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**Title:** The Total Return and Risk to Residential Real Estate

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# The Total Return and Risk to Residential Real Estate*

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**Abstract**

This paper estimates the total rate of return to residential real estate investments based on 120,658 hand-collected archival observations of prices, rents, taxes and costs for individual houses in Paris (1809–1942) and Amsterdam (1900–1979). The annualized real total return, net of costs and taxes, is 4.2% for Paris and 5.0% for Amsterdam, and entirely comes from rental yields. At the property-level, the yield at purchase is an important determinant of the total holding period return, even for longer holding periods. In the short-term, idiosyncratic risk is the dominant component of total risk, but its importance reduces over time.

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# 1 Introduction

Housing is the world's largest asset class, but with some exceptions, it did not have much institutional investor interest in the decades before the Great Recession. Since then, however, housing markets all over the world have been booming, and so has investor interest. Both private and institutional investors are putting capital into rental housing (Bracke, 2019; Mills et al., 2019). No doubt, their interest has been spurred by the recent performance of the housing markets. On top of that, however, there is academic research that would lead one to believe that the stellar returns to housing are not just a recent phenomenon, but that housing investments have performed exceptionally well historically. Jordà et al. (2019a) aim to determine the total rate of return to housing and to compare it to the performance of stocks and bonds all over the world. Their results – based on secondary data sources – suggest that housing returns are surprisingly high. Indeed, in a follow-up paper, Jordà et al. (2019b) point out an unsolved risk premium puzzle for housing investments.

The crucial piece of information that is typically lacking to accurately compute housing returns and risk, both at the aggregate and individual level, is the rental yield. This paper calculates total returns and risks to residential real estate at aggregate and individual property level by studying primary historic data on house prices and rents for the same homes, as well as property-level taxes and costs, for two important housing markets: Paris and Amsterdam.

Not only do these data allow us to accurately assess total returns and risks at the market level, but the individual property information we have also provide a unique picture of the role of idiosyncratic risk. The risk and return to total housing market investments are of limited relevance for investment performance, as most residential property investors hold highly concentrated portfolios, due to the indivisibility of assets, their capital intensity, and high transaction costs.[1] For markets in which full diversification is unattainable,

[1]In The Netherlands, for example, 47 percent of the private rental stock is owned by individuals. Of these buy-to-let investors, 80 percent own a single property and only four percent own more than five properties.

both theory (see for instance Levy, 1978; Merton, 1987) and empirical work (for example Fu, 2009; Eiling et al., 2019) suggest that idiosyncratic risk and expected returns are linked in the cross-section. However, the magnitude of this idiosyncratic risk has not yet been established for individual housing investments. Existing work has looked at idiosyncratic capital gains risk in residential properties (e.g Merton, 1987; Peng and Thibodeau, 2017; Giacoletti, 2019; Eiling et al., 2019), but not at idiosyncratic risk of total returns.

Our paper aims to measure total returns to residential real estate as accurately as possible, and to assess the risk of that investment, distinguishing between idiosyncratic risk and systematic risk.

Mismeasurement of total returns to residential real estate could occur in four dimensions: The first is the price index, which needs to be quality-adjusted. House price indices constructed before Case and Shiller (1989) tend not to be, whereas those published in the later academic literature customarily are. A failure to control for the changing quality of the underlying assets results in a biased estimate of the capital return.

The second is the rental yield. Total returns on housing tend to be calculated by combining house price and rent series from different sources (e.g Brounen et al., 2014; Eisfeldt and Demers, 2018; Jordà et al., 2019a). That also holds for the rent-price ratios that have been used to study housing market dynamics (e.g Himmelberg et al., 2005; Davis et al., 2008; Campbell et al., 2009; Duca et al., 2011; Ambrose et al., 2013). This could be problematic, given that these series tend to pertain to different housing market segments, with rental housing generally of lower quality than owner-occupied housing. These market segments may well experience different trajectories in terms of investor sentiment and consumer preferences, which would weaken the quality of any resulting total return index. Moreover, to relate the rent index to the price index, one needs actual yield levels, which are rarely observed directly. Instead, this is usually done by taking the rent-price ratio from additional sources for part of the sample period as a basis and then extrapolating based on a rent index (Brounen et al., 2014; Jordà et al., 2019a). So far, actual asset-level yield data are only available for very short time-periods: Bracke

(2015) studies gross property-level yields for London between 2006–2012, while Eisfeldt and Demers (2018) use US data on actual net residential yields for the 2012–2016 period to extend and verify their longer-term findings.

The third issue is that information regarding property-level taxes and maintenance costs are usually not available and often neglected (Brounen et al., 2014). Jordà et al. (2019a) show that running costs on housing do vary over time, but since these are only available for few countries in their sample, they use the Investment Property Database net rental yields to link prices to rents in a baseline year. Chambers et al. (2019) do directly observe information on costs and show that these are in the order of one-third of the gross yield and contribute significantly to the risk of real estate investments, even for investors with large property portfolios. Eisfeldt and Demers (2018) also have direct information on property-level costs and taxes and show that these amount to 41 percent of the gross yield, varying considerably over time due to changes in property prices to which some of the costs and taxes are linked. Over longer horizons, property tax risk likely plays an even more important role, as property taxation has historically been the most common form of wealth taxation, and, as we will show, subject to large changes over time.

The final problem that historic total return indices to housing face is representativeness. Archival data employed to construct historic house price and rent indices rarely pertain to a whole country or even a complete city. The sampling tends to be the result of historical coincidence rather than statistical considerations. So the question is how representative the resulting samples are and whether they are big enough to ensure that the volatility in the resulting index returns can be interpreted as the standard deviation of the returns rather than the standard error in the measurement. For example, the Herengracht index by Eichholtz (1997) relates to only one affluent street in Amsterdam, which may or may not be representative of the city as a whole. To reduce measurement error, this index was estimated at a biennial frequency, and Eichholtz (1997) did not interpret the index volatility as risk.

Despite the enormous size of the housing market, data limitations on each of these four dimensions have so far rendered it difficult to make estimates of the total return and risk on long-term residential real estate investments. Three recent studies have specifically attempted to construct total return and risk estimates to real estate investments.

Eisfeldt and Demers (2018) study total returns to rental housing investments between 1986 and 2014 for a panel of cities in the United States. Although they do not observe actual yields in this period, they construct implied yields by extrapolating a city-specific hedonic pricing model for rental properties to owner-occupied properties. Both within and across cities, they find that rental yields decline in price tiers. Cities with lower net yields experience higher price appreciation, but have lower Sharpe ratios because capital gains are more volatile than yields. However, within cities, this logic reverses, as low price tier areas experience higher total returns due to both higher yields and higher capital gains.

Longer observation periods are important to establish the time-series properties of aggregate housing risk and returns over different market conditions and economic cycles. With this in mind, Jordà et al. (2019a) compile total return indices from a great number of existing house price and rent indices, based on construction methods that vary over time and across countries. Given the ambition of their paper, i.e. to assess housing investment returns and risks for a large cross-section of countries, this is understandable. Their data collection is momentous as it is. However, their series may suffer from measurement error on all four dimensions discussed above, which might make inferences based on their findings unreliable.

Very recently, Chambers et al. (2019) have made an admirable effort to construct estimates of total real estate returns, using the archives of four prominent 'Oxbridge' colleges between 1900 and 1970. Because the archival ledgers report both on rental income, costs and transaction prices, their study addresses much of the mismeasurement issues described above. They find that long-run real estate investment is less profitable and riskier than suggested by Jordà et al. (2019a). However, the average annual total return they calculate is based on the change in property yield between the beginning and end of their sample, making it liable to measurement error, especially so since their sample is rather thin in the early years. Besides that, their index not only concerns residential real estate, but also agricultural land and commercial real estate. Although they do report residential real estate performance separately, their sample for that property type is comparatively small. Furthermore, the real estate holdings of the four colleges might be large compared to other investors but remain tiny vis-à-vis the overall market and are unlikely to represent the national universe of properties well.

Given housing's important role in the economy and investment portfolios, it is important to establish the annual total return and risk to residential real estate in a way that avoids measurement problems as far as possible, using a dataset that is large and representative enough for reliable inference, at least at the city level.

Our contribution is straightforward. We study two previously unexplored primary datasets of house prices and rents on individual homes for Paris and Amsterdam. These datasets are large: in total, we hand-collected over 120,658 observations of rents, sales prices, and property-level taxes and costs, covering a representative sample of about 30,000 different properties. Uniquely, the datasets include rents and prices for the same homes, and on top of that, we have enough repeated price and yield observations to employ repeated-measures regression to control for changes in housing quality. We also have data on taxes and costs. These datasets allow us to construct quality-adjusted total returns indices for rental housing, and they also provide a picture of the risk and return to rental housing investment at the individual asset level.

We find total gross geometric returns to rental housing of 6.4 percent for Paris and 8.2 percent for Amsterdam, with index-level standard deviations of 8.7 percent and 10.7 percent, respectively. In real terms, geometric returns amount to 4.2 percent per annum in Paris and 5.0 percent in Amsterdam.

Our property-level return data allow us to study idiosyncratic risk in residential real estate investment. The contribution of idiosyncratic risk to total risk changes considerably over the holding period. For one year, almost all of the total return variance is idiosyncratic, and that drops to approximately 50 percent as holding periods get longer. In the short term, most of the total return risk comes from volatility in the capital gains, but the importance of capital gains decreases over the holding period, and yield covariance within a property over time becomes an increasingly important component of risk.

Last, we find that the property yields at the moment of purchase and sale are important for the long-term total return. Properties bought at a high yield have a higher realized capital gain when sold, whereas those sold at a high yield have lower holding-period capital gains. These effects remain even for longer holding periods and suggest the short-term findings of Eisfeldt and Demers (2018) within US cities do not generalize to longer time horizons.

In the remainder of the paper, we will first discuss the data and sources. The next section will present results for capital returns, gross rental yields, taxes and costs, net rental yields and total residential real estate returns, also addressing the measurement issues discussed above, to assess how each of these can lead to a faulty assessment of the total investment return to housing and its volatility. The section after that will provide an analysis of the investment risk - both systematic and idiosyncratic - associated with residential real estate investment and the role of the holding period in risk and return. We will end the paper with some conclusions.

# 2 Data

We employ two main archival data sources to construct indices of actual rental yields and house prices, for Paris (1809–1942) and Amsterdam (1900–1979). Table 1 presents a brief overview of the number of observations employed in this paper. Importantly, all our data contain observations on the level of rents and sales prices of an entire property. In both Amsterdam and Paris, properties typically contain several housing units.

[Place Table 1 about here]

## 2.1 Paris

We have extracted the Paris housing data from the Paris land register called the Sommier foncier. It covers the period from 1809 until 1943. This register is part of the wider French administration responsible for collecting taxes on legal acts, the Enregistrement. The Sommier foncier contains for each house in Paris all changes of property ownership and served to check the veracity of the declarations of taxes paid on these changes. The first two series of the Sommier foncier, which cover the period until 1880, also contain information about leases on these properties. For later periods, we obtain data on actual rents from inheritance registrations. Appendix A provides detailed background information about the Sommier foncier.

Figure 1 presents two pages from the first registers of the Sommier. The left page (top photo) lists all transfers of property, with information about the owners, the transaction price or assessed value, and the date of the transaction and registration. In the first register, the Sommier also lists the paid property tax. The right page (bottom photo) contains the neighborhood name and street address and lists the details of all the leases on the property, including a description of the (part of) the property that was let, the lease price, duration and the names of the tenants.

[Place Figure 1 about here]

The combination of rental prices and house prices for the same properties allows one to compute property-level gross yields, for a period covering more than a century. To the best of our knowledge, this has hitherto been impossible. Although historians have described this dataset (Daumard, 1958, 1965), the Sommier has not been the subject of extensive use so far, likely because of its enormous size and the complications arising with hand-written data.[2]

It is possible to calculate gross yields for all homes in the city between 1809 and 1943, but for practicality and randomization, we collected data from all streets starting with

[2] A related register of the Enregistrement, containing the declarations of inheritances, has formed the basis for the well-known work of Piketty et al. (2006) on French inequality, as well as subsequent studies.

the letters A or B. We collected additional data from the first set of registers to obtain more observations of actual rents. In total, we digitized data for approximately 20,000 different residential properties. For each property, we listed the street address, the type of legal act, the registered price or value, and the date of registration and transfer.

We remove observations that are duplicates, not dated or outside our period, or that do not have a price registered. The reduced sample covers 74,089 registrations: regular property sales, auction sales, leases for entire properties, inheritances and donations. Information on 34,614 property prices originates from data on regular sales and auctions sales. Notaries directly sent information about these sales to the Enregistrement, so the government could collect a stamp duty. This procedure guarantees the quality of the information.

Data on 39,475 rent prices come from the leases contained in the first two sets of registers (1809–1880) and from the estate assessments recorded in the successions and donations up to the second half of the twentieth century. By law, the payment of inheritance tax resulted from an assessment of the income of the building based on the current price of the leases, or the rental value of the property in case of owner-occupation. The heirs declared these amounts to the receiver, who could verify and control these declarations subsequently. Verification was common: we find that in over 20 percent of cases the tax receiver imposed extra taxes afterward ('insuffisances'). We adjusted our valuations for these insufficiencies.

Because of legal changes and different registration practices, the denoted amount sometimes corresponded to a capitalized rent. Additionally, we typically do not observe the value of the rent price in the same year as the sales price, so that we have to adjust the rent prices for potential changes in the level of market rents. In Appendix B we explain how we adjusted these observations.

We use the combination of rents and house prices for the same properties to construct property-level gross yields. In total, we can match 28,287 observations of sales prices to a rent observation for the same property.

To obtain estimates of taxes, we collect data on paid property taxes for 2,770 observations in the first register of the Sommier. For each of these observations, we also know the sale or rental price such that we can compute a property tax rate. To obtain tax rates after 1860, we collected 1,704 property-level tax observations for a sample of streets in Sainte-Avoye, one of Paris's neighborhoods.[3] It is not necessary to diversify this tax sample since the law prescribed that property taxes were the same across districts in a city.

## 2.2 Amsterdam

The city of Amsterdam had and still has a unique history of selling property for investment purposes in public auctions, not only in cases of foreclosure but also for regular sales. Such auctions have been organized since the 1600s and still take place today. The format of these auctions has changed very little over time: before the actual auction, the auction house and organizing realtors use newspapers or other media to promote the properties for sale. During the auction, participants bid on the properties using a unique auction format: the Anglo-Dutch Premium Auction (Boerner et al., 2016). For sold properties, the buyers pay the required transaction price and fees and subsequently register the transfer of property formally.

Before the advent of modern house price indices, such auctions gave market participants important information about market prices and yields. Because most properties were purchased for investment purposes, information on rents and taxes was presented for nearly every property for sale. The auctions were public, so individuals could record and register this information. We exploit the archives of the Firma Jan Brouwer & Zn., who developed a unique card system to store information on sales prices, appraisals, rental values, rents, and taxes of properties sold in these auctions.[4] This system covers the period from 1900 to 1979 and contains information on approximately 20,000 properties.

[3] Archives de Paris, D13P2/17, 67 à 69.

[4] Source: Amsterdam City Archives, Archive 901.

