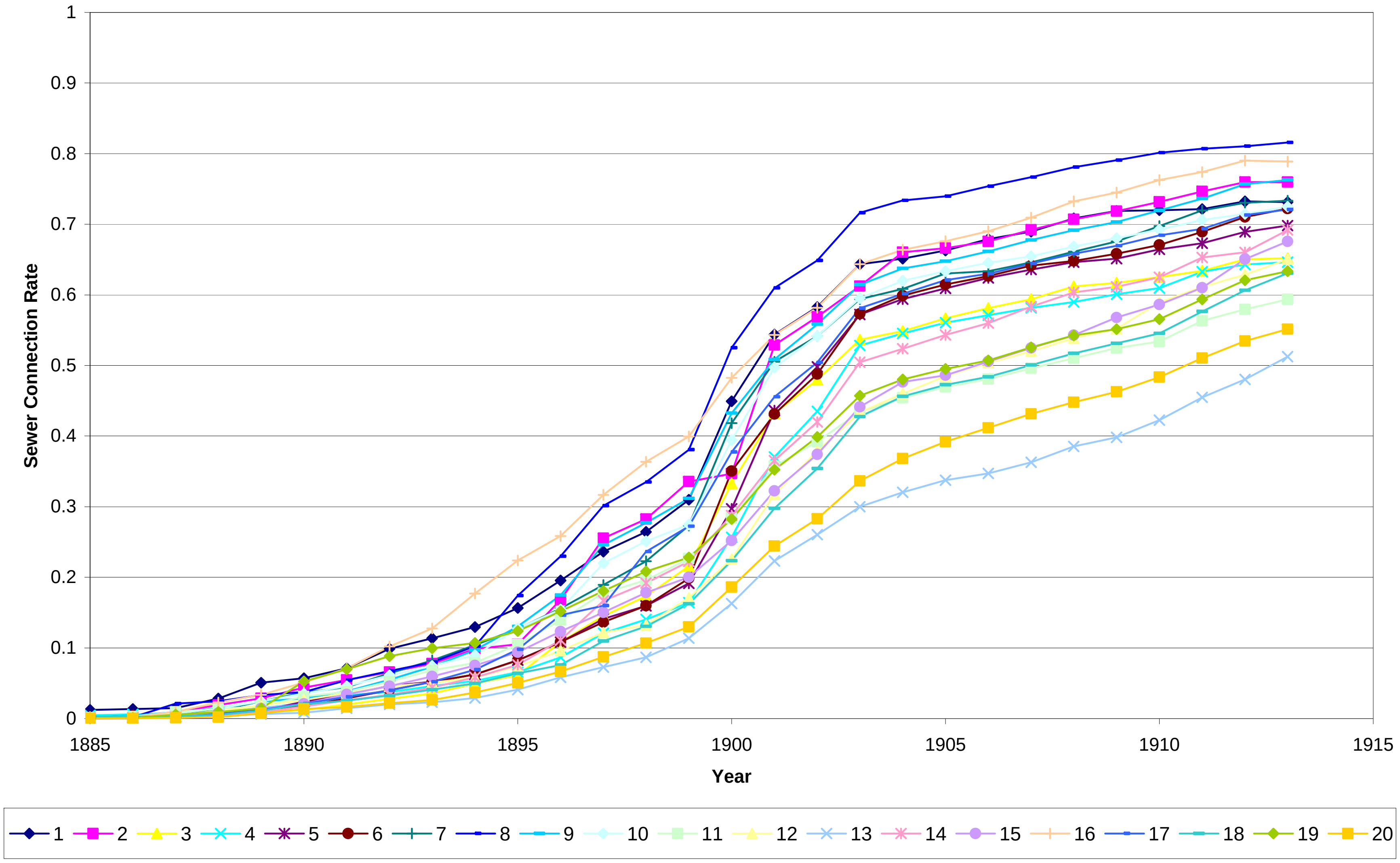


Figure III Life expectancy at age 5 within Paris, compared to France

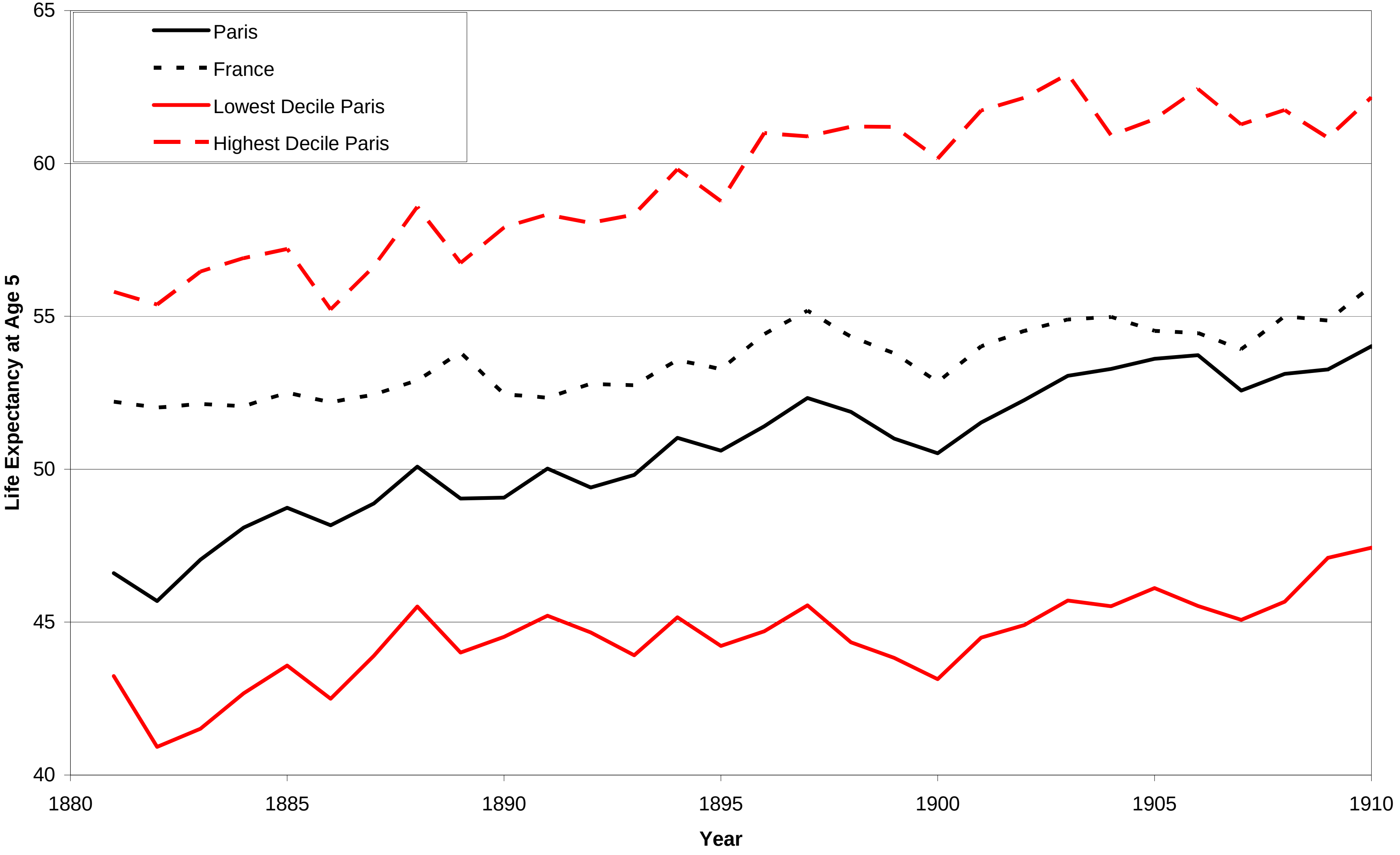


