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The Amsterdam rent index: The housing market and the economy, 1550–1850

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ABSTRACT

The paper investigates the long run historic development of the Amsterdam rental housing market (1550–1850). Using rent data on a large cross section of residential properties in Amsterdam we are able to develop an annual constant-quality rent index for the entire time period. Whereas nominal rents nearly tripled over the considered sample period, average Amsterdam house rents, in real terms, had approximately the same level in 1850 as they exhibited in 1550. Otherwise stated, nominal rents and goods prices rose at the same pace. Over these 301 years, the real index moves between a minimum level of 45.6 and a maximum of 162.4. As concerns the relation between the housing market and the real economy, we find empirical evidence that fluctuations in rents and fluctuations in proxies of business cycle activity comove, both in nominal and in real terms.

1. Introduction

The Great Recession of 2008/09 has illustrated the importance of housing markets for the macro-economy. This is not surprising, as housing is among the largest stores of value our societies have: the current value of residential real estate in the US and Europe exceeds total stock market capitalization (Case, 2000). Recent experience shows that housing market slumps can cause significant drops in financial portfolio values that can in turn erode overall domestic consumption and investment, and can do even more harm by contaminating the banking sector via the mortgage markets.

Many studies on housing rents and prices are available for the post-1945 era. However, the literature on the behavior of housing markets against the background of long-term economic developments is surprisingly scant. This lack of historical perspective on determinants and comovements of housing prices and rents is all the more problematic given the importance of housing costs for households and of house prices for the economy.

Studying the behavior of residential property prices and rents over longer periods is of potential importance for many reasons. First, investment decisions in housing have to be made with a long horizon so long-run time series are needed to study the optimal asset mix in strategic asset allocations (Campbell and Cocco, 2005). Also, longer time series enable one to disentangle possible long term relations between the housing market, the business cycle and demographic factors. Population dynamics in particular are typically varying slowly, which implies that one needs longer series if one wants to uncover potential relations. Finally, housing prices after the Second World War

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were characterized by strong growth trends in most industrialized nations, both in nominal and in real terms. However, this may not necessarily be representative for housing markets in the more distant past, in non-industrialized economies, and in the future. Otherwise stated, since most empirical studies of property performance focus only on the post-war era, they are likely to produce a biased – and potentially overoptimistic – picture of real estate investment performance.

To date, the empirical literature on long term housing market behavior remains rather limited. For some continental European cities, including Amsterdam, Ghent, and Brussels, historians have collected rental data, and have produced indices on the basis of these. Lesger (1986) has done a study of historic Dutch housing rents, while van Ryssel (1967) has looked at Ghent, and Van den Eeckhout and Scholliers (1979) have studied Brussels. The indices produced in these studies each use all available rental cash flows, and thus reflect the rent paid by the average tenant at any time, but they do not reflect time varying demand and supply conditions in the housing market. For that purpose, it is better to look at the rent formation when new rent contracts are agreed upon.

For England, studies by Clark (2002) and Feinstein (1988a,b) resulted in constant-quality rent indices that span the period between 1550 and 1909. However, these rent indices are only available on a five-year frequency. As far as we know, long-run constant-quality indices of market rents have not been constructed on an annual frequency.

For the United States, Margo (1996) has constructed a hedonic market rent index for New York for the period 1830 through 1860, on the basis of asking rents derived from newspaper advertisements. He showed that rents varied with housing quality and location, and that the relative price of housing went up during the sample period.

As for house prices, Eichholtz (1997) has estimated a biennial constant-quality repeat sales index of Amsterdam house prices for the period from 1628 to 1973 on the basis of transaction prices of houses on the *Herengracht*, one of the main canals in Amsterdam. In real terms, his *Herengracht* index did not rise very much over the 345 years it covered: starting at 100 in 1628, it reached 218.7 in 1973. This result suggests that house prices in real terms do not necessarily increase in the very long run. This result is in line with evidence from Shiller (2008), whose index for United States real house prices has remained rather stationary since 1890, staying close to 100 for most of its history, only to shoot up to levels close to 200 during the years of the great housing boom between 1997 and 2006. Since then, it has lost most of that growth in value.

This paper constructs a constant-quality housing rent index for Amsterdam, a city that began its ascent to become the global hub in trading and manufacturing in the mid sixteenth century, reaching that position in the early seventeenth century. Amsterdam maintained its preeminence as a trading center with varying degrees of success for the century thereafter, but lost much of it during the late eighteenth century, and did not partake in the Industrial Revolution until after 1850 (Israel, 1989, 1995; De Vries and Van der Woude, 1995). Since the index developed in this paper spans the period 1550–1850, it covers the rise and decline of one of the most important trading economies in the early modern period. This also enables us to judge to what extent long-term housing rent dynamics go hand in hand with the long-term economic situation.

The constructed rent index is based on a data sample collected by Lesger (1986) of 1055 dwellings owned by orphanages, hospitals, and poor-relief boards. In all, the rent data involve 48,571 annual rental cash flows, of which 7670 were 'marked to market': i.e. cash flows of new rental contracts. To build a constant-quality market rental index on the basis of these data, we implement repeated-measures regression, an oft-used technique for creating indices of real estate values that has not been employed to create a rent index before.

Anticipating on our results, the resulting index, in nominal terms, rises from 100 in 1550 to 689.5 in 1850, which is equivalent to a 0.64 annual average market rent growth. Corrected for inflation, however, the index value never gets below 45.6 or above 162.4, and has a value of 99.3 in 1850. Otherwise stated, real market rents seem remarkably stable over the long run, which implies that goods prices and nominal rents evolved in similar fashion over time. That result corroborates with the main finding from Eichholtz' *Herengracht* index.

Despite this long-term stability, the index is quite volatile in the short and medium term, and the question remains what drives fluctuations in nominal and real rents. We establish that most fluctuations in nominal and real rents can be related to the evolution in the real economy. More specifically, using different business cycle proxies, our quantitative analysis reveals that the nominal and real rent fluctuations are related to both domestic and international transmission channels (import and export relations) of the historical business cycle. The international transmission channel illustrates once more the export-oriented character of the Amsterdam economy, especially when the Republic was at its height during the Golden Age.

The remainder of this paper is organized as follows. The second section contains a description of the rental data. The next section provides a description and motivation for the repeated-measures regression method towards estimating the rent index. We also investigate whether property heterogeneity requires model adjustments or separate rent index series for different housing types. In the fourth section we present the time series dynamics of the derived market rent index. We distinguish between the nominal and real index series and discuss its evolvement over time in the light of the economic and demographic history of Amsterdam. The presence of relationships between rent series and some available proxies of the business cycle (e.g. international trade activity, construction activity, national income proxies) is investigated in the fifth section. A short summary and some suggestions for further research are included in the final section.

2. Amsterdam rental data

Amsterdam's origins as a city date back to the year 1275, which implies that plenty of historical data sources should in principle be available in order to investigate the rental housing market with a long run perspective. We already referred to Lesger's work as the first study to systematically gather rent data for the Amsterdam housing market. He identified rent information from the records and annual accounts of the major housing owners of that time: the town of Amsterdam and institutions of social service, like orphanages, poor-relief boards and hospitals. They can be considered as the predecessors of modern-day institutional investors since their investments were meant to provide the income needed to maintain their social function (caring for the sick, the elderly, the poor). They did not own real estate to provide low-cost housing.

The real estate portfolio was a crucial source of revenue for these institutions, and reducing the rents below market level would have meant jeopardizing their very essence. The business-like attitude of the social institutions is illustrated by the fact that they were very strict in the way they collected their rents: the archives of some of them contain various legal documents like exhortations, orders for seizures, and even requests for debtors' imprisonment. Moreover, rental contracts with insiders (if known) have not been included in the dataset, and that also holds for lifelong fixed-rent contracts. We can thus safely assume that the cash flow data from the institutions' accounts accurately reflect historical housing market rents.