One unique aspect of this database is that it appears to have been specifically designed to follow property yields over time for a large sample of investment properties.

Figure 2 contains an example of a card for one property. We transcribed these cards for 9,354 different properties. For each observation, we listed the street and house number, as well as the date, the type of value observation (appraisal, auction sale or regular sale), and the price.[5] In case the property was leased or its rental value appraised, we also transcribed this information. Last, we included information on all mentioned taxes. Next to regular property taxes and municipal taxes, many homes in Amsterdam were subject to mandatory ground leases, which the municipality introduced in 1896 (Nelisse, 2008). Instead of selling land for construction, the municipality let land from then onward. Initially, these leases would be for 75 years, but this system changed in 1915 so that land could be let continuously for a fixed rental price. In 1966, the fixed-price system changed to an indexed system. To account for the impact of ground leases on the expected costs of investors, we also wrote down for each property whether it was subject to ground leases, even if the actual costs of these leases were not specified on the cards.

[Place Figure 2 about here]

In total, this data collection resulted in 13,148 observations of rents, 15,235 transaction prices or appraisals and 5,364 observations of taxes. In 12,483 cases, we have both a rental price and a transaction price observation for the same home in the same year. In 4,617 cases we can also adjust this yield for taxes. To complete our database of transaction prices, we augment it with 2,854 repeated transaction prices from Verwey (1943) for property auctions between 1840 and 1940, and 3,040 transaction prices from the Herengracht index of Eichholtz (1997), covering the 1840–1972 period.

To provide estimates of non-tax costs, we compiled data on actual costs from the archives of two institutional investors: the Amsterdam Orphanage (the Burgerweeshuis) and the Doopsgezinde Gemeente, an Amsterdam church. Since the 17th century, the

[5] 95 percent of observations are within Amsterdam.

Burgerweeshuis has been among the largest institutional investors in the Amsterdam residential real estate market.

For social institutions like the Burgerweeshuis and the Doopsgezinde Gemeente, property investments provided the largest part of their funding. Eichholtz et al. (2019) used information on rental contracts from both institutions to construct multiple series of market rent prices, and we refer to their paper for information on the investment activity of these investors. Chambers et al. (2019) use similar data from Cambridge colleges to obtain estimates of costs.

Although the Burgerweeshuis reduced its property portfolio over time because it deemed investments in bonds and other financial assets more attractive (Gelderblom and Jonker, 2009), the Burgerweeshuis still owned 60 properties until the mid-20th century containing over 100 rental units.

From its archives, we collected property-level information on rental income and expenses for these units, covering the period from 1937 and 1969. For the Doopsgezinde Gemeente, we obtain data on 30 different properties spanning the period from 1889 to 1924. Ledgers are incomplete before and after these periods. The mentioned costs include expenses on maintenance and renovation, taxes, insurance, rent arrears and water use (if not paid by the tenant). In short, this database provides all asset-level costs. In total, this resulted in 2,454 property-level observations of rental prices and all costs.

# 3 Results: Computing total housing returns

In this section, we estimate the total returns for residential real estate in Paris and Amsterdam. The standard return to rental housing investments for a property (or a portfolio of properties) consists of both capital gains and net rental yields (Equation 1).

$$Return_{i,t} = \frac{Price_{i,t} - Price_{i,t-1}}{Price_{i,t-1}} + \frac{Rent_{i,t}(1 - c_{i,t} - \tau_{i,t})}{Price_{i,t-1}} \tag{1}$$

To estimate our total returns as precisely as possible, and to establish how measurement error could contribute to wrongly specified returns, we split this equation into three parts. First, we study the role of capital gains measurement in the assessment of the total rate of return to housing. The main challenge here is to adequately control for housing quality, as well as to have sufficiently large and representative samples of housing sales. Second, we look at simple rental yields: the current or estimated rent divided by the sales price.[6] We compare how these actual yields differ from implied yields derived from secondary indices. Third, we study the implications of costs and taxes on yields, with a particular focus on property-level taxes ($\tau$). We proxy for non-tax costs ($c$) with average realized non-tax property-level costs from two major institutional investors in Amsterdam. Finally, we provide aggregate statistics on total returns for Paris and Amsterdam and compare net yields on residential real estate to those on government bonds.

## 3.1 Capital gains

The literature has employed a wide set of methods to estimate house price indices, some aiming to control for changes in quality of the underlying housing stock, and some not. Of the former, the two most commonly used are the repeat-sales method (Bailey et al., 1963) and the hedonic method (Rosen, 1974). In a standard framework, the log price of a transaction can be written as the sum of a 'quality' component ($\alpha$) and a time-varying market value component ($\beta$) plus a transaction error ($\varepsilon$).

$$p_{i,t} = \alpha_i + \beta_t + \varepsilon_{i,t} \tag{2}$$

Crucial to both methods is that they attempt to separate improvements in the quality of homes from increases in market prices. Because the quality of the housing stock has increased throughout the 20th century, inadequate quality control will result in indices with an upward bias (Eichholtz et al., 2019). In the repeat-sales method, which we employ

[6]Note that rental yields formally differ slightly from the rental returns defined in equation 1. The latter express the rent price relative to the sale price in the previous period. Our rent observations specify the annual rental price at the time of the transaction: we thus assume this is equal to the rental price for the upcoming year.

for both cities in this paper, this is accomplished by focusing on repeated transactions of the same properties. Because we do not have observations on actual housing quality for the properties in our sample, using the hedonic alternative is not feasible.

#### 3.1.1 Paris

We first estimate a constant-quality house price index for Paris rental housing between 1809 and 1942. Our data do not allow us to identify changes in the quality of existing properties directly, so we use a repeat-sales method to estimate the index. We only include observations resulting from actual sales: both private sales and auction sales. In total, we have 34,614 observations of transaction prices covering 134 years, containing 13,093 pairs of transaction prices that we use to estimate the index.[7]

We plot the resulting house price index in Figure 3. Table 2 Panel A provides summary statistics of the new house price index. Most importantly, we find a geometric average log capital gain of 2.3 percent (arithmetic: 2.8 percent), with a standard deviation of 9.2 percent. Adjusted for inflation, the capital gain is 0.1 percent per year.

To compare this finding with existing work, we also plot the house price index for Paris constructed by Duon (1946), covering the 1840–1940 period. The index of Duon uses repeated transactions of the same home, implying this is likely the world's oldest repeat-sales index. Although it is unclear how Duon constructed this index exactly, it seems he traced all previous sales for the 4,389 homes sold in Paris between 1941 and 1944. Duon smoothed his index using a moving average of unknown length (see Duon, 1943).

[Place Table 2 about here]

[Place Figure 3 about here]

[7]We exclude pairs of transactions occurring in the same year and pairs resulting in extreme outliers as these may signal unobserved changes in quality. We removed observations if the log price difference relative to the rent price index of Eichholtz et al. (2019) exceeded 1.38 (> 300 percent or < -75 percent) In total, this reduced the used number of pairs from 17,935 to 13,093.

When we compare our index with that of Duon (1946) for the overlapping period, we can observe that they are very similar in terms of average capital return but very different in terms of risk: Duon's index has an annual standard deviation of only 6 percent, and we find a correlation of only 0.39 between our annual returns. This is almost certainly the result of smoothing because Duon worked with a comparable but much smaller set of transaction prices. This is a major reason why our volatility estimates differ from those presented in Jordà et al. (2019a) for France, who use the moving-average index of Duon for Paris until 1937.

### 3.1.2 Amsterdam

For Amsterdam, we estimate a standard repeat-sales index, controlling for the type of sale observed in the data. To estimate the index, we include transactions for the entire period from 1840 to 1979 but only report on the index development from 1900 to 1979, the period for which we have yield data besides transaction prices. In total, we used 9,293 repeat-sales pairs to estimate the index, excluding sales within the same year and extreme outliers.

We plot the estimated index in Figure 4, and Table 2 Panel A provides summary statistics. We find a geometric average annual log capital gain of 2.6 percent (arithmetic: 3.3 percent) and a standard deviation of 11.4 percent. Adjusting for inflation, the real log capital gain averages -0.6 percent per year. These numbers are similar to our findings for Paris. When we compare them with existing work, however, we again find notable differences. Figure 4 and Table 2 also map the performance of the annual Herengracht index from Ambrose et al. (2013) that is not smoothed, as well as the smoothed version used in Knoll et al. (2017) for the 1900–1979 period.[8] We also compute correlations relative to our new index.

[8] Existing house price indices covering 19th and 20th century Amsterdam are primarily based on the bi-annual Herengracht index of Eichholtz (1997), which employs repeated sales of properties along Amsterdam's best-known canal. Although this ensures constant quality, the number of annual transactions is small, implying that standard repeat-sales methods will result in noisy annual indices. Most annual indices based on the Herengracht data have therefore applied smoothing techniques (Boerefijn, 2010; Knoll et al., 2017; Francke and Korevaar, 2019).

[Place Figure 4 about here]

Comparing the capital gains trajectory on our new index with existing work leads to three important insights. First, there are substantial differences in annual house price growth across these indices. The annual Herengracht index has a very low number of observations from the mid-1960s onwards, resulting in very high but very uncertain growth rates of house prices in this period (Eichholtz, 1997; Ambrose et al., 2013). In previous work, Knoll et al. (2017) switch to a national house price index from 1970 built on median prices, whereas Ambrose et al. (2013) already do so from 1965. Our new repeat-sales index overcomes this hiatus and leads to substantially lower house price growth estimates than the national index based on median transaction prices.

Second, less precisely estimated indices have higher volatilities because the repeat-sales procedure results in overfitting when the number of observations is small. Without smoothing, the annual Herengracht index is highly volatile due to the low number of observations per annum. Knoll et al. (2017) have significantly smoothed this index, and the result shows volatility that is close to ours.[9]

The combination of these two issues brings us to the third and final insight: limitations in data, index estimation method and sampling lead to a weakening of the correlations of the annual percentage capital gains across different indices. The correlation between the annual capital gains in our new index and those in Ambrose et al. (2013) and Knoll et al. (2017) is around 0.3, which is rather low given that these indices are supposed to track the performance of the same asset base.

For both Paris and Amsterdam, differences with existing indices seem linked to the low number of observations and the use of smoothing techniques in previous work. For Amsterdam, limited control for changing property quality as well as index splicing play a major role in the observed differences in capital gains in the final part of the sample.

[9]That seems coincidental, since Knoll et al. (2017) use a rather forceful smoothing technique. They annualize the original biennial index by applying the bi-annual observation only for the first of the two years. To interpolate the second year, which is now missing, they take simple averages of the previous and next observation.

Although our study is specific to Amsterdam and Paris, concerns about index quality likely apply more generally to historical house price series.

Low index quality, as defined by the degree to which the index adjusts for the changing quality of the underlying housing stock, correlates with substantially higher capital gains, as Gatzlaff and Ling (1994) and Eichholtz et al. (2019) show. For rent prices in the United Kingdom, Chambers et al. (2019) suggest the estimates of Jordà et al. (2019a) diverge from those in their paper and in Eichholtz et al. (2019) due to inappropriate index splicing and insufficient control for quality changes in the underlying housing stock. Taken together, this implies that our concerns about the impact of index quality on the risk-return characteristics of capital gains likely extend beyond Paris and Amsterdam.

## 3.2 Gross rental yields

To estimate the gross annual rental yield for the two cities, we rely on two different methods. The first method estimates for each city the aggregate rental yield on all properties in the sample each year. We do this by dividing the summed rental prices of these properties by their summed sales prices, so this could be regarded as a portfolio rental yield for the entirety of the housing stock in the city. It is a value-weighted average gross yield. The second method first establishes the gross yield at the property level and then takes the city-wide median yield for each year.

To exclude outliers or erroneous observations, we trim the top and bottom one percent of yields in Amsterdam, which included implausible observations. We also remove observations with extremely high rent levels (more than 500 percent higher than the median rent for a house). For Paris, we need to make additional adjustments because some rents written in the ledgers are capitalized. We explain in Appendix B how we make these adjustments, which remove approximately 14 percent of the rent observations.

For Amsterdam, all yields are based on the rental price in the year of the sale. For Paris, this is not the case because we only observe new contracts or rent prices in case the owner dies or donates the property, which rarely happens in the same year as a sale.

We, therefore, use for each sale the nearest rent observation, with a limit of 30 years.[10] To adjust the individual rent price for changes in rents over time, we compute a rental price index and use it to estimate the rent price in the year of sale. This procedure is comparable to the one for Paris, which we describe in Appendix B. In total, there remain 19,184 gross yield observations in the sample for Paris and 11,423 for Amsterdam.

Table 2 Panel A shows a Parisian gross portfolio yield for rental housing of 7 percent, with a standard deviation of only 0.9 percent. For Amsterdam, the average gross portfolio yield equals 10.1 percent with a standard deviation of 1.6 percent.

Figure 5 shows the development of rental housing yields for Paris and Amsterdam. For Paris, the gross yield moves in a rather limited range, roughly between 5 and 10 percent. The picture is more volatile for Amsterdam than for Paris. Amsterdam yields are quite stable until 1965, and then start increasing substantially in the late 1960s, with the gross yield peaking at more than 20 percent in the 1970s. This is likely related to unprecedented increases in inflation in that period.

[Place Figure 5 about here]

In both Paris and Amsterdam, we find gross portfolio yields to be slightly lower than gross median yields. This implies that yields for expensive properties are lower than those for cheaper properties. Differences in costs could be an important explanation for this finding. We study these differences in the next subsection.

### 3.3 Taxes and other expenses

The conversion of gross yields into net yields requires property-level information about costs, such as maintenance, renovation, vacancy costs (if a property is not let for an entire year), and taxes. In this section, we make estimates for each of these.

[10] We obtain similar but less precisely estimated yields with a smaller cut-off window.

### 3.3.1 Taxes

For Paris, we use direct property-level taxes between 1809 and 1854 based on a subset of 2,770 transaction prices or rents for which we have information on the level of annual property taxes. We use these to directly estimate the average tax rate for each year. Between 1855 and 1905, we use data on 1,704 observations of annual taxes paid for properties in Sainte-Avoye, one of Paris's neighborhoods.[11] To convert these into a rental tax rate, we match these observations for each house to the rental prices in the Sommier foncier. After 1905, we compute the tax rate based on aggregate Parisian property tax revenue, which we scale by the number of properties in Paris and their average rental price. We discuss the property tax system and the sources we used in more detail in Appendix C.

For Amsterdam, a third of the rental yield observations include the required property-level taxes (4,126 observations). The most important of these were direct property taxes, street taxes and a fee for the use of water. For properties with leaseholds, we also register land lease costs. From 1924 onward, there are sufficient observations available to estimate the level of taxes as a fraction of total rents.[12] To do so, we compute the average tax rate in each year, controlling for differences in tax rates due to the presence of land leases. To estimate the level of tax yields before 1924, we estimate a repeated-tax index based on 635 annual observations of taxes for properties of the Doopsgezinde Gemeente between 1900 and 1924. We use the 1924 tax rate to splice these to the tax rate series from the yield database. For periods of missing data (1915–1916) we interpolate the tax rate.

Figure 6 reports the annual tax rate for both Paris and Amsterdam, as a fraction of rents. Relative to prices, taxes averaged 1.4 percent of the property value per year in Amsterdam and 0.8 percent in Paris. In both cities, the fraction of rental income lost in taxes varies substantially over time, however.

