The First Housing Bubble? House Prices and Turnover in Amsterdam, 1582-1810*

Matthijs Korevaar†

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Abstract

This paper uses the setting of historical Amsterdam to investigate the origins of booms and busts in housing markets. Based on archival data from more than 164,000 property transactions, I discuss the structure of the Amsterdam housing market and construct an annual house price (1604-1810) and turnover (1582-1810) index. I document the existence of various boom-bust cycles, and show that these were characterized by the same four features as modern cycles: momentum in prices, excess volatility of prices relative to fundamentals, but reversion over the longer run, and a dynamic relationship between turnover and prices. Exploiting exogenous shocks in investor demand for housing, I show that excess liquidity can be a major driver of housing cycles, in particular when accompanied by speculative behavior of investors. Changes in the availability of mortgage credit are not required for the creation of booms and busts: housing cycles appear in Amsterdam despite inactivity in its mortgage markets.

Keywords: house prices, turnover, asset bubbles, urban economic history

JEL Codes: G12, R31, N23, N93

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†Department of Finance, Maastricht University School of Business and Economics, P.O. Box 616, 6200 MD Maastricht, The Netherlands, (email: m.korevaar@maastrichtuniversity.nl).

1 Introduction

Booms and busts in housing markets are some of the most disturbing and puzzling phenomena in the economy. When US house prices rose dramatically in the early 2000s, few imagined that a bubble was building up whose burst would lead to the largest recession in the US economy since the Great Depression. Although the US housing bubble and subsequent crisis were by all means remarkable events, they do not stand alone. Kindleberger and Aliber (2003) and Shiller (2015) point to various examples of real estate booms in the 19th and 20th centuries, while Glaeser (2013) provided evidence of land speculation in the US as early as the late-18th century.

Yet these booms and busts in housing are likely a much older phenomenon. In this paper, I will show that Amsterdam experienced house price booms and busts reminiscent of modern housing cycles as early as the 17th century: excessive price increases relative to fundamentals, strong momentum effects, a positive price-turnover relationship, and, eventually, large busts that returned prices to fundamentals. The purpose of this paper is not to simply add another (earlier) example to the history of housing market cycles. Most importantly, I will to exploit the setting of the historical Amsterdam housing market to get a better understanding of what might drive dynamics in house prices and turnover, and the existence of potential bubbles, over the longer run.

There are four reasons why historical Amsterdam is an ideal setting to do so. First, and most importantly, we shall see that housing markets in the Dutch Republic were highly developed and operated under almost the same set of institutions for about 250 years. There existed a developed system of sale registrations, of which many have survived in local archives. In this paper, I will primarily draw upon data on real estate registrations from Amsterdam. These registrations were kept from 1563 until February 1811, and provide near-complete data on more than 164,000 real estate transactions. As a result, it is for the first time possible to accurately reconstitute the long-term trajectory of both house prices and turnover.

Second, the period of study coincides with the Golden Age of Amsterdam and the Dutch Republic, and its later decline at the end of the 18th century (see De Vries and Van der Woude, 1997). Correspondingly, Amsterdam's real estate market was among the

most important in the world, and by far the largest in the Dutch Republic.

Third, Amsterdam already had highly developed capital markets. This is important, since much of the recent literature on booms and busts in housing markets has focused on how changes in credit conditions, mostly through mortgage activity, can generate such cycles (e.g Mian and Sufi, 2009; Glaeser et al., 2012; Jordà et al., 2015; Favara and Imbs, 2015; Favilukis et al., 2017). Interestingly, despite an extensive legal framework for the provision of mortgages, mortgages were only used to finance a minority of housing purchases, and even disappeared almost entirely towards the end of the 17th century. Thus, historical Amsterdam provides a setting to test for the existence of housing booms and busts in a market without mortgage financing.

Fourth, excluding the mortgage channel, I can exploit exogenous variation in investor liquidity to assess the impact of excess liquidity on the creation of housing booms. This variation arises from changes in public debt policies. At various points in time, the government of Holland stopped issuing new debt, as public debt had reached very high levels. As a result of this change, bondholders started to receive large amounts of cash interest payments that they could not reinvest in their preferred instrument: Holland bonds. However, contrary to much modern monetary policy, the decision to stop issuing debt was exogenous to the state of the Amsterdam housing market: the wars that led to these high levels of debt had little direct effect on the local economy, and housing market fundamentals had been stable for many years.

I first combine the transactions data with other sources to present various stylized facts of the housing market. I estimate indices of both house prices (1604-1810) and turnover (1582-1810) to show that Amsterdam experienced three very large boom-bust cycles during the 17th and 18th century during which house prices doubled or tripled before reverting to their initial values. During most of these cycles, turnover and prices were positively correlated. Second, like modern markets, there was significant momentum in house prices, in particular during boom-bust cycles. Third, house prices were excessively volatile relative to fundamentals like rent prices and wages, while reverting over the longer run. Fourth, most real estate was owned for investment purposes: home-ownership in Amsterdam was in 1805 about 14%, and concentrated among the wealthier in society. Next to stocks and bonds, Amsterdam real estate was a major asset class. Fifth, contrary

to modern markets, mortgage markets played a small to non-existent role in the dynamics of the housing market. While there was an extensive legal framework for the provision of mortgages, they were only used in limited amounts in the 17th century, and had disappeared entirely in the 18th century. Last, while population and housing supply increased drastically in the late 16th and 17th century, they were more or less stagnant from the 1680s onward.

The stylized facts reveal that, despite the absence of mortgage markets, Amsterdam experienced boom-bust cycles similar to those observed in modern markets. In the second part of the paper, I aim to identify the causes of these cycles and their specific characteristics. Most of this analysis focuses on the late 17th and early- to mid-18th century, given that standard demand and supply fundamentals moved very little in this period. I focus in particular on the role of public debt in combination with the presence of speculators. Absent modern banks, domestic governments bonds where the preferred saving instruments of the rich of Holland. Holland issued these bonds in order to finance international warfare. However, when tax capacity was reached to finance the growing debt burden, Holland stopped increasing it. As a result, bondholders could not reinvest their interest payments in new debt issues, and were left with large sums of cash money that had to be invested in other assets. I show that this lead to a large boom in real estate prices, which was further heightened by increased speculation in the market. When the government again started issuing bonds, speculators disappeared, and prices rapidly reverted.

The combination of speculation with episodes of excess liquidity is able to explain most of the long-term dynamics in prices and turnover. Modelling prices and turnover bivariate VAR model, I show that, beyond standard fundamentals, net flows to bondholders significantly influence house price growth. Part of the momentum effect can be attributed to persistence in these flows. However, in particular during the latter phases of booms, there remain significant momentum and price-turnover effects. I argue these are best understood in a model that combines lagged responses of buyers and sellers to market conditions (e.g. Berkovec and Goodman, 1996; Genesove and Han, 2012) with optimistic speculative buyers, in spirit of Piazzesi and Schneider (2009); DeFusco et al. (2017).

The findings of this paper allow to draw some parallels to the current state of the housing market. Recently, house prices in Amsterdam have risen to unprecedented lev-

els, with an increase of more than 50% since 2013. However, although prices have kept increasing, mortgage debt has stopped growing. Instead, price rises are attributed to the increased and potentially speculative,demand of investors, who currently are purchasing over 20 percent of properties in Amsterdam (Hekwolter et al., 2017; Dröes et al., 2017). One reason is that, as as a result of extended periods of low interest rates and unconventional monetary policy, they are looking for alternative assets to invest in. Although this paper focuses on Amsterdam, these dynamics also play a role in other markets. For example, Mills et al. (2017) document this particular phenomenon in the United States single-family housing market.

1.1 Related Literature

This paper relates to several branches of the economic literature. First, it relates to a large literature on the dynamics of booms and busts in housing markets. As explained in the introduction, a major part of this literature has focused on the role of credit in house price cycles. Most of these studies have focused on the role of mortgage credit in generating housing booms, both in terms of changes in interest rates as well as changes in credit standards (e.g. Mian and Sufi, 2009, 2011; Favara and Imbs, 2015). The consensus of these papers is that the supply of mortgage credit can play a very important role in house price dynamics. More broadly, other studies document strong general effects of interest rates and monetary policy on house prices, such as Iacoviello (2005); Del Negro and Otrok (2007); Jordà et al. (2015). This paper is also related to the theoretical work of Favilukis et al. (2017), who find that financial market liberalization contributed strongly to the US house price boom between 2000-2006, while they find limited spillovers of investments in bond markets to house prices. Relative to these studies, the main contribution of this paper is twofold: I can exclude mortgage markets as a potential driver of house prices, and I exploit exogenous shocks in investor liquidity, originating from the bond market, to show that excess liquidity of investors can cause housing booms.

A second part of this literature focuses on less rational explanations of housing booms and busts. Recent examples include Piazzesi and Schneider (2009); Glaeser and Nathanson (2017); Burnside et al. (2016); DeFusco et al. (2017). In most of these mod-

els, booms and busts are generated due to heterogeneity in the expectations of investors. Boom-bust cycles appear if a sufficiently large number of investors has very rosy expectations of housing markets, or forms expectations by extrapolating past returns. Relative to this literature, the main contribution of this paper is empirical: instead of focusing only on a single episode, namely the recent boom-bust cycle in US house prices, I show that speculation already played an important role in early boom-bust cycles.

The studies of Piazzesi and Schneider (2009); Burnside et al. (2016); DeFusco et al. (2017) do not only focus on dynamics in house prices, but also incorporate dynamics in turnover. Booms and busts in housing markets are generally described by strong relations between house prices and turnover, and an extensive literature discusses the causes of these relationships. The early work of Stein (1995), generalized in Ortalo-Magne and Rady (2006), focused on the role of financing constraints. As house prices decrease due to fundamental reasons, the financial position of existing homeowners gradually worsens, such that a rising number of movers becomes financially constrained to move, as they do not have sufficient liquidity to pay the downpayment for a mortgage. A second theory, derived from Kahneman and Tversky (1979) and examined in Genesove and Mayer (2001), suggests that loss aversion might drive the unwillingness of households to sell properties in periods of low prices. The most popular group of theories, surveyed in Han et al. (2015), describe the housing market as a search and matching market. Despite the similar nature of these matching models, the suggested causes of the price-turnover relationship and their corresponding empirical implications vary. One set of models has analyzed how changes in the probability and quality of matches between buyers and sellers can induce price-volume relationships (Krainer, 2001; Novy-Marx, 2009; Genesove and Han, 2012; Diaz and Jerez, 2013). Relationships between turnover and house prices might also arise dynamically, as in Genesove and Han (2012) and Berkovec and Goodman (1996). In these models, market participants observe transactions prices, but are not aware of current market conditions. Hence, shocks in demand first propagate in turnover, and subsequently house prices adjust. Lead-lag relationships also arise in the model of DeFusco et al. (2017), but in their work these result from the behavior of speculative investors, who amplify volume and prices initially, but retract when house price growth declines.

My findings indicate that dynamics in prices and turnover are likely fundamental to

housing market, and not merely a modern phenomenon: the empirical estimates of the price-turnover relationship in Amsterdam are very similar to what is noted in modern markets (Clayton et al., 2010; De Wit et al., 2013; Ling et al., 2015; Dröes and Francke, 2017). In addition, I show that these do not require the presence of mortgage financing constraints, as in Stein (1995) and Ortalo-Magne and Rady (2006). Existing empirical studies have suggested there might be economic factors that are both related to house prices and turnover, resulting in the observed correlation. The main factors that have been suggested are income and mortgage interest rates, while for the United States Clayton et al. (2010) argue for the importance of stock prices, and Ling et al. (2015) for measures of sentiment. In this paper, in find little impact of these variables on the price-turnover relationship, although I am unable to create actual measures of investor sentiment.

Empirical studies on the dynamics of house prices of turnover so far have been confined to study data from the past few decades. However, there are some studies that look at the dynamics of real estate prices historically, or over the longer term. For housing, the chapters in White et al. (2014) give a broad perspective on various developments in historical real estate markets, with a specific focus on the cycles in the early 20th century in the United States. Fishback et al. (2010) examine the impact of the Home Owners' Loan Corporation on housing markets in the 1930s. For farmland prices, Rajan and Ramcharan (2015) and Jaremski and Wheelock (2018) investigate the importance of credit in driving the boom and bust in US farmland prices in the 1920s. Virtually all these studies emphasize the role of credit on the housing market. For house prices, Knoll (2017) conducts an analysis of house prices and fundamentals for a panel of developed countries from 1870-2015, and confirms the presence of excess volatility and return predictability in house prices. The analysis of Knoll (2017) builds upon earlier work of Ambrose et al. (2013), who investigate the behavior of Amsterdam house prices relative to fundamentals from 1650 to the present, using Eichholtz (1997) index of house prices for the Herengracht. They find that house prices can deviate significantly from fundamentals, most notably rents, but that correction towards equilibrium can take decades. Although their long-run results are striking, measurement error strongly influences their results before 1811: the underlying house price index from Eichholtz (1997) contains in this period on average only

8 observations per year. Contrary to Eichholtz (1997), this study builds upon archival data on all housing transactions in Amsterdam, thereby mitigating the small-sample problem. Correspondingly, many of the cycles identified in this paper do not clearly stand out in the index of Eichholtz (1997).

The scarcity of data is not the only difficulty in constructing long-run house prices indices. A second challenge is to control for quality differences between the different homes in the sample. This either requires detailed data on the characteristics of properties and their prices, or repeat-sales data on the same homes (Bailey et al., 1963). Probably the earliest attempt to construct a repeat-sales index has been Duon (1946), who made a house price index for Paris in the 19th and early 20th century. More recently, Raff et al. (2013) constructed a decadal house price index for Beijing from 1644 to 1840, while Karagedikli and Tunçer (2016) study house prices in Ottoman Edirne in the 18th and early 19th century. For the late 19th and 20th century, house price indices become much more prevalent, and most of these have been compiled in Knoll et al. (2017). Prior to the 20th century, most studies have focused on housing rents, given that data on these is much easier to obtain: rents had to be paid in each period, and renting was typically more common than owning. For an overview of these studies, see Eichholtz et al. (2017). Relative to this literature, the main contribution of this paper is clear: the construction of a new index. To the best of my knowledge, the index in this paper is the highest-quality house price index available prior to the 20th century, and the very first to make estimates of turnover.

