Housing markets in a pandemic: Evidence from historical outbreaks

Francke, M.; Korevaar, M.

DOI
10.1016/j.jue.2021.103333
Publication date
2021
Document Version
Final published version
Published in
Journal of Urban Economics
License
CC BY

Journal of Urban Economics 123 (2021) 103333

Contents lists available at ScienceDirect

Journal of Urban Economics

journal homepage: www.elsevier.com/locate/jue

Housing markets in a pandemic: Evidence from historical outbreaks[☆]

Marc Francke[a,b,*], Matthijs Korevaar[c]

[a] Amsterdam Business School, University of Amsterdam, Plantage Muidergracht 12, 1018 TV Amsterdam, The Netherlands
[b] Ortec Finance, Naritaweg 51, 1043 BP Amsterdam, The Netherlands
[c] Erasmus School of Economics, Erasmus University Rotterdam, Burgemeester Oudlaan 50, 3062 PA Amsterdam, The Netherlands

ARTICLE INFO

JEL classification:
G10
I19
J10
N93
R39

Keywords:
Pandemics
Housing markets
Asset prices
Mortality
Urban shocks

ABSTRACT

How do pandemics affect urban housing markets? This paper studies historical outbreaks of the plague in 17th-century Amsterdam and cholera in 19th-century Paris to answer this question. Based on micro-level transaction data, we show outbreaks resulted in large declines in house prices, and smaller declines in rent prices. We find particularly large reductions in house prices during the first six months of an epidemic, and in heavily-affected areas. However, these price shocks were only transitory, and both cities quickly reverted to their initial price paths. Our findings suggest these two cities were very resilient to major shocks originating from epidemics.

1. Introduction

The recent outbreak of COVID-19 has brought the globalized world to a standstill, costing the lives of hundred-thousands of people and keeping millions in ‘lockdown’ in their homes. Although its economic effects are still unfolding, one of the many affected sectors is the housing market. In some heavily-affected cities, early evidence suggests that prices and demand have been falling rapidly, while other areas have not, or not yet, experienced such effects. For example, rental prices have been falling rapidly in Manhattan, while demand in sub-urban areas around New York has increased.[1]

However, there is still significant uncertainty surrounding the short-term impact of COVID-19 on urban housing markets, and at this point in time, it is not yet possible to determine whether the pandemic will have any lasting impacts on the future growth trajectories of cities and their housing markets. In general, assessing the impact of epidemics on housing markets is challenging, both over the short- and long-term. While epidemics typically arrive exogenously, they are also infrequent, such that data availability is limited. Experts have argued that the current pandemic is the worst since the Spanish Flu, which happened over a century ago (Ferguson et al., 2020).

The goal of this paper is to estimate the impact of pandemics on urban housing markets over the short- and long-term. To do so, we study outbreaks of the plague in Amsterdam and outbreaks of cholera in Paris. Both cholera and plague outbreaks resulted in high mortality and significant economic disruption. Importantly, Amsterdam and Paris already had highly-developed housing markets, and unique micro-level data survived in the archives of both cities, allowing us to track mortality and the developments in the housing market following an epidemic.[2]

In the paper, we exploit the relative strengths of the Amsterdam and Paris datasets. For Paris we observe within-city variation in cholera exposure, but only two cholera outbreaks took place (1832 and 1849). For Amsterdam we have a long time span, containing a large number of plague outbreaks (ten outbreaks, 16th-17th centuries), enabling us to separate causal effects from underlying time trends, but we lack data on spatial variation in plague exposure.

☆ Korevaar has been financed by the Netherlands Organisation for Scientific Research under the Research Talent scheme (no. 406.16.552).
* Corresponding author.
E-mail addresses: m.k.francke@uva.nl (M. Francke), korevaar@ese.eur.nl (M. Korevaar).

[1] ‘New Yorkers Are Fleeing to the Suburbs: “The Demand Is Insane”’, New York Times, August 31, 2020.

[2] Our Parisian data also covers two other pandemics: the smallpox epidemic in the 1870s and the Spanish Flu in 1918. We do not study these, because they were directly linked to wars that also affected the housing market.

https://doi.org/10.1016/j.jue.2021.103333
Received 3 October 2020; Received in revised form 25 January 2021
Available online 24 February 2021

Our analyses for both cities point to substantial impacts of pandemics on property prices. We find that sales prices respond negatively to outbreaks, in particular in heavily affected areas, and that responses are short-lived, with the effects on sale prices being particularly significant in the first six months of an epidemic. Evidence from aggregate house and rent price indices suggests a smaller negative impact on rent prices. Amsterdam and Paris were very resilient to these outbreaks, with population and house price growth quickly reverting to prior trends.

We start the paper by providing a descriptive overview of the outbreaks that affected Amsterdam and Paris, and how they affected society. In both Paris and Amsterdam, the outbreaks arrived in an era of rapid urban growth. Paris grew rapidly in the 19th century, and Amsterdam experienced its Golden Age when the outbreaks hit the city. Similar to today, the epidemics had a large impact on daily life and the economy, and hit poor areas with significant urban crowding more than wealthier areas. Very recent evidence has also suggested this for the current pandemic (Borjas, 2020; Almagro et al., 2020). One important difference is that these pandemics were much deadlier, killing on average a few percent of the population. In Paris, the cholera pandemics did follow shortly after the revolutions of 1830 and 1848, and in the paper, we address how we rule out that the effects are driven by revolutionary activity.

To provide a detailed picture of the impact of the outbreak on different segments and parts of the housing market, the main specifications in this paper aim to estimate the impact of the outbreaks over the very short-term and across neighborhoods. For Amsterdam, our data cover multiple outbreaks and a sufficient number of transactions to estimate short-term price effects. Controlling for annual price trends, we find that properties sold within six months after the outbreak of an epidemic realized about 13% lower prices. This effect is robust when adjusting for month fixed effects, types of sale, and changes in the composition of properties changing hands. Importantly, this effect is temporary: it is only present in the first six months of an epidemic.

For Paris, our data only cover two outbreaks, but contrary to Amsterdam we do possess much more information about the geographic dispersion of the epidemic. We use this to study whether heavily affected neighborhoods experienced worse price declines than other neighborhoods. We find that a doubling of cholera mortality reduced neighborhood-level house price growth following the epidemic by about ten percent, but that this decline did not persist over time. After the 1849 outbreak, which affected neighborhood prices most heavily, prices in heavy-affected areas recovered to the levels of less-affected areas in about five years. These effects hold when we control for annual time trends in city-wide prices, and for differences in neighborhood poverty and revolutionary activity.

Because each epidemic and its context are different, it is difficult to directly extrapolate point estimates on price responses from previous outbreaks. Accordingly, existing literature on the impact of epidemics on house prices differs in the estimated coefficients. For example, for the less severe SARS outbreak in Hong Kong in 2003, Wong (2008) estimated a small house price decline of only 1.5 percent. For the current pandemic, Ling et al. (2020) find that a one standard deviation increase in daily local COVID-19 cases depressed REIT (real estate investment trust) returns by 0.24 percent the following day, but these effects can be mitigated if localities take non-pharmaceutical interventions. REITs themselves lost significant value, with a price drop of 49 percent in March 2020, but recovered afterward. Very preliminary evidence for house prices points to more resilience in house prices in the COVID-19 crisis (Ouazad, 2020). Relative to these studies, we cover multiple epidemics and also study the recovery of prices over longer periods of time and across neighborhoods, and the potential long-term impacts of epidemics on these cities and their housing markets.

In the final part of the paper, we aim to provide potential explanations for the empirical facts that we document in the main body of the paper. We highlight four important potential mechanisms in the response of urban housing markets to a major pandemic, which likely apply more generally. First, reductions in total housing demand due to mortality and economic and social turbulence resulted in reductions in rental prices and house prices directly following an outbreak.

Second, the comparatively large short-term impact of epidemics on house prices relative to rent prices suggests the demand for housing investment falls more than the demand for housing services (measured by rent prices). One channel through which this can happen is that epidemics temporarily increase risk perception or risk aversion and corresponding risk premia, in line with literature on other disasters.[3] The fact that this increase is temporary could help to explain why prices fall more than rents in the short-term. Uncertainty regarding future rent prices could play a role as well.

Third, we find that house and rent price growth quickly returned to their initial trends, implying Paris and Amsterdam were highly resilient to shocks caused by epidemics, despite being more affected than their national populations. One important reason is that population losses due to epidemics were quickly compensated by increasing migration. As a result, the demand for housing consumption was not strongly affected by epidemics. This finding contributes to a literature documenting the resilience of large cities to major shocks. Existing work has focused on the physical destruction of cities due to bombing (Brakman et al., 2004; Davis and Weinstein, 2002; Miguel and Roland, 2011), general warfare (Sanso-Navarro et al., 2015), or city fires (Hornbeck and Keniston, 2017). Some studies do find more persistent negative effects of urban shocks. For example, Collins and Margo (2007) document long-lasting property price declines in US cities heavily affected by urban riots in the 1960s. One potential reason for this difference is that riots might be perceived to have had within-city origins, whereas pandemics resulted from the global spread of disease. Additionally, rather than destroying physical capital, pandemics result in significant losses to human capital: the death of a substantial part of the population.

Finally, the recovery of Parisian house prices, even in heavily-affected neighborhoods that experienced large price drops, highlights the role of urban policy when cities are exposed to major shocks. In Paris, the outbreak of cholera proved to be a catalyst for significant urban redevelopment, as the outbreak made the government realize that the clogged and dense areas of Paris were detrimental to health. The government started significant urban renovations that improved local amenities, particularly in heavily affected areas. We find these coincided with recovering property prices. Hornbeck and Keniston, 2017 suggest a similar mechanism. They find that the Great Boston Fire of 1872, which burnt down many old low-quality buildings, paved the way for higher-quality housing, and accordingly increased land values. In related work, Ambrus et al., 2020 exploit the London Broad Street cholera outbreak in 1854 to show the epidemic created a pocket of poverty in the city, persistently lowering rents in the areas affected by the outbreak. This outbreak was confined to a single neighborhood, and it did not result in large changes in infrastructure or housing construction. The different nature of the London epidemic and the resulting policy response might explain why the findings of Ambrus et al., 2020 differ from those in our study and in Hornbeck and Keniston, 2017.