In Paris, large changes in taxes coincided with political and economic instability: taxes

[11] Property tax rates were the same across districts, so it suffices to use a single neighborhood to estimate the tax rate.

[12] The rental tax rate can be estimated more precisely than the tax rate as a fraction of property value.

were very high after the Napoleonic Wars in the 1810s and after the 1848 revolution. In both Paris and Amsterdam, taxes increased substantially after World War I and during the crisis years in the 1930s. Unsurprisingly, these tremendous increases in property taxes coincide with the large reductions in wealth inequality documented in Piketty et al. (2006). Taxes likely played an important role in eroding asset prices: it is exactly in this period that house prices fell substantially in real terms.

[Place Figure 6 about here]

### 3.3.2 Other costs

To estimate non-tax costs, we use 2,454 cost observations for the 90 properties of the Amsterdam Burgerweeshuis and the Doopsgezinde Gemeente. Annual spending on non-tax costs for these institutional investors varied substantially over time since the institutions typically undertook major maintenance and renovations for multiple properties at the same time. However, as these costs could be diversified for the aggregate stock of Amsterdam and Paris housing, we only use the average fraction of rents spent on non-tax costs.

Because the cost fraction might change across the distribution of properties and yields, we estimate the cost fraction at the median property. We take the median property value in the sample in 1924, when our sample contains over 600 rent observations, and track the market rent price of the 1924 median property using the rent price index of Eichholtz et al. (2019). We use this median to scale each rental observation in the database of costs, and estimate the following regression:

$$c_{i,t} = \alpha + \beta \frac{R_{i,t} - R_{median,t}}{R_{median,t}} + Type_i + \varepsilon_{i,t} \quad (3)$$

With $c_{i,t}$ denoting the fraction of non-tax costs spent on a property $i$ at time $t$, and $\alpha$ equalling the cost fraction for the median property. We additionally control for the type of property, since a small subset of residential properties also contains retail rental units.

Table 3 reports the outcome of this regression. For the median property, the average cost fraction equals 27.4 percent. We apply this percentage to both Amsterdam and Paris.

In Chambers et al. (2019), actual non-tax costs for residential real estate amount to 32.7 percent of gross rental income, which is slightly higher than our estimates. This might be related to the fact that the properties in our strictly urban sample have higher location value, and therefore lower relative maintenance costs than those in their sample, consisting of a mix of urban and rural properties. This explanation might hold within cities: the estimates in Table 3 show that the fraction of costs decrease in the rental value relative to the median.

### 3.4 Net rental yields and bond yields

The next step is to convert the gross rental yields reported in Table 2 Panel B to net rental yields, using our estimates of costs and taxes. These are reported in Panel C of Table 2, and we observe a net yield for Paris of 4.5 percent for the full 1809–1942 sample period, and a net yield of 5.9 percent for Amsterdam for the 1900-1979 period.

Comparing our net yields to those of Jordà et al. (2019a) when both samples overlap, we find our net yields are relatively similar and on average 0.6 percent lower per year. While the average values are comparable, our yields correlate only weakly with the estimates in their study: the correlation is 0.41 for Paris and 0.12 for Amsterdam.[13] When we do not adjust for taxes, in line with Jordà et al. (2019a), we also find weak correlations of 0.17 for Paris and 0.30 for Amsterdam. These low correlations suggest it is difficult to derive the evolution of rental yields over time from secondary series, particularly when these are of varying quality. For their Dutch return estimates, Jordà et al. (2019a) use quality-controlled series of Amsterdam house prices and national rent price series that do not control for quality. Brounen et al. (2014) use similar data sources and are therefore prone to the same error. The French yield series in Jordà et al. (2019a) are based on

[13] Appendix Figure 16 A and B in Appendix A compare the development of the Jordà et al. (2019a) net rental yield for Paris and Amsterdam with ours

quality-controlled series of Parisian rents and prices but from different sources.

Figure 7 plots the development in net rental yields at the portfolio level for both Paris and Amsterdam, comparing these to the yields on long-term government bonds for France and The Netherlands.[14]

[Place Figure 7 about here]

For most of the 19th century, French bond yields were comparable to or higher than Parisian net rental yields. On the other hand, rental yields tend to be higher than bond yields for most of the final part of the sample. On average, bond yields and rental yields are similar in Paris, while rental yields earn a premium over government bonds of 1.4% in Amsterdam.

In both Paris and Amsterdam, large changes in net rental yields typically coincide with large changes in government bond yields. For example, after the Napoleonic wars, Parisian rental yields decline between 1815 and 1825 from about 4.5 to 3 percent, while bond yields decline from 7.5 to 4 percent. Bond yields and housing yields also increase strongly after the Siege of Paris and the Franco-Prussian War in 1870 and fall gradually afterward. There is substantial volatility in net rental yields and bond yields, both in Paris and Amsterdam, around the two World Wars. Finally, in the 1960s and 1970s, both Dutch bond yields and Amsterdam housing yields increase substantially.

Even though movements in bond yields typically coincide with changes in housing yields, this relation is very inconsistent over time.[15] As a result, the yield premium of residential real estate over bonds is quite volatile, and is negative for numerous periods, especially in the early 19th century. Although a full explanation of this stylized fact is beyond the scope of this paper, as there are many potential explanatory channels, we

[14]For both France and The Netherlands, we use standard national series for government bonds yields. Because bill rates are not consistently available for all time periods, we use series on long-term bonds that we can apply consistently over time. For France, we use the bond yield on French 5 percent annuities before 1833, and the 3 percent annuity from 1833–1942. For The Netherlands, we take the long-term Dutch government bond yield from 1900 to 1979.

[15]The aggregate correlation between bond yields and net rental yields is 0.04 for Paris and 0.60 for Amsterdam. Using bill rates, we find a correlation of 0.00 and 0.50, respectively

want to highlight two that could be particularly salient.

First, government bonds might not have been perceived as risk-free assets at all times during the sample period. France defaulted in 1812, and all periods in the 19th century where government bond yields exceeded housing yields coincide with major changes of power: the end of the Napoleonic period (1815), the July Revolution of 1830, the February Revolution of 1848, and the collapse of the Second Empire in 1870. In these periods, housing investments may have been perceived as safer than government bonds. This may explain why we find a negative residential real estate yield premium for a large part of the 19th century, and why it turned positive later, as memories of the 1812 government default faded with the experience of the default-free subsequent changes in political power, even when these were of the revolutionary kind.

Second, real housing rents are relatively stable in the long-run (Eichholtz et al., 2019), which would make housing investments a better hedge against inflation than government bonds. In line with this, we find substantial nominal capital gains but no real capital gains on housing in both Paris and Amsterdam. Inflation became a particularly important factor in the 20th century, and periods of high inflation correlate strongly with periods of housing yields falling relative to bond yields. This effect is particularly visible during the period of high inflation after World War I and in the 1970s. In both periods, bond yields exceeded housing yields.

### 3.5 Total returns

We combine the housing capital value index reported in Section 3.1 with the net yield development in Section 3.4 by directly applying Equation (1) to get the total net return to rental housing in Paris and Amsterdam. Table 2 Panel D provides statistics for these series. First, the geometric average net return to rental housing is 6.4 percent for Paris (arithmetic: 7.0 percent) and 8.2 percent for Amsterdam (arithmetic: 9.1 percent). In real terms, geometric returns in both cities were more similar: 4.2 percent in Paris and 5.0 percent in Amsterdam. Relative to long-term government bonds, housing earned a risk premium of 2.4 percent in Paris and 3.8 percent in Amsterdam, implying a Sharpe ratio of 0.27 for Paris and 0.36 for Amsterdam. Excess returns increase by about one percent when using bill rates instead of bond rates.

Comparing this to Jordà et al. (2019a), our estimates result in lower total returns for both Amsterdam and Paris. For Paris, the difference in geometric returns is 0.9 percent per year, and it is 2 percent per year for Amsterdam. While the volatility estimates for Amsterdam are almost the same, we find much higher volatility for Paris because our results do not rely on smoothing. Correspondingly, we find Sharpe ratios that are, on average, about 40 percent lower. The correlation between our return series and those of Jordà et al. (2019a) is 0.31 for Amsterdam and 0.44 for Paris, even as both series attempt to track the same asset base. This suggests that the validity of conclusions regarding the diversification benefits of rental housing from implied return estimates is doubtful. In short, our series suggest a substantially lower risk-adjusted performance of residential housing than Jordà et al. (2019a).

The lack of any real capital gains on housing for both Paris and Amsterdam also implies that the real total long-term returns on housing over time accumulate from rental cash flows rather than capital gains, in line with the broader findings in Jordà et al. (2019a). Eisfeldt and Demers (2018) find that capital gains and net rental yields contribute about evenly to the total return, but this seems to result from the specific period they study and the fact they exclusively focus on nominal returns. In nominal terms, capital gains contribute about a third to our total returns.

To better understand how total returns moved over medium-term horizons, Table 4 shows the level of annualized returns per decade for both Paris and Amsterdam.

[Place Table 4 about here]

In nominal terms, housing investments always realized positive ten-year returns, with the lowest nominal 10-year returns occurring in Amsterdam around the Great Depression and in Paris in the second quarter of the 19th century. In both cases, nominal house prices declined substantially (see Figures 3 and 4). In real terms, housing returns reached their minimum in Paris following World War I and in Amsterdam following World War II, with inflation and the consequences of war substantially eroding asset prices. These episodes also show that there remains a substantial risk to housing investments even over longer time horizons. In both cities, ten-year house price volatility is in the range of 2.8–3.8 percent, both in real and nominal terms.

Of course, our aggregate risk and return estimates display some sensitivity to the assumptions we have made throughout the paper. First, we have used the non-tax cost estimates of the Burgerweeshuis and Doopsgezinde Gemeente to proxy for portfolio maintenance costs in both Paris and Amsterdam. If maintenance and vacancy costs for the entire housing stock varied substantially over time relative to rents, we might underestimate return volatility. We have also ignored administration and management costs to make our indices comparable to stock and bond indices, from which the costs of managing and administering a portfolio are always excluded. For comparison, using the cost estimates of Chambers et al. (2019) would result in annual portfolio returns that are 0.5 percent per year lower for Amsterdam, and 0.4 percent lower for Paris. On the other hand, using median net yields rather than portfolio net yields would result in estimates about 0.3 percent higher for Amsterdam and 0.2 percent for Paris. Second, we have assumed no pass-through of taxes to tenants. If some taxes were passed through to tenants without being specified in the rental price, this would have increased our rental returns. Finally, we may overestimate volatility in periods where data is thin, which is the case in the very early parts of both city samples.

# 4 Idiosyncratic risks

The indivisibility of assets, high transaction costs and the capital intensity of real estate investments constrain the construction of well-diversified direct property portfolios.[16] For

[16] In 1832, half of Amsterdam's property investors owned one building only; 90 percent owned fewer than five properties (Fryske Akademy, 2014).

markets in which investors cannot fully diversify, theoretical (for instance Levy, 1978; Merton, 1987) and empirical studies (e.g. Fu, 2009; Eiling et al., 2019) suggest a link between idiosyncratic risk and expected returns in the cross-section.

Differences in the property-level total returns stem from the variation in capital returns, yields and costs that differ across geographic submarkets and price segments. Also, deal-specific deviations from city-wide point estimates for prices and rents further broaden the distribution of observed returns: asset picking skills and the ability to buy and sell opportunistically can improve returns.

Ignoring costs, the total gross log return for a portfolio of properties of any size $i$ from purchase at time 0 to sale at time $n$ is defined as follows, with $y_{i,t}$ denoting the $log(Yield + 1)$ at time $t$, and $g_{i,t_0,t_n}$ the log capital gain between time $t_0$ and $t_n$:

$$r_{i,t_0,t_n} = \sum_{t=0}^{n-1} y_{i,t} + g_{i,t_0,t_n} \tag{4}$$

Correspondingly, the variance of any individual gross property return can be written as follows:

$$Var(r_{i,t_0,t_n}) = \sum_{j=1}^{n-1}\sum_{k=0}^{n-1} Cov(y_{i,t=j}, y_{i,t=k}) + 2 \times \sum_{t=0}^{n-1} Cov(y_{i,t}, g_{i,t_0,t_n}) + Var(g_{i,t_0,t_n}) \tag{5}$$

If the variance of log yields is assumed to be constant over time, we can rewrite Equation 5 as:

$$Var(r_{i,t_0,t_n}) = n \times Var(y_i) + 2 \times \sum_{j=1}^{n-1} Cov(y_{i,t}, y_{i,t+j}) + 2 \times \sum_{t=0}^{n-1} Cov(y_{i,t}, g_{i,t_0,t_n}) + Var(g_{i,t_0,t_n}) \tag{6}$$

Equation 6 shows that the variance of a gross housing return is a function of the variance of the yield and the capital gain, as well as the covariance of the yield with the capital gain, and the covariance in yields over time. In contrast to earlier studies (e.g.

Peng and Thibodeau, 2017; Eisfeldt and Demers, 2018), we can observe capital returns over the holding periods of residential real estate investments in combination with rental income for the very same assets at each point of sale.[17] This implies that we can estimate each of these components and assess their relative contribution to house-level property returns.

In the remainder of this section, we aim to assess each of these quantities both at the property level as well as across space. Most of our analysis will focus on Amsterdam's gross returns since the Amsterdam data contain sufficient observations of capital gains and repeated actual gross yields on the same properties to estimate their covariances over time. Because we do not have sufficient house-level observations on costs, we only look at gross returns.

## 4.1 The dispersion of yields

For Paris and Amsterdam, the standard deviations of all log gross yields are 3.1 and 4.4 percent, respectively.[18] Only a minor part of these differences in yields is due to changes in aggregate housing yields: the volatility of residual yields after controlling for changes in market yields is 2.9 percent for Paris and 4 percent for Amsterdam.

However, the dispersion in yields is spatially dependent: Moran's I statistic of spatial dependency is positive and significant for our yield cross-sections, which suggests that their distributions are influenced by local factors that introduce non-random deviations from the city-wide trends.

Figure 8 displays the spatial gross yields at different periods for neighborhoods in the two cities. For Paris's core, the highest yields can be initially (1810–1835) found in the southern arrondissements along the left bank with a few additional small pockets right in the center. The stark local contrasts and lack of a clear gradient pattern are difficult

[17] For commercial real estate, Peng (2016) combines capital returns and Net Operating Income (NOI) figures to arrive at asset-level total return estimates.

[18] Note that we might underestimate the standard deviation of Parisian gross yields because we truncated them to account for capitalized yields.

to align with the monocentric city model that is the standard in urban economics. A few decades (and the Haussmann renovation) later, the relative distribution of yields in space has gradually changed, with yields rising in the east and the center. As Haussmann's reconstruction progressed, makeshift housing moved from the northern outskirts to the expanding Latin and south-eastern districts of the city (Faure and Lévy-Vroelant, 2007). The left bank of Paris, already impoverished, saw its populations of disadvantaged inhabitants grow.