The remainder of this paper is structured as follows. Section 2 provides the historical context of the Amsterdam housing market, and introduces the data. Section 3 uses the data to present various stylized facts of the housing market, including developments in the newly-estimated house price and turnover indices. Section 4 investigates the causes of the identified boom-bust cycles, and estimates an empirical model to account for the dynamics in house prices and turnover. Section 5 concludes.

2 Data and Historical Background

The bulk of analysis in this paper is drawn from one major set of data: the registrations of real estate transactions in Amsterdam. There existed a comprehensive and mandatory system of real estate registrations in Holland since the 16th century (see Van Bochove et al., 2015). This system likely evolved from medieval practices in the Southern Netherlands, where such registrations took place already in the medieval period. The central authority in the registrations of real estate were local law courts (*schepenbanken*), where aldermen (*schepenen*) ratified and registered each real estate transaction. Although there were central laws governing the registration of mortgages and real estate in the Dutch republic, exact customs and practices varied slightly from place to place.[1] For Amsterdam, much of the practicalities and customs regarding the real estate and mortgage markets can be found in the books of Rooseboom (1656) and Van Wassenaer (1737). These two documents formed an important source for the remainder of this section.

In Amsterdam, the oldest surviving register of real estate sales dates from 1563, while the last transactions were registered in February 1811, when the French changed the system. In total, there were five different legal ways to transfer real estate. The first, and by far the most common, were regular property sales. To ratify these sales, the buyers and sellers had to appear in front of the aldermen, who created an act of *ordinaris kwijtschelding* (ordinary remission). Buyers had to bring two guarantors for the transfer. Buyers and sellers that were legally not allowed to transact property, such as women or children, had to be represented by guardians. The acts followed a standard format, and a full English transcription of one such act is given in Appendix A, for the purchase of property by the painter Rembrandt. The acts contained the most important information regarding the sales. First, they contained the date and the names of the buyer(s) and seller(s) of the property, and sometimes also their profession. While representatives were often listed as well, the names of the original and future owners of the property were always mentioned. For example, if the owner had deceased, the seller(s) would be referred to as the 'heir(s) of' the original owner. The same applied for buyers and sellers not legally allowed to transact property, such as women and children. Properties could have multiple

[1] Many of the applicable rules can be found in the *placaatboeken*, published in Cau et al. (1658), which contained ordonnances of the Dutch Republic

sellers, while multiple buyers occurred less frequently. Second, the act contained a short description of the property, and its location. Most transactions are simply classified as 'house and land', but sometimes the acts give more detail. It was also possible to own only part of a property: many acts list that parts of properties were sold. Since homes were not numbered in this period, the location was identified based on the name of the street, a near point of interest and sometimes the names of the owners of the properties right next to it. Unfortunately, the latter has not been collected in the database used for this study. Last, and most importantly, the aldermen also included the transaction price for each transfer. Unfortunately, this practice only started in 1637: for earlier periods, no prices are available.

In case a homeowner defaulted on a private loan, which were full recourse, his property could be transferred via an *executie kwijtschelding*. In this case, the property would sold in a foreclosure auction organised by the City of Amsterdam, and the transfer registered with the aldermen. Before this could happen, the creditors first had to seize of the assets via the bailiff of Amsterdam, which would give the debtor (and homeowner) the possibility to repay. If he did not, the aldermen provided the creditors a letter that would allow them to auction the property. Creditors were not allowed to participate in the auction, but had the right to buy the asset from the winner of the auction in case the proceedings of the auction were not sufficient to fully repay the debt. The earliest registrations of these *executie kwijtscheldingen* date from 1604 and already include transaction prices.

Because there was an extensive market for private credit, and real estate the most important collateral for credit, it was possible that creditors still possessed claims on properties that the debtor had already sold. Normally, creditors retained this claim until one year after the purchase. However, to shorten this period, buyer and seller could agree to sell via a procedure of *willig decreet* at the Court of Holland (see Van Iterson, 1939). The sale would be announced publicly three times with intervals of 14 days, which would give creditors the time to announce themselves, and settle the debt. Afterwards, the sale would be registered and creditors would lose their claim on the asset, and could only be paid directly by the debtor. Such a procedure also existed for foreclosures sales, when the sale would be registered as *onwillig decreet*. Note that although not a foreclosure sale in itself, *willige decreten* seem to have been used particularly when there was significant

concern that the debt would not be repaid: the number of *decreten* correlates closely with the number of foreclosure sales.

The last way to transfer property was via the *weeskamer* (orphan chamber), a local authority in charge of the asset management of orphans' possessions. They had the legal authority to registers property transactions involving the property of orphans, and recorded those in their books of *weesmeesterverkopingen*. They were not registered with the aldermen.

With the exception of *onwillige decreten*, the registers containing the property transfer acts have almost entirely survived in the Amsterdam City Archives (ACA).[2] The *ordinaris kwijtscheldingen* registers are missing for some years in the 16th and 17th century.[3] For *executie kwijtscheldingen*, registers are missing prior to 1605, between 1622-1623 and from 1794-1795. The registers on *willige decreten* and *weesmeesterverkopingen* are complete. Over the course of many years, the archive and its volunteers have recorded data on each of the more than 150,000 real estate transactions that survived in the archives, and these have been made available for the purpose of this study.[4] Although no registrations of *onwillige decreten* have remained in the Amsterdam Archives, these could be recovered from the archives of the Court of Holland.[5] These transactions were very uncommon: in total, only 59 have occurred in Amsterdam.

Because this system of real estate registration existed in the entire Dutch Republic, registrations have also survived for many other cities, and some of these have already been digitalized. Beyond Amsterdam and various smaller settlements, real estate registrations have also been digitalized for Dordrecht and Den Bosch. In Appendix C, I discuss these sources and compare prices in these cities to Amsterdam.

[2]Sources: ACA 5061, inv. nrs. 2163-2182; ACA 5062 inv. nrs., 1-200; ACA 5066, inv. nrs. 1-58; ACA 5067, inv. nrs. 1-47; ACA 5073, inv. nrs. 910-931

[3]These cover the following years either partially or entirely: 1566-1581, 1589-1590, 1593-1595, 1602, 1607-1608, 1613, 1628-1629, 1632-1637, 1640-1641, 1643-1644, 1660, 1664-1679, 1692, 1695, 1697 and 1699

[4]I want to gratefully acknowledge the support of the ACA. Note that the registrations have been indexed, and can be found online at https://archief.amsterdam/indexen. Data on house prices, occupations and various other variables is only available from the full database

[5]Source: Nationaal Archief 3.03.01.0, inv. nr. 3259

2.1 Real estate taxation

The system of real estate registration helped both to identify and define property ownership, and allowed for the taxation of real estate, which was among the most important forms of taxation in the Dutch Republic. There were various different taxes on real estate, which existed until the French changed the sytem of real estate registration and taxation in the beginning of the 19th century.[6] The first tax was the *ordinaris verponding*, which was a tax on the rental revenue that could be generated from a property, independent of tenure status or actual rental prices. Prior to 1733, this tax was 12.5% on the calculated annual rental value. From 1734 until 1805, the tax was reduced to 8.33%.[7] Records of these taxes were organized by the aldermen, and most of these have survived in the archives.[8] The second tax was the *extraordinaris verponding*. This was a tax on the total value of the property, and was 1% or 0.5% of total value. It was levied about once a year on all homes in the city, but the frequency varied depending on the financing needs of Holland. The tax continued to be levied until the early 19th century.[9] The valuations of each property were written down in the tax registers, but rarely updated: in the period of study only in 1632 and 1732 completely new valuations occurred. In other years, only homes that were newly constructed had to be revalued, as well as properties that were split.

The taxation of property in Amsterdam differed from the practices in most modern economies. In most countries, the tax system favors homeownership, because imputed rents are not taxed or because mortgage interest can be deducted from taxable income. Such policy-induced frictions between renting and owner-occupation were not present in Amsterdam. This is important, since some theories on the price-turnover relationship, most notably Krainer (2001) and Stein (1995), require frictions between owner-occupied and rental markets for their results to hold. In addition, there is significant evidence that such tax policies can have a significant effect on house prices and rents (Sommer and Sullivan, 2018).

[6]Note that beyond specific real estate taxes, the Dutch government also frequently levied wealth taxes, which included real estate (see e.g. Liesker and Fritschy, 2004)

[7]Effectively, this did not reduce taxes, since rent prices had increased substantially since 1632, when the last assessment of rental values was made

[8]Source: ACA 5044, inv. nrs. 228-454

[9]Source: ACA 5045, inv. nr. 1-323

Although fiscal frictions between housing and rental markets were absent in Amsterdam, there was one aspect of taxation similar to some modern markets: the presence of transaction taxes. In Holland, such transaction taxes existed at least since the late 16th century. Regular sales beared a 2.5% transaction tax, and notary records reveal that this transaction tax was typically shared by buyers and sellers.[10] For execution sales, the transaction tax was 1.25%, because the seller could not contribute to the tax for obvious reasons. In 1645, Amsterdam added a city transaction tax, amounting to 1.25% on regular sales and 0.625% for execution sales. Being a city tax, this tax was only levied on homes sold within the walls of Amsterdam. In 1687, all transaction taxes were increased by 10%, so that the total tax on regular sales was 4.125% and execution sales 2.0625%. Very recent work of Best and Kleven (2017) shows, inspired by the model of Stein (1995), that such transaction taxes can magnify the relationship between prices and turnover.

2.2 Housing supply: the historical expansion of Amsterdam

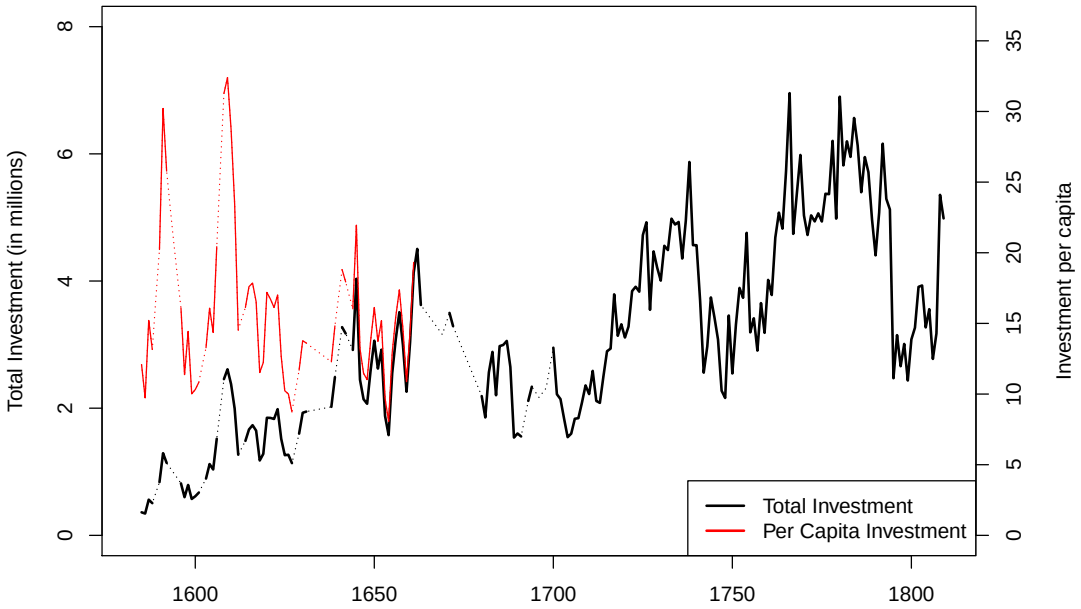
Any discussion of the historical housing market in Amsterdam cannot bypass the drastic evolution of the city and its economy during the 16th and 17th century. In the 1570s, Amsterdam was a small city with an estimated population of only 25,000 people (Nusteling, 1985). After joining the Dutch Revolt against the Spanish in 1578, and aided by a large inflow of refugees from the Spanish Southern Netherlands, the city started growing substantially both economically and demographically. It was in this period that Amsterdam developed into the mercantile capital of the world: the Golden Age. From the 1580s until the 1660s, Amsterdam's population increased to over 200,000, approximately a quarter of the total population of Holland. To accomodate these increasing population numbers, the city's government started a coordinated expansion of the city, which has been described extensively in Abrahamse (2010). This four-stage expansion took place between 1585 and the late 17th century, and expanded the size and housing supply of the city substantially.

The extensions of the city left a crucial mark on the developments in Amsterdam's real estate market. In the first place, the growth of the city significantly increased housing

[10]Source: ACA 30452, inv. no. 504

demand and supply, leading to increased activity in the real estate market. Second, during the extensions, real estate investment boomed. Figure 1 presents statistics on the annual transaction value in the Amsterdam housing market, in total and per capita terms.[11]

Figure 1: Annual transaction value of Amsterdam real estate



Data is only for years in which data is complete or available for at least 6 months (with transactions adjusted for missing months). If the number of transactions with a price is low (below 100), mean prices are taken as moving averages

Per capita housing investments peaked in the late 1580s and early 1590s, when the first and second extension of the city took place, and during the 1610s, when the third major extension took place. It was during this extension, that the first part of Amsterdam's famous canal ring was constructed. Developments in total transaction value and transaction value per capita were virtually the same since the 1660s, as the population of Amsterdam did not change much after 1660. As a result of the stagnation, the city was unable to sell all plots of land made available during the fourth extension of the city, which took place in the second half of the 17th century. The city took its loss, and converted part of these plots into gardens. These were only converted into residential areas when population started expanding again in the late 19th century (Abrahamse, 2010).

[11]Population estimates are from Nusteling (1985) before 1680, and from Van Leeuwen and Oeppen (1993) for 1680-1810

The historical developments of Amsterdam's housing stock have important implications for the cycles studied in this paper. First of all, house prices and turnover should be strongly influenced by the extension of housing supply and demand in the 16th and 17th century (see also Knotter, 1987). Second, supply considerations can only play a minor role in the evolution of prices and turnover in the 18th century, when population and housing supply were more or less stagnant.