Figure IV Life Expectancy at Age 5 within Paris and within France

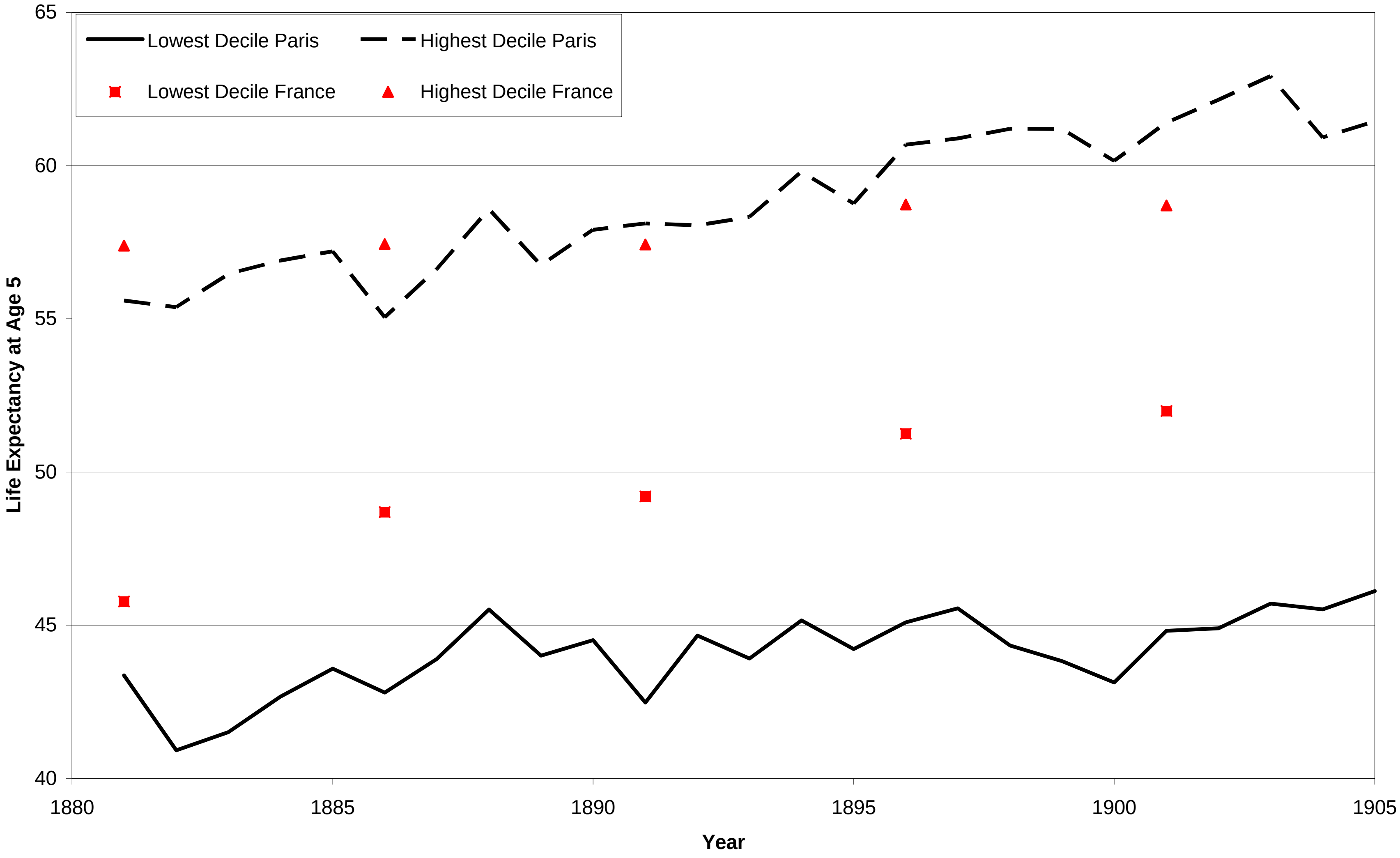