Moreover, rent controls or subsidies were absent over the considered sample period, which ensures that rents were not distorted by government intervention but were set by market forces. Rent regulation only started as late as 1917 (with the introduction of the *Huurcommissiewet*).

The data set covers 1055 properties. Most of the dwellings are located in the urban area that was developed before 1660 (the western and central parts of the half circle encompassed by the outer canal called the *Buitensingel*). This canal was the external boundary of the city until deep in the nineteenth century. Within that area, the dwellings are well spread out over the different locations of Amsterdam. We find dwellings in the database at top locations on the primary canals, at lesser locations in the older areas developed before 1585, and at outright weak locations in the *Jordaan* area.

For these rental properties the database provides 48,571 annual rent amounts. However, it is important not to use all available rental cash flows in the construction of a market rent index because the majority of the rents in the dataset were fixed for the duration of a contract. Thus, continuing rental cash flows at time t do not reflect the (time t) market rent level, but the market situation at the moment of origination of the rental contract, possibly with anticipated market rent growth for longer lease terms. Therefore, in order to accurately track the housing market, and to investigate the influence of economic fundamentals on the housing market, a rent index should only be based on those rental cash flow observations that have been recently marked-to-market.

To achieve this, moments of lease origination should be known, but our data set does not provide sufficient information to fully reconstruct the moments of contract renewal. We therefore have to infer these moments in an "indirect" way from the cash flow data. Since all rental cash flows are for fixed leases only, we interpret each change in due rents as an adjustment in the housing market due to contract renewal. It follows that annual observations involving the same rental cash flow as the preceding year will be excluded from our rent construction procedure.

Provided one only considers changes in the rent series, we end up with 7670 presumed contract originations or renewals in our 1550–1850 sample. On average, we have approximately three observation pairs per housing unit. The average dwelling is under observation for just over 46 years.

Table 1 sketches the distribution of rent changes (our proxy for market rents) together with some descriptive statistics. We report statistics for the full sample as well for subsamples of 25 years. The number of observed rent changes averages 24.5 per year, and is quite volatile, with a standard deviation of 16.8. The minimum amount of annual rent changes is 2. Although the number of observations changes quite a lot across the 25-year subsamples, this density of observations compares favorably with existing historical studies of real estate markets, and allows us to construct an annual index. For example, Wheaton et al.

Table 1
Distribution of observations over time. *Sources:* Lesger (1986).

Period	Number of rent changes			
	Total	Average per year	St. Dev. per year	Minimum per year
1550–1575	439	16.9	13.5	2
1576–1600	729	29.2	15.9	5
1601–1625	908	36.3	22.7	17
1626–1650	734	29.4	14.7	5
1651–1675	602	24.1	10.8	9
1676–1700	685	27.4	10.0	11
1701–1725	444	17.8	7.4	7
1726–1750	525	21.0	8.5	5
1751–1775	595	23.8	13.5	5
1776–1800	501	20.0	14.2	6
1801–1825	1,110	44.4	25.2	12
1826–1850	398	15.9	12.3	4
1550–1850	7,670	24.5	16.8	2

Notes: Shown are the number of rent changes per sub-period, as well as the average, standard deviation and minimum for that period.

(2009) create a decadal index for Manhattan commercial properties using only 8 observations per decade. Margo's (1996) index for New York rents in the 19th century has an average of 24 observations per year. Ambrose et al. (in press) use an annual index for Amsterdam house prices, and have just under 13 transactions per year.

3. Construction method of the rent index

Infrequent trading and asset heterogeneity in the housing market make the construction of real estate value and rent indices cumbersome. The existing literature on rental index estimation suggests remedying this problem by means of either hedonic regressions, repeated-measures regressions or a combination of these two regression methods.

An important drawback of the hedonic regression method constitutes the requirement to select a set of appropriate property quality characteristics. However, identifying a complete set of historic property characteristics is practically impossible and one has to make assumptions about which factors to include and which not. This bears the risk of omitted variables and functional misspecification.[1]

The repeated-measures regression approach requires less stringent assumptions as it is based on the repeated price or rent observations of the same property. The index consists of the weighted averages of the log changes of these repeated prices or rents. As such, the only data required for the construction of this index are observations of house prices or rents, making this index method better suited for the construction of a long-run historic index.[2]

To calculate the weighted average rent changes we use the standard repeated-measures regression model (1):

$$\ln\left(\frac{\text{RENT}_{t_1,i}}{\text{RENT}_{t_0,i}}\right) = \sum_{t=1}^{T}\beta_t D_{t,i} + \varepsilon_i \tag{1}$$

Time indicators t_1 and t_0 indicate two succeeding moments of rental contract origination or renewal for the same property. The log differences of the rental cash flows are regressed on a set of dummy variables defined as $D_{t,i} = 1$ if $t = t_1$, $D_{t,i} = -1$ if $t = t_0$, and zero otherwise. Estimations of parameters β_t are transformed into index numbers by

$$\text{INDEX}_t = 100\ \exp(\hat{\beta}_t) \tag{2}$$

The index represents expected values of geometric mean growth rates.[3] To construct a rent index using the repeated-measures methodology, it is important that the quality of a residence is similar at both moments of the paired market rents. Since the rent registrations of the institutions also contain detailed information about rebuilding and renovations, it is possible to judge whether the quality of the properties has been changing over time. In case of changing quality, the property is considered a new property and the rent differences caused by quality changes are excluded from regression (1).

As previously discussed in the data section we only involve (log) rent changes in the regression but not the absolute levels. Of the 7670 observed rent changes, we have to form repeat pairs of two market rents for the same property. We were able to form 5694 "repeat" pairs in this way.[4] With the repeated-rent regression based on these pairs of presumed market rents, on average 19 pairs of rent amounts are available per year. This is sufficient for accurate index estimation, with more than 10 paired market rents available for approximately 70% of all years, and more than 15 changes for approximately half of all years. In only one year (1846) the rent sample does not contain a paired rent change at all. For that year, we determine an index number by interpolation.

The original rent index is constructed on the basis of nominal rent observations. We subsequently adjust this nominal market rent index for changes in the general price level, for which we use a consumer price index developed by Van Zanden (2005). The price index is based on a basket of consumer goods, including rye bread, beer, butter, meat, potatoes, peas, different kinds of fish, and various textiles.[5] The basket weights of these goods were updated in case of significant shifts in consumer habits. For example, potato consumption quickly increased after 1770 and therefore enters the index from 1792 onwards.[6]

The repeated-measures regression framework in (1) is typically used in conjunction with estimators for $\hat{\beta}_t$ that are robust to heteroskedasticity, temporal aggregation bias, and sample selection bias.

"Heteroskedasticity" refers to the phenomenon that the variance of regression residuals in Eq. (1) may not be constant over time. Applying the heteroskedasticity correction proposed by Case and Shiller (1987, 1989) has become common practice when estimating repeat-sales indices. Whether heteroskedasticity poses a problem in Eq. (1) can be determined by regressing the squared residuals on the time interval between the two relevant transactions. If the time interval variable is significantly positive, both the dependent and independent variables used in Eq. (1) should be adjusted using the Case and Shiller correction. Anticipating on our results, we find the time interval statis-

[1] More information regarding this estimation method can be found in Case et al. (1997) and Hoesli et al. (1997), among others.

[2] The repeated-measures method was introduced by Bailey et al. (1963) and further developed by Case and Shiller (1987, 1989). Since then, the technique has been applied to transaction prices by a growing number of authors, such as Clapp and Giaccotto (1992), Carter Hill et al. (1997) and Goetzmann and Spiegel (1997). Crone et al. (2003) are amongst the few that applied these index construction methods to residential rents.

[3] In principle, arithmetic means are more appropriate to estimate house price changes, so we applied the ex-post adjustment suggested by Goetzmann (1992) to derive values of arithmetic means. However, because of the very small differences between the log changes of the geometric and arithmetic indices, we used the unadjusted transformation to obtain the repeated-rent index, as described in Eq (2).