3 Stylized facts of the housing market

In order to gain a good overview of the evolution of the Amsterdam housing market, this section presents five stylized facts of the development and structure of the housing market of Amsterdam. First, I will estimate and discuss developments in prices and turnover. Second, I will examine the presence of momentum and excess volatility in prices. Last, I will discuss the scale and financing of real estate investments.

3.1 Developments in house prices and turnover

3.1.1 Index construction

To transform the transaction data into a house price index, I apply a repeat-sales methodology, modified from Bailey et al. (1963) and Case and Shiller (1987). Given the absence of precise hedonic data, the only viable option is to rely on repeat-sales. I assume that the transaction price of a home i in year t can be separated into the following five components:

$$P_{it} = A_i + B_t + T_i + M_t + e_{it} \tag{1}$$

A_i represents the quality of home i and is assumed to be invariant over time. B_t reflects the current level of market prices, and is the parameter of interest. T_i and M_t are dummies to account for both the type of sale as well as monthly seasonality. e_{it} captures transaction noise. Taking log differences of prices, the return on home i between time t and time s can be written as follows:

$$p_{it} - p_{is} = \beta_t - \beta_s + \tau_t - \tau_s + m_t - m_s + \varepsilon_{it} - \varepsilon_{is}, \quad s < t, \quad \varepsilon \sim N(0, \sigma^2) \tag{2}$$

This equation can be estimated for all transaction pairs using OLS, where the time period (years), type of sale and transaction month are identified by dummy variables for each period, type or month. These dummies take the value of 1 in period t and -1 in period s. Ordinary sales occurring in January 1810 are chosen as baseline. To control for heteroskedasticity that might arise due to differences in the holding periods, I apply the Case and Shiller (1987) correction.

While the estimation procedure is relatively straightforward, the main complication comes from the selection of the data: finding repeat sales of constant quality. Absent street addresses, the only feasible way to identify repeat sales is to match buyers and sellers: a buyer should eventually sell his property, either by himself or through his heirs. However, this is far from trivial: not every person has a unique name and a person might own multiple properties. In addition, there might be errors in the data due to spelling mistakes or difficulties in the transcription of the old manuscripts. Nevertheless, this painstaking procedure resulted in 72,000 matched observations, which seems a satisfactory result given the original sample size of 164,373 transactions, and the strict requirements on finding matches. A more detailed description of the matching procedure is given in Appendix B.

To estimate the index, I only make use of residential observations that have a positive price, and remove extreme outliers, as these are likely false positives or substantially changed properties. Due to the low number of observations before 1625, annual standard errors increase above 10%. To maintain precision, the index is at three-year frequency between 1604-1625. After 1625, the index becomes increasingly precise, with a median standard error of 2.8%. For the empirical models of this paper, I also estimate a bi-annual house price index between 1611-1810.

The estimation of a turnover index is more straightforward: this only requires estimates of the number of transactions and the number of homes in the city, which can be retrieved from archival data and existing studies. The individual series are aggregated in two different series: a series of execution turnover (foreclosure sales), which add data from the onwillige decreten and the executie kwijtscheldingen (1605-1810), and a series of 'ordinary' turnover, using data from the ordinaris kwijtscheldingen (1582-1810). The latter will be used for most of the empirical analysis in this paper, as these constitute

voluntary sales.[12] Correspondingly, in the remainder of the paper, turnover will be used to refer to 'ordinary' turnover.

The main complication in the construction of these series arises from the fact that in some years a substantial share of data is missing. If in a given year all data on *ordinaris kwijtscheldingen* is missing, no estimation is made. If only part of the data is missing, the number of transactions is estimated. Appendix B provides a more detailed discussion of this estimation. It is most important to realize that, as a result of estimation and missing data, the turnover series are less reliable during part 16th and 17th century.

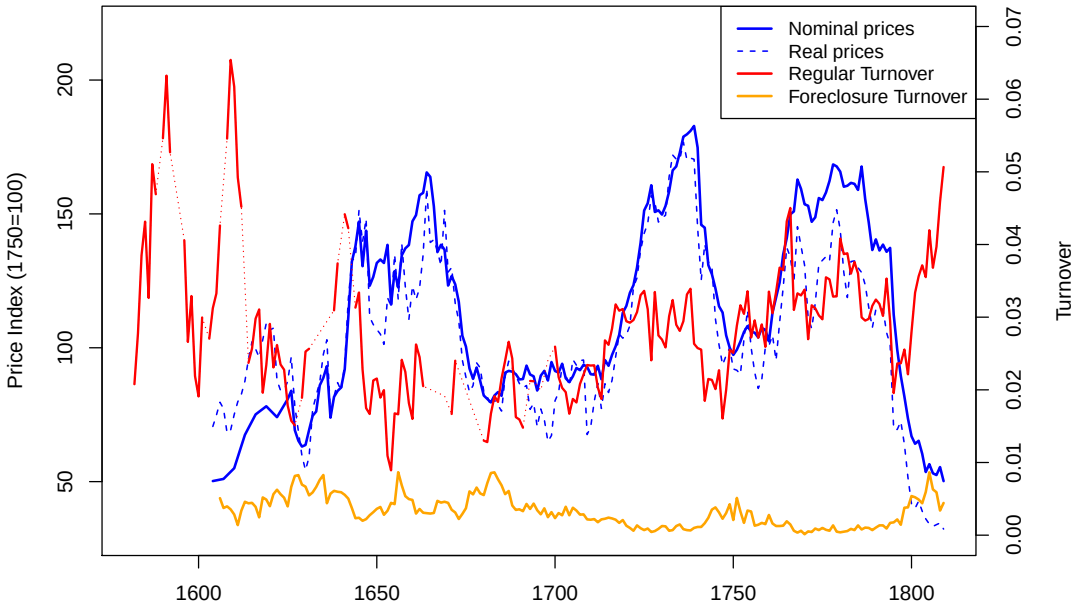
3.1.2 Index developments

Figure 2 plots developments in nominal and real house prices, where the CPI (from Van Zanden, 2009) is used as deflator, together with estimates of regular turnover and foreclosure turnover. In the long-run, house prices have not changed much, while real price declined.[13] The average level of turnover (adding both voluntary and involuntary sales) is about 3%, which makes market activity similar to what is reported for various European countries today (Dröes and Francke, 2017). The general decline in house prices does not seem very surprising in the historical context: the index starts during the Dutch Golden Age, while ending in the French period, which is widely considered as a period of major crisis in the Dutch economy (De Vries and Van der Woude, 1997).

[12] Note that including foreclosure sales in total turnover does not change any of the results I document

[13] The long-term developments in prices are simliar to the Herengracht index from Eichholtz (1997). However, the Herengracht index from does not reveal the very strong boom-bust cycles of the index in figure 2. The correlation of the log growth rates between the updated annual Herengracht index (Ambrose et al., 2013) and my index is also very low: 0.068. As indicated previously, this seems the result of the low number observations in the Herengracht index, rather than differences in house prices at the street level: an unreported index of all three major Amsterdam canals (Herengracht, Keizersgracht, Prinsengracht) almost entirely mimics Figure 2.

Figure 2: House prices and turnover, 1625-1810



Of course, the most interesting developments in house prices and turnover are over the shorter-term: there are very strong cycles in both house prices and turnover. The first cycle appeared in the 1580s and 1590s, coinciding with the first and second extension of the city, which led to large activity in the real estate market. Plans for the third extension of the city were made in 1609, when the 12-year truce in the Eighty Years' War with the Spanish started. At the same time, activity in the real estate market spiked again, most notably for properties outside of the city walls, which were the subject of the planned extensions. Prices increased during the 12-year truce, but started falling substantially between 1625 and 1629, when nominal prices declined by 25% and real prices even by 45%. The subsequent recovery was strong, and likely constituted one of the largest booms in Amsterdam housing history: between 1629 and 1645 nominal and real house prices increased respectively by 133% and 180%, while turnover increased significantly as well. Although there was a downward trajectory in prices during the late 1640s and early 1650s, house prices remained at high levels, and increased towards the peak of the boom in 1664, coinciding with the height of the Dutch Golden Age (De Vries and Van der Woude, 1997).

Until 1682, following significant political turbulence in the Republic, both nominal and real house prices declined by more than 50%. The decline was particularly strong following the Dutch 'year of disaster' 1672: between 1672-1674 house prices decline by

8% per year in nominal terms and even 11% in real terms. Following the large decline, the number of foreclosure sales spiked as well.

After more than 30 years of stable house prices, a second major boom-bust cycle starts in 1714. Prices reach their peak in 1739, and reverted to their initial values by 1750. Although less significant, turnover appears to have experienced a similar cycle. The last major boom-bust cycle started in 1760, with the bust being particularly significant. After the Batavian Revolution in 1795, which made the Republic almost entirely dependent on France, prices declined in the following five years on average by 11% per year in nominal terms and 13% in real terms. By 1810, nominal house prices had declined by more than 70% relative to 1786, and real prices even by 75%. Interestingly, this was also the only period where turnover moved opposite to house prices. These increases in turnover were mostly driven by relatively cheaper properties. It is thus very well possible that these were distress sales, where low-income households sold their assets to obtain liquidity for basic needs. However, over the entire sample the contemporaneous correlation between house prices and turnover is positive and significant (r = 0.114).

Fact 1: *Amsterdam experienced various significant boom-bust cycles in the 17th and 18th centuries, which affected both house prices and turnover. Over the very long-run, prices and turnover did not move much*

3.2 House price momentum

Since Case and Shiller (1989), it is widely known that house price developments contain significant price momentum, and these momentum effects are one important characteristic of housing booms and busts (Glaeser and Nathanson, 2014). To estimate whether such momentum effects also existed in Amsterdam, I run simple regressions of current price changes on lagged price changes. To take account of serial correlation arising as an artifact of the noise in the estimation, I follow Case and Shiller (1989) and randomly split the sample of repeat-sales in two parts: sample A and B. Subsequently, I regress log price changes in sample A on lagged changes in sample B and vice versa, which by construction should have uncorrelated errors. Table 1 reports the result using both one year and two year changes. Columns 3 and 6 refer to regressions where the regular index is used.

Table 1: Momentum effects in Amsterdam, 1625-1810

	Dependent variable:					
	$\Delta_A r_t$	$\Delta_B r_t$	Δr_t	$\Delta_A^2 r_t$	$\Delta_B^2 r_t$	$\Delta^2 r_t$
$\Delta_X r_{t-1}$	0.253***	0.183**	0.140*	0.517***	0.400***	0.502***
	(0.069)	(0.071)	(0.073)	(0.068)	(0.082)	(0.090)
Constant	−0.003	0.0001	−0.003	−0.001	−0.001	−0.001
	(0.006)	(0.006)	(0.005)	(0.008)	(0.008)	(0.008)
Observations	184	184	184	92	92	92
Adj. R-squared	0.063	0.030	0.014	0.385	0.198	0.249
Note:						*p<0.1; **p<0.05; ***p<0.01

Both at the one-year level, but in particular at the two year level there is strong and highly significant evidence for momentum effects. There is some evidence that noise in the one-year index leads to attenuation of the momentum effect, as Case and Shiller (1989) suspected. At two-year levels, this is not the case, and momentum effects are in the order of 0.5.

Fact 2: *Amsterdam house prices displayed significant price momentum*

3.3 Excess volatility of prices relative to rents and income

The two most common fundamentals to explain developments in house prices are rent prices and income (examples include Himmelberg et al., 2005; Gallin, 2006, 2008; Campbell et al., 2009; Ambrose et al., 2013; Sommer et al., 2013). Income might be related to housing because it reflects the annual funds households have available to consume housing services. Rent prices should correlate with house prices, because both are subject to the same demand and supply for housing. From an asset pricing perspective, rent prices should be related to prices because they are the dividend on housing investments. Hence, a standard discounted cash flow model implies that house prices (P_t) are related to rents (R_t) as follows:

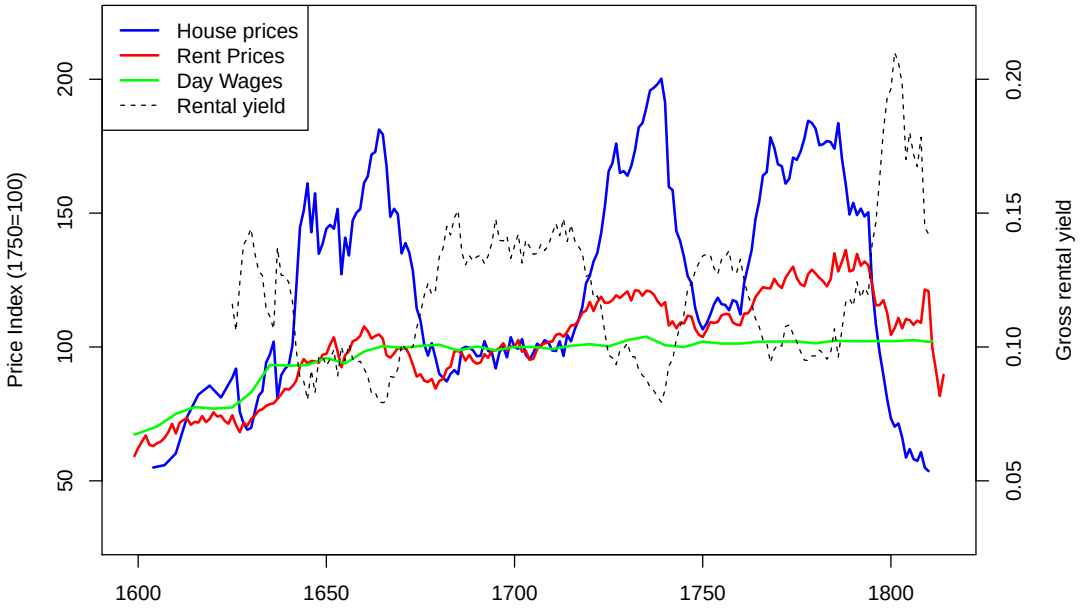
$$P_t = E\left(\sum_{s=1}^{T-t} \frac{R_{t+s}}{(1+m_t)^s}\right) \tag{3}$$

Although house prices do seem to respond to changes in these fundamentals, the con-

sensus in the literature for modern housing markets is that this only explains a small part of the variation in house prices. This relates to a second characteristic of modern housing booms and busts: excess volatility of prices relative to fundamentals, but reversion over the longer run (Glaeser and Nathanson, 2014).