Note that the focus of our paper is different from that of Ambrus et al., 2020. Ambrus et al., 2020 exploit the cholera outbreak to estimate how local income shocks affect neighborhood sorting and wealth over the longer-term and achieve identification from the fact that the epidemic was highly local. The contribution of our paper is that we study the housing market impacts of epidemics that affect an entire city

[3] Existing literature has shown that exposure to major natural disasters (Cameron and Shah, 2015; Goetzmann et al., 2016) or violence (Callen et al., 2014) can result in increased risk aversion or pessimism. Epidemics might have similar consequences.

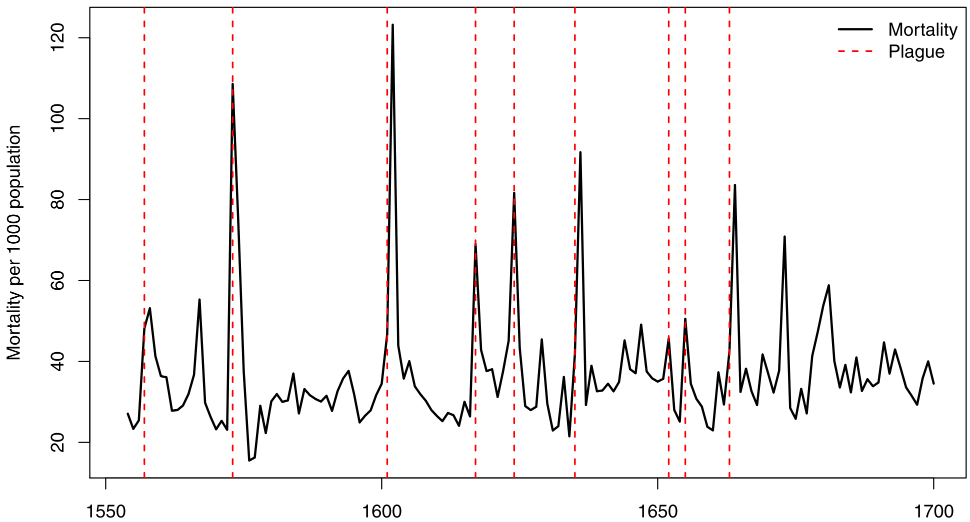


Fig. 1. Mortality per 1000 Inhabitants in Amsterdam. *Notes:* The dashed line represents the starting year of an identified plague epidemic. To convert these into approximate death rates, we extrapolated, based on mortality rates reported in Van Leeuwen and Oeppen, 1993 for the late 17th century.

and its economy, focusing specifically on the housing market. Inherent to a disastrous pandemic is that everyone is exposed to the health and economic consequences of the outbreak, although in varying amounts. This makes it difficult if not impossible to observe a control group, but also implies that the outbreak will have larger and likely differentiated impacts on the dynamics in housing markets relative to more concentrated outbreaks.

2. Data

In this paper, we focus on estimating the housing market impact of various plague outbreaks in Amsterdam during the 16th and 17th century, and the outbreaks of cholera in Paris in 1832 and 1849. To do so, we make use of micro-level data on housing transactions in both cities that we combine with detailed mortality rates for each of these outbreaks. To the best of our knowledge, comparable data is not yet available for other major cities in these time periods. As a result, our analysis and discussion will focus entirely on these two cities.

2.1. Mortality data

To obtain mortality data for both cities, we use official statistics from death records. For Paris, we obtain neighborhood-level data on mortality from official government reports about the epidemics of cholera in 1832 and 1839 (De Châteauneuf, 1834; Administration Générale de l'Assistance Publique, 1850). To obtain mortality data for Amsterdam, we use burial registers from parishes and cemeteries provided to us by the Amsterdam city archives (from 1554). Because parish registers are missing in some periods, we construct relative estimates of mortality. We compute these by dividing per parish or cemetery in each month and year the number of deaths relative to the preceding and following five years. To aggregate data into a single statistic, we take the average of all parishes and cemeteries, weighted by the number of deaths in each parish or cemetery.

The burial records of Amsterdam do not indicate which deaths were due to the plague and which were due to other causes. To identify plague outbreaks, we use data from Noordegraaf and Valk, 1996. Their study lists each year for which historical sources mention a plague outbreak. They do not provide information on the severity or timing of these. In this paper, we will use two mortality measures. At the annual level, we define a year to be a plague year if annual excess mortality is higher than 35% and Noordegraaf and Valk, 1996 mention a plague year. To be more precise about the start of plague outbreaks, we construct a monthly measure. We define the start of a plague epidemic if, for the first time, excess mortality in a given month exceeds 100%, and Noordegraaf and Valk, 1996 mention a plague outbreak in the same year.

2.2. Housing market data

To estimate changes in house values and volume, we gather data on sale and rent prices from administrative records. For Amsterdam, we use mandatory governmental registrations of property purchases, provided by the Amsterdam city archives. This data provides information on 158,757 house transactions, both regular sales and foreclosure sales, between the late 16th century and 1811. Although registers are missing for some years, in particular in the 16th and 17th centuries, the registers that have survived do contain the universe of housing transactions in the period they cover. Transaction prices on regular sales were only recorded from 1637, implying the number of transaction prices is more limited before 1637. For our analysis, we use the repeat-sales price pairs and aggregate index Korevaar, 2021 identified.

For Paris, we use data from Eichholtz et al. (2021) originating from the *sommier foncier*, a government register containing information on the universe of sale prices in Paris between 1809–1943. In total, we draw on a sample of 39,786 sales prices, covering 17,300 properties. We match the addresses in the data to their respective neighborhoods, in order to link housing transactions and rent prices to neighborhood mortality measures published in the official government reports.

For the first part of the 19th century, the sommier foncier also includes data on the rental contracts of these properties. However, most of these contracts only pertain to part of a property, implying the sample of repeated-contracts for entire properties is too small for a detailed neighborhood-level analysis. Next to these rental contracts, rental prices were also registered in case a property was donated or inherited. However, the rental prices registered for these observations correspond to current lease prices, rather than newly-signed contracts. Given that rent contracts and corresponding lease prices were typically set for several years (3, 6, or 9 years), these observations are not suitable to measure the direct response of market rental prices to pandemics.

To track developments in rental prices, we use existing annual repeat-rent indices from Eichholtz et al. (2019). For Paris, this index is based on newly-signed rental contracts for entire properties from the *sommier foncier*. For Amsterdam, data is based on new rental contracts, identified by lease price changes, for various institutional investors.

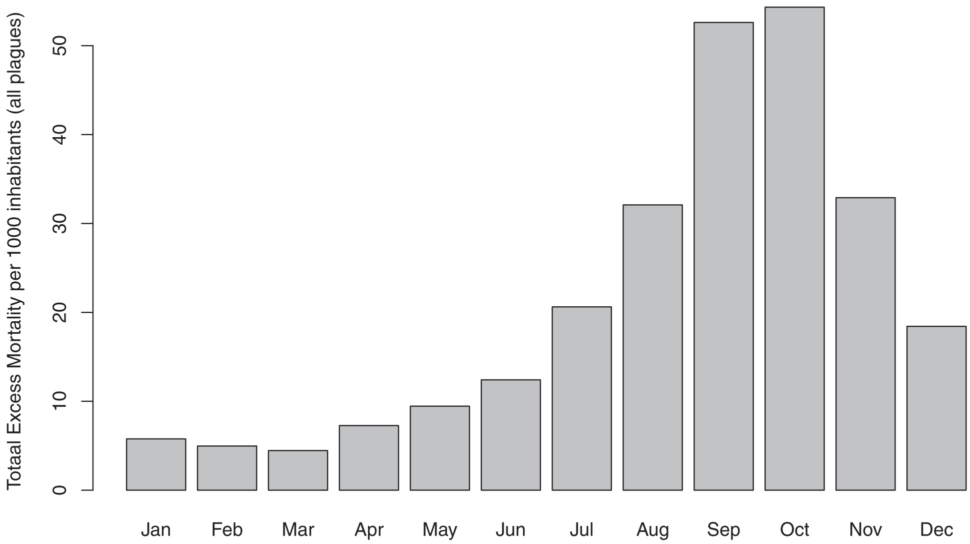


Fig. 2. Aggregate Monthly Excess Plague Mortality (all outbreaks). *Notes:* This plot shows the intensity and frequency of plague epidemics per month. For all months we identify a plague outbreak, we sum the excess mortality in that month relative to the five preceding and five next years. For example, if a plague epidemic was going on 14 times in October, and the average excess mortality during those months was 400%, then aggregate monthly excess mortality equals 56. Most people died of the plague in the fall, when epidemics were also most frequent.

3. Historical background

3.1. Plague in Amsterdam

In the 16th and 17th centuries, outbreaks of plague frequently ravaged large parts of Europe (Alfani, 2013) and also hit Amsterdam. Fig. 1 plots the estimated evolution of annual mortality in Amsterdam between 1554 and 1700. Nearly all major spikes in annual mortality coincide with the ten different periods we identified as major plague epidemics.[4] The duration of a major plague outbreak varied between four months and two years, with an average of nine months.[5] Major plague epidemics were deadly; the largest epidemics wiped out over ten percent of the total population. Potentially, this number is even higher due to the under-registration of deaths during severe outbreaks (Noordegraaf and Valk, 1996).

These outbreaks often ravaged other parts of the Dutch Republic and Europe at the same time, but it remains unclear why and how the plague reached Amsterdam exactly in these years. Because of the high levels of urbanization, trade activity, and frequent warfare, diseases could spread quickly in the Dutch Republic (Rommes, 2015). However, trade activity and war cannot explain the exact timing of these outbreaks, nor the disappearance of plague after 1667, because they were near-permanent features of the Dutch economy. While the Dutch Republic was engaged in wars for the majority of years in this period, war activity did not happen within or close to Amsterdam except in the 1570s. Most likely, the exact timing of the outbreaks was thus exogenous to the state of the Amsterdam economy and its housing market.