[4] We lose the first rent observation for each of the 1055 properties that we follow through time. Moreover, the dataset contains 921 major property renovations which implies a change in property quality. The rent changes corresponding to these renovations have also been taken out of the sample in order to guarantee the "constant quality" feature of the index.

[5] Amsterdam rents have been denoted in guilders since the year 1563. For the first 12 years of the data set, rent prices are converted from so-called Flemish pounds into guilders at prevailing exchange rates.

[6] Van Zanden (2005) provides additional information concerning the consumer price index and its composition over time, and so does the website of the International Institute of Social History in the Netherlands (http://www.iisg.nl/hpw/data.html).

tically significant, and therefore do apply the Case and Shiller correction.

A second type of bias in Eq. (1) could arise due to aggregation of rent changes within one specific time interval. Fortunately, from about the year 1400 until the beginning of the 20th century, the Amsterdam rent contracts always expired on April 30th of the year stated in the contract. Therefore, all rent changes in our data set are dated on May 1st (Moving Day) which implies absence of any temporal aggregation bias.[7]

Furthermore, if the composition of the data set with respect to property quality would not be representative for the composition of the analyzed housing stock over time and if properties of different quality would show different market rent changes, the repeated-measures regression results could also be biased. For rental housing units, this problem might exist as well if different market segments faced different demand and supply conditions. However, we have analyzed this issue in-depth, and conclude that the regression performance improvements resulting from alternative specifications taking account of property quality appear to be very small, just as differences across log index changes of these different specifications. Furthermore, sample selectivity and reduced sample size, which play a role in repeated measures regression in short time series, do not play a role here. Due to the long time interval, we have repeated observations for all properties in the sample. We therefore continue our analysis with the index estimated by means of the standard repeated-measures regression.[8]

Finally, one could argue that it cannot be a priori excluded that we overestimate the volatility of the rent index, due to the fact that we assume that a new lease was signed only when we see the paid rent change. This assumption implies that stable periods are not counted in the index. To investigate the sensitivity of the index to this assumption, we have also estimated the index using three alternative specifications relating to contract renewal. For these specifications, we assume, like before, that a changed rent always implies a new contract, but that this contract then has a fixed duration of 5, 6, or 7 years. The statistical characteristics of the three alternative indices thus constructed turn out to be comparable to those of the index we present below. The real changes in annual rent of that index are correlated very highly with the five-, six- and seven-year contract duration indices: 94%, 96% and 97%, respectively. The volatilities are also very similar. Whereas the real rent changes of the index presented in the paper have an annual standard deviation of 11.16%, these numbers are 10.85%, 10.87%, and 11.19% for the other indices, respectively. So we believe we can safely conclude that our index does not overstate the true volatility.

In the next section we discuss the derived repeated-rent housing index for Amsterdam for the period 1550 through 1850. We will analyze this index with respect to levels and volatility against the background of some of the historic developments of the city of Amsterdam, and will briefly study regularities in the time interval between lease renewals.

4. The Amsterdam housing market 1550–1850

Fig. 1 depicts the estimated repeated-rent index for Amsterdam for the period 1550–1850, both in nominal and in real terms. The full time series data of the nominal and real rent index are included in the Appendix, both with base year 1550.

Table 2 provides average annual rent changes and corresponding standard deviations, both in nominal as well as in real terms. Within the 300 years covered by the index, there are long time periods that have had widely different rental developments both in terms of average rent developments as well as historical volatility. Decades of large rent growth have been succeeded by decades of almost constant or decreasing rents. This implies an average annual rent growth in nominal terms of 0.64%, while the standard deviation of that rental growth is 5.36%.

However, the most striking observation to be made on the basis of the market rent index concerns real rents. Despite the considerable annual volatility, real market rents appear to be rather "stable" over the long run. Indeed, the real rent index, having a starting value of 100 in 1550, ends at 99.3 in 1850. This implies a small negative (but statistically insignificant) annual average real rent change of -0.003%. Moreover, the real index is never lower than 45.6 (in 1574) and never higher than 162.4 (in 1732). Considering the length of the time period, this is a very narrow band. Annual average real rent changes for subsample periods are also often insignificantly different from zero. One economic interpretation of this result is that market forces seem to suffice to keep rents relatively stable, at least over longer periods of time. This is a potentially important result that casts doubt on the rationale for the still pervasive government interference with housing rents.

Table 2 also shows that real rent volatility is nearly double as high as compared to nominal volatility (10.94% over the full sample). The differences in annual means and standard deviations for nominal and real series are due to the fact that nominal rent changes and goods price inflation evolve in a very similar way over time, which results in comparable full sample and subsample averages and standard deviations.

Table 3 provides statistics regarding market rent growth for unequal sub-periods demarcated by structural changes in population growth and economic development in Amsterdam. In the early years covered by our market

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7 Interestingly, New York's historical moving day was on exactly the same date, which may have been a legacy of New York's Dutch period. See also Margo (1996).

8 We do *t*-tests for differences in mean annualized rent changes and lease terms for four property quality classes distinguished in the dataset. As shown in Panel A of Appendix Table A1, we do find statistically significant differences between the rent developments in different market segments. Average contract lengths also appear to differ across these market segments. We therefore also run regression specifications with inclusion of dummy variables indicating the properties of different quality. Panel B in Appendix Table A1 shows regression performance statistics for these different specifications, as well as averages and standard deviations of log changes of the resulting indices. The inclusion of quality dummies to the regression does not seem to make much difference for the performance of the regression, nor for the statistical behavior of the index.

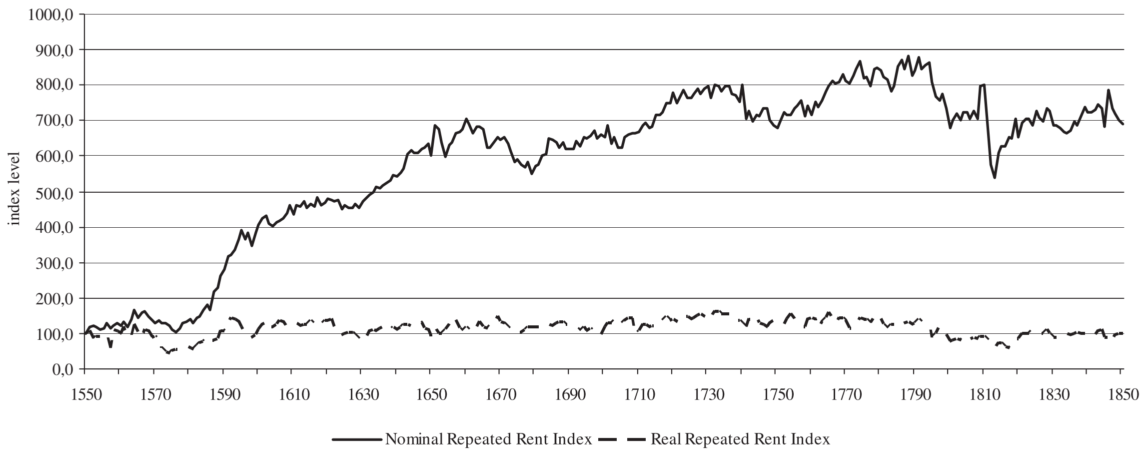

Fig. 1. Repeated-rent index for Amsterdam in nominal and real terms, 1550–1850 (1550 = 100). *Sources:* see Lesger (1986) for rent data; see Van Zanden (2005) for the consumer price data to convert nominal rents into real rents; see the text for details on index construction.

Table 2
Rent changes for equal 25 year sub-periods: descriptive statistics. *Sources:* see Lesger (1986) for rent data; the consumer price index used to deflate nominal rent series into real rent series is taken from Van Zanden (2005); see the text for details on nominal rent index construction.