Figure 3 plots the level of house prices relative to rent prices and wages. The rent price index is a repeat-rent index from Eichholtz et al. (2017), and wages are day wages from Van Zanden (2009). To make the relation between rents and prices more clear, I transformed the rent-price ratio to actual average gross yields using means of 750 gross rental yields between 1799-1803 and 1737-1739. I collected these from archival records of auctions that listed for each property the transaction price and rents.[14]

Figure 3: House prices and fundamentals



Consistent with observations from modern markets, house prices are excessively volatile relative to rents and wages. This can be confirmed statistically: the standard deviation of annual nominal house price growth is 7.35%, while the standard deviation of nominal rent and wage growth are respectively 2.16% and 0.51%.[15] Second, although booms and

[14]Source: ACA 5068. For more information on these auctions, see Van Bochove et al. (2017). Benchmarking using actual gross yields from 1799-1803 implied the same gross yield in 1736-1739 as would be achieved when using actual 1736-1739 gross yields. This is reassuring for the quality of the index: if the house price index would contain any bias, this would not hold (as long as the rent price index does not contain exactly the same bias. However, this is unlikely given that the repeat-rent index from Eichholtz et al. (2017) is solely based on well-maintained properties)

[15]Excess volatility can also be confirmed using predictability regressions. At various time horizons,

busts in house prices can last for extended periods of time, prices do seem to revert to fundamentals over the longer term. These observations also hold if other measures of income, such as GDP per capita (Van Zanden and Van Leeuwen, 2012), are used. While GDP is substantially more volatile, it does not show any of the cyclical trends revealed in house prices.

From an asset pricing point of view, the strong swings in rental yields also imply that it is difficult to account for the variation in house prices using changes in cash flows. If the discount rate m_t is constant and gross yields are a good estimate for net yields, rental yields should be constant if investor's expectations are fully myopic. If investors have perfect foresight, they should even correlate negatively with boom-bust cycles (since rent prices also rise slightly during booms). Hence, to account for the booms and busts in prices using discounted cash flow models we either need significant variation in discount rates, running costs, or non-standard expectations of returns to housing investments (e.g. Glaeser and Nathanson, 2017).

Fact 3: *House prices were excessively volatile relative to rents and wages*

3.4 Real estate as investment asset

The previous facts imply that the total value of Amsterdam real estate, and the returns to investing in it, varied significantly over time. In order to get an idea of the significance of these facts, it is important to identify how significant real estate investment was in the first place. Using tax records identifying the number of homes,[16] and mean sales prices from the transactions data it is possible to make a relatively precise estimate of total real estate value in Amsterdam. Between 1660 and 1810, when the number of properties in the city is close to fixed, Amsterdam real estate was worth on average about 130 million guilders. However, due to the large fluctuation in house prices the total value fluctuated roughly between 50 and 200 million guilders.

These amounts imply that Amsterdam real estate was a significant asset class relative to stocks and bonds. For example, the Dutch East India Company was only capitalized with 6.3 million guilders in the early 17th century, and total stock capitalization reached

rent-prices ratios negatively predict future house price changes, consistent with Ambrose et al. (2013)

[16] Source: ACA 5044

its maximum at 75 million guilders in 1720, although prices did not decline much afterwards. However, bond investment was much larger: the astronomous public debt of Holland averaged 270 million guilders between 1660 and 1810, about 170% of GDP.[17] Much of this debt was owned by citizens of Amsterdam (De Vries and Van der Woude, 1997).

Most Amsterdam real estate was owned by relatively wealthy people. Faber (1980) studied 478 probate inventories of deceased persons between 1700-1709, and classified these into wealth groups based on burial taxes, which were levied progressively per wealth group. His analysis results in two important observations. First, his sample suggests that more than half of the homes in Amsterdam were owned by the the richest 14% of society, the first four groups of the burial tax, and that these were responsible for about 80% of total real estate investment. In case persons from the lower income group owned real estate, this was on average worth little, suggesting that non-wealthy families could only purchase very small properties. Second, those that possessed real estate also invested large sums of wealth in other assets. Between 1700-1709, about a third of their total financial assets were invested in real estate, while the remaining was invested in other securities, most likely government bonds. This is likely a lower bound: as can be seen from figure 2, house prices were at very low levels in this period.

The relative wealth of homeowners is also confirmed by the low rate of home-ownership. Unfortunately, 1805 is the only year in which it is possible to compute the actual home-ownership rate, due to a one-time tax levied on all real estate units in the city. The registers of this tax indicate for each residential unit whether it was owner-occupied or not. 75% of the registers have survived in the archives, reporting on 41,247 real estate units (2.3 per property), which I have all digitized.[18] Of all residential units, 14% were owner-occupied. Although these numbers seem relatively low for modern standards, it is important to realize home-ownership in Amsterdam has only exceeded this figure in the 21st century. For most of the 20th century, home-ownership was just a few percent.

Fact 4: *Amsterdam real estate was a major asset class, primarily owned by the rich*

[17] Sources: Liesker and Fritschy (2004) and Van Zanden and Van Leeuwen (2012)
[18] Source: ACA 5045

3.5 Mortgage financing

Much of the dynamics in recent housing booms and busts have been attributed to mortgage markets, both as a result of changing interest rates and changing credit standards. In Amsterdam, there existed an extensive framework for the provision of private credit, including mortgage financing. Absent modern banks, debt contracts were signed among private persons, and often formally registered with the aldermen or a notary. There were various types of debt contracts used, and for the purpose of this paper I will only focus on mortgage financing. For a more detailed discussion of private credit markets in Holland, see Gelderblom et al. (2017) and Van Bochove and Kole (2014).

It was by law required to register any loan that used a specific piece of real estate as collateral with the aldermen, and the registers of these have survived in the archives.[19] If such a loan was used to finance a real estate purchase, it was referred to as a '*custingh*'. In practically all cases, these were supplied by the seller of the property. A '*custingh*' was attractive to both borrower and lender: it was legally defined as the most senior debt claim (see Cau et al., 1658), and, contrary to other loans registered with the aldermen, free of tax.[20]

Such a '*custingh*' could be a short-term loan (*schepenkennis*) or a long-term loan (*losrente*). Short-term mortgage loans were most commonly used to specify a payment schedule for the real estate purchase, that did not involve interest payments.[21] In some cases, they had maturities of a few years and did required annual interest payments. Long-term loans, *losrenten*, were annuities very similar to modern mortgages. They usually did not specify a repayment schedule: the borrower had to pay the annual interest, and could repay the principal at any time to end the annuity. The large majority of these loans were used to finance real estate purchases.

To investigate whether these long-term mortgages could have had an impact on house prices developments, I have counted the number of contracts in each of the registers of

[19] Source: ACA 5063 and 5065

[20] There was a mandatory 2.25% tax on other loans with the aldermen, and this tax could also (voluntary) be paid for non-registered loans (See ACA 5047). Any taxed loan would be senior to all other loans, except for loans with *custingh*

[21] Very often, the buyer had to pay one third of the purchase price directly, one third in six months, and the last third in 12 months

losrenten (annuities) from 1629 until 1810.[22] The large majority of these contracts were used as long-term mortgages. Figure 4 plots the total number of real estate transactions (if registers are complete), the annual number of contracts of *losrenten* (including transfers), and the number of loans registered with the aldermen which were not specifically used to purchase real estate. The latter are a subset of the total number of loans, and encompass both *schepenkennissen* and *losrenten*, and are based on data from Gelderblom et al. (2017).

Figure 4: Real estate transactions and private credit

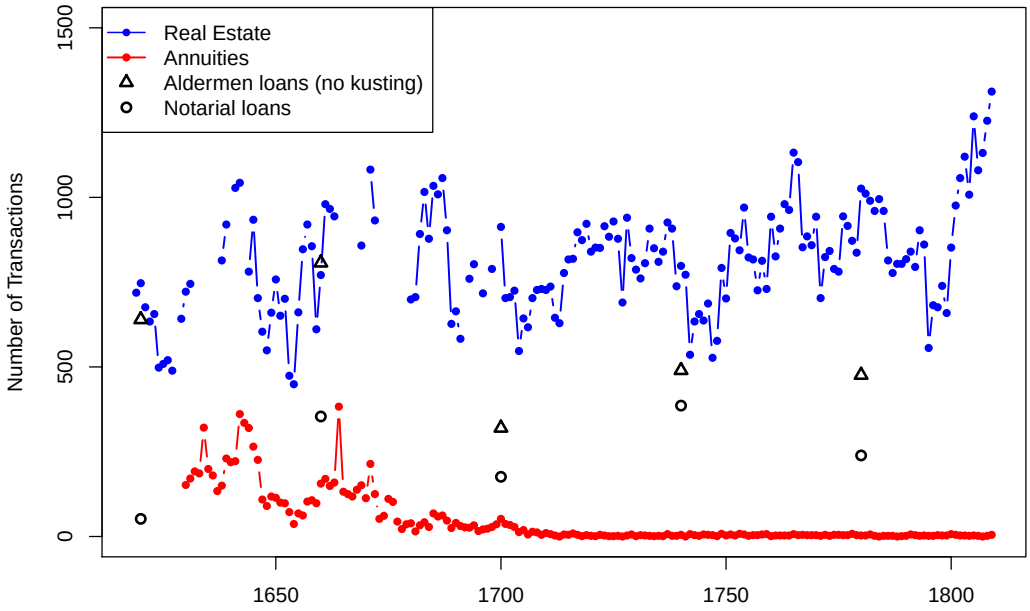


Figure 4 shows that even at the high point in the 17th century, the number of annuities is still much less than the total number of transactions in the housing market, with about 20% of real estate transactions fully or partially financed using a long-term mortgage. At the end of the 17th century, the mortgage market dries up entirely. This implies that the majority of real estate purchases were financed using readily available cash. Although limited in size, the sample of Faber (1980) confirms that most real estate owners possessed large sums of direct cash or other liquid assets that could be sold to obtain the required cash. The decrease in mortgage funding might have also coincided with a decline in home-ownership: Ryckbosch (2016) shows for various other cities in the Low Countries that home-ownership declined in the 17th century, while De Vries and Van der Woude (1997)

[22]Source: ACA 5065, inv. nrs. 22-34

argue that in the late 17th century a rentier class emerged, with capital increasingly concentrated.

The fact that mortgages played a limited a role in the housing market does not imply that there exist no links between housing markets and credit markets at all. Most notably, home-owners might have used their home equity to secure debt. If that is the case, private credit might expand as house price increase. Evidence from taxed loans, discussed in Appendix D, indeed suggests this is the case. Nevertheless, registered private credit was minor relative to the total size of the real estate market.

Fact 5: *Amsterdam real estate purchases were rarely financed using mortgage credit*

4 The causes of boom-bust dynamics in Amsterdam

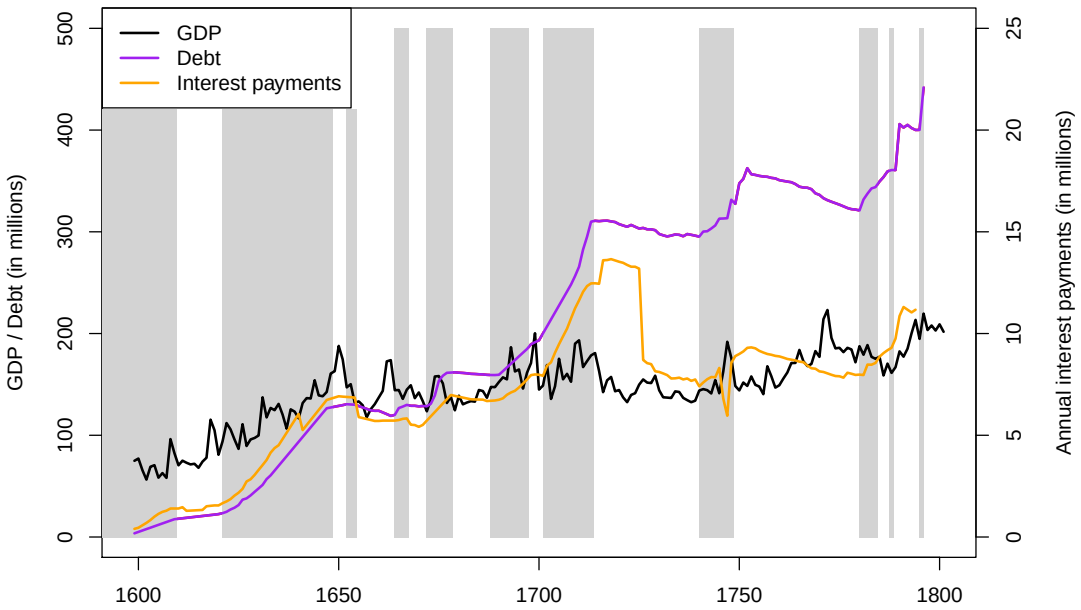
In the first part of this paper, I have presented a descriptive overview of the housing market in Amsterdam, showing that Amsterdam has experienced various boom-bust cycles which share the same empirical characteristics as modern housing booms and busts. However, contrary to modern markets, mortgage markets seem unable to explain any of the variation in house prices, given their disappearance in the late 17th century. In this part of the paper, I aim to identify other potential causes of these booms and busts.

For practical reasons, I will not be able to give a full explanation of each boom-bust cycle that appeared durng the 200 years covered in this study: most of this is left for future research. A detailed anatomy of each boom-bust cycle could easily fill a book and it would be audacious to expect that a single paper could do so, particularly when comparing to the enormous literature on the US boom-bust cycle. Instead, I will focus primarily on the boom-bust cycle in the first half of the 18th century, and the two main factors that I argue were responsible for it: excess cash liquidity of investors, and speculative buying. Contrary to the boom-bust cycle in the 17th century, which coincided with the enormous expansion of Amsterdam, and the bust at the end of the 18th century, which marked the end of Amsterdam's importance, the first half of the 18th century has been considered a period of stagnation of the Dutch economy (De Vries and Van der Woude, 1997). As a result, the relative stability of standard demand and supply factors makes it easier to identify alternative causes of this particular cycle.