Figure V Average Rents by Neighborhoods in Paris, 1876

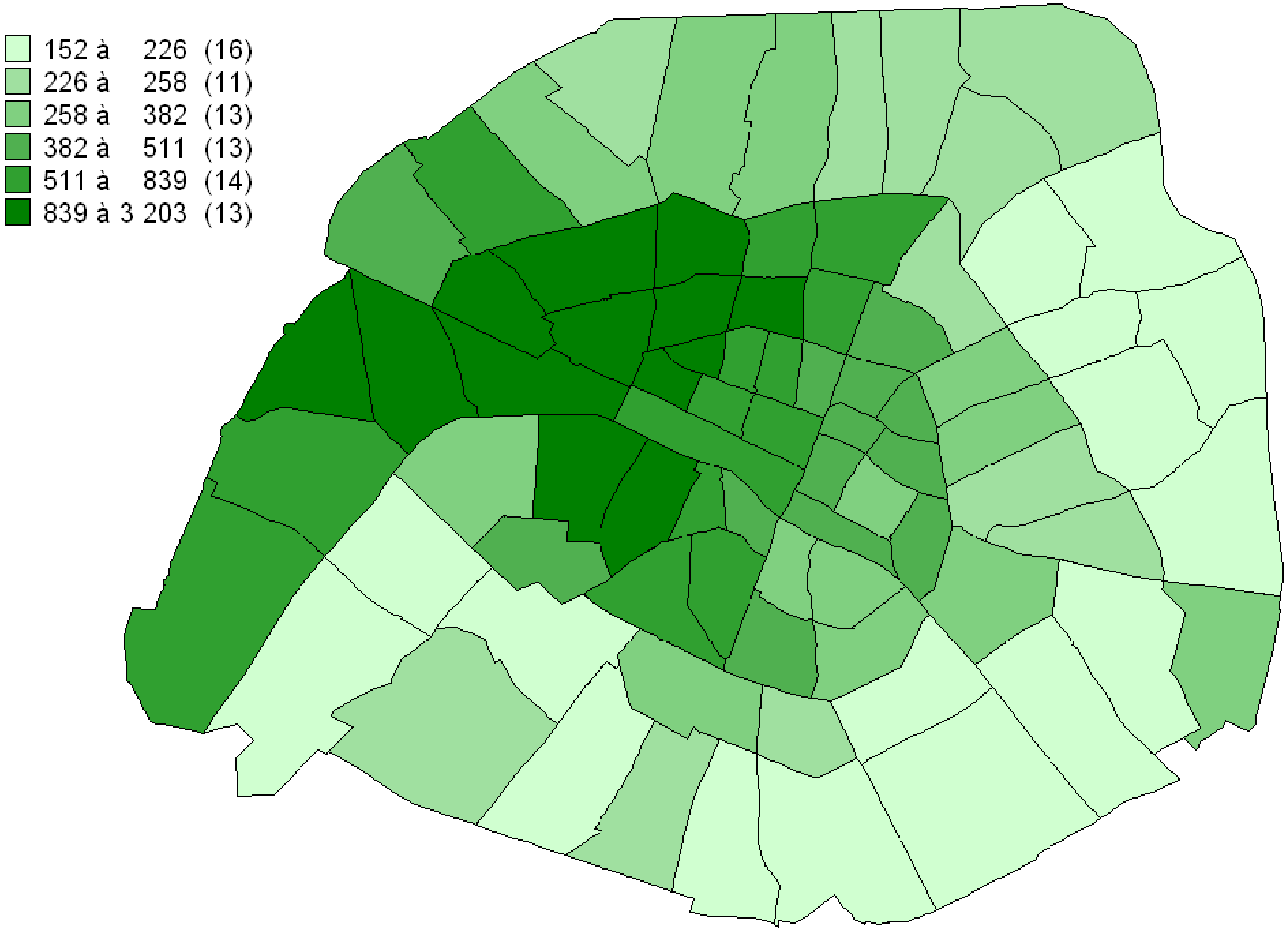


Figure VI: Life Expectancy and the Share of Poor Households