Period	Nominal rent index		Real rent index	
	Mean rent change (%)	Std. (%)	Mean rent change (%)	Std. (%)
1551–1850	0.64	5.36	0.00	10.94
1551–1575	0.45	9.74	−2.56	22.42
1576–1600	5.15	8.66	2.93	10.51
1601–1625	0.50	3.60	−0.38	8.12
1626–1650	1.08	2.38	−0.25	8.66
1651–1675	−0.09	4.44	0.37	10.98
1676–1700	0.41	2.90	0.53	6.62
1701–1725	0.64	3.05	0.75	10.42
1726–1750	−0.47	3.78	−0.40	6.66
1751–1775	0.75	2.86	0.34	9.64
1776–1800	−0.75	3.95	−2.32	10.71
1801–1825	0.27	7.02	1.42	10.66
1826–1850	−0.21	4.24	−0.44	8.48

Notes: This table provides means and standard deviations of rent changes based on the nominal and real market rent index for the complete sample period and for 25-year sub-periods. Real rents equal nominal rents divided by a consumer price index. Both nominal and real rent changes are calculated as the first difference of the natural logarithm of the corresponding series in levels. This amounts to the growth rate of the series.

rent index, Holland's main industries – like textiles and brewing – experienced a prolonged crisis, resulting in stagnation of the population growth in the cities. Amsterdam was no exception, and this crisis lasted until 1570–1580 (Van Zanden, 1994). The market rents clearly reflect this state of affairs. The rent index in real terms oscillates around 100 until approximately 1570, and decreases substantially in the years after that, reaching a lowest level of 45.6 in 1574. Real rents then stabilized at these low levels. Between 1550 and 1574, real rents decreased with an annual average of −2.56%, and this rent development was very volatile.

From 1580 onwards, the Dutch cities – and especially Amsterdam – experienced a period of rapid economic growth and urbanization (De Vries, 1984). This was largely caused by a greatly improved economy, causing a structural and growing shortage of certain types of labor. In most pre-industrial European cities the mortality rate exceeded the birth rate, and Amsterdam was an extreme example of this, with a mortality rate that was high compared to other cities.[9] As a result, the success of Amsterdam's economy depended critically on an influx of newcomers all through the late 16th and 17th century. The fall of Antwerp to the Spanish army and the closing of the river Scheldt in 1585 were important events in that regard, causing fundamental social and economic disruption in the Southern Netherlands, and a considerable displacement of people, know-how and financial means. Much of that displacement ended up in Amsterdam, and the city's population grew strongly in the period after 1585.[10]

As a result, whereas the City of Amsterdam approximately counted 27,000 inhabitants in 1560, the population rapidly reached a level of 104,932 in 1622[11] and continued to rise to 116,000 in 1632.[12]

Despite this strong population growth, the city's surface area did not expand much in the years directly after 1585. Due to the ongoing war with Spain, the Dutch cities' defense hinged upon the existing fortifications, and an expansion of the city's surface together with the need to build new city walls and fortifications was most probably considered to be too expensive and too risky from a point of view of military strategy. In 1585 a relatively insignifi-

[9] Van Zanden (1994, p. 46). Among other causes, this high mortality rate for Amsterdam was caused by the extremely high mortality in shipping. Of all seamen who sailed on V.O.C . ships between 1602 and 1795, only one third returned to the Netherlands (van Zanden, p. 9), while the number of deserters and permanent emigrants was small (De Vries and Van der Woude, 1995, p. 525).

[10] De Vries and Van der Woude (1995, p. 395). Large inflows of French Huguenots and Spanish and Portuguese Jews constitute two other traditional textbook explanations for the large increase in the city's population during this period.

[11] The number is based on a census.

[12] The population numbers are from De Vries and Van der Woude (1995) and Israel (1995).

Table 3
Rent changes for sub-periods based on economic and demographic developments: descriptive statistics. *Sources:* see Lesger (1986) for rent data; see the text for details on nominal rent index construction.

Period	Period characterization	Nominal rent index		Real rent index	
		Mean rent change (%)	Std. (%)	Mean rent change (%)	Std. (%)
1551–1575	Economic and demographic stagnation	0.45	9.74	−2.56	22.42
1576–1614	Strong economy, inflation, rapid urbanization, constrained city	3.59	7.55	2.26	9.53
1615–1670	Strong economy, rapid urbanization, city expansion	0.63	3.52	0.08	9.83
1671–1720	Economic slowdown, slow population growth	0.37	3.02	0.10	8.61
1721–1780	Economic slowdown, stable population	0.13	3.27	0.02	8.11
1781–1814	Economic crisis, shrinking population	−0.94	6.20	−1.86	10.98
1815–1850	Economic stabilization, modest population growth	0.34	4.34	0.77	9.16

Notes: This table provides sample means and standard deviations of rent changes based on the nominal and real market rent index for economically meaningful sub-periods. "Economically meaningful" here refers to the fact that subsamples are chosen in line with historical demarcations that are generally accepted as relatively homogeneous sub-periods in the economic history literature. More specifically, the historical period demarcations are based on De Vries (1984), Van Zanden (1994), Spies et al. (1993) and De Vries and Van der Woude (1995). Real rents equal nominal rents divided by a consumer price index. Both nominal and real rent changes are calculated as the first difference of the natural logarithm of the corresponding series in levels. This amounts to the growth rate of the series.

cant expansion was undertaken, followed by a more significant one in 1593. It took until 1614 before a larger-scale expansion was started that saw the emergence of Amsterdam's three main canals *Herengracht*, *Keizersgracht* and *Prinsengracht*. This nearly doubled the walled surface area of the city, and it probably took until the 1630s for this area to get fully developed and occupied.[13]

The rapid increase in population combined with an almost unchanged city surface area implied a tight housing market in the years before 1593, and especially before 1614, with rapidly increasing demand and a very inelastic supply. Again, the market rents are testimony of these developments. In nominal terms, the rent index more than quadruples between 1576 and 1614, and stabilizes after that. The average annual nominal rent growth for the period is relatively high at 3.59%. Real rents more than doubled over the whole of that same period, but they went down considerably in the years directly after the expansion of 1593, only to go up again in the early 1600s. Annual real rent growth for the period 1576 through 1614 averages 2.26%.

The economic prosperity – the so-called Golden Age – continued for nearly a century until approximately 1670. Amsterdam continued to grow, both in terms of population and surface area. By 1670, Amsterdam had reached a population size of approximately 205,000 inhabitants. Throughout this period, the birth deficit remained, and even increased because of the mortality peaks in the plagues of 1617, 1625 and 1635. It is estimated that approximately 10% of the population died in each of these plagues. In order to maintain the immigration needed to fuel the still growing economy, Amsterdam's real wages were considerably higher than those in the rest of Europe. Real wages in Amsterdam and Holland – for indigenous workers as well as for immigrants – kept increasing in the first half of the seventeenth century, while they were declining in the rest of Europe (Van Zanden, 1994).

Despite the fact that the average annual population growth in the period 1615–1670 did not reach the level prior to 1615, the city undertook another major expansion plan in 1660, in which the *Herengracht*, *Keizersgracht* and *Prinsengracht* were extended towards and beyond the Amstel river. In 1663, the city received permission for the expropriation and purchase of the required land from the *Staten van Holland*, allowing the required construction of the new city walls and the extension of the canals. As a result of this expansion, the surface area of Amsterdam grew by approximately 70%. From then on, housing supply most likely was better able to react to population growth than before. As a result, population density was probably less volatile than it had been between 1576 and 1614, creating a less tight urban land market and housing market.[14]

Again, this urban development can roughly be traced in the index, which is far more stable between 1615 and 1670 than it was before 1614. Nominal market rent growth averaged 0.63% per annum, with a standard deviation of 3.52%, which is considerably lower than the 7.55% standard deviation of the preceding period. Real average rent growth was 0.08% per year. Interestingly, the three plagues do not seem to have had much of an influence on market housing rents. This may be caused by Amsterdam's openness to immigration combined with excess demand for labor and the resulting upward pressure on wage levels. As a result, population and the labor force probably adjusted quickly after the plagues, but data on population size for this era is too infrequent in order to perform a proper test of this hypothesis. As for the first three Anglo-Dutch wars (1652–1654; 1665–1667; 1672–1674), they do appear to have left their traces in the development of housing rents. More specifically, in the year that each of these three wars

[13] Spies et al. (1993) show a reprint of the 1625 Amsterdam city map by Balthasar Florisz van Berckenrode, on which much of the city expansion is still marked as undeveloped land, while van Eeghen et al. (1976) provide a copy of the 1640 Amsterdam city map by Henricus Hondius, in which this land is marked as completely built up.