Although we observe plague mortality in all months of the year, plague mortality had a seasonal component. Fig. 2 plots the estimated aggregate excess plague mortality. This statistics shows per month the sum of excess mortality for months in which we register an ongoing plague epidemic, aggregating data from all plagues between 1557 and 1664. As becomes evident from the graph, most excess plague mortality concentrated in the second part of the year. Plague epidemics most frequently broke out in the summer or fall. Given their average duration of nine months, plague epidemics were most frequent in September, October, and November. In these months, we register 12 to 14 times an on-going epidemic and often with very high levels of excess mortality. In the first six months of the year, we only register an ongoing plague-epidemic 5 to 6 times, and with comparatively lower excess mortality. Note that this mortality pattern was not specific to the plague, as the months from September to January also had comparatively high mortality in non-plague years.

Although it is hard to compare mortality estimates over time and across space, the plague likely affected Amsterdam more heavily than other places in the Low Countries (see Curtis, 2016). While people died of the plague across all classes, poor people seem to have been more affected. For example, during plague months relative mortality on the *Karthuizerkerkhof*, the cemetery in the poor Jordaan area, was about 50% higher than on other cemeteries, although this effect varied substantially across epidemics. Unfortunately, the data do not allow for a more detailed breakdown of mortality by neighborhood, because the burial records do not report the addresses of the deceased.

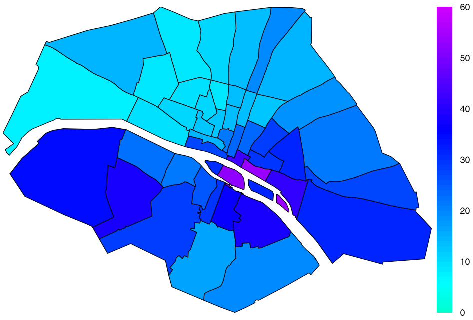
The Amsterdam plague outbreaks resulted in widespread death and despair, and also affected the economy. Mooij (2001) writes that during plague outbreaks “the merchant city became a ghost city: trade and business activity came to a halt, market squares were empty, and shops and workshops closed their doors.” Sometimes this was the result of direct government interventions. Noordegraaf and Valk, 1996 mention that the plague law of 1558 prohibited people from visiting markets, inns, churches, and other places where many people gathered. These had real economic consequences: Noordegraaf and Valk, 1996 quote owners of inns who complained they lost most of their income because travelers avoided Amsterdam due to the epidemic. How large these impacts were is nonetheless hard to identify. With Amsterdam’s economy build on trade, it seems unlikely interventions lasted very long. For example, De Vries (1981) writes that, to his surprise, passenger volumes on barges in Holland were barely affected in the years with major plague outbreaks.

3.2. Cholera in Paris

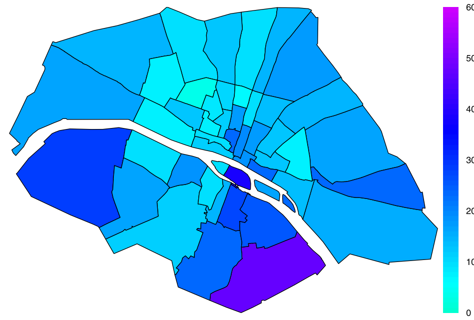
Cholera arrived in Paris for the first time in March 1832, and the outbreak came unexpectedly. As late as 1831, when cholera started breaking out all across Europe, the famous French doctor Baron de Larrey (1831) wrote that “the topographic situation of France is so advantageous, that there is little reason to worry about the introduction of cholera-morbus in this country.” However, within a month of the outbreak in March, the ‘cholera-morbus’ killed over 11,500 people in

[4] Based on our definition, epidemics started in 1557, 1573, 1601, 1617, 1624, 1635, 1652, 1652 and 1663.

[5] To estimate the duration of an epidemic, we assume that a severe epidemic continues for as long as monthly excess mortality remains above 100% or if excess mortality is positive and exceeds 100% again within six months.



(a) Paris, 1832



(b) Paris, 1849

Fig. 3. Cholera Mortality per 1000 Inhabitants in Paris. *Notes:* In both epidemics, in each neighbourhood 1 to 6 percent of the population died. Boundaries are based on Vasserot quartiers. The correlation in neighborhood mortality between epidemics is 0.5.

the city. The total death count of the epidemic amounted to more than 18,500 people or about 2.5 percent of the total population. It took until March 1849 for the second epidemic to arrive. Although the outbreak spread less quickly than the initial epidemic in 1832, by the end of the epidemic in 1849 over 15,000 people had died, 1.5 percent of the total population.

Among the most vivid descriptions of the 1832 epidemic is that of German writer Heinrich Heine (1872). He describes the epidemic left the city in a quiet state of despair, with increased security measures and sanitary committees. But the epidemic also raised tensions across social classes, and stories went around quickly that the government had poisoned wells, fueling a rebellion in 1832 prominently described in Victor Hugo's Les Miserables. Tensions in Paris were already high before the outbreaks, following one to two years after the revolutions of July 1830 and February 1848. Although the outbreaks were exogenous to the state of the local Parisian economy, originating from abroad and affecting the entire French population, they did arrive in already turbulent times.

The outbreaks did not affect everyone equally. Fig. 3 reports the mortality per neighborhood in Paris during both epidemics. Although cholera affected people of all ages and classes, the first outbreak of cholera, visible in Panel 3a, primarily affected the most central areas of the city, where up to six percent of the total population died. In these areas, the working class lived in a maze of narrow streets in over-populated and unhealthy homes (Le Mée, 1998). Even in better neighborhoods, the most impoverished alleys and streets were most affected. This is also reflected in housing values: our data show average house prices and rents were substantially lower in heavily affected areas.

The government recognized that there existed a close link between poor and dense neighborhoods and cholera mortality, although, unaware of the exact cause of cholera, they primarily believed such poor neighborhoods favored the development of miasmas (De Châteauneuf, 1834). This link was confirmed during the 1849 outbreak. Mortality levels were high in the working-class areas in the cities on the left bank but had gone down in the historical city center (Panel 3 b), where much of the slum housing had been cleared (Le Mée, 1998).

3.3. Urban growth and the housing market

One important element to understanding the impact of the epidemics on the Parisian and Amsterdam property market is that both cities were growing substantially in the decades around the epidemics.

From the late 16th century to the late 1660s, the period when most plague epidemics ravaged the city, Amsterdam's population grew from about 30,000 people in the 1580s to over 200,000 people by 1670, with no periods of population decline over 5-year horizons (Nusteling, 1985). This implies that population levels recovered quickly after outbreaks, although detailed data at the annual level is not available to track the exact speed of this recovery. Economic historians have named this Dutch Golden Age the 'first round of modern economic growth' (De Vries and Van der Woude, 1997). Similarly, the population of Paris increased from about 600,000 in 1810 to almost 1.7 million in 1860 Mairie de Paris (1967). Only between 1846 and 1851, a period of crisis and cholera, population growth was halted temporarily. Crucial to the sustained growth of both cities were high levels of immigration.

The growth of these cities is also visible in the developments in aggregate property prices and rents. In Fig. 4 we plot the evolution in rent prices and house prices in this period, together with vertical dashed lines that mark the price level just before the start of an outbreak. Note that the rent price indices are based on observations of new rental contracts, such that their changes reflect changes in market rental prices. In Amsterdam, rental leases and corresponding prices were typically set annually.

In both Paris and Amsterdam rent prices rose substantially over the studied period. This is not only the case in nominal terms, which is depicted in Fig. 4, but also in real terms. In Amsterdam, rent prices and house prices did fall substantially after the 1660s, following the end of the Golden Age and a decline in population. The large increase in house prices relative to rent prices in the period before 1670, and the contraction afterward is primarily the result of falling interest rates in the Dutch Golden Age and increasing rates afterward. For Paris, the upward trends in rental prices in the 19th-century match evidence from other global cities such as London (Clark, 2002) and New York City (Margo, 1996).[6]

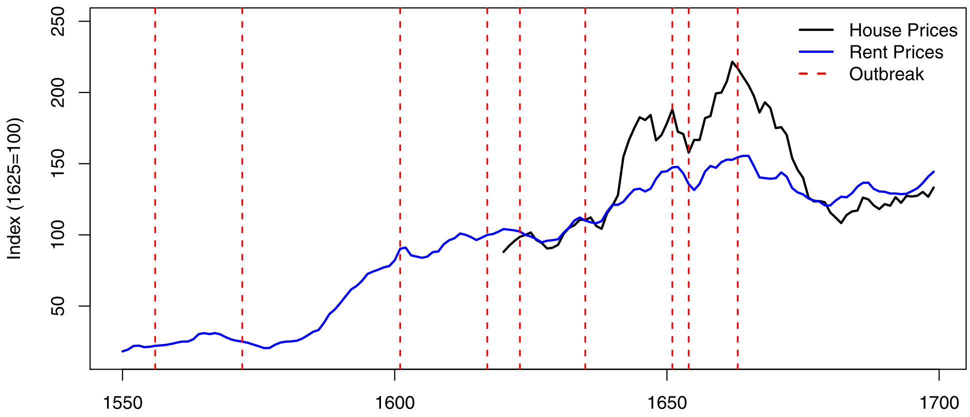
In both cities, outbreaks of epidemics typically coincided with a fall in house prices and rent prices. In the year of the outbreak, house prices on average dropped by six percent and rental prices by three percent. Because outbreaks typically started in the second part of the year, we observe house prices and rental prices dropped again by similar amounts in the year following the start of the epidemic. In Online Appendix C we test this formally and show that the average price drop is significant and robust to controlling for pre-trends and other economic conditions.