4.1 Public debt, investor liquidity and speculation

Before linking investor liquidity to house prices, it is important to take a closer look at the evolution of the public finance of Holland and its crucial role in investment. A wide range of studies, including Dormans (1991); De Vries and Van der Woude (1997); Liesker and Fritschy (2004); Gelderblom and Jonker (2011), have explored the evolution of Dutch public finance and its impact on economic growth and investment. Figure 5 reports the evolution of annual public debt (Dormans, 1991) and interest payments (Liesker and Fritschy, 2004), relative to total Holland GDP (Van Zanden and Van Leeuwen, 2012). Shaded areas cover years when the Dutch Republic was engaged in war. Most Holland debt was owned by domestic investors.

Figure 5: The evolution of Holland public debt



Notes: The large drop in interest payments in 1726 is the result of the direction deduction of the bond tax. Most of this tax was already introduced in 1687, but was prior to 1726 not directly deducted from interest payments

In line with the existing historical literature, the figure shows various important characteristics of Holland public debt. First, and most notably, debt-to-GDP ratios rose substantially in the 17th century and early 18th century, increasing to roughly 200 percent of GDP. This ratio stayed relatively stable for most of the 18th century, and only started

to increase further in the 1780s and 1790s. In 1795, Holland debt was nationalized.[23] Second, the growth in public debt can mostly be attributed to warfare. Given the high costs of warfare, it was necessary to issue large sums of debt. It is important to note that most of these wars had a limited direct impact on the Holland economy: they took place at sea or at the borders of the Dutch Republic, far away from Amsterdam.[24] Accordingly, De Vries and Van der Woude (1997) argue that their main impact was the increasing debt burden: to finance interest payments, taxes had to be raised substantially, providing a strong drag on future growth (in spirit of Reinhart and Rogoff, 2009). Third, curiously, Holland managed to decrease the actual interest rate payments on its debt, despite the large increase in the debt-to-GDP ratio. Unfortunately, the complicated structure of Dutch public debt and the variety of taxes imposed make it difficult to define a single bond yield series (see Gelderblom and Jonker, 2011). However, Gelderblom and Jonker (2011) show that issuing rates of Holland annuities dropped from 8.5 percent in 1600 to just 2 percent at the end of the 17th century. At the start of the 18th century, bond yields for these annuities fluctuated between 2 and 3 percent. They argue that bondholders were willing to accept these low interest rates, because they had substantial savings, and had limited opportunities to invest these elsewhere after the economy slowed down in the second part of the 17th century. Hence, much of the growth in Holland public debt was made possible because wealthy citizens preferred to save their accumulated wealth using domestic government bonds. As a result of this preference, bondholders rarely redeemed their debts (bondholdings could always be redeemed at par) and reinvested their interest payments in new bond issues whenever possible (De Vries and Van der Woude, 1997; Gelderblom and Jonker, 2011).

The combination of these aspects of Dutch public finance has important implications for the demand and supply of other financial assets. If debt levels were expanding, bondholders could reinvest their interest payments in new bond issues. If this was not possible, or only partially, investors had to invest their money elsewhere. These considerations became increasingly important throughout the 17th and early 18th century, as debt levels

[23] Dutch debt increased strongly after 1795, and when The Netherlands became an official part of France (1810-1813), bondholders had to accept that only one third of interest was paid out. Debt was restructured in 1814, with further cuts on interest payments

[24] In his travels to Holland in 1729, Montesquieu even noted that the economy of Amsterdam was more "flourishing during war than during peace" (de Montesquieu and de Montesquieu, 1894)

and annual interest payments expanded, while the number of profitable investment opportunities disappeared. Figure 6 plots the developments in annual net flows towards Holland bondholders (that is, interest payments plus changes in total debt) relative to house prices and stock prices (from Golez and Koudijs, 2017). The first time that bondholders started receiving substantial sums of money was in the 1650s and early 1660s, after the end of the Eighty Years War. De Vries and Van der Woude (1997) hypothesize that much of this money might have funded the large construction boom in Amsterdam in this period, identified in Knotter (1987), and lead to substantial house price increases. A second period of large net transfers to bondholders occurred in the 1680s. Again, the resumption of the extension of Amsterdam might have absorbed part of investors increased demand for other assets (Abrahamse, 2010).

The most significant change in public debt policy took place in 1713. Following the Nine Year's War and the War of the Spanish Succession, which ended in 1713, public debt had reached over 300 million guilders. The fiscal capacity to pay for the debt service had been reached. Holland was, in the words of contemporary politician Van Slingelandt, 'burdened to sinking' (Wagenaar, 1767). The government realized there was no other option than to start reducing debt levels, and to refrain from further engagement in warfare. As a consequence, bondholders would start receiving large sums of cash without possibility of reinvestment in new bond issues.

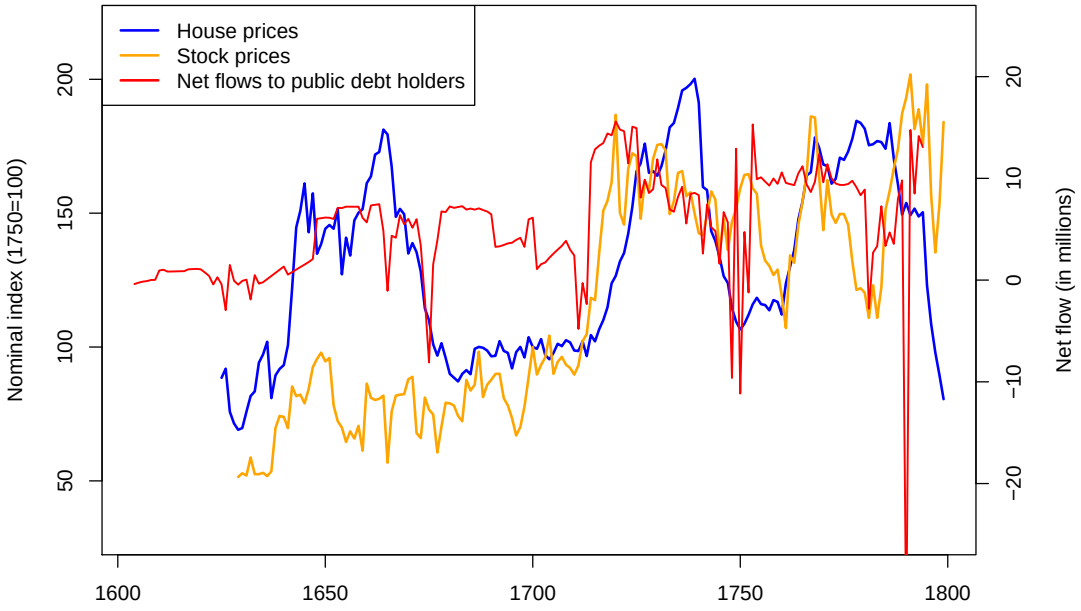
This change provides an historical experiment to assess the impact of a large exogenous liquidity shock on real estate prices. First, most bondholders lived in Amsterdam and thus could also invest in its housing market. Second, the decision to stop borrowing money was exogenous to the state of the housing market, which had been stable for 30 years: it was the result of high public debt. Third, while the 17th-century changes in flows to bondholders coincided with the extensions of the city, there were no changes in housing demand or supply that could distort the housing market, or absorb the additional liquidity, in the 18th century. Population did not move much between 1714 and 1740 (Van Leeuwen and Oeppen, 1993), and tax records indicate that the supply of housing stayed constant.[25] Fourth, because homes were not financed using mortgages in this

[25]Data from Knotter (1987) indicate that there was still active construction going on in the 1720s, while the number of homes did not expand. Most of this investment was likely related to the renovation and beautification of homes on existing parcels.

period, the changes in the bond market did not affect the market for mortgage financing, as would be the case in modern markets. Fifth, contrary to the 17th century, other domestic investment opportunities were much more limited as the economy had stagnated.

Between 1714 and 1740, when the War of the Austrian Succession started and Holland resumed borrowing large sums of money, about 294 million guilders flowed to Holland bondholders. During the same period, house prices doubled, while about 110 million guilders of real estate changed hands. Based on mean sales prices and the estimated number of private properties in Amsterdam, the total value of Amsterdam real estate increased by about 75 million guilders. This suggests that many of the flows to bondholders were invested in Amsterdam real estate, and that, absent large changes in fundamentals, this liquidity shock did nothing but inflating asset prices. Correspondingly, when the first major new debt issues occurred in 1740 house prices started falling.

Figure 6: House prices, stock prices and net flows to bondholders



Although the Amsterdam housing cycle of 1713-1750 coincided perfectly with the change in debt policy, there are two potential arguments why the large flows of money towards bondholders might not been enough to generate such an enormous boom-bust cycle. First, when in the 1750s Holland again attempted to decrease its debt, this did not lead immediately to a large housing boom, and the eventual boom was much smaller than the boom between 1713-1739, despite similar levels of interest payments. One reason for

this is that Dutch investors could invest in a much broader set of financial assets in the 1750s, and increasingly invested their money abroad (e.g Carter, 1953). For example, Dutch investors financed much of the Seven-Year-War between 1756 and 1763 (Schnabel and Shin, 2004). Second, and most importantly, while stock prices rose initially much faster than house prices, they peaked already in 1720 and started to decline slightly afterwards. To understand why house prices continued to rise until 1739, while stock prices stagnated or even declined, it is important to add one more factor: speculation.

4.1.1 Speculation

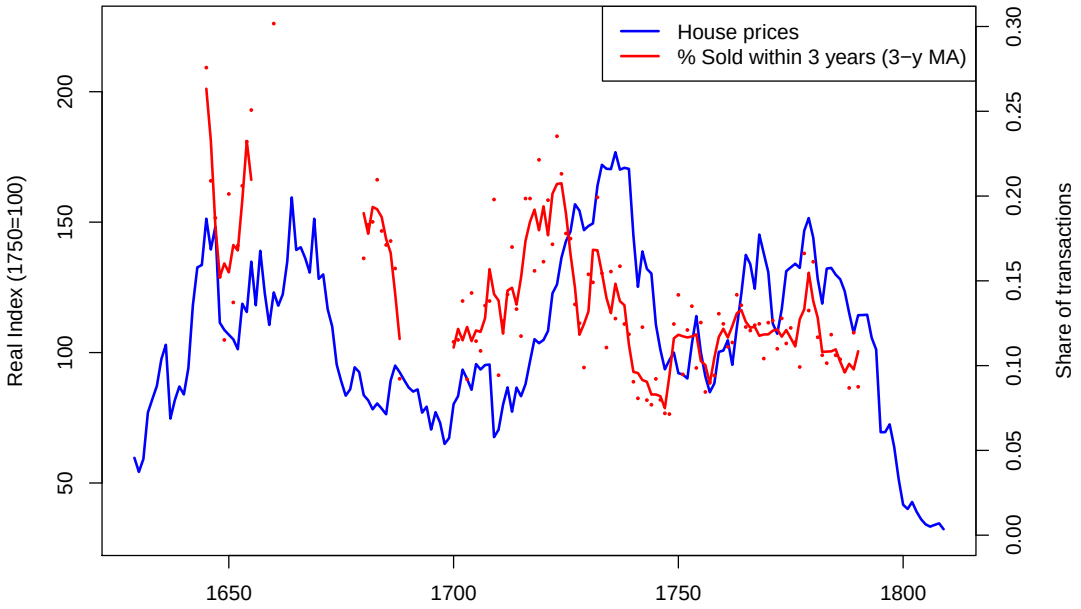
Existing studies have frequently linked the dismal state of public finances in the 1710s to the build-up of speculative asset price booms. Most notably, the Mississippi and South Sea Bubble in France and Britain are often attributed to large-scale debt-to-equity conversions, that followed high levels of debt after the War of of the Spanish Succession (e.g. Temin and Voth, 2004). Although the Dutch Republic did not engage in such a conversion, and was much less affected by the 1720 bubble, it did experience significant speculative trading in newly chartered insurance companies (Frehen et al., 2013). The burst of the 1720 bubble brought an end to all of this, and might have very well restrained investors from further equity investments, as also hypothesized in Frehen et al. (2013).

Although the Amsterdam housing market, consisting of real assets, was certainly much less speculative than stock investments had been in 1720, it is still very well possible that speculators might have helped to push up prices. For the modern housing bubble, Piazzesi and Schneider (2009) and DeFusco et al. (2017) show how the presence of speculative or optimistic buyers can generate a housing boom. Mian and Sufi (2018) suggest that credit supply expansion might have fueled speculation, and that the combination of these events triggered the large mortgage default crisis.

Figure 7 provides an estimate of the share of speculative buyers ('home flippers') in the market. To construct this estimate, I used the repeat-sales pairs to identify for each year the share of purchased homes that would be sold within three years (if sufficient data was available).[26]

[26]To avoid strong sensitivity to outliers and missing data, I truncated holding periods at 40 years, and adjusted for missing years based on the distribution of holding periods over the entire sample. If any data was missing in the year of sale or in the first three years after the sale, I did not construct an

Figure 7: Share of properties sold within 3 years of purchase



Interestingly, the number of speculative buyers in the market increases substantially during the boom of 1713-1740, while there are barely any changes in the number of speculative buyers during the second boom-bust cycle in the 18th century. Hence, the combination of speculative buyers with excess liquidity might have been part of the reason why house prices rose strongly and directly after the change in public debt policy in 1713, and much less after the change in the 1750s. Second, there also is substantial evidence for speculative purchases in the 17th century. We should be more careful in interpreting these: both speculation cycles coincide with the expansion of Amsterdam, such that speculative purchases might also be related to construction sites (this has been suggested in Abrahamse, 2010).

4.2 A simple empirical model of house prices and turnover

Together with the stylized facts presented in the previous section, the analysis so far has yielded five important insights to further understand the drivers of housing cycles in historical Amsterdam. First, changes in prices and turnover seem positively related to each other, although this is not very consistent. Second, while prices have evolved

estimate. I also did not construct an estimate if more than 20 years of data are missing in the first 40 years after the sale.

similar to fundamentals like rent prices and wages over the very long-run, they do not seem to have played a large role in the actual booms and busts. Third, the provision of mortgages cannot have played a role in the build-up of house prices booms, since mortgage markets were negligible for most of the sample period. Fourth, changes in public borrowing strongly impacted the liquidity of investors, and likely also influenced house prices. Last, speculation might have played an important role in strengthening some of the booms and busts in Amsterdam.