[14] This land was given out in a gradual way. For example, a 1675 map by De Wit (see van Eeghen et al., 1976) shows that only about half of the lots between the 1614 development area and the Amstel were occupied, while almost all the land to the east of the Amstel was unoccupied. That land was to be developed gradually during the 18th century (see Spies et al., 1993).

started, rents were considerably lower than in the preceding year.

By 1670, Amsterdam's Golden Age had reached its zenith. The three Anglo-Dutch wars together with the French invasion of 1672 disrupted the Dutch trading system. The increasingly mercantilist trading policies of traditional trading partners like France and England led to a further deterioration in international trade flows. As a result, the economic boom of the preceding decades gave way to a period of stagnation (De Vries and Van der Woude, 1995). Population was still growing but at a rather slow pace, reaching an estimated maximum of approximately 220,000 by 1720.[15] Large city expansions and infrastructural investments no longer occurred after 1672, and the city gradually built over the land it acquired in 1663. These evolutions are reflected in the lower growth rate of market rents, reaching an annual average of 0.37% for the period between 1671 and 1720, with a standard deviation of 3.02% (even lower than in the preceding period). As for real market rents, these only increased by 0.10% per annum, on average.

After 1721, Holland's great economic successes were over. The country was still rich, and Amsterdam was a strong financial center, but the economy had lost much of its dynamics and innovativeness, which is illustrated by the number of patents granted by the States General. For the 17th century, this number had been approximately 70 per decade, while that was less than 10 for the period after 1720 (Jansen, 1979). The Netherlands was still a trading nation, but its trading could now only take place with the blessing of the British, who had taken over the role of dominant power in international waters from the Dutch. From about 1730, wages in the western parts of the Netherlands began to show a decreasing trend in real terms, while they had generally trended upwards in the 150 years before (De Vries and Van der Woude, 1995).

This lack of growth in the economy was reflected in the size of Amsterdam's population, which no longer grew structurally from 1721 onwards, but fluctuated around a level of roughly 220,000: the city had 217,094 inhabitants in 1795, which was comparable to the number in 1720. The death surplus continued, and the city still had to attract immigrants on a regular basis to sustain its economy, even when the era of great economic successes were passed. Market rent growth, in nominal as well as in real terms, virtually stopped. Average annual rent growth was 0.13% per annum in nominal terms, and 0.02% in real terms, with a standard deviation comparable to the preceding period. The financial crises of 1763 and 1773 do not leave any traces in the index. In both of these years, market rents went up, both in real and in nominal terms.

The fourth Anglo-Dutch war of 1780 marked the beginning of the end for the Dutch republic. This war finished the neutrality of Dutch shipping, meant the end of the V.O.C., and led to the demise of Amsterdam as a leading trading center. The French occupation of the Netherlands, starting in 1795, structurally hampered what remained of Dutch trading activities. Because of the war with France, the English blockaded continental European harbors, and from 1806 onwards, when the Netherlands were formally annexed by France, the Dutch ceased to have legal access to any of their important foreign markets. Even trading with France was not allowed. As a result, all harbor activities came to a stop, and the remainder of the industrial sector collapsed. Besides obstructing trade, the French occupation created a substantial financial debt to France, thus overwhelming the tax system, which was stressed to begin with. This increased the national debt and terminated Amsterdam's role as a prime financial center (De Vries and Van der Woude, 1995).

Throughout this period, Amsterdam's population decreased, and by 1814, it had reached a level of approximately 180,000, which implies an average annual decrease of 1% per year since 1795. This state of affairs is visible in the market rent index. Housing market rents decreased, both in nominal (−0.94%) and in real terms (−1.86%), and the standard deviation of nominal rent changes was 6.20%, much higher than it has been in the preceding periods.

When the Netherlands regained independence in 1814, the economy was in a desperate state. The Napoleonic era had destroyed the remaining foundations of the Dutch economy: shipping and finance. By 1814 the Dutch merchant fleet's total shipping capacity was a third of what it had been in 1780 (De Vries and Van der Woude, 1995). The government debt was still high compared to the economy, causing a severe tax burden, and hampering economic growth: approximately 30% of total tax revenue was needed to service the national debt (Fritschy and Van der Voort, 1997). This high debt, combined with a generally low confidence in the country's public finances, pushed Dutch long interest rates far above those in the neighboring countries, hampering economic recovery (Jonker, 1996). The southern Netherlands, which had been separated from the Dutch Republic until 1814, was the first continental economy to participate in the industrial revolution from approximately 1800. The northern Netherlands, and Amsterdam with it, did not partake in this development until about 1850.

The demographic situation picked up again at a moderate pace, with the population reaching a number of 224,000 in 1849. This was close to the number before the economic and social depression of 1780–1814, and the city's housing stock probably had no trouble accommodating this amount of inhabitants. This, combined with the very moderate economic development, probably caused the modest growth in market rent during this period, reaching an annual average level of 0.34% in nominal terms and 0.77% in real terms.

In sum, the market rent development suggested by the repeated rent index appears to be related to the economic and demographic fortunes of Amsterdam. Rental growth tended to be high in times of economic progress and demographic growth, especially when the city's land market was constricted and housing supply inelastic. Times of economic and demographic stability were associated with low or even zero structural rent growth, and the deep economic and demographic depression of the late 18th and

[15] Nusteling (1985) provides a table (Appendix 1.1) of Amsterdam's population numbers from 1400 to 1859, based on a comprehensive investigation of the relevant literature.

early 19th century coincided with decreasing housing market rents, both in nominal and in real terms.

5. Rents and the real economy

In the previous section we approached the relation between housing rents and the economic and demographic environment in a purely narrative way. This qualitative analysis already provided some casual evidence that the business cycle, either driven by domestic factors, international trade or exogenous factors like wars and famines may have played a role in the price formation of the rental housing market. In this section we complement this with a more formal regression analysis.

Price formation in financial markets has been the subject of an enormous research program in financial economics during the post-war era. However, the determinants of property prices and rents, and more specifically their relation to real economic activity, have been investigated for relatively short time periods only.[16] We believe this gap in the literature is mainly due to the lack of reliable data on property prices, rents and real economic activity over sufficiently long periods of time. This paper makes an attempt to link existing long-run economic activity proxies for the Netherlands with housing rents.

Since no continuous business cycle series are available for the 300 years covered by our study we use different (partly overlapping) business cycle indicators in order to span the time period 1550–1850. For Dutch pre-industrial times, different business cycle proxies are available for different time periods. Given the export-led economic structure of 17th century Amsterdam, we use an index of international trade activity as a business cycle proxy for the period from 1624 until 1700. This series reflects income on import and export duties levied by the city of Amsterdam (Becht, 1908). From 1650 until 1806, we use an index of construction activity based on tax income on construction materials used for residential and commercial properties in the Western Netherlands.[17] The third business cycle series we employ is a gross national income index starting in 1807, which extends through 1850 (Smits et al., 2000). Finally, series in real terms for all these variables are obtained by deflating the nominal series with the historical price index due to Jan Luiten Van Zanden (also previously used for determining the real rent index). Fig. 2 shows the nominal housing rents together with the considered business cycle proxies.[18]

The graph already provides some casual evidence for a possible relation between the business cycle proxies and the rent series. The most notable peaks and troughs in the cycle proxies not only seem to coincide with increases or decreases in housing rents but also with the earlier demarcated episodes (Table 3) of economic and demographic expansion or contraction. Also notice the clear comovement between international trading activity and construction activity (the correlation between the changes in both business cycle proxies equals 0.616).