Both Paris and Amsterdam already had highly-developed and active housing markets at this time. Most properties were buy-to-let properties owned by investors, with only a minority of the population owning its own house.[7] In both cities, properties could be sold in private sales via search-and-matching, and in public auctions. These auctions were a transparent way for investors to gauge the state of the housing market, and they were used for a large fraction of housing sales. Some of these sales were foreclosures, but most were regular sales.[8]

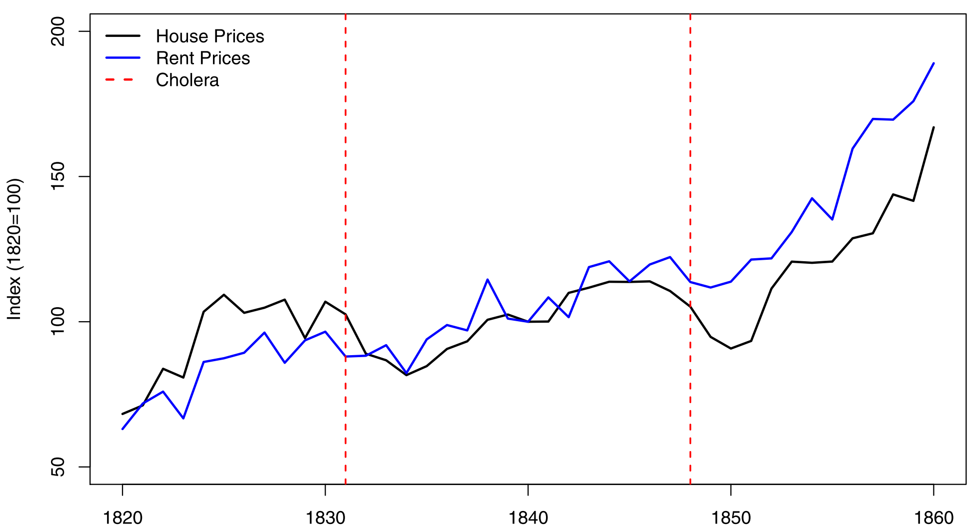
[6] London and New York City were also hit by cholera in 1832 and 1849, but the rental samples in the studies of Margo (1996) and Clark (2002) are too small to analyze their impact precisely.

[7] In 1562 in Amsterdam 31% of properties were owner-occupied, and this reduced to 15% by 1805 (Korevaar, 2021). In Paris, home-ownership was only a few percent (Kesztenbaum and Rosenthal, 2017).

[8] In Paris, 36% of properties were sold in auctions, and in Amsterdam, this fraction was likely even higher. For more detail, see Online Appendix C.



(a) Amsterdam



(b) Paris

Fig. 4. Housing Prices and Rents Around Epidemics. *Notes:* These figures plot the evolution of house prices and rents in both Amsterdam and Paris with dashed lines representing plague or cholera outbreaks. These are repeat-sale or repeat-rent indices using the same data sources as this paper (sources: Eichholtz et al., 2019; 2021; Francke and Korevaar, 2019). The rent price indices only use data from new rental contracts, so they reflect market conditions. The rent price indices cover 12 epidemics lasting together 17 years, and the house price indices cover 8 epidemics lasting together 10 years. The Amsterdam house price index covers a smaller period because there is insufficient data to estimate an index before 1620. The large growth of Amsterdam house prices relative to rent prices until the 1660s is likely related to a fall in interest rates.

4. Analysis

Cholera and the plague caused significant mortality and economic disruption in Paris and Amsterdam. In this section, we analyze specifically how these factors influenced house prices. We refer the interested reader to Online Appendix C for a broader discussion on the effects of the epidemics on other parts of the housing market.

4.1. Modified repeat sales model

We exploit the relative strengths of our data for Amsterdam and Paris to estimate the impact of an outbreak on property prices. First, we use the differences in the exact timing of the arrival of the plague in Amsterdam to estimate its short-term impact on prices. Our Amsterdam data covers a much larger number of epidemics, and we correspondingly have more transactions happening around epidemics relative to Paris, for which such an analysis is not possible.

Controlling for annual time trends and month fixed effects, we aim to identify whether the arrival of plagues resulted in significant price distortion in the six months following the start of the outbreak. This enables us to measure short-term price effects precisely. Additionally, this alleviates concerns about potentially unobserved economic time trends, as this methodology only requires the outbreak of plague to be exogenous *within* a calendar year, rather than across years, as assumed in the previous analysis. By controlling for month fixed effects, we rule-out that our price effects are driven by seasonality in the housing market. As in modern housing markets (e.g Ngai and Tenreyro, 2014), housing market activity in Amsterdam was seasonal, with most activity taking place in Spring.[9]

For Paris, mortality data is available at the neighborhood level. We exploit cross-sectional differences in the severity of the cholera outbreak to study whether more or less-affected neighborhoods experience different price trajectories after an outbreak, controlling for city-wide trends. This also enables us to control for aggregate economic changes in the city such as the 1830 and 1848 revolutions, that happened shortly before the outbreaks. By tracking price differences in these neighborhoods over time, we also estimate whether price differences among differently affected neighborhoods persist over time and if these are confounded by existing pre-trends or other neighborhood-specific factors.

We estimate annual price trends and the impact of epidemics in both cities by a repeat sales model (Bailey et al., 1963), including differ-

[9] The main moving day in Amsterdam was May 1, such that most transactions happened around this period. Mortality concentrated in the fall, both in plague years and non-plague years, which might also explain part of the seasonality, for example, if investors were waiting for the epidemic season to be over.

ences in transaction characteristics at the time of purchase and sale, such as auction transactions. We apply three modifications to the repeat sales model. First, in order to reduce the impact of noise on the index, due to a low number of observations and/or outliers, we replace the time fixed effects with a stochastic specification. Second, we use a time-weighted repeat sales model to control for periodic price changes as precisely as possible, by taking into account the proportion of the period during which the property was "held". Third, we add time invariant variables (for example the neighborhood mortality rate) with time varying coefficients (at a lower frequency, say two year periods, due to data limitations), to estimate differences in the responses to epidemics. Details of the modified repeat sales model can be found in Appendix A.

4.2. Short-term price responses in Amsterdam

To estimate the short-term impact of the plague on house prices in Amsterdam we estimate the modified repeat sales model. The covariates in the repeat sales model contain monthly dummy variables to deal with seasonal effects and dummy variables to control for potential price discounts due to distressed sales after a foreclosure or after the death of the owner. Most importantly, the covariates include the variables of interest related to the plague. The dummy variable Plague is equal to 1 when within the six months prior to the transaction date, a plague epidemic has started. The 6 and 12 months lagged variables are denoted by Plague.L6M and Plague.L12M.

The repeat sales sample contains seven plague outbreaks in the periods: 1601Sep–1602Dec (1), 1617Aug–1617Dec (3), 1624Jul–1624Dec (1), 1635Oct–1636Nov (12), 1652Aug–1652Nov (46), 1655Aug–1655Dec (61), and 1663Oct–1664Nov (67), where between brackets the number of sales within the first six months of a plague outbreak are given, in total 191. Note that the number of sales is relatively small because the archival records rarely list prices before 1637, and repeat-sales are not easily identified.[10]

Table 1 presents estimation results from the modified repeat sales model.[11] We find a negative short-term effect of the plague on house prices of 0.136 (in logs), see the first column. If we do add lags of the plague variable (columns two and three), the results for the Plague variable are similar. The coefficients for the first lag (Plague.L6M) in the second and third column are small and statistically insignificant. The coefficient for the second lag (Plague.L12M in the third column) is positive, 0.089, and statistically significant[12], suggesting prices partly recover after 12 to 18 months from the start of the plague.

In column four we test whether the effect is different for the bottom and top third of properties, based on the average log transaction price per street.[13] We estimate the log average transaction price by taking the coefficients on street fixed effects from a regression of the log transaction price on sale type, year fixed effects, and street fixed effects. In column four we have two variables (Plague Cheap and Plague Expensive), where the plague variable is interacted with the bottom and top third transaction average price. We do not find a significant difference between cheap, medium, and expensive properties.

The results in column four (and column five in Table B.3 in Online Appendix B.1) do not provide significant evidence for large differences in the price effects of a pandemic on cheap areas, which were likely more affected by the plague outbreaks, relative to expensive areas. However, these results might be driven by the fact that the coefficients are imprecisely estimated. Some streets have only a few observations, resulting in noisy estimates of the price level, and the rapid change of Amsterdam in the 17th century implied that neighborhood status could also change quickly. We only have street names and no exact addresses, so it is not possible to use another level of aggregation, like neighborhoods. The major canals in Amsterdam, for which we have most transactions, are very long and therefore located in multiple neighborhoods. In the next section, we conduct a similar analysis for Paris, for which we have detailed data on epidemic intensity and on the precise location of the properties in our sample of transactions, allowing for more precise identification.

Finally, as a robustness check, Table B.4 in Online Appendix B.2 reports output based on a hedonic price model (Rosen, 1974), which is due to the limited number of hedonic variables less precisely estimated but has more price observations around plagues. The estimated price drop in the first six months after the start of an epidemic is around 0.09 in logs.

Table 1
Estimation Results Price Responses Amsterdam.