In this section, I develop and estimate a simple empirical model that accommodates for these observations. In line with existing empirical work on the price-turnover relationship (e.g. Clayton et al., 2010; Ling et al., 2015; Dröes and Francke, 2017), I have modeled house prices (HPI) and (non-foreclosure) turnover (TO) using a bivariate VAR in differences.[27] The dependent variables are the log-differenced nominal house price index and ordinary turnover, which both have a straightforward economic interpretation. The lag length in each VAR was selected based on the Bayesian Information Criterion (BIC), which always favored the VAR(1). Allowing for exogenous variables, I estimate the following model:

$$\begin{bmatrix} \Delta log(HPI)_t \\ \Delta log(TO)_t \end{bmatrix} = \begin{bmatrix} \beta_1' \\ \beta_2' \end{bmatrix} \begin{bmatrix} \Delta log(HPI)_{t-1} \\ \Delta log(TO)_{t-1} \end{bmatrix} + \begin{bmatrix} \gamma_1' \\ \gamma_2' \end{bmatrix} \begin{bmatrix} log(\frac{IntInc}{Pop})_t & \Delta \frac{Debt}{Pop} & \mathbf{x}_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} \quad (4)$$

The assumed endogeneity of house prices and turnover is consistent with various theoretical models of the housing market, including models building on speculative or optimistic investors, that postulate a dynamic relationship between prices and turnover. The lagged coefficient on house prices changes allows for momentum effects. If these relationships indeed arise endogenously, we should not expect their significance to be affected much by the inclusion of control variables that might correlate with both prices and turnover.

Based on the discussion in the previous subsection, the two most important exogenous

[27] Based on the Augmented Dickey-Fuller test (with drift term), the null of a unit root could not be rejected for the house price series, while it was rejected for the turnover series, although only at the ten percent level. Note that including the level rather than the difference in logged turnover does not significantly alter the results presented here

variables relate to the developments in flows to bondholders. The amount of interest payments influences the annual sum of cash bondholders have available for investment. The change in debt levels determines whether these can be reinvested in newly issued bonds. Both variables are therefore included as controls.[28] To account for changing market size, I express both in per capita levels. Other control variables include log differences in consumer prices and day wages (from Van Zanden, 2009), stock prices (Golez and Koudijs, 2017), GDP per capita (Van Zanden and Van Leeuwen, 2012) and population (Nusteling, 1985; Van Leeuwen and Oeppen, 1993). All these variables were included in differences as the null of a unit root could not be rejected for their levels. The last control variable is the (stationary) level of construction cost (Van Zanden and Van Leeuwen, 2012). For debt changes and the log of interest payments, the null of a unit root could be rejected as well. Descriptive statistics of all these variables are reported in Table 2.

Table 2: Descriptive statistics, bi-annual, 1629-1794

Statistic	N	Mean	St. Dev.	Min	Max
Δlog(HPI)	83	0.008	0.079	−0.207	0.282
Δlog(TO)	83	0.003	0.155	−0.441	0.484
log(Interst Income PerCap)	83	2.255	0.276	1.531	2.809
Δ Debt PerCap	83	2.724	5.317	−4.229	28.852
Δ log(GDP PerCap)	83	0.008	0.089	−0.227	0.231
Δ log(Population)	83	0.006	0.015	−0.023	0.049
log(ConstrCost)	83	4.626	0.077	4.421	4.800
Δ log(CPI)	83	0.004	0.091	−0.195	0.312
Δ log(Wages)	83	0.003	0.010	−0.013	0.047
Δ log(Stock Prices)	82	0.015	0.105	−0.202	0.283

I estimate the VAR(1) using two year differences, as two-year differences provide a substantially better fit compared to one-year differences. This is not merely due to the increased precision of the indices at the two-year level. For the United States, DeFusco et al. (2017) also report that the predictability of turnover to house prices is stronger for two year differences rather than one-year differences. For data reasons, I exclude the period before 1628, when house price developments are imprecisely estimated and stock

[28] Although there is no proper series of bond yields in this period, including (insignificant) interpolated nominal interest rates from Holland bills and other interest rates did not change any of the results

prices not available, and the period after 1794. After 1794, data on debt changes and interest payments are missing.

Table 3 reports the estimation results of the VAR(1), both in nominal and real terms. Prices are deflated using the CPI. In both nominal and real terms, there is highly significant evidence for house price momentum. Second, there are strong relationships between house prices and turnover, in particular in nominal terms: a 1% change in turnover increases next periods house price growth by 0.15%, while a 1% increase in house prices reduces turnover by 0.65%. For house price changes, the fit of the model is very good: despite significant periods of missing data in the 17th century, the nominal model explains more than half of the variability in house price changes. It should not be surprising that momentum and price-turnover effects are much weaker in real terms. As can be seen from Table 2, about half of the volatility in real prices changes is the result of consumer price volatility, as food prices were highly volatile in the early modern period. Note that this also inflates the fit of the model substantially, as consumer prices are used to deflate variables on both sides of the regression equation. As a result, the wage coefficient turns out highly significant in the real regression, as nominal wages are the least volatile of all variables (see Table 2).

There are only two exogenous variables that help explain house prices changes in both the nominal and real model: the flows to bondholders. Consistent with the descriptive discussion in the previous subsection, annual interest payments increase house prices. This effect is economically large: a doubling of annual interest payments per capita, as happened between the 1680s and 1710s, implies that house prices should grow by an extra 4.7 percent per two years. Such an effect can be cancelled out if debt increases substantially as well, consistent with the reinvestment hypothesis: it would require 15 guilders of net debt issuance per capita. Issuances of that size were rare, but did occur several times during major wars. Beyond population, which enters with the predicted sign, none of the other control variables seems to have had significant effects on house prices. Last, none of the control variables is significantly related to turnover. Generally, it is much more difficult to explain developments in turnover compared to changes in house prices.

Table 3: 2-year VAR regressions, 1610-1794

	Dependent variable:			
	Nominal prices		Real prices	
	Δlog(HPI)	Δlog(TO)	Δlog(HPI)	Δlog(TO)
$\Delta\log(\text{HPI})_{-1}$	0.343^{***}	-0.727^{***}	0.167^{**}	-0.267
	(0.092)	(0.243)	(0.065)	(0.210)
$\Delta\log(\text{TO})_{-1}$	0.147^{***}	-0.116	0.118^{***}	-0.115
	(0.044)	(0.116)	(0.036)	(0.117)
Constant	0.498	-0.905	0.421^{***}	0.384
	(0.567)	(1.497)	(0.142)	(0.461)
log(IntInc)	0.069^{**}	0.129	0.091^{***}	0.083
	(0.032)	(0.084)	(0.031)	(0.100)
DebtChange	-0.003^{**}	-0.003	-0.032^{**}	-0.019
	(0.001)	(0.003)	(0.013)	(0.042)
$\Delta\log(\text{GDPcap})$	0.125	0.001	0.158	-0.069
	(0.084)	(0.223)	(0.097)	(0.314)
$\Delta\log(\text{Pop})$	1.247^{*}	2.373	1.971^{***}	1.864
	(0.677)	(1.786)	(0.544)	(1.767)
log(ConstrCost)	-0.141	0.132	-0.137	-0.096
	(0.117)	(0.309)	(0.089)	(0.290)
$\Delta\log(\text{CPI})$	-0.047	-0.016		
	(0.091)	(0.240)		
$\Delta\log(\text{StockPrices})$	-0.004	0.059	-0.029	0.168
	(0.067)	(0.176)	(0.066)	(0.215)
$\Delta\log(\text{Wages})$	0.917	2.009	1.139^{***}	-0.286
	(0.848)	(2.238)	(0.125)	(0.405)
Observations	82	82	82	82
R^2	0.527	0.138	0.778	0.056
Note:				*p<0.1; **p<0.05; ***p<0.01

4.2.1 Examining temporal variation

So far, I have implicitly assumed that the estimated coefficients should be fixed over time. However, there are various reasons why there might be structural changes in the estimated relationships. First of all, if dynamics between prices and turnover are driven by speculative forces, they are likely much stronger during boom-bust cycles, when such considerations play a more important role compared to 'quiet' periods. Second, periods with constrained housing supply, most notably during the first part of the 17th century, might make house prices much more sensitive to changes in demand fundamentals. Third, the impact of flows to bondholders on house prices might have changed with the size and concentration of bond-holdings, as well as the availability of other investments. Last, from a statistical point of view, measurement error might lead to noisy estimates in periods where data is interpolated, in particular during the 17th century.

To examine temporal variation, I estimate VAR models over rolling windows of 50 years. The period of 50 years is substantially shorter than the full sample, but still leaves sufficient observations (25 per window) to obtain significant coefficients. Also, the longest house price cycles last about 50 years, such that one window can cover the entire cycle. To reduce overfitting, I use the set of five nominal variables that leads to the highest average adjusted R-squared: log differences in house prices, turnover and population, as well as log interest rate income per capita, and net debt changes per capita. In addition, I exclude the period before 1637, given that turnover data is entirely missing between 1632 and 1637. To get an indication how much of the momentum and price-turnover effects might be due to persistence in flows to bondholders and population changes, I also report unconditional rolling window-regressions (for these, I use the entire sample period).

Figures 8, 9, and 10 plot the coefficients of the rolling window regressions.[29] The year on the x-axis represents the median year in the rolling window sample, and the thickness of the line indicates the significance: the thickest lines imply significance at the 5 percent level, while medium thickness represents significance at the 10 percent level. For reference, the figures also report developments in house prices and turnover.

[29]Unconditional regressions for turnover are not reported, as these are virtually the same as the conditional ones

Figure 8: Rolling windows, house prices, no controls

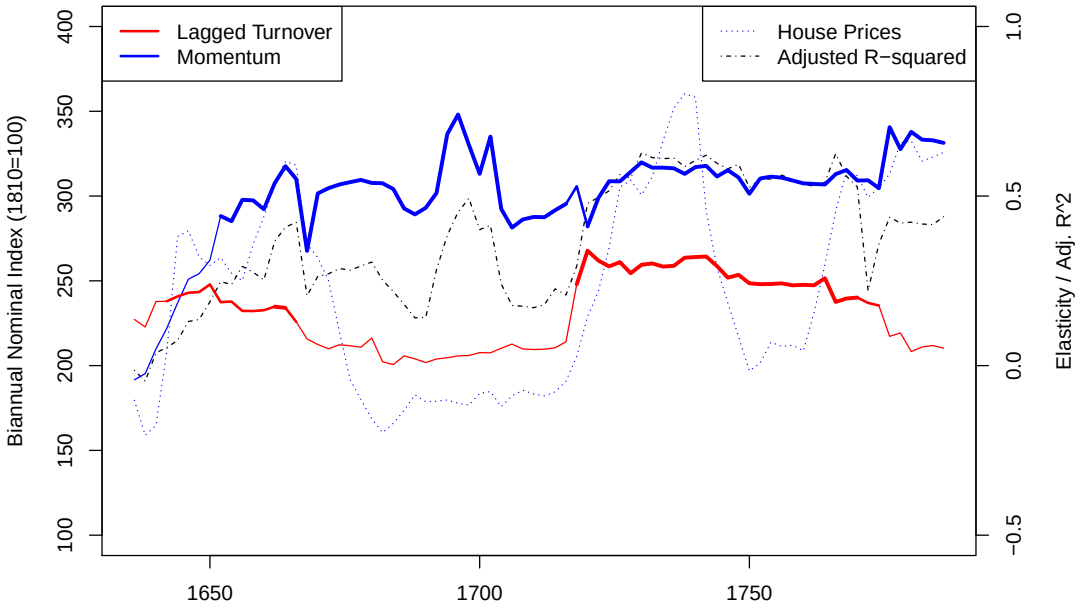


Figure 9: Rolling windows, house prices, with controls

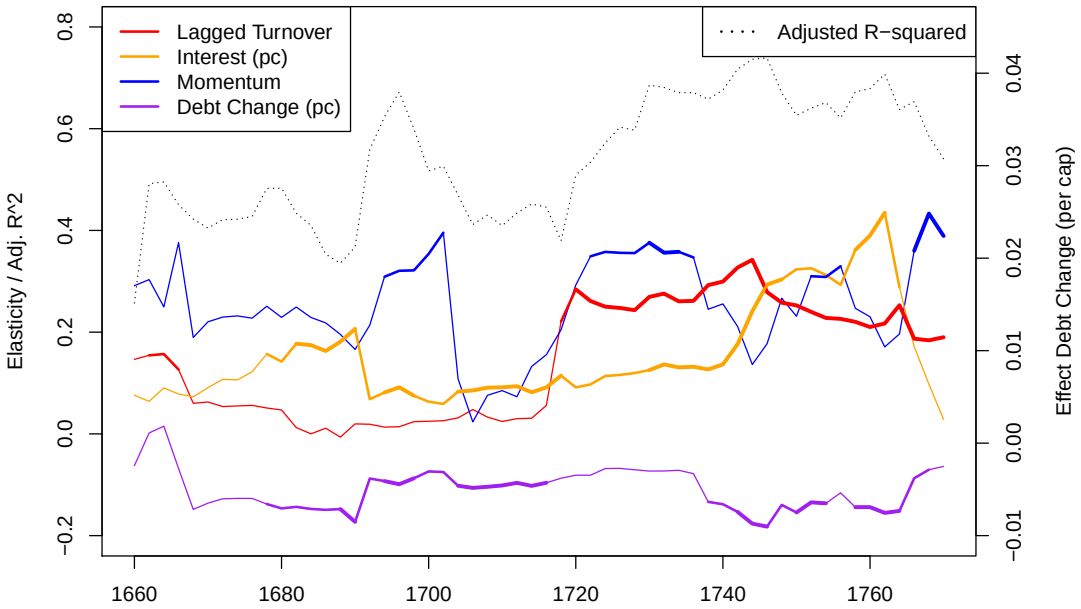
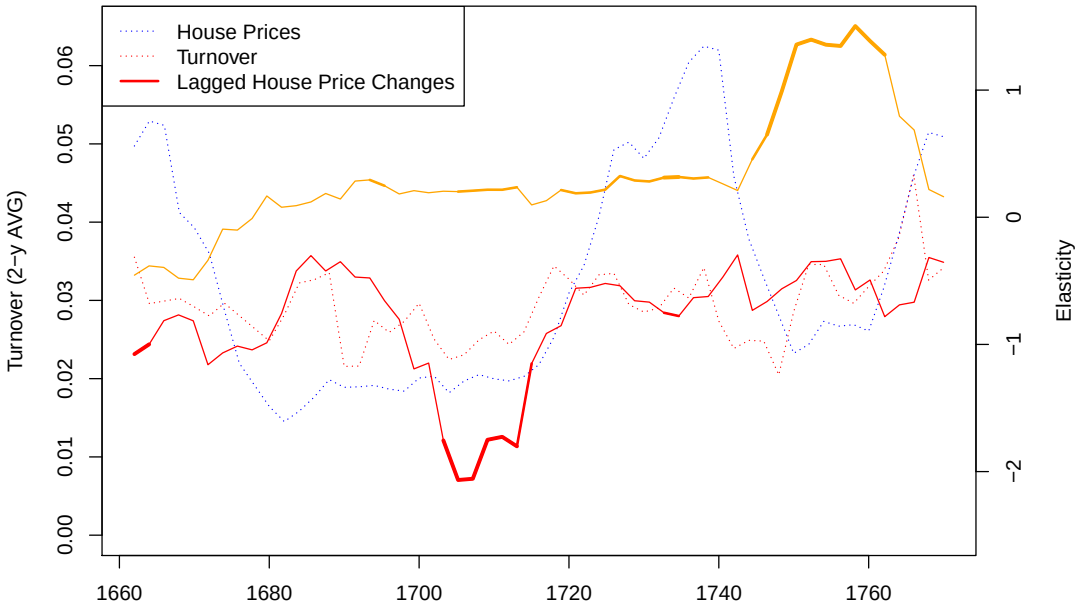