In addition to Fig. 2, we summarize subsample averages and standard deviations of the growth rates (log changes) in the considered economic activity proxies in Table 4, using the same subsample demarcations we used earlier in Table 3. Due to differences in data availability for the business cycle proxies, the considered subsamples and accompanying descriptive statistics differ per series. The table shows that averages and standard deviations are quite unstable over time. Moreover, real volatilities dominate nominal volatilities. Notice these are the same stylized facts as for the nominal and real rent series. This already suggests that rent series and proxies of economic activity bear some similarity. Most interestingly, however, Tables 3 and 4 provide some casual evidence that averages of the rent series tend to comove a bit with the averages of the economic activity proxies if one considers common subsamples. Let us now turn to a more thorough statistical analysis of potential underlying relations between these variables.

In order to investigate this, we regress *changes* in the rent index on *changes* in the business cycle indicators. Table 5 reports results of regressing housing rent changes on changes in our business cycle proxies. The considered regression model looks as follows:

$$R_t = \alpha + \beta_1 BC_t + \beta_2 BC_{t-1} + u_t \tag{3}$$

Let $R_t \equiv \ln(r_t/r_{t-1})$ stand for the (log) rent changes (with r_t referring to the level of the rent index series) whereas $BC_t \equiv \ln(y_t/y_{t-1})$ refer to the (log) economic activity changes (with y_t referring to the level of the output proxy). The rent level and output proxy levels can both be expressed in nominal terms and real terms (deflated with the price index). Thus, we will consider regression outcomes for nominal series as well as price deflated series. The latter requires dividing the original nominal series with the consumer price index before applying the logarithmic transforms referred to above. We estimate the model by an Ordinary Least Squares (OLS) regression. The last table column also reports the adjusted goodness-of-fit measure R^2.

We regress housing rent changes on both changes in contemporaneous and lagged business cycle proxies. We perform the latter exercise in order to check whether the macro-variables "lead" the housing rents.

The table shows that both changes in domestic business cycle indicators (construction activity, and gross national product) and international indicators (trade activity) positively comove with housing rent changes. The choice for nominal or real series seems to determine whether this "procyclicality" of rents is predominantly contemporaneous or lagged: whereas the real series regressions suggest a contemporaneous relation, the nominal series outcomes are more suggestive of lagged relations. Moreover, the linkages between the real economy and housing rents seem stronger (both in terms of statistical and economic significance) for the real than for the nominal growth rates. An obvious explanation could be that the real series at the left hand side and the right hand side of regression (3) share the inflation rate as "common factor" which

[16] See for example Englund and Ioannides (1997).

[17] Algemeen Rijksarchief (ARA), *Financie van Holland*, Inv. Nos. 826–828.

[18] We let the graph start in 1600 because the earliest available data on business cycle proxies (international trade activity) dates back to the year 1624.

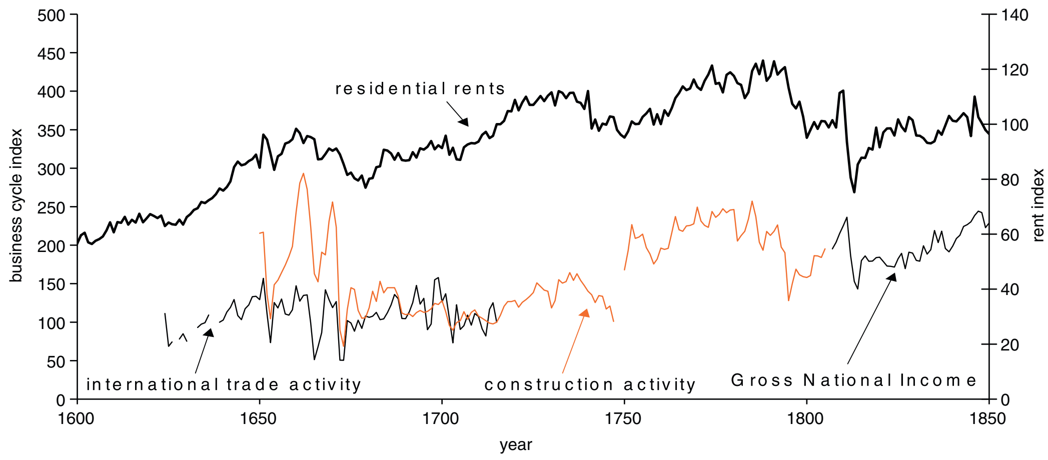

Fig. 2. Residential rents and business cycle indicators, in nominal terms, 1600–1850. *Sources:* see Lesger (1986) for rent data; see Becht (1908) for international trade activity data; see Algemeen Rijksarchief (ARA), *Financie van Holland*, Inv. Nos. 826–828, for construction activity data; see Smits et al. (2000) for Gross National Product (GNP) data; see the text for details on index construction.

Table 4

Changes in economic activity proxies for sub-periods based on economic and demographic developments: descriptive statistics. *Sources:* see Lesger (1986) for rent data; see Becht (1908) for international trade activity data; see Algemeen Rijksarchief (ARA), *Financie van Holland*, Inv. Nos. 826–828, for construction activity data; see Smits et al. (2000) for Gross National Product (GNP) data; see the text for index construction.

Period	Nominal terms		Real terms	
	Mean change (%)	Std. (%)	Mean change (%)	Std. (%)
(a) International trade activity				
1624–1715	−0.33	24.33	−0.74	25.54
1624–1670	−0.27	23.40	−0.75	27.08
1671–1715	−0.39	25.35	−0.73	24.48
(b) Construction activity				
1650–1806	−0.22	13.87	−0.40	16.63
1650–1670	0.86	19.81	2.25	25.48
1671–1720	−0.90	17.81	−1.1	19.51
1721–1780	0.27	7.34	0.15	10.09
1781–1806	−0.88	11.65	−2.32	14.51
(c) Gross national product				
1807–1814	−4.43	12.62	−4.15	14.38
1815–1850	1.30	6.66	1.74	10.67

Notes: Subsamples are the same as in Table 3. Both nominal and real variable changes are calculated as the first difference of the natural logarithm of the corresponding level series.

strengthens the relation between the real variables as compared to the nominal variable regressions. Moreover, historical inflation volatility was often found to exceed the volatility of the other series like the nominal rent changes and the proxies of changes in real economic activity which further amplifies the common factor effect of the inflation rate in the real regressions.[19]

The significant relation between domestic business cycle indicators (construction activity, gross national product) and housing rents seems to confirm previous research on the existence of building cycles in pre-industrial Amsterdam (see also De Vries and Van der Woude, 1995). The significantly positive relation between construction activity and housing rental movements is also interesting, as this may imply that housing supply is increasing more when rents go up, and less when they go down. This may have contributed to the long-term stability in real housing rents we observe in the index.

Our results also reveal the presence of a significant association between international trade and the housing market. This seems to confirm earlier findings (see also Israel, 1989). Upon comparing the construction activity relation with the international trade relation, the results in panel A of Table 5 suggest that this association between market rents and international trade is weaker than that

[19] Multiple regressions of housing rents on proxies of domestic and international economic activity do not lead to any significant outcomes. This is due to the multicollinearity problem that arises between the construction activity variable and the international trade activity variable (the two variables are so highly correlated that it does not pay to simultaneously include them in a regression). We therefore decided to limit the discussion to single regressions.

Table 5
Relation between rent changes and changes in economic activity. *Sources:* see Lesger (1986) for rent data; see Becht (1908) for international trade activity data; see Smits et al. (2000) for Gross National Product (GNP) data; see Algemeen Rijksarchief (ARA), *Financie van Holland*, Inv. Nos. 826–828, for construction activity data; see Van Zanden (2005) for the consumer price data to convert nominal variables into real variables; see the text for details on index construction.