	Dependent variable:			
	$\ln P_{i,t} - \ln P_{i,s}$			
	(1)	(2)	(3)	(4)
Plague	-0.136	-0.137	-0.121	-0.150
	(0.045)	(0.045)	(0.046)	(0.051)
Plague.L6M		0.000	0.019	
		(0.036)	(0.037)	
Plague.L12M			0.089	
			(0.045)	
Plague Cheap				0.006
				(0.110)
Plague Expensive				0.099
				(0.120)
Foreclosure Sale	-0.021	-0.021	-0.021	-0.021
	(0.013)	(0.013)	(0.013)	(0.013)
Widow	-0.046	-0.045	-0.046	-0.045
	(0.009)	(0.009)	(0.009)	(0.009)
Heirs	-0.036	-0.036	-0.036	-0.036
	(0.007)	(0.007)	(0.007)	(0.007)
Constant	0.061	0.060	0.061	0.060
	(0.005)	(0.005)	(0.005)	(0.005)
σ_ε	0.380	0.380	0.380	0.380
	(0.001)	(0.001)	(0.001)	(0.001)
σ_μ	0.071	0.071	0.071	0.071
	(0.005)	(0.005)	(0.005)	(0.005)
PSIS-LOO value	-31,381.5	-31,382.8	-31,382.3	-31,384.2
Month FE	Yes			
Observations	39,281			
Sample Period	1602 - 1811			

Notes: This table presents estimation results from the modified repeat sales model (A.2), estimating the effect of the outbreak of plague on changes in house prices in the first six months of an outbreak. The model controls for month fixed effects, foreclosure discounts and price discounts following the death of the original owner. "Widow" is a dummy variable equaling one if the seller sold the property after the death of a spouse and "Heir" is a dummy variable equaling one if the seller inherited the property. Standard errors are given between parentheses. PSIS-LOO stands for leave-one-out cross-validation using Pareto-smoothed importance sampling (Vehtari et al., 2017).

4.3. Neighbourhood price responses in Paris

For Paris we compare developments in house prices across neighborhoods more or less affected by cholera by the modified repeat sales model (A.2). We interact time fixed effects with the cholera mortality in the neighborhood in which the property is located. For additional precision, the time dummy variables cover periods starting from the 1st of April, because both cholera outbreaks started around the end of March. We estimate these models separately using 1832 neighborhood mortal-

[10] See Korevaar, 2021 for the procedure that we used to identify repeat-sales.

[11] Our results on the effect of the plague variables are robust to various specifications: The exclusion of the constant in the repeat sales model, the inclusion of property-specific random walks (Case and Shiller, 1987, 1989), and the exclusion of the prior for the log price index, leading to the standard repeat sales model with time fixed effects.

[12] The 95% credible interval is (0.001; 0.178).

[13] See also Table B.3 in Online Appendix B.1.

ity and 1849 neighborhood mortality (in logs). We do not include variables that indicate the six months after the start of the cholera outbreak (like the Plague variable in Amsterdam), because Paris 'only' had two cholera outbreaks, and therefore a very limited number of total transactions in the first few months after outbreaks.[14] To maximize the number of repeat-sales, we estimate the model on the entire period before World War I. Similar to Amsterdam, we again include month fixed effects to account for seasonality in the housing market.

Because the epidemics happened shortly after the revolutions of 1830 and 1848 and affected poor neighborhoods more than wealthier neighborhoods, price effects might not be driven by cholera mortality, but by differential trajectories in neighborhoods after the revolution, in particular between poor and wealthy neighborhoods. To adjust for neighborhood poverty, we first estimate the average log transaction price per neighborhood over the entire 1809–1848 period, before the major renovations of Haussmann, controlling for aggregate price changes using annual time fixed effects. Absent neighborhood-level data on income, we assume that average housing values are a close proxy for neighborhood status, following Ambrus et al., 2020 and Kesztenbaum and Rosenthal, 2017.[15] Similar to neighborhood mortality, we interact time fixed effects with the log average transaction price for each neighborhood.

For the 1849 period, we can additionally test whether our results are driven by revolutionary activity. During the main insurgencies in February and June 1848, barricades were put up in the east of the city, where most worker neighborhoods were located, and not in the conservative west of the city.[16] In 1830, there was no such a spatial division in revolutionary activity, with barricades all across the cities, and the main skirmishes taking place among the main boulevards and along the embankments of the Seine. To adjust for these, we construct a dummy taking the value 1 if a property is in the west of the city (no barricades), and 0 if it is in the east (with barricades)

Note that cholera mortality correlates significantly with both revolutionary activity in 1848 ($r = 0.36$, where r denotes correlation) and neighborhood-level average prices ($r = -0.49$ for 1832, $r = -0.63$ for 1849). We control for these two variables and estimate the effect of cholera mortality with interaction effects per four-year time interval. Given the correlation across these measures and the limited amount of data, using shorter time intervals results in imprecise estimates.

Fig. 5 plots the evolution of the mortality coefficients, where 1820 is the base year. We show results for three different model specifications, where the differences concern the interaction effects. The first specification (red in Fig. 5) has as interaction effects: (i) log mortality in 1832 and (ii) the average neighborhood log transaction price, the second specification (in blue): (i) log mortality in 1849 and (ii) the average neighborhood log transaction price, and the third specification (in green): (i) log mortality in 1849, (ii) the average neighborhood log transaction price, and (iii) a dummy variable indicating revolutionary activity. More details on the estimation results can be found in Table 2.

Mortality correlates across the two epidemics, so the mortality coefficients in the models using 1832 and 1849 mortality rates evolve similarly over time. Between 1820 and 1828, neighborhoods with a high cholera-mortality in 1832 experienced higher levels of price growth relative to less-affected neighborhoods.

This is a period of rapid price and population growth in the city, which might have led to particularly fast price growth in the central areas, which were also most affected by the outbreak in 1832.

Table 2
Estimation Results Price Responses Paris.

	Dependent variable:		
	$\ln P_{i,t} - \ln P_{i,s}$		
	(1)	(2)	(3)
Auction sale	0.044	0.043	0.041
	(0.009)	(0.008)	(0.008)
Constant	0.118	0.119	0.116
	(0.009)	(0.009)	(0.008)
$\lambda^{Mortality}_{1836} - \lambda^{Mortality}_{1832}$	-0.102	-0.040	-0.064
	(0.061)	(0.068)	(0.077)
$\lambda^{Mortality}_{1840} - \lambda^{Mortality}_{1832}$	-0.101	-0.043	-0.050
	(0.054)	(0.059)	(0.068)
$\lambda^{Mortality}_{1852} - \lambda^{Mortality}_{1848}$	-0.090	-0.133	-0.151
	(0.055)	(0.064)	(0.072)
σ_ϵ	0.366	0.366	0.365
	(0.003)	(0.003)	(0.003)
σ_μ	0.091	0.069	0.077
	(0.011)	(0.011)	(0.012)
PSIS-LOO value	-7299.2	-7307.9	-7288.5
Month FE	Yes	Yes	Yes
Interaction effects (λ)			
Mortality (in log)	1832	1849	1849
AvgVal	Yes	Yes	Yes
West	No	No	Yes
Observations		9,531	
Sample Period		1809–1913	

Notes: This table presents estimation results from three specifications of the modified repeat sales model (A.2), corresponding to the ones plotted in Fig. 3. These estimate the impact of differences in neighborhood mortality on changes in house prices following a cholera outbreak. The interaction effect 'AvgVal' is a proxy for neighborhood status using average transaction price, and the interaction effect 'West', a dummy variable measuring revolutionary activity based on the position of barricades. The coefficient on auction sales is positive and statistically significant in all specifications. Auctions were widely used to efficiently sell proprieties. Finally, we also control for month fixed effects. PSIS-LOO stands for leave-one-out cross-validation using Pareto-smoothed importance sampling (Vehtari et al., 2017).

Prices remain relatively stable in the years leading to the epidemic. Between 1832 and 1836, high-mortality areas fall in prices relative to low-mortality areas, with a relative price drop of 0.102 in logs, see the first column in Table 2. The probability that the price change is positive is 0.048.[17] Relative prices in more- and less affected neighborhoods remain at similar levels until the late 1840s. In summary, there is evidence that the outbreak of 1832 led to large price declines in heavily-affected areas. Prices of more- and less affected neighborhoods experienced different price developments in the years leading to the epidemics.

For 1849 mortality the evidence is more consistent and significant. After the outbreak of 1832, prices in more and less-affected neighborhoods in the 1849 epidemic do not display any visible and significant time trend until the outbreak, both in the model that only controls for aggregate time trends and differences across poor and rich neighborhoods, and the model that additionally controls for east-west differences during the 1848 Revolution. After 1848, we find sharp drops in property prices, with prices in high-mortality areas falling by significantly more than prices in low-mortality areas. The additional drop between 1848 and 1852 is 0.133 in logs (the probability that the price change is positive is 0.019), and 0.151 in logs (the probability that the price change is positive is 0.017) when controlling for differences in revolutionary activity, see the second and third column in Table 2. However, prices also bounce back quickly, with no significant differences anymore after 1860.[18]

[14] We do have estimates of (lagged) cholera variables (not reported). The corresponding coefficients are negative (apart from the first lag), however statistically insignificant.

[15] The correlation between average prices estimated for the 1809–1831 period (4907 observations) and the 1809–1848 period (9263 observations is 0.97. Given the higher precision of the 1809–1848 estimates, we use these for both samples.

[16] For a map of barricades, see L'Histoire (2018).

[17] In this Bayesian setting we do not report p-values.

[18] This pattern also persists after 1860.