Figure 10: Rolling windows, turnover, with controls



The first panel panel shows that unconditional momentum effects are relatively stable over time, and almost consistently present in the sample, in line with Table 1. Only in the first half of the 17th century there do not seem momentum effects, but this is most likely the result of measurement error in the indices. This might also explain why the effect of lagged turnover on house prices is smaller in the 17th century, as turnover data is often missing in this period. Generally, lagged turnover seems a strong predictor of house prices, in particular during strong boom-bust cycles. If momentum effects and price-turnover relationships are merely driven by speculation and sluggish responses of prices to market conditions, we should not expect their effects to be modified by the inclusion of control variables. While this seems to hold for the relationship between house prices and turnover, it is not the case for house price momentum: Figure 9 shows that much of the momentum effect results from the persistence in flows to bondholders, and to a lesser extent from persistence in population changes, which are omitted in the figure.

Figure 9 also shows that flows to bondholders only became a significant factor at the end of the 17th century, when interest payments had become increasingly important for total liquidity, and other investment opportunities limited (De Vries and Van der Woude, 1997). However, as long as debt increased significantly, debt changes limited house price growth: the significance of the change in debt levels coincides closely with the increases

in public debt presented in Figure 5. The combination of interest payments and changes in public debt levels seems to particularly relevant for the windows that are centered around the 1700s and 1710s, when none of the other variables enters significantly. This supports the hypothesis that the take-off of the housing boom in the 1713-1739 period can be attributed to the change in debt policy. Similar considerations seem important as well around 1760, when the second large boom period starts.

For the rolling windows centered between 1720 and 1740, which cover the entire boom-bust cycle, there is still significant evidence for momentum effects, together with positive predictability of prices with turnover. Such dynamics are in line with house prices models that include elements of optimism or speculation (Piazzesi and Schneider, 2009; DeFusco et al., 2017). While the take-off of the boom might be attributed to debt policy changes, speculative purchases might have helped to further inflate it, eventually resulting in a very large bust when the government started borrowing again.

The persistence of the price-turnover effect for the remainder of the 18th century also supports theories that assume sluggish adjustment of prices to changes in market conditions (e.g. Berkovec and Goodman, 1996; Genesove and Han, 2012), as well as the potential presence of loss aversion Genesove and Mayer (2001). It is not yet entirely clear why the price-turnover effect persists almost the entire 18th century, while being insignificant for most of the 17th century. Potentially, this is related to measurement error in turnover before 1700.

As also evident from the fixed regressions in the previous subsection, turnover is substantially less predictable than house prices. Generally, house prices negatively predict changes in turnover, but these effects are highly variable over time and only significant in a handful of cases. This contrasts to the predictability of house prices: despite the simplicity of the model, it explains on average over half of the changes in house prices. During the 18th century, the adjusted R-squared even increases to over seventy percent.

5 Conclusion

Our journey through the Amsterdam housing market has yielded several new insights. House price booms and busts are nothing new under the sun: in this paper I have doc-

umented the existence of significant boom-bust cycles in Amsterdam in the pre-modern era. Although the organization and financing of the Amsterdam housing market was different compared to modern markets: there were no fiscal benefits to home-ownership, the mortgage market was small to non-existent, and explicit monetary policy did not yet exist. Despite the absence of these factors, Amsterdam went through three large boom-bust cycles which were characterized by the same features as those in modern markets: momentum in house prices, excess volatility of prices relative to fundamentals but reversion over the longer run, and a price-turnover relationship. This suggests, somewhat paradoxically, that booms and busts might be 'fundamental' to the nature of housing markets: although housing cycles might each have very different reasons, they have occurred as far as historical data can stretch.

The absence of mortgage markets for most of the boom-bust cycles has important implications for current debates. Inspired by the recent US housing bubble, much of the literature has focused on whether changes in mortgage credit can help to generate boom-bust cycles, and it is beyond doubt that such considerations are relevant. However, the case of Amsterdam shows that mortgage credit booms are not a necessary condition for large housing booms to appear. This implies we should also be concerned about housing booms when mortgage credit is not expanding. This becomes particularly relevant in relation to the main cause of the 1713-1739 boom identified in this paper: excess liquidity. When Holland debt did not expand anymore, bondholders received large amounts of cash interest payments that they could not save in Holland bonds. Much of this was invested in Amsterdam real estate, and it did nothing but inflating asset prices. Although 18th century Amsterdam was still very different from the modern economy, we can draw some parallels to current conditions. After the recent crisis, the combination of low interest rates and unconvential monetary policy has led to large increases in the monetary liquidity available for investment, while asset prices have increased substantially. Correspondingly, much of the current surge in Amsterdam house prices (and in many other cities), has been attributed to increased demand from investors who are looking for profitable investment opportunities (e.g. Hekwolter et al., 2017). However, contrary to the 18th century, it is much more difficult to identify the price effects of this increased demand, given the endogeneity of monetary policy and the fact that house price developments are highly

connected to the state of the general economy. What the historical Amsterdam case shows, is that such episodes are able to trigger large and prolonged increases in house prices, which might eventually lead to a bust when conditions change.

This paper also has imported implications for the debate on the drivers of the price-turnover relationship. My empirical findings indicate there are two components that are possibly driving the price-turnover relationship in Amsterdam. First, house prices respond sluggishly to demand, while turnover responds much quicker. This creates a lead-lag relationship between turnover and house prices, which is strongest at the two year level, consistent with Berkovec and Goodman (1996); Genesove and Han (2012); DeFusco et al. (2017). Changes in turnover positively predict changes in house prices, while to a lesser extent house price changes negatively predict future turnover. Second, the share of short-term investors increases significantly during the initial phase of booms, which suggests that speculators, potentially attracted to the market by predictable price increases, might have helped to further build up house price booms and generate momentum effects, as in Piazzesi and Schneider (2009) and DeFusco et al. (2017). This effect is most pronounced during the boom and bust in the first half of the 18th century. The combination of speculative investors with excess liquidity also relates to the findings of Mian and Sufi (2018). In their paper, shocks in the supply of mortgages can induce speculation, which together led to the bubble in US house prices in the 2000s. In this paper, the large cash flows towards bondholders are the suggested trigger of speculation. However, in both paper it is not possible to identify exactly how much speculators contributed to the boom. Third, the absence of mortgage markets in Amsterdam indicate that models that build on mortgage credit constraints, as in Stein (1995) and Ortalo-Magne and Rady (2006), cannot account for the observed price-turnover relationship. Last, although beyond the scope of this paper, it is also very well possible that loss aversion (Genesove and Mayer, 2001) or other forms of history dependence (Bracke and Tenreyro, 2016; Hong et al., 2016) contributed to aggregate dynamics in prices and turnover.

There still remains one important, but highly sensitive issue that needs to be addressed: can these boom-bust cycles be classified as traditional bubbles? Of course, much of the answer to this question depends on what we define as a bubble. Since the 18th century, the traditional Dutch word for a bubble has been 'windhandel', metaphorically

meaning that only wind is being traded (Leemans, 2017). Of course, the Amsterdam real estate market was much more than 'wind': despite strong booms and busts, most of the variability in individual transaction prices was reflecting different housing quality rather than changing market prices. However, based on rent-price and price-income ratios, Amsterdam prices provide strong indications for bubbles: house prices strongly diverted from fundamentals during booms, but quickly reverted during busts. However, much of these deviations have rational explanations. When bondholders could not reinvest their accumulated wealth into government bonds, there were limited alternative investment opportunities available. As a result, bondholders might have reduced their required return on alternative investments, implying that a simple change in the discount rate can be responsible for most of the increase in prices. Over the long-term real estate might have been considered a relatively safe investment: if homes were held long enough, the received rental yields would likely exceed the money lost in a potential housing market crash. This line of reasoning would also explain why deviations from rents and income could last for such a long period of time: each of the housing cycles spanned about 40 to 50 years, much longer than modern cycles or bubbles.

Accordingly, increases in the number of speculative buyers provide the strongest evidence for the existence of 'bubbly' components in the boom-bust cycle between 1713-1750. Some investors might have indeed realized that real estate was overvalued: McCants (1997) describe how the Amsterdam Burgerweeshuis, the largest institutional investor, did not make any investments in the real estate market after 1712, and started to shift its asset portfolio towards financial securities (see also Gelderblom and Jonker, 2009). In addition, the decline of 50 percent in gross rental yields must have at least pulled away some investors from further real estate investments. However, despite these concerns, investors continued to buy properties in the Amsterdam housing market, until the boom went bust and prices reversed. Hence, the 1713-1750 cycle has at least some elements that make it a contender for the title of 'earliest documented housing bubble'. Hopefully, it does not keep that status for too long: there still is a wealth of historical real estate data remaining to be explored in future research, and undoubtedly some of these might help to improve our understanding of housing markets.

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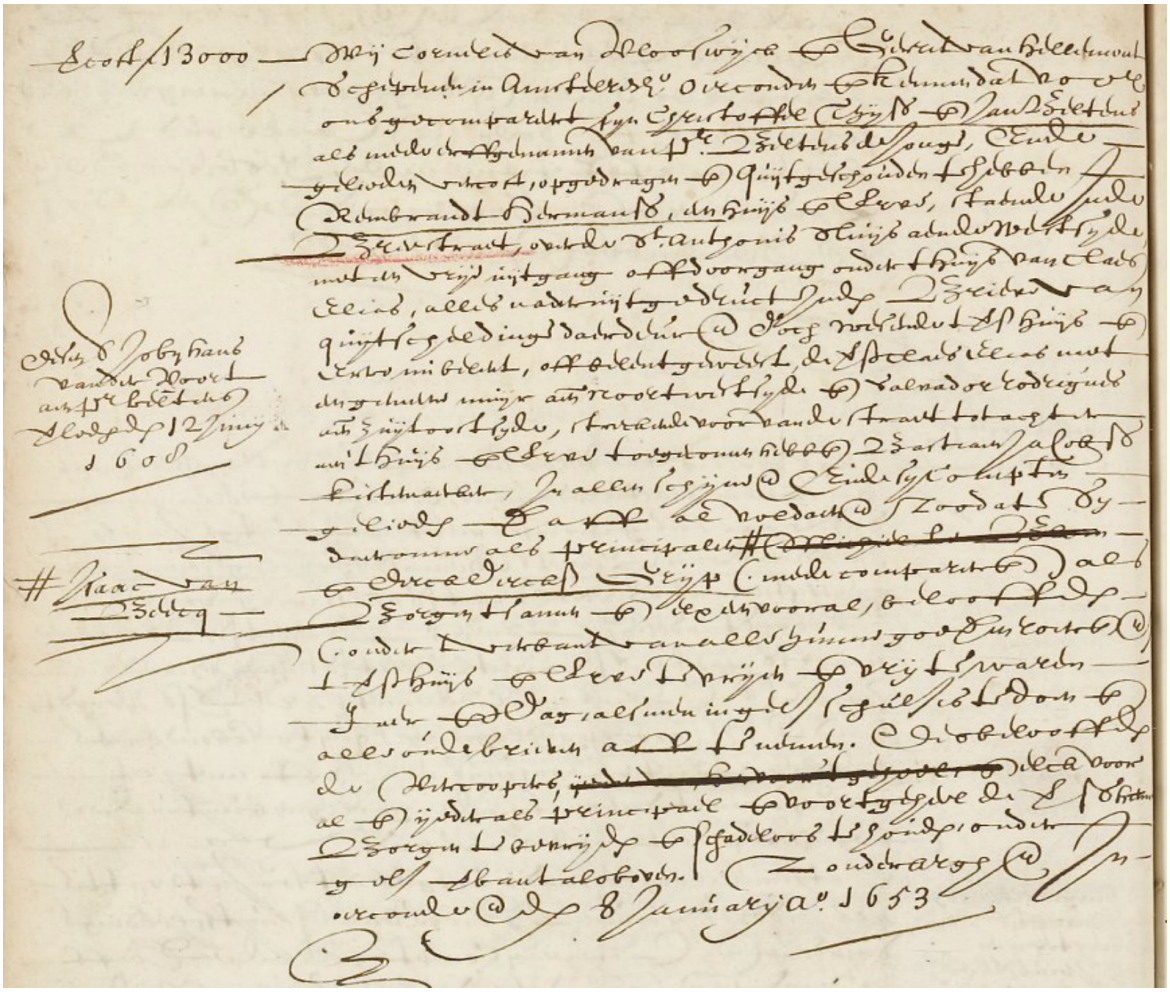
Appendix A: Example of act with transcription

Figure 11 contains an example of an *ordinaris kwijtschelding*, which formed the main bulk of data. The form was standardized. This particular example relates to the purchase of property by Rembrandt Hermansz, the well-known painter, from the heirs of Pieter Beltens de Jonge. The (approximate) transcription contains in bold the data that is also included in the digitalized dataset.