[Place Figure 8 about here]

Similar to Paris, we find that yields in Amsterdam are higher in poorer districts. Before World War II, central Amsterdam was characterized by high yields in the working-class areas of the Jordaan in the northwest and the harbor regions along the river IJ. Yields are low in the affluent parts of the canal belt, along the river Amstel and in the vicinity of the Rijksmuseum in the south-west of the city. The most central areas display a diverse mix of yield levels, all at very close quarters. After World War II, the yields in the prestigious neighborhoods around the main canals remain low while the southeast, devastated by the deportation of its Jewish population during the German occupation, is characterized by higher yields.

## 4.2 The covariance of yields and capital gains

The large differences in yields across properties and space show there are substantial idiosyncratic differences in yields. In line with Eisfeldt and Demers (2018), we find that yields are higher in poorer neighborhoods. However, in contrast to their findings, we observe that differences in yields are partially offset with higher subsequent capital gains. Property-level correlation between the yield observed at purchase and the subsequent capital gain is 0.19 for Amsterdam, with the correlation exactly opposite (-0.22) for the yield observed at the sale. Thus, investors purchasing a high-yield or selling a low-yield property typically realize higher capital gains, irrespective of the holding period. For

Paris, we find slightly lower correlations of respectively 0.12 and -0.11 because we do not observe the actual yield at the time of sale and purchase. This suggests that the yield at purchase has important consequences for the holding-period return, even if these holding periods are long.

At the same time, the maps in Figure 8 display a strong persistence in the distribution of yields across neighborhoods over time. At the property level, these differences might have important implications for investor risk. If an investor buys a property that at the time of purchase has a yield $y_{i,t_0}$, the covariance between the initial yields and future yields on this property will be an important component of its total return during the holding period. If yields correlate strongly over time, the yield at purchase will have a further lasting impact on returns.

Figure 9 plots the correlation in yields across holding periods in years, based on 3,265 pairs of repeat yields on the same properties for Amsterdam. We also report the residual correlation after controlling for market yields, by subtracting the median yield across the sample at the time of each transaction from the property-level yields.[19]

[Place Figure 9 about here]

The variation in median gross yields over time is small relative to the total variation in yields, which implies that the correlation is similar with and without controlling for market prices. Importantly, the correlation across yields decays over time. Thus, properties with higher or lower yields will continue to earn above- or below-market yields, but the magnitude will gradually decline over time. So for longer holding periods, this effect weakens.

## 4.3 Total return risk and its components

Next, we estimate the contribution of each component of Equation 6 to the variance of total returns to housing investments. However, as we only observe the yields on a

[19]The sample features few repeat yields with holding periods longer than twenty years, so we refrain from estimating correlations for longer holding periods.

property at the time of purchase and sale, and not continuously over the entire holding period, we cannot compute the volatility of total gross returns, nor the realized covariance of annual yields and the total capital gains directly.

To estimate the covariance in yields across holding periods ($Cov(y_{i,t}, y_{i,t+j})$), we directly compute the realized covariance between pairs of yields for each holding period, in line with Equation 6 and Figure 9. To approximate the covariance in yields with capital gains across holding periods ($Cov(y_{i,t}, g_{i,t_0,t_n})$), we take for each holding period a weighted average of the estimated covariance between capital gains and yields at purchase, and the estimated covariance between capital gains and yields at a sale.[20] To reduce noise in our estimation of the covariance between yields and capital gains for periods with few observations, we use the fitted values from a linear regression that estimates the realized covariance as a function of the holding period.

Using these estimates, we can directly compute the variance of total returns as well as the role of idiosyncratic risk in it. Figure 10 plots for each holding period between 1 and 20 years the estimated variance of the total return, differentiating between idiosyncratic and systematic risk.

[Place Figure 10 about here]

A clear pattern emerges. For investments with short holding periods, most risk is idiosyncratic. However, for investments with longer time horizons, idiosyncratic risks reduce to about 50 percent of total risk.

If the idiosyncratic risk is assumed to follow a random walk, as is typical in most housing studies, the idiosyncratic variance of total returns should increase linearly over time (and volatility by the square root). Our series suggests this is not the case, as variances increase much less. For example, the two-year variance of Amsterdam housing returns is 0.06, whilst this increases to around 0.3 (instead of 0.6) for holding periods of 20 years. Although we work with a much smaller set of transactions, this suggests

[20] Thus, for an investment with holding period $n$, the covariance between the yield at time $t$ and the capital gain between time 0 and time $n$ equals $\frac{n-t+1}{n} \times \widehat{Cov}(y_{i,t=0}, g_{i,t_0,t_n}) + \frac{n-1}{n} \widehat{Cov}(y_{i,t=n}, g_{i,t_0,t_n})$.

that the findings of Giacoletti (2019) for capital gains in housing and of Sagi (2017) for commercial real estate also extend to total housing returns, and across centuries. This also implies that the volatility of annualized log-returns decays quickly over time, from 12.5 percent after two years to around 2.8 percent for holding periods of twenty years.

Importantly, the contributions of the different components to total return volatility change over time. In Figure 11 we show the relative contributions of each variance component to the total variance in returns, across holding periods of up to 20 years.

[Place Figure 11 about here]

Unsurprisingly, most variance in the short term comes from capital gains risk, because the variance of yields is small relative to the variance of capital gains. However, the importance of capital gains variance decays over time. This pattern is even stronger for residual yields, which we plot in Appendix D Figure 17.

Because yields on a property correlate positively over time, even for long holding periods (Figure 9), yield covariance becomes an increasingly important ingredient of total return risk. This implies that for a long-term investor the initial yield is a much more important source of risk than for a short-term investor, who primarily bets on capital gains. Over time, the negative covariance of yields and capital gains somewhat reduces the risks of property investments. Thus, if yields go down over time because prices have appreciated faster than rents, most of the decline in yields will be made up by an increase in the capital gain.

Taken together, the findings in Figures 10 and 11 have three important implications for our understanding of the risk and return of individual properties. First, nearly all short-term investment risk at the property level is idiosyncratic, originating from volatility in capital gains. Second, the fraction of idiosyncratic risk decreases with the holding period, as changes in market yields and capital gains become more important over the long term. Finally, and most importantly, we document that persistence in property-level yields is a crucial risk component for investors, especially in the long run.

## 5 Conclusion

This paper creates new indices describing the net total returns of rental housing for extended periods. We create total return indices for Paris and Amsterdam, for the periods 1809–1942 and 1900–1979, respectively. These indices are based on previously unexplored archival data that we hand-collected and digitized for this study. Its unique contribution lies in the fact that we observe rental yields and values for the same properties, and that we have enough observations to use a repeated measures approach to reliably control for changes in asset quality. In all, we have 39,475 rent and 34,614 price observations for Paris, and 13,148 rent and 21,129 price observations for Amsterdam.

The first main finding is that the geometric average net total return to rental housing was 6.4 percent in Paris and 8.2 percent in Amsterdam. These returns come with considerable volatility of 8.7 percent and 10.7 percent, respectively. We find that using actual rental yields and capital gains for the same set of properties is essential to obtain precise estimates of housing return and risk. Relative to Jordà et al. (2019a), who use secondary series, we find substantially lower risk-adjusted returns to housing for both cities and a low correlation with their total return series.

We show that most of the long-term total return to rental housing stems from the net yield, and that capital returns are small and even negative in real terms for Amsterdam. This is in contrast to Eisfeldt and Demers (2018), who find that the roles of rental yield and capital return are about equally important.

Besides these findings at the index level, our study also makes important contributions regarding property-level investment performance. Our findings regarding the geographic dispersion of rental housing performance and the importance of the holding period show that the yield at purchase is a key determinant of the holding period return at the individual asset level. We find that higher-yielding properties subsequently have higher capital gains, irrespective of the holding period.

Regarding the composition of total return risk, we find that the idiosyncratic risk is the dominant part of total risk in the short term, but that the importance of market risk increases over the holding period. Moreover, we show that variation in the capital gain is the dominant factor in total asset risk only in the short term. For holding periods going up to 20 years, yield covariance becomes as important.

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# 6 Tables and Figures

Table 1: Sample Sizes Property-Level Data

| *Data Type* | *Period* | *# Obs.* | *Source* |
|---|---|---|---|
| *Paris* | | | |
| Sale Prices | 1809–1942 | 34,614 | Sommier Foncier |
| Rent Prices | 1809–1942 | 39,475 | Sommier Foncier |
| Matched Yields | 1809–1942 | 28,287 | Sommier Foncier |
| Taxes | 1809–1926 | 4,474 | Sommier Foncier, Tax Registers Sainte-Avoye |
| *Amsterdam* | | | |
| Sale Prices | 1840–1979 | 21,129 | Brouwer & Zn., Eichholtz (1997), Verwey (1943) |
| Rent Prices | 1900–1979 | 13,148 | Brouwer & Zn. |
| Matched Yields | 1809–1942 | 12,438 | Brouwer & Zn. |
| Taxes | 1917–1979 | 5,364 | Brouwer & Zn. |
| Costs | 1889–1967 | 2,454 | Burgerweeshuis, Doopsgezinde Gemeente |

*Notes:* Paris transaction prices are based on auction prices (34%) and regular sales (66%), while Amsterdam data are auction prices (46%), regular sales (15%) and appraisals (39%). Amsterdam rental prices are based on lease contracts (89%) and appraised rental values (11%).

Table 2: Capital Gains, Rental Yields and Total Returns

| *Index* | *Period* | *Arithmetic* Mean | SD | *Geometric* Mean | SD | *Real Geom.* Mean | SD | *Corr.* |
|---|---|---|---|---|---|---|---|---|
| *Panel A: Capital Gains* | | | | | | | | |
| Paris | 1809–1942 | 2.8% | 9.4% | 2.3% | 9.2% | 0.1% | 10.8% | 1.00 |
| Paris | 1840–1942 | 2.8% | 9.6% | 2.3% | 9.5% | -0.5% | 10.8% | 1.00 |
| Paris (Duon, 1946) | 1840–1942 | 2.9% | 6.0% | 2.7% | 5.8% | -0.1% | 8.4% | 0.39 |
| Amsterdam | 1900–1979 | 3.3% | 11.7% | 2.6% | 11.4% | -0.6% | 11.3% | 1.00 |
| Amsterdam (Ambrose et al., 2013) | 1900–1979 | 7.6% | 27.3% | 3.6% | 25.9% | 0.4% | 25.3% | 0.33 |
| Amsterdam (Knoll et al., 2017) | 1900–1979 | 4.6% | 11.2% | 3.9% | 10.9% | 0.8% | 9.5% | 0.32 |
| *Panel B: Gross Yields* | | | | | | | | |
| Paris (portfolio) | 1809–1942 | 7.0% | 0.9% | 6.8% | 0.8% | | | 1.00 |
| Paris (median) | 1809–1942 | 7.5% | 1.1% | 7.2% | 0.8% | | | 0.92 |
| Amsterdam (portfolio) | 1900–1979 | 10.1% | 1.6% | 9.6% | 1.4% | | | 1.00 |
| Amsterdam (median) | 1900–1979 | 10.8% | 2.5% | 10.2% | 2.2% | | | 0.94 |
| *Panel C: Net Yields* | | | | | | | | |
| Paris (portfolio) | 1809–1942 | 4.3% | 0.5% | 4.2% | 0.4% | | | 1.00 |
| Paris (portfolio) | 1870–1942 | 4.4% | 0.4% | 4.3% | 0.4% | | | 1.00 |
| Paris (Jordà et al., 2019a) | 1870–1942 | 4.9% | 0.8% | 4.8% | 0.7% | | | 0.41 |
| Amsterdam (portfolio) | 1900–1979 | 5.9% | 0.9% | 5.7% | 0.9% | | | 1.00 |
| Amsterdam (Jordà et al., 2019a) | 1900–1979 | 6.5% | 2.3% | 6.3% | 2.1% | | | 0.12 |
| *Panel D: Total Returns* | | | | | | | | |
| Paris (portfolio) | 1809–1942 | 7.0% | 9.3% | 6.4% | 8.7% | 4.2% | 10.4% | 1.00 |
| Paris (portfolio) | 1870–1942 | 7.2% | 10.3% | 6.5% | 9.8% | 2.8% | 11.5% | 1.00 |
| Paris (Jordà et al., 2019a) | 1870–1942 | 7.9% | 6.9% | 7.4% | 6.1% | 3.7% | 9.1% | 0.44 |
| Amsterdam (portfolio) | 1900–1979 | 9.1% | 11.8% | 8.2% | 10.7% | 5.0% | 10.7% | 1.00 |
| Amsterdam (Jordà et al., 2019a) | 1900–1979 | 11.4% | 11.6% | 10.2% | 10.6% | 7.1% | 9.2% | 0.31 |

*Notes:* The correlation coefficient is computed as the correlation in log-returns, capital gains or yields. The price index of Duon (1946) for Paris was smoothened using a moving average of unknown length. This explains the low volatility and correlation of this series and that of Jordà et al. (2019a), who use Duon's index. Until 1965, the Ambrose et al. (2013) index for Amsterdam is based on a small number of transactions along the Herengracht, Amsterdam's most affluent canal, resulting in very high volatility and low correlation. Knoll et al. (2017) and Jordà et al. (2019a) use a smoothened version of this index.

Table 3: Expense Fraction, Rental Property Institutional Investors

| | All Costs | Non-Tax Costs |
|---|---|---|
| $\text{Commercial}_i$ | $-0.053$ | $-0.077$ |
| | (0.053) | (0.053) |
| $\log(\text{Rent})_i$ - log(MedianRent) | $-0.153^{***}$ | $-0.117^{***}$ |
| | (0.022) | (0.022) |
| Constant | $0.369^{***}$ | $0.274^{***}$ |
| | (0.019) | (0.019) |
| Observations | 2,453 | 2,453 |
| $R^2$ | 0.035 | 0.024 |
| F Statistic | 44.185 | 29.547 |

*Notes:* The constant in the regressions in Table 3 shows the estimated fraction of rents spent on expenses such as taxes, maintenance costs, and renovations, either including taxes (Column 1) or excluding taxes (Column 2). Both regressions control for commercial property (non-residential) and the rental level of each property relative to the Amsterdam median. More expensive rental properties have a lower cost fraction.