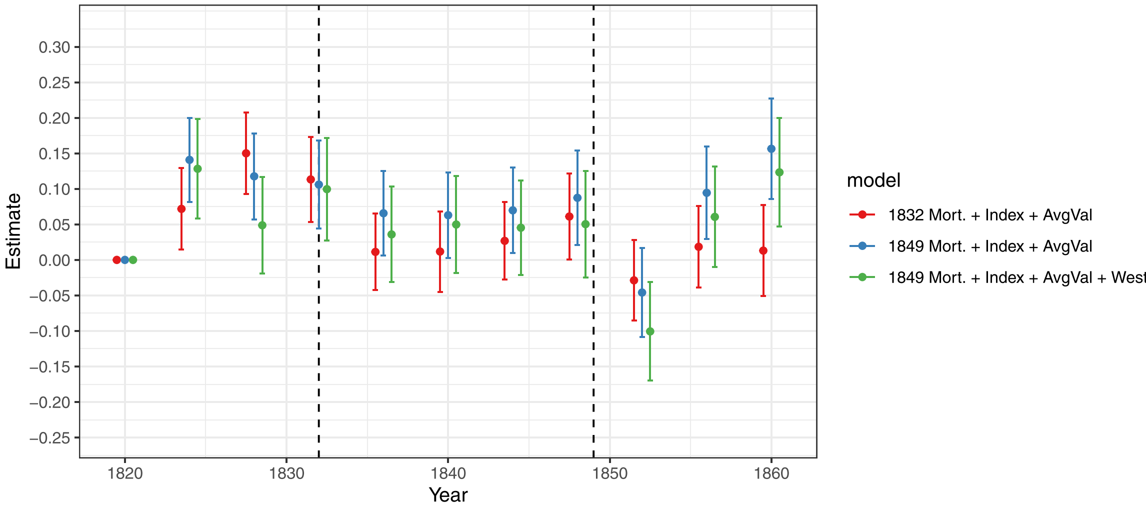


Fig. 5. Price-Variation in Neighbourhoods by Cholera Mortality. *Notes:* This figure plots the estimates of the mortality interaction coefficients in the period from 1820 to 1860, the λs in Eq. (A.2), based on 1832 (1832 Mort., in red) and 1849 cholera log mortality (1849 Mort., in blue and green). A coefficient of 0.1 implies that in the year of observation a neighborhood had ten percent higher prices compared to a neighborhood with half its cholera mortality, relative to the base year of 1820. Around the point estimate, we plot +1/-1 standard deviation of the estimated coefficients. We use 4-year periods for the lower frequency process λ. In the legend 'AvgVal' and 'West' refer to additional interaction effects (z-variables in Eq. (A.2)), where 'AvgVal' is a proxy for neighborhood status, and 'West' is a dummy variable measuring revolutionary activity. 'Index' is the annual log price index μ in Eq. (A.2). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

5. Mechanisms and implications

Our combined findings on Paris and Amsterdam point to several important effects. Descriptively, we show that house prices and rental prices declined following the outbreak of an epidemic, although the impact is smaller on rent prices. To identify house price impacts precisely, we exploit our data for Amsterdam and Paris to show house price declines are particularly significant in the first six months and in heavily-affected areas. However, these large initial price declines are transitory: heavily affected areas recover in prices, and the large price drops during the initial phases of an outbreak revert.

In this section, we discuss potential mechanisms driving these effects and the role of policy responses in shaping the trajectories of house prices and rents after the epidemics.

5.1. Housing demand & urban growth

The first and most direct way in which pandemics affect the demand for housing is through mortality. Although it is difficult to estimate plague mortality, we estimate that the outbreaks of plague in Amsterdam on average killed seven percent of the population. For Paris, cholera on average killed two percent of the population. The impact of such population shocks depends on the elasticity of house prices with respect to the population, or more precisely, the fall in housing demand due to mortality. Because population shocks are rare, estimating this elasticity is difficult. For shocks to migration, existing literature points to a price elasticity around one (Gonzalez and Ortega, 2013; Saiz, 2007). In the very short-term, price responses might be even larger due to the fixed nature of housing supply, in particular in response to negative demand shocks (Glaeser and Gyourko, 2005).

Beyond the fall in housing demand due to mortality, reductions in economic activity due to the epidemic might have contributed to a further decline in the demand for housing. Given that we only have anecdotal evidence for the significant economic impact of these pandemics, it is difficult to assess to what extent these contributed to initial price drops. Reductions in housing demand could also have been strengthened by out-migration, particularly by wealthy people. Beyond anecdotal evidence for Paris and Amsterdam (Heine, 1872; Mooij, 2001), Piketty et al. (2018) observe a significant decrease in average wealth at death during the 1832 cholera epidemic, suggesting many wealthy individuals fled the city. Coven and Gupta, 2020 show the same pattern during the COVID-19 epidemic in New York City. In Paris, this does not seem to have resulted in substantial drops in prices, given that we observe comparatively small effects in wealthy areas of the city.

Despite these sizable drops in housing demand due to a pandemic, prices recovered fairly quickly. One important reason is that population losses in cities were quickly made up by increasing migration. Five-yearly estimates of population growth from Nusteling (1985) show that the Amsterdam population increased in each five-year period, growing from 25,000 inhabitants in 1583 to 206,000 inhabitants in 1673. Despite seven extremely deadly plague epidemics, Amsterdam experienced its famous Golden Age in this period. In Paris, the population grew by almost 15% between 1831 and 1836 but stagnated between 1846 and 1851. This could explain why we observe larger price differences across neighborhoods following the 1849 cholera epidemic compared to the 1832 epidemic. If population growth returned quickly, the existing housing stock had to be used entirely to house new migrants, annulling much of the loss in housing demand due to cholera mortality and reducing potential stigma effects on heavily-affected areas.

One important implication of this finding is that large pandemics, and their corresponding demographic shocks, do not seem to affect the long-term growth trajectories of large cities. Of course, these effects might be different in less successful cities, or in rural areas, for which do not have data (see Alfani and Percoco, 2019).

5.2. Large short-Term house price drops

One challenge for a housing-demand based explanation of the developments in house prices around pandemics is the comparatively small response in rental prices relative to house prices.

Although our data on rental prices is limited to annual rent price indices, these indices suggest that drops in house prices in pandemic years were about twice as large as drops in rental prices. Because these rental price indices are based on observations of new rental contracts or observations where rental payments actually changed, they likely overstate the impact on average lease prices, since tenants with on-going contracts would not experience a drop in their lease prices. Of course, it is possible that the pandemics led to significant payment defaults, but the rental records of institutional investors in Amsterdam do not provide any evidence that this was the case (Eichholtz et al., 2019).

The more muted response of rental prices relative to house prices seems at odds with standard asset pricing models. Given that most properties were investor-owned, their valuation likely depended heavily on the expected discounted stream of rental cash flows on these properties. As rental prices only dipped temporarily and by relatively limited amounts, we would ex ante expect that property prices fall by much less than rental prices, at least if investors had perfect foresight or extrapolated the rental price experience of previous outbreaks. This suggests that short-term reductions in housing demand can only explain a small part of the initial drop in house prices.

One reason why we observe comparatively large drops in house prices is that investors might have become very pessimistic about the future due to the pandemic, and expected housing demand to continue falling in the future. Although we cannot test how likely this channel is, such pessimistic expectations were unjustified ex-post and whether investors considered previous outbreaks.[19] For the current pandemic, Ling et al. (2020) also document that the stock prices of REITs exposed to areas with increasing case numbers fell much more significantly in early 2020, even though stock prices recovered afterward. Giglio et al., 2020 show that equity investors became substantially more pessimistic during this stock market crash, even though stock prices recovered quickly.

A channel closely related to increased pessimism is that epidemics temporarily increased discount rates, most likely through increasing housing risk premia. Interest rate fluctuations do not seem to be driving this effect since bond rates in both Paris and Amsterdam did not move much during an outbreak (Gelderblom and Jonker, 2011; Hautcoeur, Riva).[20] Interest rate changes also do not explain why house prices fall much more substantially in heavily-affected areas.

It is likely that an epidemic temporarily increased perceived investment risk and risk aversion, and so risk premia. For example, changes in wealth or expected income triggered by epidemics could increase risk aversion, such as in the canonical model of Campbell and Cochrane, 1999. The prospect of uncertainty in future income can generate similar increases in risk aversion (e.g. Guiso and Paiella, 2008). Second, theoretical and empirical work shows that when risks are salient, and when events trigger negative emotions, risk aversion can temporarily increase significantly (e.g. Bordalo et al., 2012; Cohn et al., 2015; Guiso et al., 2018; Loewenstein, 2000), and affect risk perception (Slovic et al., 2007). This mechanism, combined with a temporary increase in investor pessimism, could explain why the fall in house prices is particularly large in the short-term and in heavily-affected areas. Uncertainty resolves when the epidemic ends, while home-owners in heavily-affected areas are more exposed to the outbreak, either directly or through their tenants.

One concern is that properties might sell at lower property prices due to changes in the composition of buyers, sellers, and properties for sale, instead of an increase in aggregate risk premia. For example, properties might sell at discounted prices because distressed sellers sell to the first available buyer, rather than waiting to realize the fundamental market price. This mechanism has been well-documented for foreclosure sales (e.g. Campbell et al., 2011), but might also apply to regular fire sales. Table 1 shows that different types of properties did not realize different prices during plague epidemics in Amsterdam, and that foreclosed properties did not realize lower prices either.[21] In Online Appendix C.4 and C.5, we show there is no difference in total foreclosure volume and realized holding periods during an outbreak, implying evidence for fire sales is limited.

5.3. Housing supply & urban planning

In the short-term, epidemics coincided with falling construction activity, with estimated completed construction going down on average by 40% (see Appendix C.2). However, epidemics had more significant consequences on the housing supply over the long run. The city of Paris is probably the most prominent example. After the 1832 outbreak, the government quickly realized that the areas worst affected by cholera were those with high population densities, narrow streets, and with poor inhabitants. When Count de Rambuteau came to power in Paris in 1833, he proclaimed that his mission was to provide "air, water and shadow" to all citizens in Paris, and started clearing unhealthy housing in the worst-affected central areas of the city, as well as introducing public urinals to improve sanitation (Park, 2018). The 1849 outbreak confirmed the validity of this approach, since the central areas that were most affected by Rambuteau's renovations, had much lower mortality than in 1832. This confirmation paved the way for the renowned Haussmann renovations that started in the 1850s. These destroyed nearly all of the unhealthy medieval Paris and gave the city the image it still has today, with its wide boulevards and large apartment blocks. Although the movement to create a more healthy Paris already started before the outbreak of cholera (Park, 2018), following the huge increases in population density of the central parts of the city, cholera turned out to be the catalyst that was needed to push through large scale renovations.