Figure 11: Property transfer act, ACA 5062, inv. nr. 45, page 195v



Transcription:

In margin: sold for fl. **13000**

We, Cornelis van Vlooswijck and Gerrit van Hellemont, alderman in Amsterdam, write

and acknowledge that for us have appeared Christoffel Thys and Jan Beltens as **heirs** of **Pieter Beltens de Jonge**, and have sold and remitted to **Rembrandt Hermansz** a **house and yard** standing on the **Breestraat, over the Sint Anthonis sluice**, on the west-side, with a free exit or pass-through to the house of Claes Elias, as has been explained in the acts of remittance about those, and this being the house and yard that is or was next to that of Claes Elias, with the entire wall on the north west side and that of Salvador Rodrigues on the south east side, and reaches from the street until the house and yard that belongs to Bastiaen Jacobsz Kistemaecker. And those that have appeared have already committed to the terms, and the principal has brought Isaac van Beecq and Dirck Dircks Grijp (jointly appeared) as joint guarantors, and each has promised with all their movable property that this house and yard has and will be remitted year and day, as one has promised to do, and to remove older acts. This is what the sellers have each promised, and the principal has also promised to keep the guarantors free from losses under the agreements written above. Entered **January 8, 1653**.

Appendix B: Procedure to find repeat-sales and estimate turnover

Identifying repeat-sales

This procedure outlines the three steps taken to identify repeat-sales pairs. In the first step, I aim to identify transaction pairs based on the names of buyers and sellers. The name of the original owner is always mentioned on each transaction, even if her or she is deceased, so a seller should have been listed as a buyer in an earlier recorded transaction, as long as the home has been transacted previously and the register is not missing. To reduce the number of potential matches, I search for buyers and sellers with the same name (and sell date after buy date) for each street separately. Streets were likely always entered correctly, and could only change if a home on a corner changed its main door to face the other street, which would indicate a renovation and should therefore be excluded anyhow. There are four caveats here. First of all, names might not be spelled exactly the same due to errors in the transcriptions or registrations, or because a person did not

tell exactly the same name on both occasions. Second, multiple persons can share the same name. Third, a person might have owned multiple properties on the same street. Fourth, a property might have changed in quality

To avoid missing matches or making errors, I sort names alphabetically for each street, and compute for each person the Jaro-Winkler distance (Winkler, 1999) with the two persons around it in the list. The p-value is set at 0.1.

A pair is matched automatically in case the following four conditions hold. First, the buyer and seller should have JW-distace of less than 0.1 for both the first name and the last name. Second, the sale should take place after the purchase. Third, there should be not other buyer and seller on the street with a similar name. This is identified by examining the surrounding names. If any of these has a JW-distance of less than 0.15 for both first name and last name, no match is made. Fourth, the type of property that is being sold should be the same. Although no detailed quality information is available, the sale acts list what type of good is being sold, such as land, house and land, warehouse and land, shipyard etc. This avoids large quality changes among repeats.

In the second step, I re-evaluate the data that was excluded from matching in case there was a buyer or seller with potentially the same name. I check all these cases by hand, making use of various sorting mechanisms. Although this is very time consuming, it is usually possible to verify based on the information about names, location and property description whether two observations are a match or not. In case there is any reason for doubt, no match is made.

In total, this lengthy procedure resulted in 72,544 repeat-sales, which is about 44% of the total number of transactions. Of these 72,544 repeat sales, 68,143 have a positive price and 67,295 involve residential property. Beyond data errors, there are three reasons why it id not possible to match all transactions. First of all, due to missing registers in the 16th and 17th century, the initial purchase or subsequent sale do not always show up in the dataset. Second, many homes were never sold or sold only once during the period covered by my dataset. Last, it is typically close to impossible to match transactions where buyer or seller have very common names, such as "Jan Jansz" (John Johnson).

Estimating turnover

The construction of a turnover index requires estimates of both the number of homes transacted in each year, as well as the total number of homes in the city. To start with the first, I identify for each transaction the number of homes that is involved; most transactions are for one home, but partial sales or multiple sales occur frequently as well. For transactions which combine residential and non-residential sales, only the residential part is counted. Subsequently, I adjust for periods with missing data. Since the registers were chronological, data is either complete or entirely missing. If a missing register does not cover an entire year, and more than three months of data is still available for that year, I estimate annual turnover by dividing the total number of transactions in these months by the share of transactions that on average occur in these months. No estimates of turnover are made for the *ordinaris kwijtscheldingen* prior to 1582, due to lack of data. Data from orphan sales are excluded, as it does not represent the buying and selling behavior from property owners, but rather the management of the orphan chamber.

In the last step, each of the series is scaled by the size of the market. Such a step is necessary, as the city of Amsterdam expanded significantly in size during the 16th and 17th century. Tax registers reveal that from the 1680s, the size of the city and number of homes stayed constant. In this period, there are in total around 25,000 properties in the city, of which about 90% is assumed to contain residential real estate.[30] It is more difficult to obtain estimates on the number of homes prior to 1680, when Amsterdam expanded significantly in size and had very large suburbs, which were rarely included in the tax records. I therefore rely on existing estimates of the Amsterdam population from Nusteling (1985) and Van Leeuwen and Oeppen (1993), and scale these based on estimates of the number of people per home. For 1680, I assume the number of people per home was equal to the number obtained from the tax records of 1733 (9.4 people per home). Before 1632, it is set at 8.42 based on the number of homes reported in Lourens and Lucassen (1997). Between 1632 and 1680, the number of people per home is interpolated linearly.

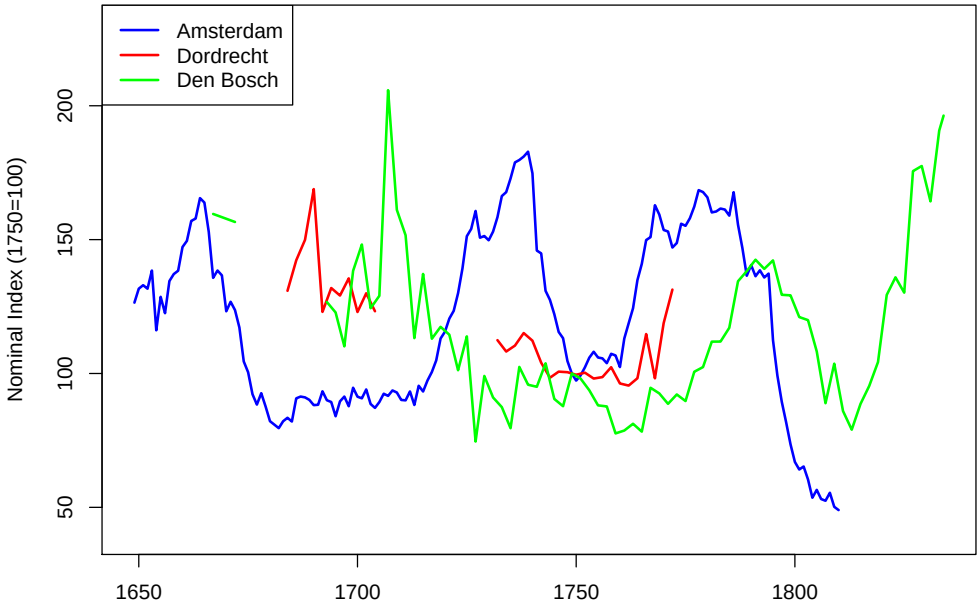
[30] Source: ACA 5044, inv. nrs. 402-405

Appendix C: Locality of price developments

Beyond Amsterdam, house price records have also been digitized for Dordrecht and Den Bosch. Records of these are publicly available from the Regional Archives of Dordrecht and Wetzer (2018). These two cities, with average populations of respectively 18,000 and 15,000, were among the largest cities in the Republic between 1600-1800, and located within 100 kilometers of Amsterdam. I will use these records to compare price developments in Amsterdam to other cities in the Republic. For Dordrecht, data is completely available between 1683-1703, and 1730-1773. In total, there are 6785 sales in this period. For Den Bosch, there are registrations of 11,489 transactions, between 1650-1672 and 1692-1838.

Figure 12 reports house prices in Amsterdam relative to bi-annual indices of house prices in Dordrecht and Den Bosch. Note that due to the low number of data points, the precision of these indices is smaller compared to Amsterdam, [31] but long-term trends still stand out clearly.

Figure 12: House prices in Amsterdam, Den Bosch and Dordrecht



Interestingly, neither Den Bosch nor Dordrecht seem to have experienced the large house price cycle that occurred in Amsterdam between 1713-1750. Prices declined in

[31] the average standard error of the bi-annual index is about 0.06 for both cities, relative to 0.025 for the annual Amsterdam index

Den Bosch, and did not move much in Dordrecht, although data is missing between 1706-1730. During the second cycle, prices also increased substantially in Den Bosch and Dordrecht, although with a substantial delay, in particular for Den Bosch. It might be that the housing boom only spread gradually to other, less important cities, as has also been observed in modern markets. Unsurprisingly, the fall in prices in the 1790s and early 1800s was common to both Amsterdam and Den Bosch: the French period is widely considered as the crisis that ended the important position of the Dutch Republic. However, more general, it seems that house price cycles, in particular their exact timing, is highly local. This also implies that we should look in detail at developments in local housing markets to understand exactly why prices are going up or down.

Because this paper focuses on Amsterdam, a detailed look and explanation for price developments in Den Bosch and Dordrecht is beyond its scope. However, both cities seem to experience booms that did not appear in Amsterdam: Dordrecht in the late 17th century, and Den Bosch in the early 18th century. The latter boom is particularly significant, and coincides with the War of the Spanish Succession. It might be that investors speculated that Den Bosch, being the most important city in Dutch Brabant, would gain a more important status within the Republic as the allied forces, including the Republic, had conquered the Spanish Netherlands. Although this explanation requires more detailed investigation, it might also explain why prices went down towards the end of the war: following the Peace of Utrecht, the Spanish Netherlands went to Austria, and the Republic barely gained any territory.

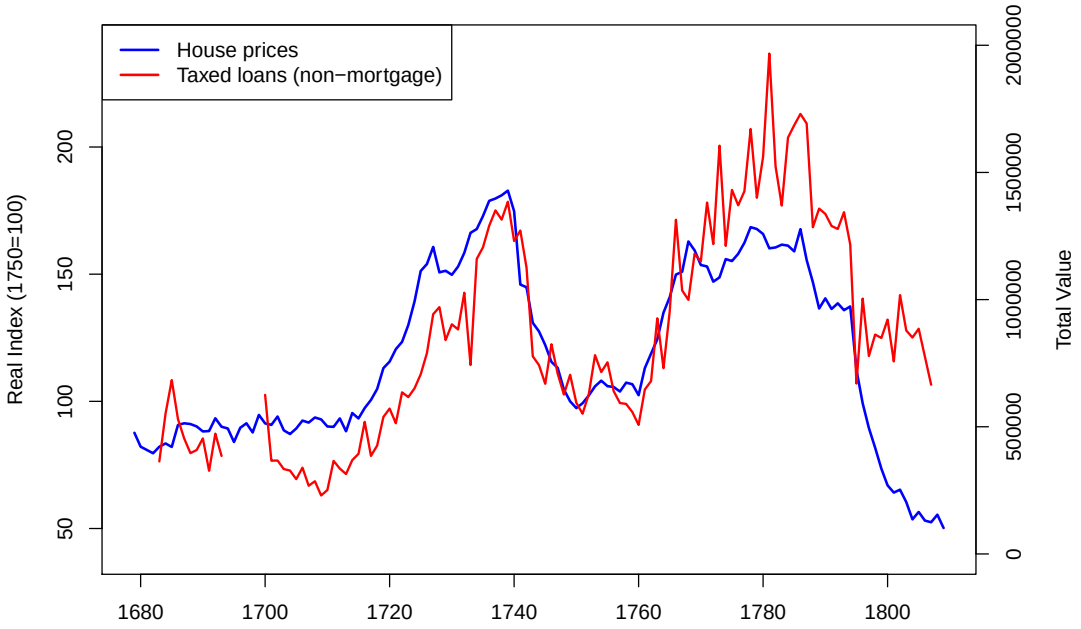
Appendix D: Developments in registered loan values

Figure 13 plots the developments in house prices relative to the total amount of non-mortgage credit (credit without *kusting*) registered with the aldermen in Amsterdam. To construct the latter series, I used payment registers of the tax on registered loans, available between 1682-1805.[32] Note that from the 1780s, notarial loans and private non-registered also start to appear in the tax registers. Creditors and debtors likely voluntary paid the tax on these loans in order to increase the seniority of the loan in case of default.

[32]Source: ACA 5047

Although the share of notarial and non-registered loans increases strongly between 1780 and 1805, it never exceeds 25 percent.

Figure 13: House prices and registered non-mortgage loans



The relation between total taxed loan value and house prices is very strong: there is no other series as closely correlated to developments in house prices. This suggests that home-owners were indeed making use of the increased collateral value of their properties, and implies that developments in house prices are crucial to understand developments in private credit markets in this period. There are two important remarks to be made. First, total registered loan value was on average only 25 percent of the total transaction value in the real estate market. This suggests the relation between private credit and house prices mostly goes from house prices to private credit supply, rather than vice versa. This becomes even more clear if one realizes that the average holding period of real estate is several times larger than the average maturity of these loans. Second, however, since not all loans were registered with the aldermen (Gelderblom et al., 2017), the actual collateralization of real estate was likely significantly higher than reported here. Nevertheless, the registered credit markets themselves were very small compared to the well-studied case of Paris (Hoffman et al., 2000): per capita, the number of taxed loans in Amsterdam was on average only 10% of the credit supply in Paris.