Series pair	$R_t = \alpha + \beta_1 BC_t + \beta_2 BC_{t-1} + u_t$		Adj. R^2
	$\hat{\beta}_1$ (s.d.)	$\hat{\beta}_2$ (s.d.)	
Panel (A) full sample			
Nominal terms			
(Rent; constr. activity)	0.039 (0.021)*	0.056 (0.023)*	0.073
(Rent; int. trade activity)	−0.005 (0.016)	0.045 (0.015)**	0.107
(Rent; GNP)	0.202 (0.117)	−0.106 (0.117)	0.081
Real terms			
(Rent; constr. activity)	0.339 (0.038)**	−0.022 (0.042)	0.360
(Rent; int. trade activity)	0.105 (0.040)**	0.068 (0.039)	0.106
(Rent; GNP)	0.595 (0.103)**	−0.104 (0.103)	0.469
Panel (B) 1650–1715			
Nominal terms			
(Rent; constr. activity)	0.024 (0.023)	0.058 (0.027)*	0.112
(Rent; int. trade activity)	−0.007 (0.017)	0.043 (0.017)**	0.101
Real terms			
(Rent; constr. activity)	0.265 (0.048)**	−0.013 (0.056)	0.345
(Rent; int. trade activity)	0.096 (0.043)*	0.074 (0.043)	0.102

Note: The variable *R* represents (log) rent changes. The variable *BC* represents (log) changes in the business cycle proxy. With "changes", we refer to the growth rates in these variables. The "levels" of rent and proxies of economic activity can both be nominal or real. The levels of the real variables are obtained by dividing the levels of the nominal variables with a consumer price index (prior to taking logarithms). We run the regression with Ordinary Least Squares (OLS). Standard deviations are reported to the right of the point estimates (s.d.).
* Indicate significance at the 5% significance level (one tailed).
** Indicate significance at the 1% significance level (one tailed).

between rents and domestic business cycle indicators. The adjusted goodness of fit, as reported in the last column of Table 5, tells the same story. However, we compare the association of rents with construction activity and international trade activity for different time periods, so the differences in the association may partly be driven by that. As a robustness check, we also report regression outcomes for construction activity and international trade activity over the common subsample 1650–1715 in panel B in Table 5. The subsample results lie in the same direction as their full sample counterparts.

So our analysis does not settle the debate among historians regarding the question whether the housing market was driven by domestic or exogenous (i.e. outside) factors. While the association with the domestic business cycle indicators is stronger than with the international indicator, our results suggest that the two channels are not mutually exclusive.

6. Summary and conclusions

We analyze the long-run development in housing market rents by constructing a constant-quality rent index for Amsterdam, covering the period between 1550 and 1850. The index is based on a broad cross-section of rent changes, and is estimated using the repeated-measures regression method. The specific characteristics of the used data allow us to circumvent some important drawbacks (potential biases) of this index construction method. All rent changes concern residences that have remained fairly constant in quality. Furthermore, the repeated-rent index does not suffer from temporal aggregation bias because of the fixed expiration dates of Amsterdam rent contracts. Also, sample selection bias, caused by systematic differences in annualized rent changes and lease terms, appears to produce negligibly small differences in estimated indices.

According to the Amsterdam market rent index, the development of housing rents is closely related to economic and demographic developments in the city. Amsterdam's economic fortune appears to be reflected in its housing market, and decades of continuous rental growth have been succeeded by decades of almost constant or even decreasing rents. Rent growth volatility has also shown remarkable differences over time, again largely in line with the growth in the economy and the population. In the long run, real rents show structural shifts besides short-run volatility, but the most significant finding of this study is that real market rents in Amsterdam had approximately the same level in 1850 as they did in 1550, despite strong growth of the city and its population during that time period. Over these 300 years, the index moves between a minimum level of 45.6 and a maximum of 162.4.

For students of contemporaneous housing markets, whose opinions may be potentially biased by the large increases of property prices and housing rents over the post-1945 era in most housing markets in the world, the relative stability of real housing rents over such a long time period is likely to be surprising.

This result has an important policy implication, as it should be noted that Amsterdam's housing rents were free of government interference during the whole sample period. Rents were formed in a free market, and the fact that real housing rents did not trend upward casts doubt on the rationale for government interference in housing rents, especially in the form of rent protection, which is meant to protect tenants against rent increases. Indeed, if such rises do not structurally occur, as our research suggests, rent protection is essentially redundant.

After having constructed the market rent index, we also do an exploratory analysis of the market rent development against various business cycle indicators. The results show a positive relation between (log) rent changes and pre-industrial business cycle proxies like (log) changes in domestic construction activity, construction wages and international trade activity. Moreover, the statistical and economic significance of the results is higher for real series (corrected for goods price inflation) than for nominal series. This shows that the relations are not driven by some common underlying factor like inflation. We offer our rent index in the appendix for a more in-depth study of the long-term fundamentals driving the housing market, possibly also involving house values.

We hope that the index here constructed will be a basis for further research into the long-run performance of the housing market. There are some evident directions such research could take. One of those directions is the further analysis of the relationship between housing rents and house prices, while another logical extension is a more in-depth statistical study of the behavior of house rents against macro-economic and demographic developments, and against macro-shocks like wars, plagues and political turmoil. A third way to use the index for further study is in the relation between housing costs and inflation. Based on the dataset used in this paper it should also be possible to investigate the relationship between housing rents and urban location in the long run. A final possible avenue for future research lies in the development of additional historic indices for housing rents and prices for cities besides Amsterdam. Such indices could be used to generalize the inferences made for Amsterdam in this study.

Acknowledgments

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Appendix A

Appendix Table A1
House quality and index representativeness.

(A) Differences in rent changes across different house quality segments

1551–1850					1616–1850				
Difference between and		Low quality	Lower middle	Upper middle	Difference between and		Low quality	Lower middle	Upper middle
Lower middle	Mean diff	−0.005			Lower middle	Mean diff	−0.012		
	t-value	−1.287				*t*-value	−3.074		
Upper middle	Mean diff	−0.008	−0.003		Upper middle	Mean diff	−0.012	0.000	
	t-value	−1.773	−0.919			*t*-value	−2.832	−0.144	
High quality	Mean diff	0.005	0.010	0.012	High quality	Mean diff	−0.011	0.001	0.001
	t-value	1.056	3.949	4.178		*t*-value	−2.829	0.247	0.332

(B) Testing for quality bias

Performance statistics of index estimation with and without property quality dummies

	R^2	Adj. R^2	SE (est)	F	Sig.	RSS
Standard regression	0.418	0.386	0.137	12.92	0.000	100.52
With dummy high quality	0.419	0.387	0.137	12.90	0.000	100.43
With dummy low quality	0.418	0.386	0.137	12.87	0.000	100.52
With dummies high and low quality	0.419	0.386	0.137	12.86	0.000	100.43

Index characteristics with and without property quality dummies

Regression	Geometric		Arithmetic	
	Average	Std.	Average	Std.
Standard regression	0.648	5.513	0.650	5.512
With dummy high quality	0.658	5.513	0.659	5.512
With dummy low quality	0.648	5.513	0.648	5.517
With dummies high and low quality	0.658	5.514	0.660	5.513

Notes: In Panel (A) read: 'column class' compared to 'row class': a negative mean difference indicates the quality mentioned in the column header has a lower average annual log rent change than the property quality mentioned in the row header. The table provides mean differences in annual log changes (as well as *t*-values) between the four quality classes: high, upper middle, lower middle, and low. Panel (B) provides statistics for different specifications of the repeated-measures regression. We refer to the text for more details on the underlying data sources.

Appendix Table A2
The Amsterdam rent index, 1550–1850.