Plague also affected urban planning and housing supply in Amsterdam. Similar to Paris, Amsterdam experienced enormous inflows of migrants, forcing the city to expand significantly. Just prior to the outbreaks in the years 1617–1618 and 1663–1664, the government had started selling plots of land for these expansions. Strikingly, plots continued to be sold in the plague years, and the city even started selling these plots with mortgages, such that investors did not have to pay the full price upfront (Abrahamse et al., 2015). These mortgages were used widely, in particular around outbreaks.[22] We do not know if the government took these measures because of the outbreaks, but they do display a strong commitment to keeping supply expansion going even during epidemics. Beyond housing, the outbreaks of the plague caused the city to focus on improving the urban water infrastructure, which was thought to be related to the spread of the plague (Abrahamse, 2010).

Each of these developments might have contributed to the evolution of house prices and rents we observe after epidemics. First, the regeneration of areas heavily affected by cholera likely played an important role in the fact that house prices and rents in these areas did not stay persistently lower relative to less affected areas in Paris, as Ambrus et al., 2020 find for London. The introduction of wider streets, the clearance of slum housing, and access to clean water could improve the valuations of both new and existing properties.[23] Second, the continued expansion of housing supply in both cities after epidemics limited longer-term price growth and could reinforce migration towards the city.

[19] In Online Appendix B.1, we test for a learning effect by investors. We interact the plague variable with the sequence of occurrence of the plague outbreak. We do not find evidence for learning, but this might be due to the low number of sales during the first six months after the outbreak of the plague, in particular for the first three outbreaks in our sample.

[20] In Online Appendix C, we show that our estimates on the impact of epidemics on annual house prices changes do not change when controlling for changes in interest rates. We should note that bond interest data for Amsterdam is less precise than for Paris, but more granular archival data on mortgage interest rates revealed these changed little during outbreaks (Amsterdam City Archives, Archive 5065).

[21] The likely cause for the absence of a foreclosure discount is that there was a large and liquid auction market for real estate property in Amsterdam, where both regular and foreclosed properties were sold.

[22] Amsterdam City Archives, Archive 5065: Register van Rentebrieven.

[23] In London the policy response was restricted to the shutdown of the affected pump.

6. Conclusion

This paper studies the impact of pandemics, the plague in 17th-century Amsterdam and cholera in 19th-century Paris, on house prices and rents, using micro-data. We find that these major epidemics caused economically and statistically significant but short-lived declines in house prices. The impact on rental prices was likely smaller. Declines in house prices are most substantial just after the outbreak of an epidemic and in heavily-affected areas.

Although various mechanisms could explain this finding, the most plausible explanation for the large and temporary decline in property prices is that epidemics temporarily increase housing risk premia, due to increased uncertainty and economic disruption. Additionally, mortality and economic turbulence temporarily depress housing demand.

About one to two years after the end of an epidemic, price growth is not significantly different anymore from its average trend. We attribute the absence of any long-term effect on house prices and rents to the resilience of cities to major shocks. In both Paris and Amsterdam, the outbreaks did not stop a massive flow of migrants from coming to the city. In Paris, the epidemic even proved to be a catalyst for significant urban change, and house prices recovered even in the worst-affected areas.

Are these historical estimates still relevant today? On the one hand, these epidemics might be the closest comparison to the current situation in major cities. The pandemics we study resulted in a large number of deaths and caused major disruptions to economic activity. They happened in growing cities with a substantial flow of migrants and large buy-to-let property markets. On the other hand, cities in developed countries today are different from historical Amsterdam and Paris, and the pandemic has resulted in unprecedented policies that provide financial support to citizens and aim to limit the spread of the virus. Correspondingly, our results might be most representative for cities in developing countries facing epidemic outbreaks. In developing countries, major epidemic outbreaks are more frequent, living conditions more comparable to historical Amsterdam and Paris, and governments also tend to have fewer options to support their citizens during an outbreak.

CRediT authorship contribution statement

Marc Francke: Methodology, Software, Validation, Formal analysis, Data curation, Writing - review & editing, Writing - original draft. **Matthijs Korevaar:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - review & editing, Writing - original draft, Visualization.

Acknowledgements

We thank two anonymous referees, Bram van Besouw, Dorinth van Dijk, Martijn Dröes, Piet Eichholtz, Robert McClelland, Alex van de Minne, Elias Oikarinen, Paul Smeets, Niko Szumilo, Ronan Tallec, Patrick Tuijp, Aart de Vos and seminar participants at Maastricht University and the Virtual Real Estate Research Seminar for helpful comments and / or data.

Appendix A. Modified Repeat Sales Model

We estimate price trends and the impact of epidemics by a repeat sales (RS) model (Bailey et al., 1963), given by

$$\ln P_{i,t} - \ln P_{i,s} = \alpha + \mu_t - \mu_s + (x_{i,t} - x_{i,s})'\beta + \varepsilon_{i,t} - \varepsilon_{i,s}. \tag{A.1}$$

The left-hand-side is the difference in log prices of house i at the time of sale t and purchase s, where $s < t$, $t = 1, \dots, T$ and T is the number of periods. The vector $\mu = (\mu_0, \dots, \mu_T)'$ represents the log price index, where $\mu_0 = 0$. The term $\mu_t - \mu_s$ is the change in the log price index between the time of purchase and sale. The vector $(x_{i,t} - x_{i,s})$ consists of changes in characteristics between the date of purchase and sale. The constant α is a holding period independent return (Goetzmann and Spiegel, 1995). The error terms $\varepsilon_{i,t}$ are independently and normally distributed with zero mean and variance σ^2_ε.

We apply three modifications to the RS model (A.1). First, to reduce the impact of noise on the index, due to the low number of observations and/or outliers, we replace the time fixed effects with a stochastic specification, following Goetzmann (1992), Kuo (1999) and Francke (2010). The log price index is specified as a random walk, given by $\mu_t \sim N(\mu_{t-1}, \sigma^2_\mu)$.

Second, we use a time-weighted RS model to control for periodic (annual) price changes as precisely as possible, by taking into account the proportion of the period during which the property was "held" (Geltner, 1997). For that reason, we replace the integer values s, t by continuous variables, where for example $t = 1.25$ indicates that the property has been sold 1 year and 3 months after the start of the index. Define $f_s = \lfloor s \rfloor + 1 - s$, and $f_t = t - \lfloor t \rfloor$, denoting respectively the proportion was held in the period of purchase and sale, where $\lfloor t \rfloor$ is the greatest integer less than or equal to t. We subsequently replace $\mu_t - \mu_s$ in Eq. (A.1) by $(1 - f_t)\mu_{\lfloor t \rfloor} + f_t \mu_{\lfloor t \rfloor + 1} - (f_s \mu_{\lfloor s \rfloor} + (1 - f_s)\mu_{\lfloor s \rfloor + 1})$.

Third, we add time invariant variables z_j (for example the neighborhood mortality rate) with time varying coefficients λ^j (at lower frequency), to estimate differences in the responses to epidemics. λ^j is a $(T' + 1)$-vector, where T' is the number of periods at the lower frequency. We use lower frequencies because we have an insufficient number of observations to compute annual time fixed effects λ_j precisely.

The modified RS model can be expressed as

$$\ln P_{i,t} - \ln P_{i,s} = \alpha + d^\mu_{i,s,t}\,\mu + \sum_{j=1}^{J} d^\lambda_{i,s,t}\, z_{i,j}\, \lambda^j + (x_{i,t} - x_{i,s})'\beta + \varepsilon_{i,t} - \varepsilon_{i,s},$$
$$\mu_\tau \sim \mathcal{N}(\mu_{\tau-1}, \sigma^2_\mu),\ \mu_0 = 0, \tau = 0, 1, \dots, T, \tag{A.2}$$

where $d^\mu_{i,s,t}$ is given by

$$\Big(\underbrace{0 \cdots 0}_{1,\dots,\lfloor s \rfloor -1}\ \underbrace{-f_{i,s}}_{\lfloor s \rfloor}\ \underbrace{-(1 - f_{i,s})}_{\lfloor s \rfloor + 1}\ \underbrace{0 \cdots 0}_{\lfloor s \rfloor+2,\dots,\lfloor t \rfloor -1}\ \underbrace{1 - f_{i,t}}_{\lfloor t \rfloor}\ \underbrace{f_{i,t}}_{\lfloor t \rfloor + 1}\ \underbrace{0 \cdots 0}_{\lfloor t \rfloor+2,\dots,T}\Big),$$

and $d^\lambda_{i,s,t}$ is defined likewise at the lower frequency. The model has been estimated by Stan, a flexible probabilistic programming language for Bayesian statistical modeling. We use non-informative priors for $(\sigma^2_\varepsilon, \sigma^2_\mu, \beta, \lambda)$.[24]

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.jue.2021.103333

References

Abrahamse, J.E., 2010. De grote uitleg van Amsterdam: Stadsontwikkeling in de zeventiende eeuw. Thoth.

Abrahamse, J.E., Deneweth, H., Kosian, M., Schmitz, E., 2015. Gouden kansen? Vastgoedstrategieën van bouwondernemers in de stadsuitleg van Amsterdam in de Gouden Eeuw. Bulletin KNOB 229–257.

Administration Générale de l'Assistance Publique, 1850. Rapport sur les épidémies cholériques de 1832 et de 1849: Dans les établissements dépendant de l'administration générale de l'assistance publique de la ville de Paris. Paul Dupont.

Alfani, G., 2013. Plague in seventeenth-century Europe and the decline of Italy: an epidemiological hypothesis. Eur. Rev. Econ. Hist. 17 (4), 408–430.

Almagro, M., Coven, J., Gupta, A., Orane-Hutchinson, A., 2020. Racial disparities in frontline workers and housing crowding during COVID-19: Evidence from geolocation data.

Alfani, G., Percoco, M., 2019. Plague and long-term development: the lasting effects of the 1629–30 epidemic on the Italian cities. Econ. Hist. Rev. 72 (4), 1175–1201.

Ambrus, A., Field, E., Gonzalez, R., 2020. Loss in the time of cholera: long-run impact of a disease epidemic on the urban landscape. Am. Econ. Rev. 110 (2), 475–525.