$^{*}p < 0.1; ^{**}p < 0.05; ^{***}p < 0.01$

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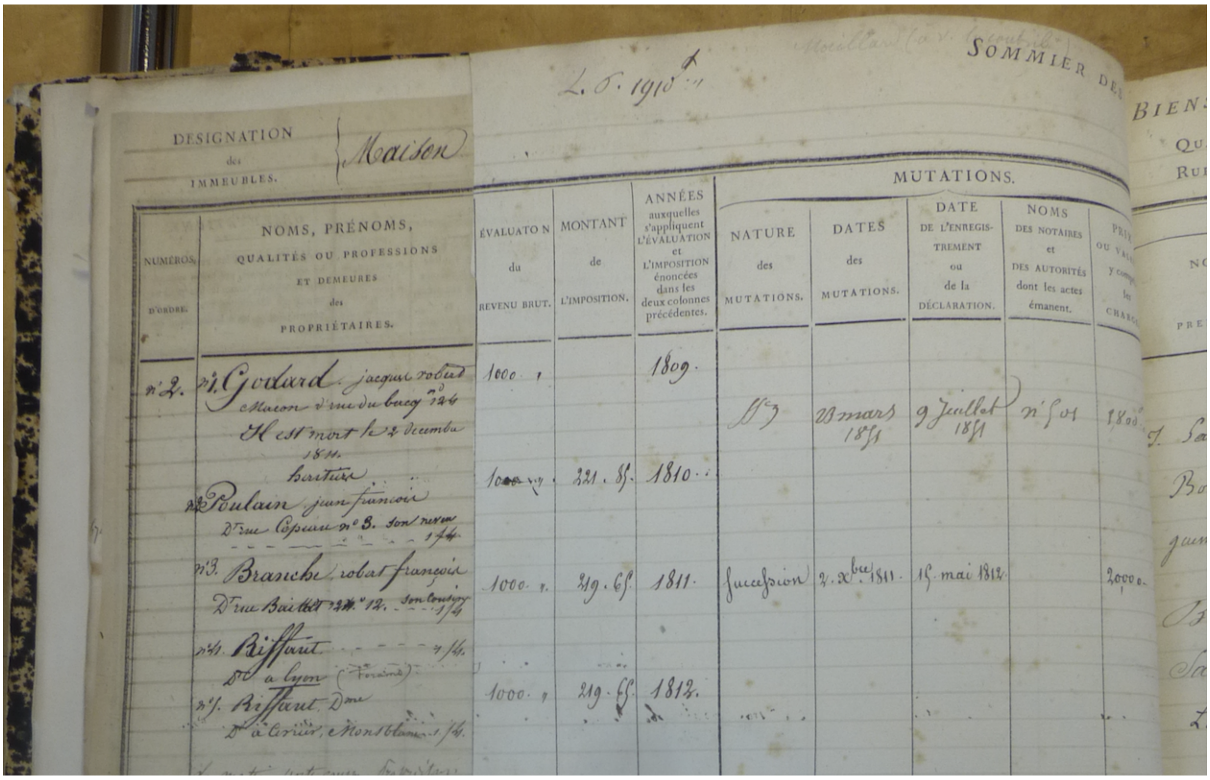
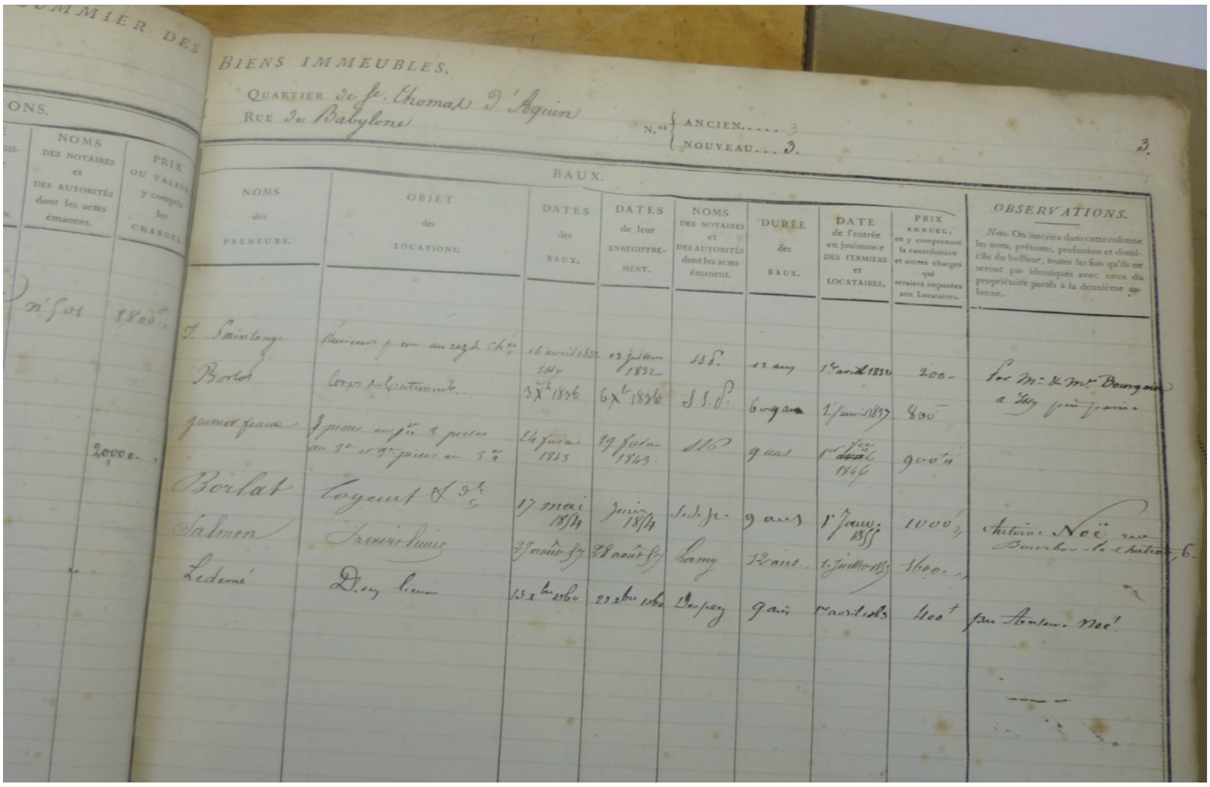
Table 4: Annualized Total Returns, per Decade

| | Paris | | | Amsterdam | | |
|---|---|---|---|---|---|---|
| *Period* | *Arithm.* | *Geom.* | *Real G.* | *Arithm.* | *Geom.* | *Real G.* |
| 1810–1820 | 9.3% | 8.0% | 7.2% | | | |
| 1820–1830 | 10.3% | 8.4% | 8.2% | | | |
| 1830–1840 | 4.3% | 3.8% | 3.7% | | | |
| 1840–1850 | 4.2% | 3.7% | 4.1% | | | |
| 1850–1860 | 12.5% | 9.9% | 8.3% | | | |
| 1860–1870 | 6.8% | 6.1% | 5.3% | | | |
| 1870–1880 | 6.4% | 5.8% | 5.3% | | | |
| 1880–1890 | 4.5% | 4.1% | 4.8% | | | |
| 1890–1900 | 4.9% | 4.4% | 4.6% | | | |
| 1900–1910 | 5.9% | 5.3% | 5.0% | 5.2% | 5.0% | 3.9% |
| 1910–1920 | 6.6% | 6.0% | -8.0% | 12.8% | 10.8% | 3.8% |
| 1920–1930 | 19.4% | 13.2% | 8.0% | 4.3% | 4.1% | 7.9% |
| 1930–1940 | 4.1% | 3.4% | -0.5% | 3.6% | 3.1% | 3.2% |
| 1940–1950 | | | | 8.1% | 7.5% | 0.4% |
| 1950–1960 | | | | 14.4% | 11.9% | 9.1% |
| 1960–1970 | | | | 5.0% | 4.7% | 0.5% |
| 1970–1979 | | | | 28.3% | 18.4% | 11.6% |

*Notes:* Table 4 shows the annualized total returns for each decade for both Paris and Amsterdam. We report arithmetic returns, geometric returns, and real geometric returns. The final row corresponds to an annualized nine-year return because our series stop in 1979.

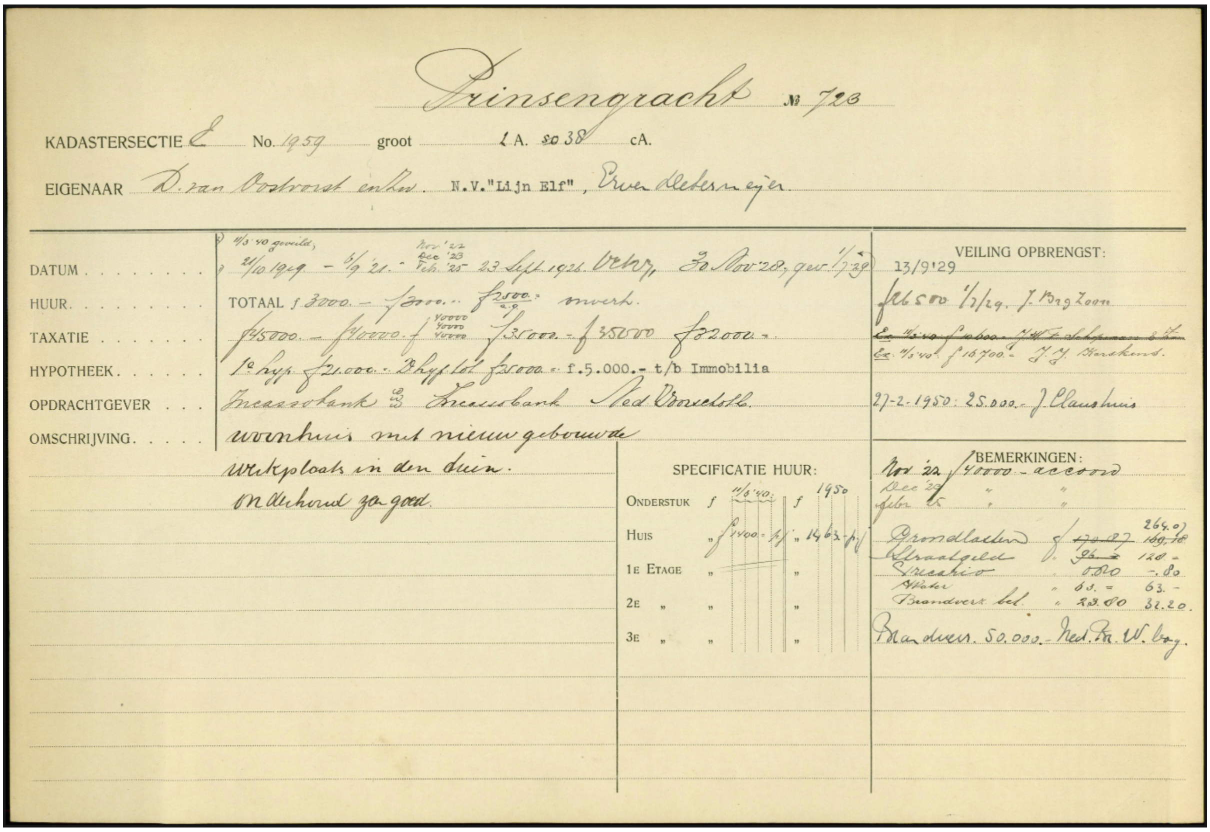
Figure 1: Example of Sommier Foncier Property Information





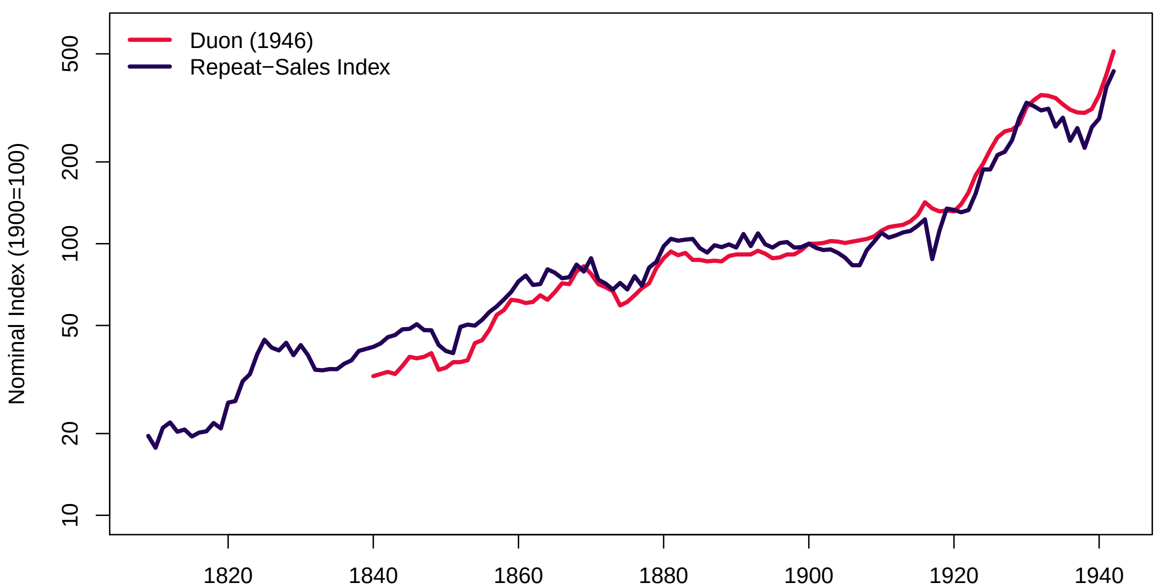
*Notes:* This is an extract of two pages from the Sommier foncier, in the early register for the house on the Rue de Babylone, number 3. The first picture contains all ownership transfers, the second picture lists the leases on this property.

Figure 2: Example of an Amsterdam Auction Card



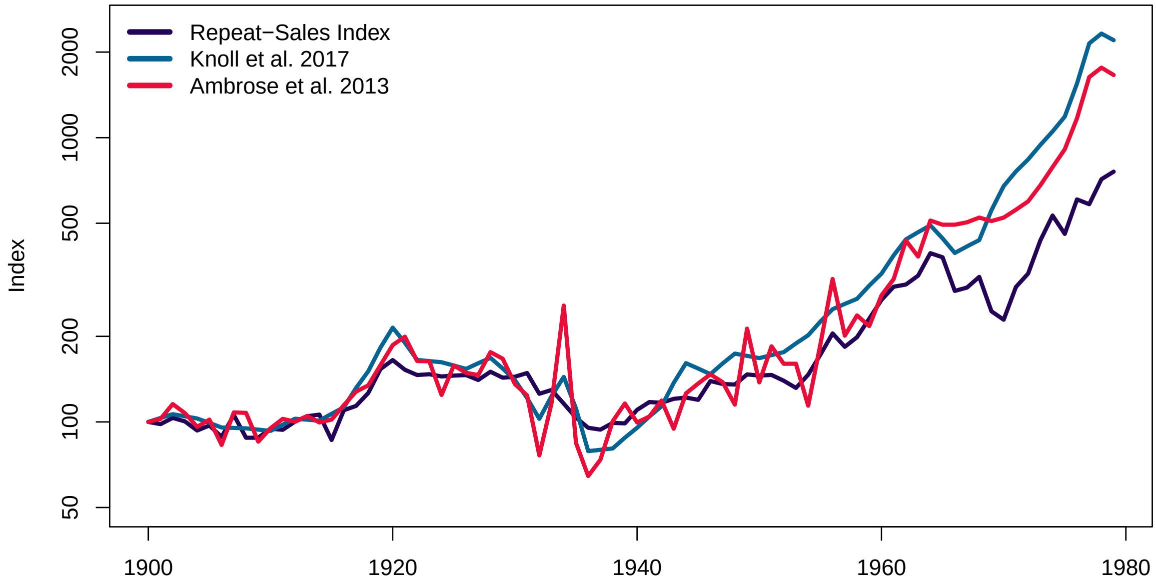

*Notes:* This figure provides an example of one Amsterdam auction card, for the property on the Prinsengracht 723.