Year	Nom index	Real index	Year	Nom index	Real index	Year	Nom index	Real index	Year	Nom index	Real index	Year	Nom index	Real index
1550	100.0	100.0	1610	433.6	121.2	1670	645.8	132.7	1730	797.9	154.8	1790	840.7	128.9
1551	119.6	108.7	1611	460.6	127.4	1671	651.6	130.9	1731	763.6	144.9	1791	878.4	140.2
1552	121.6	85.8	1612	458.5	122.0	1672	636.5	119.2	1732	801.0	162.4	1792	843.9	131.5
1553	117.9	90.9	1613	473.9	125.9	1673	611.0	115.8	1733	796.6	161.1	1793	854.8	124.4
1554	109.8	90.5	1614	453.7	127.1	1674	583.3	105.9	1734	782.5	155.4	1794	863.1	117.7
1555	116.2	102.0	1615	466.3	135.5	1675	589.2	102.6	1735	796.2	153.8	1795	809.9	89.8
1556	130.5	96.1	1616	459.0	124.1	1676	574.1	102.1	1736	796.9	154.3	1796	767.7	99.5
1557	113.7	59.3	1617	482.2	124.7	1677	568.6	109.8	1737	773.4	142.6	1797	755.9	116.6
1558	122.5	110.5	1618	459.9	125.5	1678	581.4	118.5	1738	770.5	141.7	1798	773.6	115.7
1559	130.7	106.6	1619	470.3	135.4	1679	549.7	116.5	1739	754.3	136.9	1799	734.6	96.2
1560	120.5	99.0	1620	481.0	138.2	1680	573.0	119.5	1740	801.1	130.9	1800	679.5	77.9
1561	132.8	116.5	1621	476.3	140.3	1681	574.8	118.6	1741	703.4	118.5	1801	700.5	80.7
1562	119.1	91.0	1622	470.8	112.6	1682	603.3	121.0	1742	727.2	138.7	1802	720.5	85.6
1563	140.1	92.7	1623	477.4	104.5	1683	605.6	120.1	1743	697.8	140.0	1803	702.9	83.0
1564	165.9	126.4	1624	450.2	96.1	1684	648.4	124.8	1744	716.5	145.8	1804	723.0	90.5
1565	143.8	100.2	1625	459.5	99.5	1685	646.3	122.8	1745	713.4	127.5	1805	722.1	83.4
1566	159.4	88.6	1626	454.7	102.6	1686	638.9	128.5	1746	735.3	127.0	1806	706.4	82.0
1567	161.9	111.6	1627	453.4	101.8	1687	622.4	131.7	1747	733.1	119.2	1807	725.4	87.6
1568	146.4	105.4	1628	466.6	97.4	1688	639.8	132.5	1748	700.3	128.7	1808	706.2	84.7
1569	135.0	89.4	1629	453.7	84.0	1689	621.7	125.8	1749	687.5	136.9	1809	796.2	94.1
1570	130.8	92.2	1630	473.5	78.8	1690	620.1	123.8	1750	680.1	128.0	1810	802.2	92.5
1571	135.1	80.8	1631	480.9	82.1	1691	621.6	121.3	1751	696.0	128.0	1811	668.5	79.5
1572	130.8	60.1	1632	492.1	105.4	1692	642.0	118.1	1752	722.2	126.9	1812	576.3	64.8
1573	128.4	49.1	1633	496.5	110.5	1693	628.0	108.2	1753	715.1	140.4	1813	538.1	60.4
1574	120.5	45.6	1634	512.9	107.3	1694	652.1	116.2	1754	715.9	153.3	1814	610.2	75.2
1575	111.8	52.7	1635	509.9	115.9	1695	648.8	108.1	1755	733.7	139.5	1815	627.6	74.7
1576	103.0	56.3	1636	517.1	119.0	1696	656.3	114.7	1756	742.7	127.5	1816	627.3	63.4
1577	113.8	53.0	1637	522.7	108.4	1697	671.2	108.7	1757	754.9	123.2	1817	653.3	60.9
1578	128.7	56.6	1638	532.7	109.0	1698	649.6	96.4	1758	713.8	116.3	1818	648.7	72.0
1579	134.6	62.5	1639	547.9	117.8	1699	660.0	94.7	1759	740.9	140.1	1819	706.1	87.1
1580	141.5	59.5	1640	542.3	110.0	1700	652.8	117.2	1760	715.0	142.7	1820	654.9	85.3
1581	128.6	55.7	1641	551.9	116.6	1701	685.0	129.4	1761	751.3	140.2	1821	693.5	98.7
1582	142.8	67.2	1642	566.0	124.4	1702	635.4	129.3	1762	736.9	117.7	1822	703.9	101.1
1583	147.5	73.4	1643	603.4	125.6	1703	653.9	136.8	1763	757.5	132.0	1823	704.0	100.2
1584	164.8	76.9	1644	617.8	123.2	1704	623.5	121.8	1764	782.7	143.8	1824	685.5	108.9
1585	181.7	88.4	1645	608.2	128.6	1705	622.0	128.6	1765	795.9	157.2	1825	727.4	111.0
1586	166.4	76.8	1646	610.7	134.9	1706	654.8	137.5	1766	813.1	144.7	1826	708.4	104.8
1587	218.1	80.6	1647	619.3	130.2	1707	662.2	143.3	1767	803.3	129.4	1827	696.3	99.3
1588	228.1	86.5	1648	624.0	114.4	1708	665.9	142.2	1768	807.9	142.7	1828	733.4	109.0
1589	262.1	106.1	1649	635.8	110.1	1709	664.9	97.8	1769	831.2	142.3	1829	725.6	98.8
1590	279.2	106.3	1650	601.9	93.5	1710	669.3	106.2	1770	811.8	136.0	1830	685.6	86.9
1591	317.0	118.8	1651	687.7	116.6	1711	687.2	124.6	1771	804.1	113.4	1831	684.7	87.6
1592	320.0	143.3	1652	674.8	98.8	1712	695.2	125.2	1772	827.8	117.5	1832	678.6	94.9
1593	334.0	140.1	1653	638.1	100.3	1713	678.7	118.5	1773	844.3	129.8	1833	666.6	99.0
1594	365.7	131.8	1654	596.0	110.4	1714	684.5	122.1	1774	867.6	145.5	1834	665.0	99.2
1595	391.0	117.1	1655	631.5	123.8	1715	714.9	125.5	1775	819.9	139.2	1835	670.5	97.1
1596	366.9	102.8	1656	637.8	123.8	1716	714.9	126.0	1776	822.2	138.4	1836	698.1	101.0
1597	382.0	97.5	1657	664.6	138.6	1717	723.5	136.9	1777	797.5	127.5	1837	687.5	102.9
1598	345.0	87.2	1658	668.1	115.2	1718	749.2	149.3	1778	843.2	146.5	1838	711.9	100.2
1599	382.8	97.2	1659	675.9	107.2	1719	748.3	134.9	1779	849.8	152.9	1839	736.5	98.7
1600	405.2	109.5	1660	703.3	119.2	1720	778.1	139.8	1780	840.4	141.6	1840	724.0	97.8
1601	426.0	125.2	1661	691.8	110.4	1721	750.8	132.6	1781	821.9	125.4	1841	722.1	97.9
1602	432.7	131.9	1662	665.9	104.5	1722	771.4	151.8	1782	817.2	112.8	1842	732.0	95.4
1603	407.9	114.3	1663	684.0	118.2	1723	786.6	150.7	1783	782.9	124.6	1843	743.6	105.3
1604	403.3	116.9	1664	681.3	133.6	1724	765.2	147.9	1784	798.1	126.0	1844	733.2	111.7
1605	411.9	126.5	1665	675.9	116.4	1725	765.2	141.4	1785	853.1	134.5	1845	684.1	88.6
1606	416.0	136.0	1666	623.3	114.3	1726	776.2	144.0	1786	872.1	126.6	1846	786.8	89.9
1607	423.1	132.9	1667	624.6	121.6	1727	788.2	150.1	1787	844.9	128.3	1847	733.5	78.8
1608	439.0	116.4	1668	637.3	122.1	1728	774.9	155.1	1788	880.4	132.5	1848	717.8	94.6
1609	459.7	121.6	1669	651.9	147.6	1729	788.8	149.2	1789	827.8	124.5	1849	699.8	98.5
												1850	689.5	99.3

Sources: see the text for further details on the nominal rent index construction; see Van Zanden (2005) for further details on the consumer price index used to deflate nominal into real index values.

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