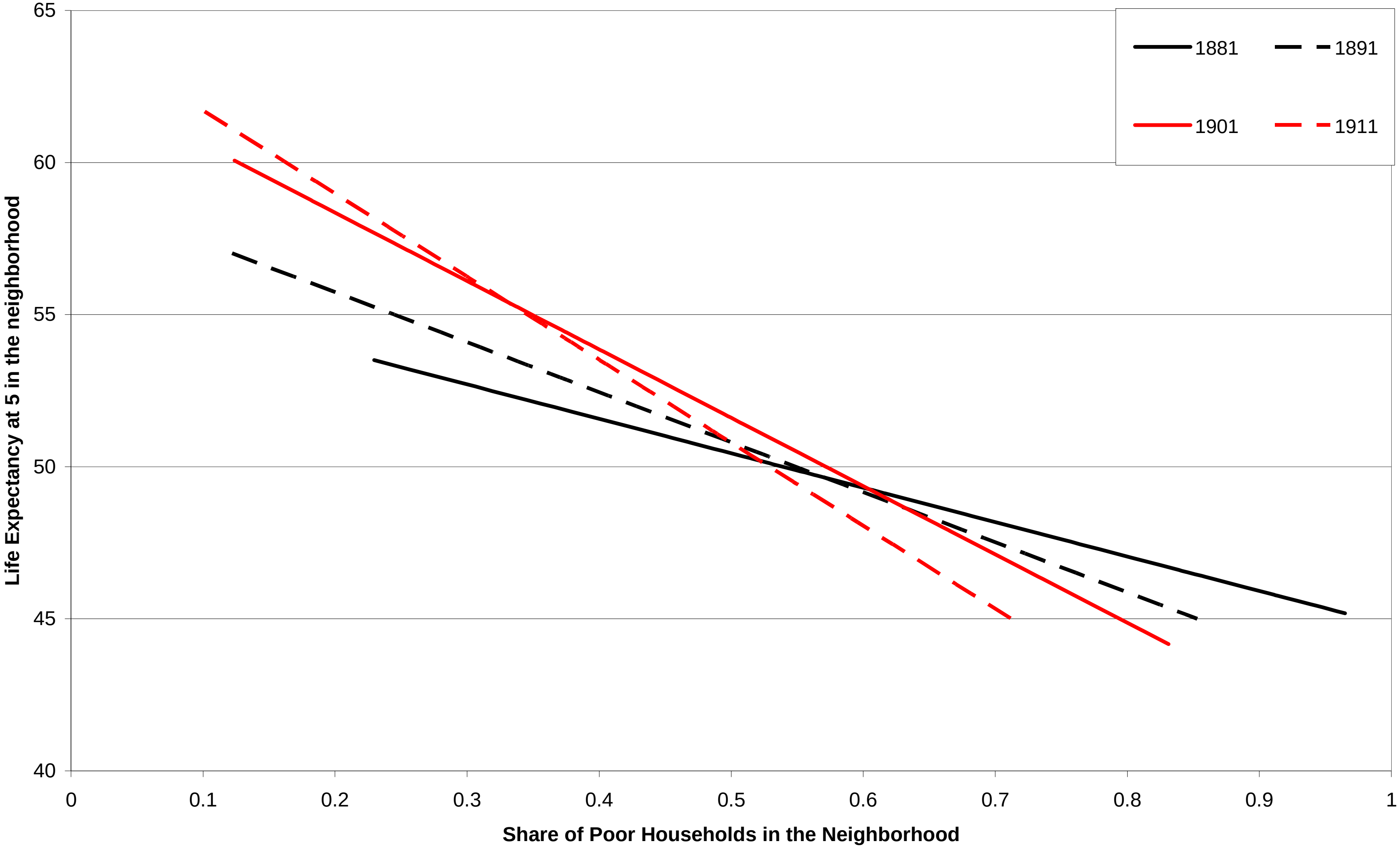


Figure VII Predicting Life Expectancy at different Times with the Share of Poor in 1876