Figure 3: Price Index, Paris



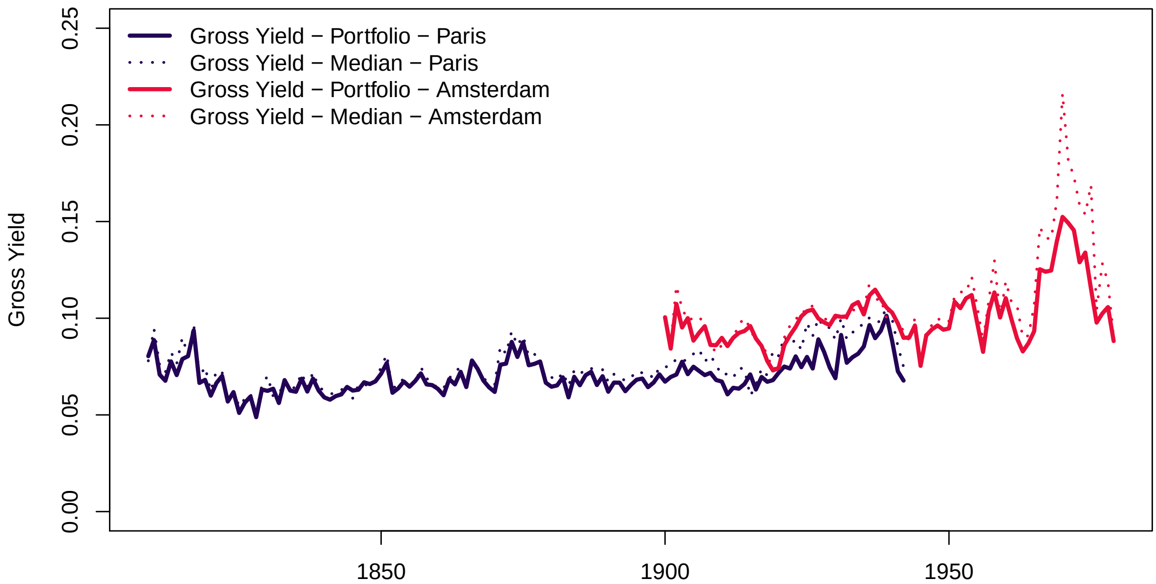

*Notes:* The new repeat sales index is estimated based on micro-data on house transactions from the Sommier foncier. In the long run, the development of the new index is comparable to the (smoothened) index by Duon (1946).

Figure 4: Price Indices, Amsterdam



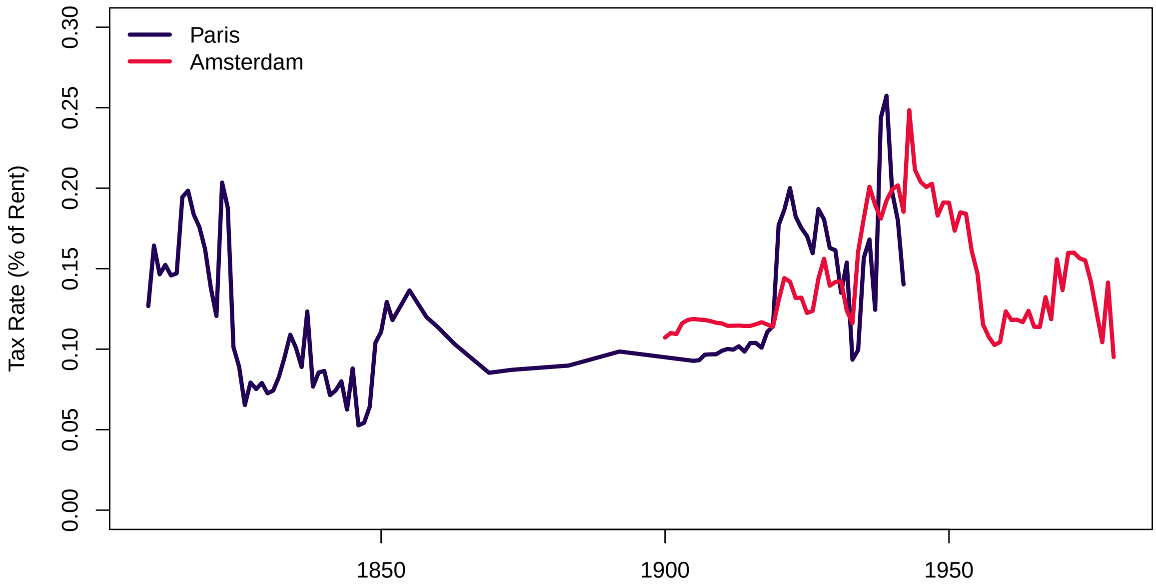

*Notes:* The new repeat sales index is based on transaction data from all of Amsterdam, while Ambrose et al. (2013) and Knoll et al. (2017) rely on data from the Herengracht canal only, and switch to national indices based on median prices from 1965 and 1970 respectively.

Figure 5: Gross Housing Yields, Paris and Amsterdam



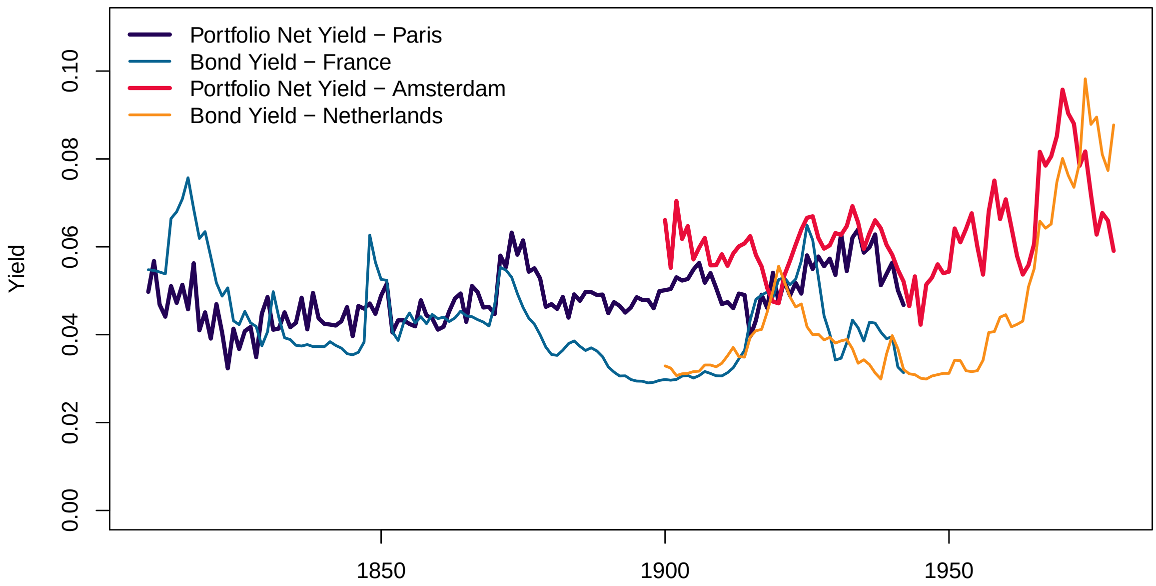

*Notes:* For Paris, the gross yield moves in a rather limited range, roughly between 5 percent and 10 percent. For Amsterdam, the average gross yield is 10 percent. Amsterdam's yields are more volatile than Paris's, with gross median yields peaking at more than 20 percent in the 1970s.

Figure 6: Tax Yields, Paris and Amsterdam



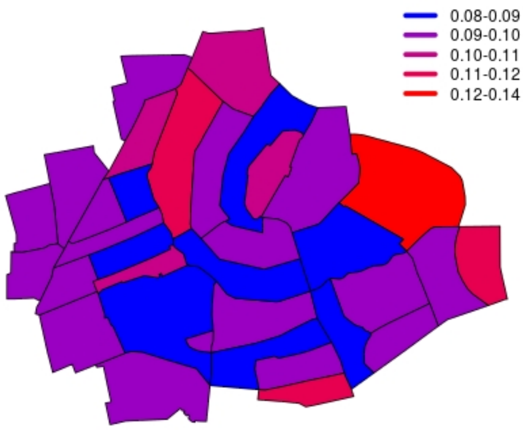

*Notes:* Tax rates are the ratio of property taxes over gross rental income. On average, taxes amounted to 12 percent of rental income in Paris and 14 percent in Amsterdam. In both cities the tax yields varied substantially over time, strongly affecting net property returns.

Figure 7: Net Yields and Bond Yields, Paris and Amsterdam

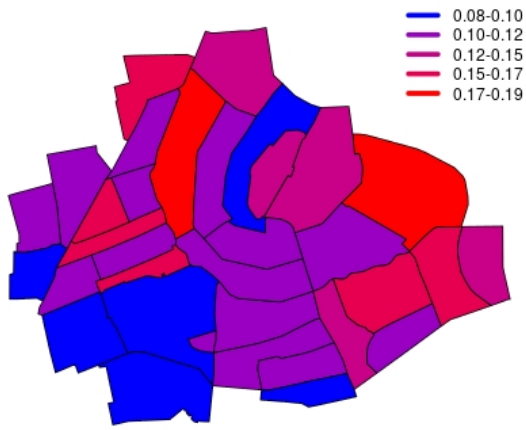



*Notes:* Net rental yields tend to exceed government bond yields in Amsterdam but not in Paris. Bond yields are based on long-term Dutch government bonds (1900–1979), French 5 percent annuities (before 1833) and French 3 percent annuities (1833–1942).

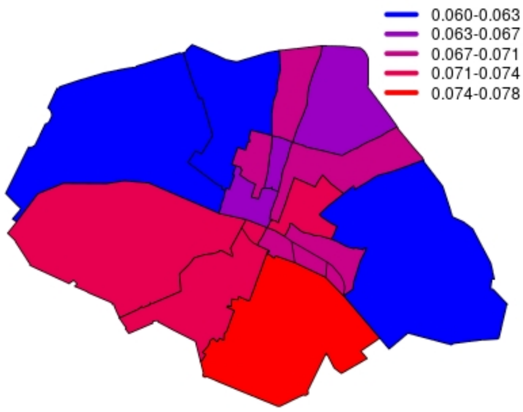
Figure 8: Spatial distribution of Gross Yields



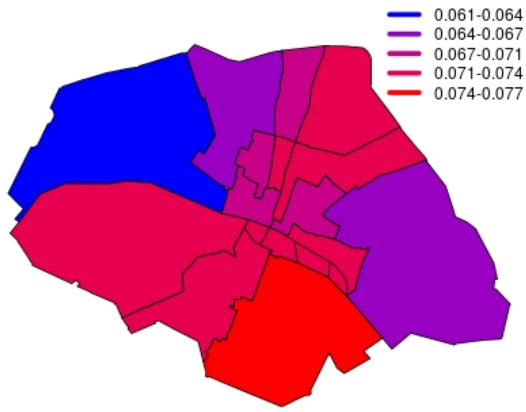

(a) Yields, Amsterdam, 1919–39




(b) Yields, Amsterdam, 1950–70




(c) Yields, Paris, 1820–40

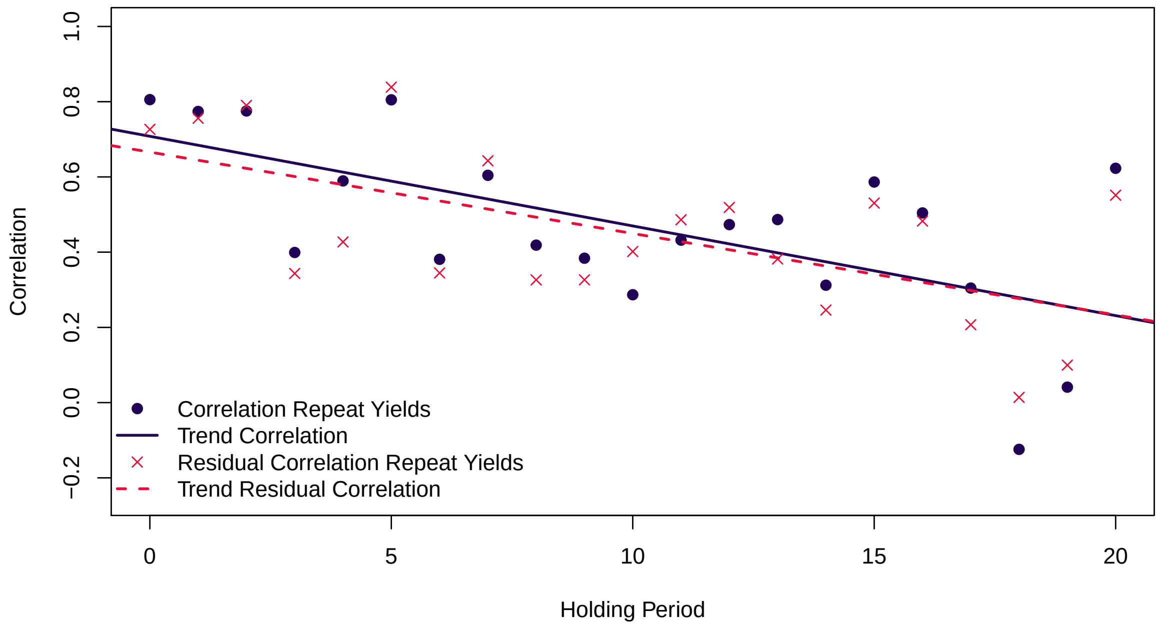



(d) Yields, Paris, 1870–1900

*Notes:* Median gross yields are not homogeneously distributed in space. Clusters of low yields are found close to high yield areas. These deviations from the city-wide averages are large and persistent in time. The general picture shifts only gradually across periods but changes can be substantial for individual submarkets. Differences in yields are partially offset by higher subsequent capital gains (in contrast to zipcode level findings by Eisfeldt and Demers (2018)). House-level correlation of the yield observed at purchase and the subsequent capital gain is 0.12 for Paris and 0.19 for Amsterdam. Boundaries are based on Vasserot arrondissements[a] for Paris and contemporary neighborhoods for Amsterdam.