[24] Alternatively, conditional on the variances $(\sigma^2_\varepsilon, \sigma^2_\mu)$ the time-weighted RS model (A.1) can be estimated by generalized least squares, providing estimates of (μ, β, λ). The variance parameters are subsequently estimated by maximum likelihood (see for more details Francke, 2010). Results are similar.

Bailey, M.J., Muth, R.F., Nourse, H.O., 1963. A regression method for real estate price index construction. J. Am. Stat. Assoc. 58 (304), 933–942.

Bordalo, P., Gennaioli, N., Shleifer, A., 2012. Salience theory of choice under risk. Q. J. Econ. 127 (3), 1243–1285.

Borjas, G.J., 2020. Demographic determinants of testing incidence and COVID-19 infections in New York City neighborhoods. NBER Working Paper.

Brakman, S., Garretsen, H., Schramm, M., 2004. The strategic bombing of german cities during world war II and its impact on city growth. J. Econ. Geogr. 4 (2), 201–218.

Callen, M., Isaqzadeh, M., Long, J.D., Sprenger, C., 2014. Violence and risk preference: experimental evidence from Afghanistan. Am. Econ. Rev. 104 (1), 123–148.

Cameron, L., Shah, M., 2015. Risk-taking behavior in the wake of natural disasters. J. Hum. Resour. 50 (2), 484–515.

Campbell, J.Y., Cochrane, J.H., 1999. By force of habit: a consumption-based explanation of aggregate stock market behavior. J. Political. Econ. 107 (2), 205–251.

Campbell, J.Y., Giglio, S., Pathak, P., 2011. Forced sales and house prices. Am. Econ. Rev. 101 (5), 2108–2131.

Case, K.E., Shiller, R.J., 1987. Prices of single-family homes since 1970: new indexes for four cities. New England Economic Review (Sep) 45–56.

Case, K.E., Shiller, R.J., 1989. The efficiency of the market for single-family homes. Am. Econ. Rev. 79 (1), 125–137.

Clark, G., 2002. Shelter from the storm: housing and the industrial revolution, 1550–1909. J. Econ. Hist. 62 (2), 489–511.

Cohn, A., Engelmann, J., Fehr, E., Maréchal, M.A., 2015. Evidence for countercyclical risk aversion: an experiment with financial professionals. Am. Econ. Rev. 105 (2), 860–885.

Collins, W.J., Margo, R.A., 2007. The economic aftermath of the 1960s riots in american cities: evidence from property values. J. Econ. Hist. 849–883.

Coven, J., Gupta, A., 2020. Disparities in mobility responses to covid-19. NYU Stern Working Paper.

Curtis, D.R., 2016. Was plague an exclusively urban phenomenon? plague mortality in the seventeenth-century Low Countries. J. Interdiscip. Hist. 47 (2), 139–170.

Davis, D.R., Weinstein, D.E., 2002. Bones, bombs, and break points: the geography of economic activity. Am. Econ. Rev. 92 (5), 1269–1289.

De Châteauneuf, L.-F.B., 1834. Rapport sur la marche et les effets du choléra-morbus dans Paris et les communes rurales du département de la Seine, par la commission nommée... année 1832. Imprimerie royale.

De Vries, J., 1981. Barges and capitalism: Passenger transportation in the Dutch economy, 1632–1839, 4. Utrecht: HES Publishers.

De Vries, J., Van der Woude, A., 1997. The first modern economy: Success, failure, and perseverance of the Dutch economy, 1500–1815. Cambridge University Press.

Eichholtz, P.M.A., Korevaar, M., Lindenthal, T., 2019. 500 Years of urban rents, housing quality and affordability. SSRN Working Paper no. 3418495.

Eichholtz, P.M.A., Korevaar, M., Lindenthal, T., 2021. The total return and risk to residential real estate. Rev. Financ. Stud. forthcoming.

Ferguson, N., Laydon, D., Nedjati-Gilani, G., et al., 2020. Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand.

Francke, M.K., 2010. Repeat sales index for thin markets: a structural time series approach. J. Real Estate Finance Econ. 41 (1), 24–52.

Francke, M.K., Korevaar, M., 2019. Baby booms and asset booms: demographic change and the housing market. SSRN Working Paper no. 3368036.

Gelderblom, O., Jonker, J.P., 2011. Public finance and economic growth. The case of Holland in the seventeenth century. J. Econ Hist. 71 (1), 1–39.

Geltner, D.M., 1997. Bias and precision of estimates of housing investment risk based on repeat sales indices: a simulation analysis. J. Real Estate Finance Econ. 14, 155–171.

Giglio, S., Maggiori, M., Stroebel, J., Utkus, S., 2020. Inside the mind of a stock market crash. National Bureau of Economic Research.

Glaeser, E.L., Gyourko, J., 2005. Urban decline and durable housing. J. Pol. Econ. 113 (2), 345–375.

Goetzmann, W.N., 1992. The accuracy of real estate indices: repeat sale estimators. J. Real Estate Finance. Econ. 5 (1), 5–53.

Goetzmann, W.N., Kim, D., Shiller, R.J., 2016. Crash beliefs from investor surveys. National Bureau of Economic Research.

Goetzmann, W.N., Spiegel, M., 1995. Non-temporal components of residential real estate appreciation. Rev. Econ. Stat. 77, 199–206.

Gonzalez, L., Ortega, F., 2013. Immigration and housing booms: evidence from Spain. J. Reg. Sci. 53 (1), 37–59.

Guiso, L., Paiella, M., 2008. Risk aversion, wealth, and background risk. J. Eur. Econ. Assoc. 6 (6), 1109–1150.

Hautcoeur, P.-C., Riva, A., 2018. The data for financial history (DFIH) database. http://dfih.fr/.

Guiso, L., Sapienza, P., Zingales, L., 2018. Time varying risk aversion. J. Financ. Econ. 128 (3), 403–421.

Heine, H., 1872. Französische zustände, 8. Hoffmann und Campe.

Hornbeck, R., Keniston, D., 2017. Creative destruction: barriers to urban growth and the great boston fire of 1872. Am. Econ. Rev. 107 (6), 1365–1398.

Kesztenbaum, L., Rosenthal, J.-L., 2017. Sewers diffusion and the decline of mortality: the case of Paris, 1880–1914. J. Urban Econ. 98, 174–186.

Kuo, B.S., 1999. Asymptotics of ML estimator for regression models with a stochastic trend component. Econ. Theory 15, 24–29.

Baron de Larrey, D.J., 1831. Mémoire sur le choléra-morbus. Imprimerie de Mme. Huzard (née Vallat la Chapelle).

Le Mée, R., 1998. Le choléra et la question des logements insalubres à Paris (1832–1849). Population (French edition) 379–397.

Korevaar, M., 2021. Reaching for Yield: How Investors Amplify Housing Booms and Busts. SSRN Working Paper no. 3794782.

L'Histoire, 2018. La révolution de février 1848 á paris. https://www.thinglink.com/scene/1020670863348858883?buttonSource=viewLimits.

Ling, D.C., Wang, C., Zhou, T., 2020. A first look at the impact of COVID-19 on commercial real estate prices: asset-Level evidence. The Review of Asset Pricing Studies doi:10.1093/rapstu/raaa014. https://academic.oup.com/raps/advance-article-pdf/doi/10.1093/rapstu/raaa014/33725684/raaa014.pdf.

Loewenstein, G., 2000. Emotions in economic theory and economic behavior. Am. Econ. Rev. 90 (2), 426–432.

Mairie de Paris, 1967. Annuaire statistique de la ville de paris, 1900, 1950, 1967. Paris, FR: Impremerie Nationale.

Margo, R.A., 1996. The rental price of housing in New York City, 1830–1860. J. Econ. Hist. 56 (3), 605–625.

Miguel, E., Roland, G., 2011. The long-run impact of bombing vietnam. J. Dev. Econ. 96 (1), 1–15.

Mooij, A., 2001. Van pest tot aids. vijf eeuwen besmettelijke ziekten in Amsterdam.. Thoth, Bussum.

Ngai, L.R., Tenreyro, S., 2014. Hot and cold seasons in the housing market. Am. Econ. Rev. 104 (12), 3991–4026.

Noordegraaf, L., Valk, G., 1996. De gave gods. De pest in Holland vanaf de late middeleeuwen. Bert Bakker.

Nusteling, H.P.H., 1985. Welvaart en werkgelegenheid in Amsterdam, 1540–1860: een relaas over demografie, economie en sociale politiek van een wereldstad. Bataafsche Leeuw.

Ouazad, A., 2020. Resilient urban housing markets: shocks vs. fundamentals. arXiv preprint arXiv:2010.00413.

Park, S.-Y., 2018. Ideals of the body: Architecture, urbanism, and hygiene in postrevolutionary Paris. University of Pittsburgh Press.

Piketty, T., Postel-Vinay, G., Rosenthal, J.-L., 2018. The end of the rentiers: Paris 1842–1957.

Rommes, R., 2015. Plague in northwestern Europe. The Dutch experience, 1350–1670. Popolazione e storia 16 (2), 47–71.

Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. Journal of Political Economy 82 (1), 34–55.

Saiz, A., 2007. Immigration and housing rents in American cities. J. Urban Econ. 61 (2), 345–371.

Sanso-Navarro, M., Sanz, F., Vera-Cabello, M., 2015. The impact of the American civil war on city growth. Urban Studies 52 (16), 3070–3085.

Slovic, P., Finucane, M.L., Peters, E., MacGregor, D.G., 2007. The affect heuristic. Eur. J. Oper. Res. 177 (3), 1333–1352.

Van Leeuwen, M.H., Oeppen, J.E., 1993. Reconstructing the demographic regime of Amsterdam 1681–1920. Economic and Social History in the Netherlands 5, 61–102.

Vehtari, A., Gelman, A., Gabry, J., 2017. Practical bayesian model evaluation using leave-one-out cross-validation and WAIC. Stat. Comput. 27 (5), 1413–1432.

Wong, G., 2008. Has SARS infected the property market? Evidence from Hong Kong. J. Urban Econ. 63 (1), 74–95.