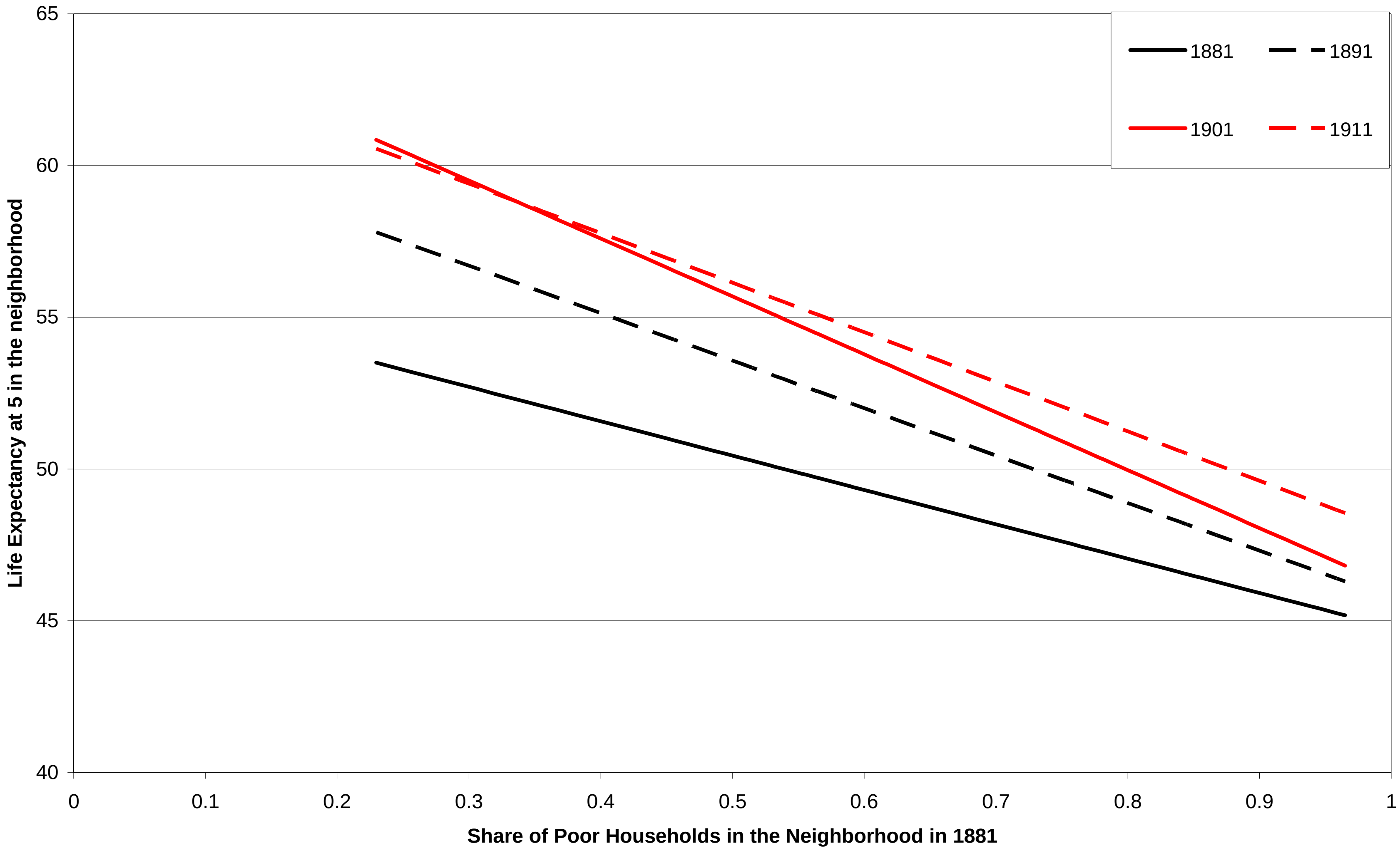
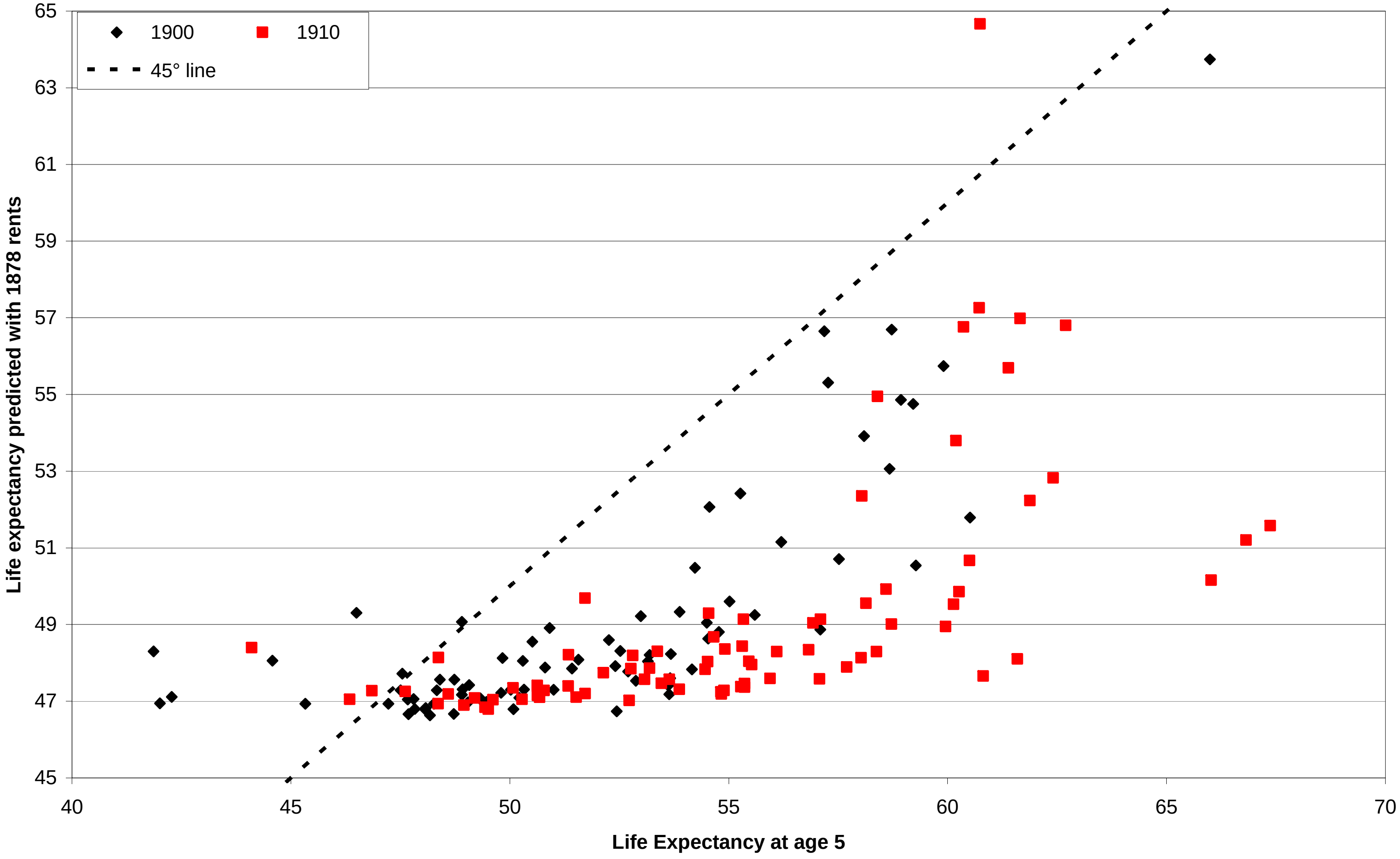


Figure VIII: Life Expectancy in 1910 as predicted by the 1880 Rent-Life Expectancy Relationship



Life expectancy predicted by the coefficients from a regression of life expectancy in 1881 on rents in 1878 as applied to rents in 1900 (black) 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 dotted line is what we should see if the regression was perfect.