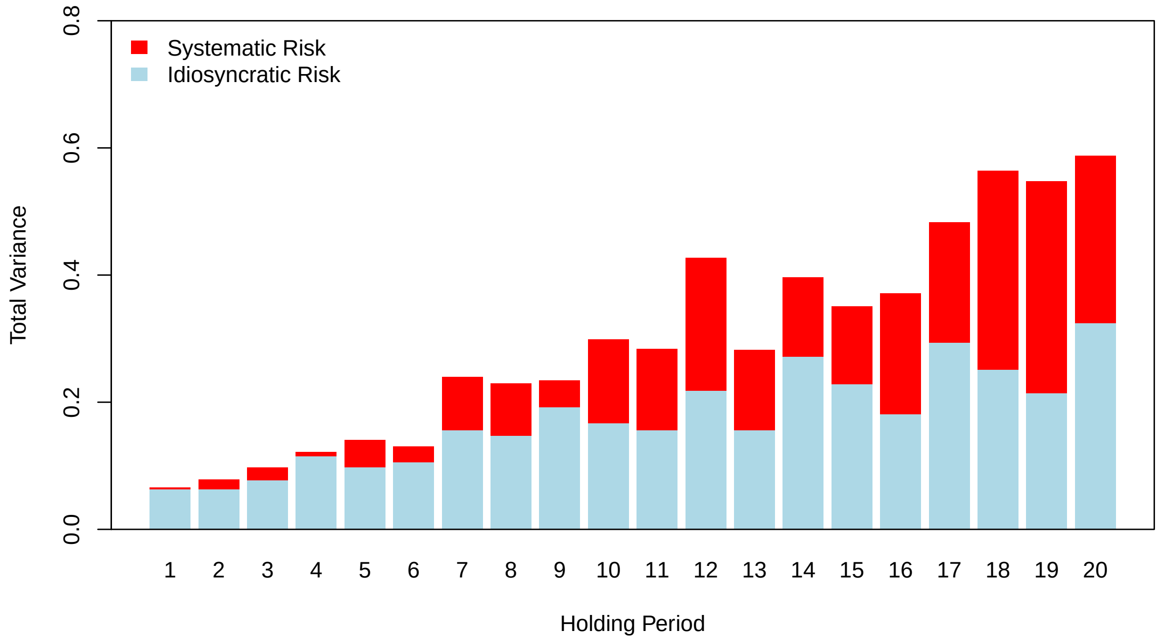
[a]https://maps.princeton.edu/catalog/stanford-cj936rq6257

Figure 9: Correlation Repeated Yields



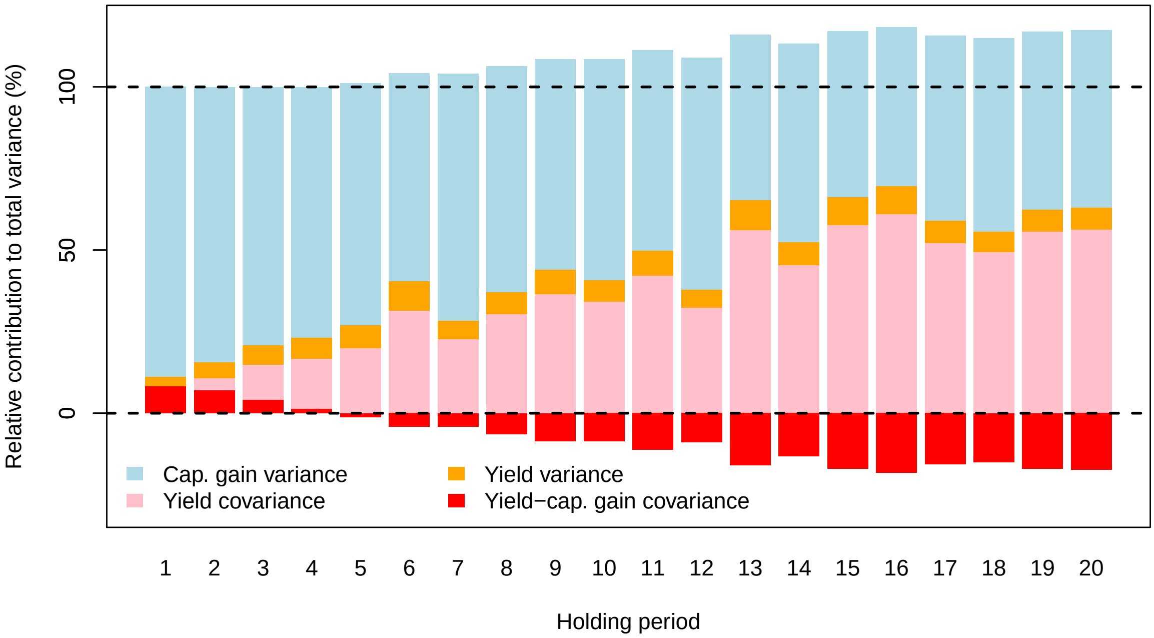

*Notes:* Based on 3,265 pairs of repeat sales in Amsterdam, the correlation of yields at purchase and sale is estimated for various holding periods (in years). In general, both yields are positively correlated. The effect fades away for longer holding periods. The residual correlation is calculated after subtracting the median yield at the time of each transaction from the respective yields.

Figure 10: Systematic and Idiosyncratic Risk




*Notes:* Short-term investment risk at the property level is predominantly idiosyncratic, originating from volatility in capital gains. Changes in market yields and capital gains carry more weight over the long term, increasing the relevance of systematic risk.

Figure 11: Composition of Total Variance




*Notes:* Most variance in the short term stems from capital gains risk as the variance of yields is small relative to the variance of capital gains. However, the dominance of capital gains variance decays as holding periods increase.

# A Historical background of the Sommier foncier

We collect primary residential real estate data from the Paris land register called Sommier foncier. This covers the period 1800–1945 and was compiled by the administration of the Enregistrement. These data are now kept in the Archives de la Seine under the archive rating DQ 18. With other documents of the same origin, this set of archives is a collection of several thousand manuscript records that have already been used by economic historians (pioneering work by Hoffman et al. (2001); a more recent fiscal perspective in Dherbécourt (2013)). The real estate information of this very rich collection of data, although described by historians (Daumard, 1958, 1965), has not yet been the subject of statistical analysis.

The Enregistrement is the tax administration responsible for collecting taxes on legal acts. The Sommier foncier is an internal document that serves to check the veracity of the declarations of taxpayers and notaries who draft the acts. The data collected, within a restrictive legal framework, were used to evaluate the cadastral values on which tax assessments were based.

The Sommier foncier includes all the houses of the French capital, neighborhood by neighborhood and street by street. It gives a very precise picture of the city's fundamental urban transformation in the nineteenth century, and it can be used for all kinds of exciting research in urban and financial economics. We use the first three series of records constituted from 1809 onward: the first covers the period 1809–1854, the second the years 1850–1880 and the third the years 1880–1950.

The records of the Sommier foncier are all handwritten, but their size and presentation are standardized. The clerk inscribed, following the order of the streets and houses, any land transfer as and when it came to the knowledge of the tax administration. Writing is often tight with many abbreviations. This makes data collection difficult and complex.

The records contain, for each house, the names and surnames of the successive owners. Their professions are indicated as well as their social status and tax address. The property mutations associated with these owners are then described in chronological order. The registers mention the sales of buildings and the different types of inheritance transmissions (mainly because of death). The first two series of the Sommier foncier contain the names of the tenants in rental properties, as well as the amounts of the related leases and the circumstances of their conclusions. Reference tax data are also systematically reported, especially in the first two registers. The cadastral values are fairly accurately reported until 1880.

The accuracy of the data in the Sommier foncier was enhanced through the involvement of notaries in all contracts relating to real estate sales. Declarations of succession are referred to by registration officers responsible for the collection of inheritance tax, who have extensive investigative powers to verify the securities presented by individuals and can carry out expert assessments and public confrontations. The tax adjustments were numerous, attesting to the thoroughness with which these verifications were carried out. The investigative power of the receiving agents of registration was enshrined in law in 1851.[21]

The selling prices are extracted from notary deeds resulting from free contracts. Also, there are sometimes auctions and expropriations. Rents come from the leases contained in the first two sets of registers (1809–1880) as well as the estate assessments recorded up to the second half of the twentieth century. Since the French Revolution, the law provided that the payment of inheritance rights was based on an assessment of the income of the building corresponding to twenty times the gross rent.[22] When paying taxes, heirs had to declare and justify the gross rents they received from the property. Ex-post, the registrar could check these amounts to verify whether they were correct. In a substantial number of cases, this led to an increase in the tax to be paid, and these increases were registered as insufficiencies. We adjust our rent prices for these.

Difficulties related to the principle of value assessment by rent capitalization led to its reform in 1918. Henceforth, the property valuation was made on the market value of the properties as declared by heirs.[23] However, the high number of adjustments made by the registration services testifies to the persistence of the practice of rent capitalization until the second half of the 20th century.

Our sample is randomly constructed. We first collect all observations on property ownership changes relating to all streets of Paris beginning with the letters A and B. We thus collect data for almost 500 streets between 1800 and 1940. At the time of the Revolution, Paris had 1,337 public roads. The annexation of suburbs brought this

[21] Arrêté du 3 mai 1851, article 2.
[22] Loi du 22 frimaire an VII, article 27.
[23] Loi du 27 mai 1918, article 1er.

number from 1,474 in 1848 to 3,750 in 1865. In 1904, Paris had approximately 4,500 streets (Hillairet, 2004). During this period, the urban transformations by Haussmann changed the city from its medieval shape to straight and wide streets with orderly facades (Pinon, 2016).

# B Computing Parisian property yields

There are two challenges in computing property returns with the Parisian property data. First, we do not always observe rents and sales prices at the same time. Second, the successions and donations in some cases do not refer to actual rent prices, but a capitalized rent price. This is particularly common in the early parts of the sample and the 20th century. To deal with these issues we apply the following steps.

First, we use repeated observations of rental contracts, successions, and donations to compute a repeat-rent index. To deal with outliers and capitalized rents, we deflate all observations with the existing rent index from Eichholtz et al. (2019) and exclude pairs that have an absolute index-corrected log rent difference of more than 1. We estimate the index based on all remaining pairs, using their original prices.

Second, we match each sales price to the nearest rent price observation on that particular property. If the housing transaction and the rental price are not in the same year, we adjust the rent for differences in aggregate market rents using the rent index we specifically constructed for this. We only match observations where the rent price is less than 30 years away.

Figure 12 shows the distribution of property yields resulting from this procedure. Because some rents are capitalized and other rents are not, this distribution is bimodal with peaks around 7.5 percent (log yield of -2.6) and around 100 percent (log yield of 0). To construct a series of yields that is insensitive to adjustments for capitalized rents, we compute an initial yield series based on the repeat-rent and repeat-sales index. Since both series are based on the same rental properties, this should induce no bias. To scale the index, we use the median gross yield in the unadjusted data (7.2 percent), only including observations with unadjusted yields between 2.5 and 20 percent.

[Place Figure 12 about here]

We use this yield as a prior to adjust the capitalized yields. Before 1918, some successions and donations were capitalized with a rate of 0.075. In line with the distribution in Figure 12, we divide the unadjusted yield by 0.075 if the yield is higher than $\frac{1}{0.075}$ times the exponential of the log initial yield minus one ($e^{log(InitYield)-1}$).

After some legal changes in 1918, the gross rent was capitalized using a rate of 0.1. To verify this, we again computed the index-deflated log price differences for properties that changed hands repeatedly. This distribution peaks at log values of zero and of 2.3, with the latter corresponding to a factor 10 (see Figure 13). Similar to the case before 1918, we divide the unadjusted yield by 0.1 if the log yield is higher than 10 times the exponentiated log initial yield minus one ($e^{log(InitYield)-1}$).

[Place Figure 13 about here]

After making these adjustments, we remove all yields that do not fall within the range of $e^{log(InitYield)-1} < AdjustedYield < e^{log(InitYield)+1}$. Figure 14 shows the final distribution of property yields for our sample.

[Place Figure 14 about here]

Reassuringly, Figure 15 shows that the initial median yield series and the final yield series have a very comparable evolution, except that the final yield series appears to be smoother due to the larger number of observations, in particular in the 20th century. Importantly, there are substantial increases in yields between the end of World War I and 1930. This confirms that declarations of successions also used capitalized rents in this period.

[Place Figure 15 about here]

# C Tax data and analysis for Paris

Fluctuations in property-level tax rates impact the return to residential real estate. We adjust the gross yield by using a direct tax index levied annually on the inhabitants of Paris. We describe here the nature and the evolution of the taxes that were in effect until 1940.

The French Revolution defined the fundamental principles of taxation that remained in place until World War I. The best description of this tax system is due to legal practitioner Lemercier de Jauvelle (1906). Three main taxes directly affected real estate: the *contribution foncière* (a land tax in proportion to a property's income), the *contribution personnelle-mobilière* (a personal wealth tax based on the rental value of citizens' dwellings) and the *contribution des portes et fenêtres* (a tax on doors and windows, proxies for the luxury of dwellings as manifested by the number of openings to illuminate them). These taxes were annually assessed by the government.

These three taxes were levied according to the presumed value of dwellings. A standard deduction was applied taking into account the owner's costs (20 percent tax allowance) to calculate the net cadastral income over which the tax was distributed. The tax was due by property owners, not tenants. The rate for each of these three taxes was set annually and was uniform within a city.

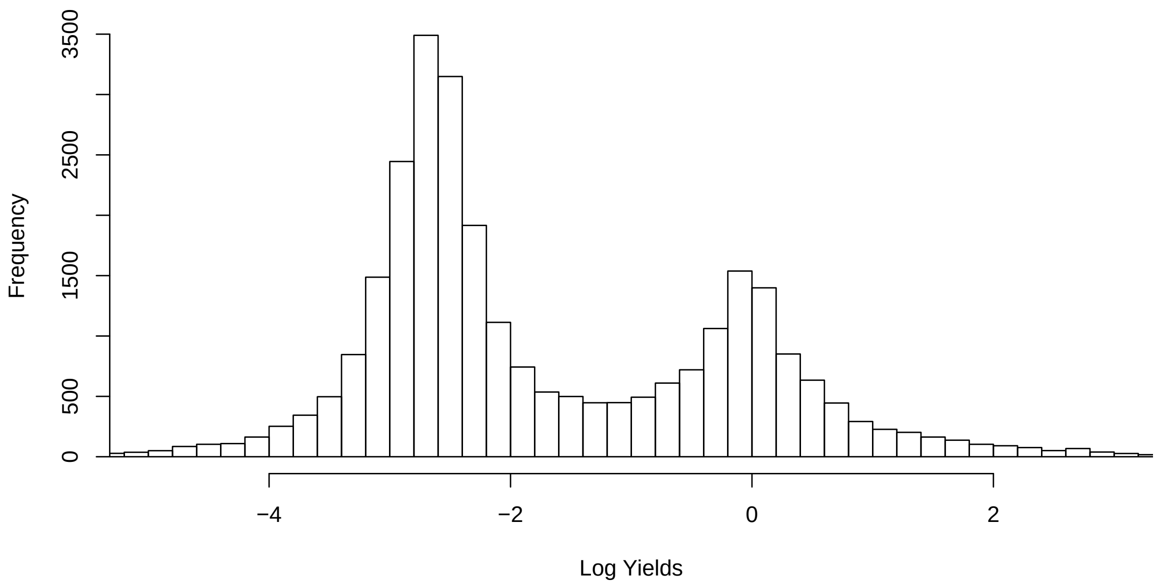
The income tax introduced in 1914 radically changed these old taxes. Specifically, its adoption led to the abolition of the tax on doors and windows in 1926. Until the 1950s, the income tax affected less than a quarter of French tax households (Piketty, 2001).

The law of May 15, 1818, required French cities whose revenues exceed 100,000 francs to publish their accounts and expenses as well as their budgets. These publications make it possible to reconstruct the tax amounts that were levied each year on the inhabitants of Paris, despite the destruction of Parisian archives during the Commune (1871). We use a series of accounts covering the 1807–1880 period. It can be found in the City Library of Paris (Massa-Gille, 1973). After 1880, we use the annual statistical publications, appearing under the title *Annuaire statistique de la ville de Paris* and kept in the same place. We compare these results with the financial laws published by the State in the *Bulletin des lois* and with the retrospective data published by General Statistic of France (SGF).

At the individual asset level, we use the annual amount of taxes imposed on the net cadastral income for almost 4,500 properties between 1807 and 1926. We then compare these to the income generated by the assets to assess the average tax burden. For the period between 1805 and 1860, we used the tax information noted in the first series of the Sommier foncier which is the most complete available. They give for each house the amount of rental income received, the net cadastral income and the effectively levied taxes. After 1860, we used the statistical data compiled in the land registers of the city of Paris which provide the real rental values of the houses for the years 1862, 1878, 1889, 1901 and 1911 (Département de la Seine, 1890, 1901, 1911). Unpublished tax data relating to the Sainte-Avoye district were used to supplement these statements.

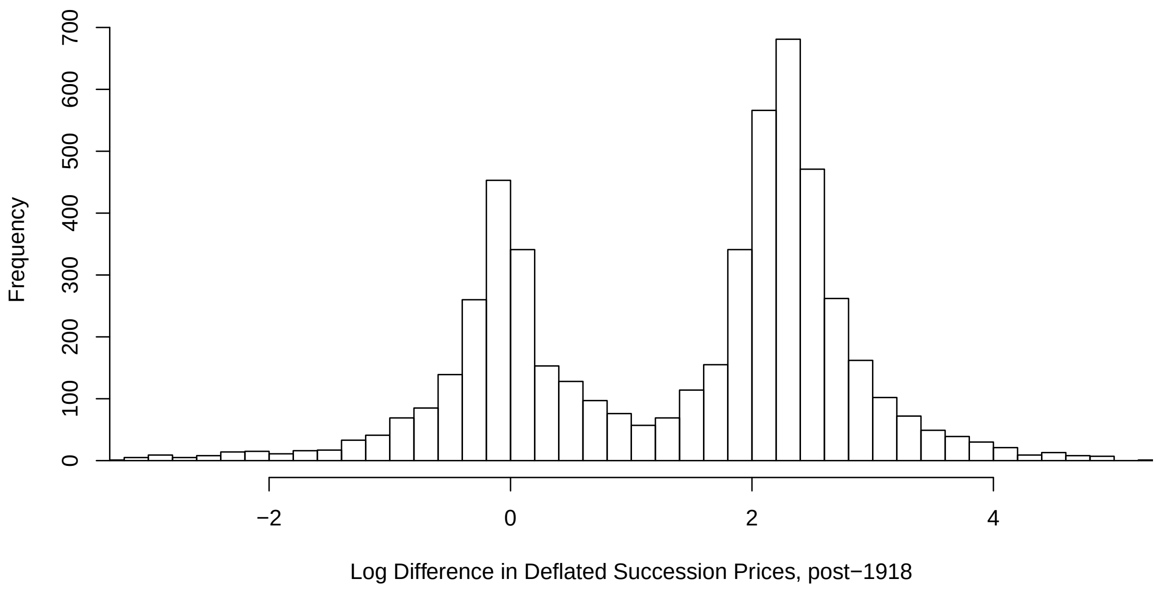
# D Supplementary Tables and Figures

Figure 12: Distribution of Non-modified Yields, Paris



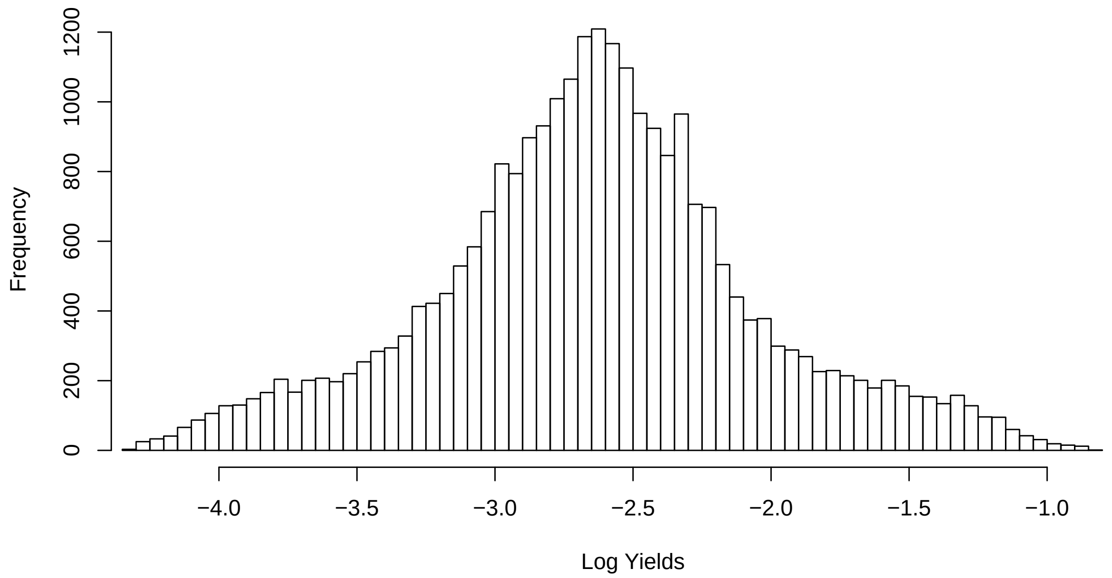

*Notes:* Seemingly bimodal distribution of yields in Paris is caused by some rents being recorded at capitalized values (capitalization rate of 0.075 applied).

Figure 13: Distribution Deflated Succession Values, Paris



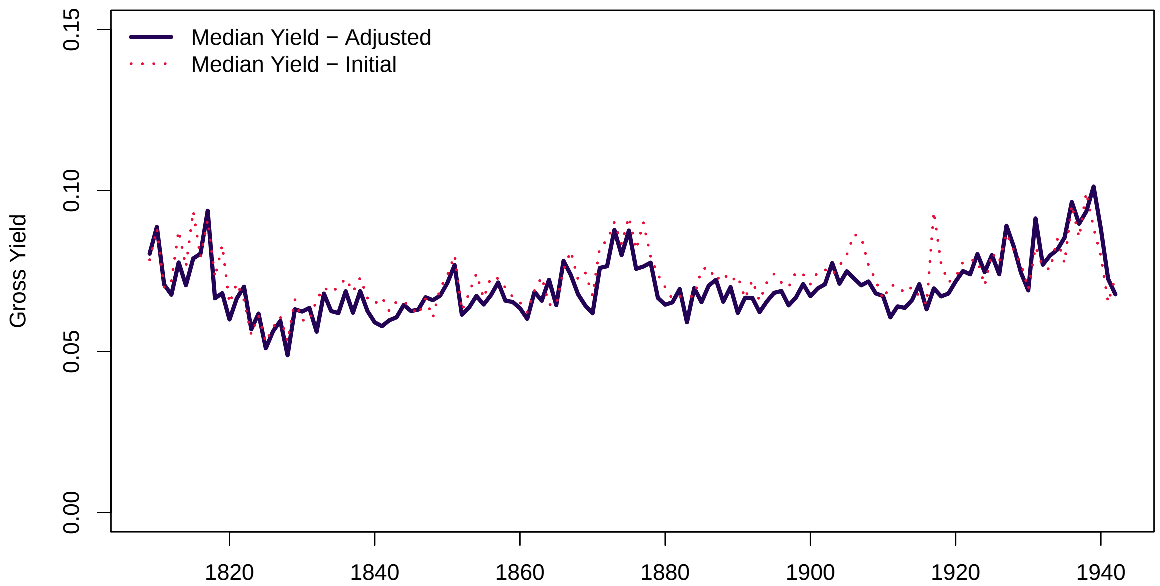

*Notes:* After 1918, the law changed and successions were supposed to be valued at market value instead of the traditional valuation of 13.33 times the gross rent. It appears, however, that new valuations were set to 10 times the gross rent, as the distribution above shows: It peaks at a log value of 2.3, which corresponds to a multiplier of 10.

Figure 14: Distribution of Yields, Modified, Paris




*Notes:* Distribution of Parisian yields, after accounting for various ways of recording values and rents in the archival records.

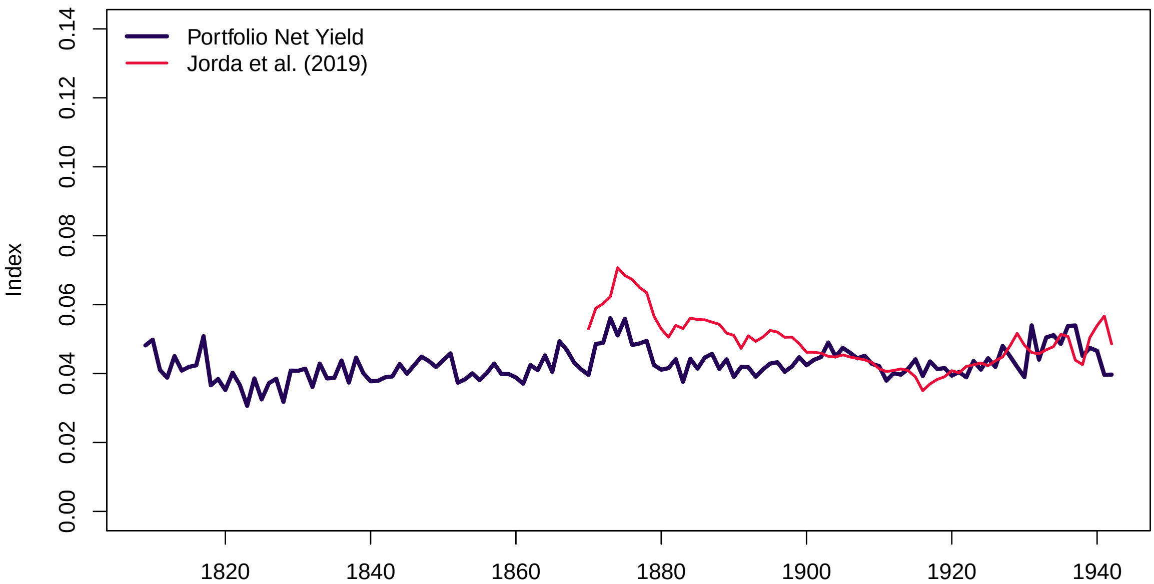
Figure 15: Median Adjusted and Unadjusted Yields (trimmed), Paris



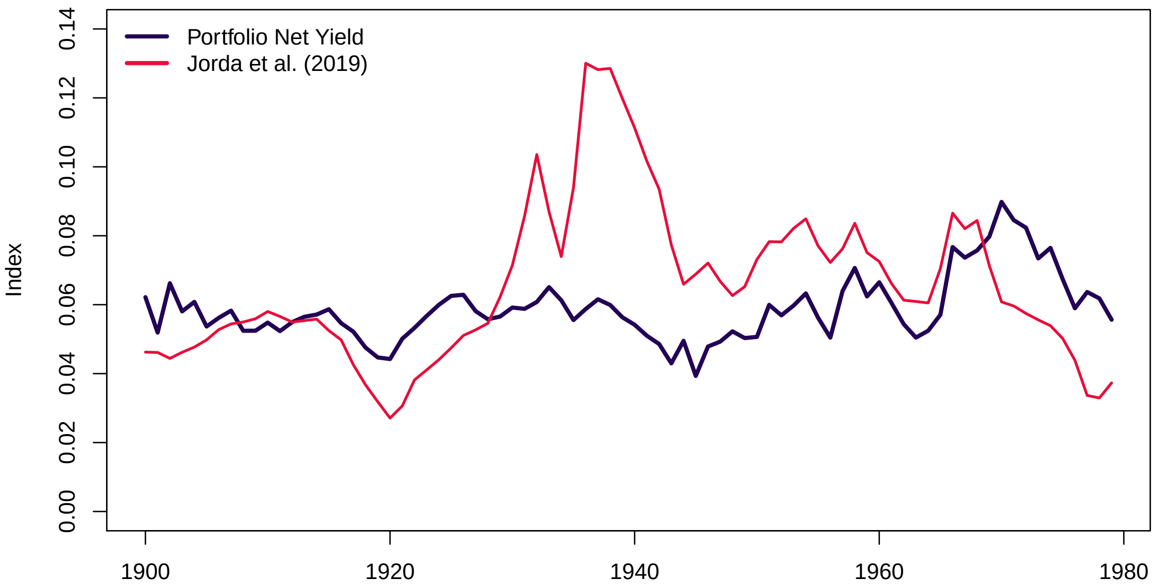

*Notes:* The final yield series (bold line) does not differ significantly from the initial median yield series that excludes observations of rents recorded at capitalized values (Fig. 12). The final yield series appears to be smoother due to the larger number of observations, in particular in the 20th century.

Figure 16: Net Yields in Jorda et al. (2019) and Our Study

(a) Paris

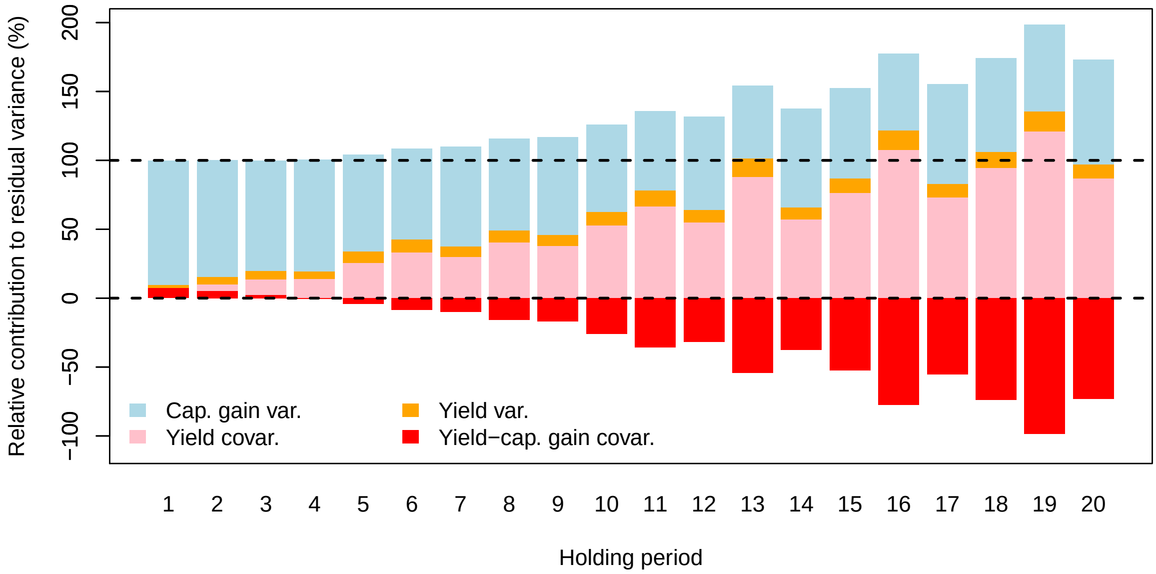



(b) Amsterdam




*Notes:* Net yield estimates for both cities are compared to the imputed yield underlying the Jordà et al. (2019a) total return calculation. For Paris, both series provide evidence of a large cycle in yields in the 1870s. In other periods, yields are more stable but less correlated. In aggregate, both series are significantly but imperfectly correlated (0.41).
For Amsterdam, the imputed yield provides very different developments in yields, in particular between the 1930s and early 1950s. As a result, the net rental yields are barely correlated (0.12) with those in Jordà et al. (2019a).

Figure 17: Composition of Residual Variance




*Notes:* Residual variance is calculated in excess of city-wide yield and price trends. Most variance in the short term can be attributed to capital gains risk because the variance of yields is small relative to the variance of capital gains. However, the importance of capital gains variance decays over time.