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Global Housing Returns, and the Emergence of the Safe Asset, 1465-2024*

Paul Schmelzing†

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HOOVER INSTITUTION
434 GALVEZ MALL
STANFORD UNIVERSITY
STANFORD, CA 94305-6010

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This paper presents new stylized facts and time series on global real estate returns and inflection points over centuries, by combining new historical primary data with machine learning approaches and econometrics. The evidence from different methodologies is consistent with the idea of inefficiencies having existed for the very long run in housing, with (excess) returns secularly increasing since the 1600s – showing few structural breaks, relatively fast mean reversion, and benefiting from a secularly falling cost of capital (mortgage rates). The evidence allows a broader contextualization of real estate in the long-run asset universe. Notably, real estate dynamics are consistent with the idea of a broader asset universe trend towards the "low expected returns" environment of the early 21st century: sovereign interest rates declined alongside rental yields over centuries, but the former did so more aggressively and from around 1600 appear to command an ever-rising "safety premium".

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† Boston College and Hoover Institution, Stanford. Contact: schmelzi@bc.edu, schmelzing@stanford.edu.

1 Introduction

It is now known that since at least the Renaissance, residential real estate consistently represented one of the largest financial assets by value, a fact continuing right into the present 21st century: the average share of land plus real estate in household net worth stands close to 40% over 1465-1850, a figure quite close to contemporary shares. Not least, even centuries ago housing already represented a portfolio asset for advanced economy households, which they benchmarked against other assets to optimize returns and diversification.[1] But despite various recent forays into the longer-run performance of real estate – much of it motivated by the "historic" boom and bust of housing in the 21st century – its long-horizon properties remain widely understudied, certainly compared to progress made in recent years for other asset classes. Yet this long-horizon could be essential, since we now know that long-horizon analyses can potentially qualify very basic insights into the financial and economic properties of an asset class – and thus advances could critically contextualize the elevated valuations and basic market features of housing in the 21st century itself, but also its *relative* dynamics in the wider asset universe over time.

For instance, the canonical paper establishing the benchmark methodology of modern house price indices and its basic econometric properties – Case and Shiller (1989), who first proposed market inefficiencies in housing on the basis of novel repeat sales indices for U.S. cities – only covered the horizon of 1970-1986, and expanding this methodology consistently into the past has always run into major source problems. Related obstacles make even recent ambitious "global" housing overviews – and propositions of specific "turning points" in the 20th century – likely sensitive to cleaner estimations and much longer horizons.[2] For it is known from recent debates in the currency or interest rate literature, for instance, that even 100-year annual time series offer comparatively low statistical power in critical exercises – and consensual narratives on other asset classes have on such bases been qualified.[3]

By design, progress on most of these fundamental housing questions would require more granular long-run total return time series than available thus far. The first contribution of this paper is therefore to make empirical progress, and offer new very long-horizon real estate time series that follow modern methodologies. While measurement bars are higher in residential real estate relative to alternative asset classes, one advantage is that real estate represents an "ancient" asset class with comprehensive long-run documentation in primary archival sources providing both price and rental data points. I utilize new primary sources for the example of Germany to build new multi-

[1]On capital stock and financial asset composition estimates over time see Goldsmith (1985), and more recent data in Schmelzing (2026). On investors diversifying their portfolios opportunistically across residential real estate and sovereign bonds in 18th century markets, see Korevaar (2021).

[2]See Knoll et al. (2017) for the proposition of a "hockey stick" trajectory of global house prices, inflecting only in the 1960s, with the authors using data that starts in the late 1800s.

[3]For the sensitivity of general asset properties to long-horizons, see the very recent example for real sovereign interest rates (Rogoff et al., 2024). The authors show that the consensual views on interest rate inflections and econometric properties are meaningfully qualified when long sample date is introduced – including stationarity and structural break features.

century price and total return series, linked in consistent ways to contemporary data. Meanwhile, the availability (or possible reconstruction) of a large amount of known covariates of house price changes for the long-run for other countries lends this asset market almost ideally to machine learning approaches to reconstruct historical time series. These approaches are nonparametric (do not assume any statistical form) and display high predictive power in our historical environment. On this basis, in a second empirical step, therefore, I utilize long-run time series that are known drivers for house prices to reconstruct four additional countries – including building cost indices and interest rates – to reconstruct multi-century prices for four additional countries: the U.S., the U.K., the Netherlands, and France. Together, these five countries account for over 60% of advanced economy GDP over time and for the first time allow a truly secular analysis of "long cycles" in real estate.

Having two such very different approaches represents a valuable cross-check for estimation challenges, and can pinpoint the critical commonalities. I proceed with presenting new long-run stylized empirics and asset features. Real estate does indeed show forecastability over the very long-run, a fact suggesting that contemporary market inefficiencies apparently have very deep historical roots: as I show, such forecastability holds for a variety of real estate return measures, including plausible assumptions for housing costs and also excess returns. Ex post real estate total returns are increasing over the very long run, and I find that a first broad-based house price boom spanned the 150 years between the Peace of Westphalia and the French Revolution. Afterwards, global house prices receded through the 19th century, and finally bottomed out globally towards the end of the Great Depression. The ongoing, modern secular "housing boom" in many ways represents a very long correction of a generational post-1800s slump in residential real estate: conversely, both primary source indices and those reconstructed via machine learning agree on key qualifications of current literature, with both suggesting that existing narratives on a "hockey stick" in global housing that only inflected in the mid-20th century appears questionable: house prices and housing returns were highly dynamic prior to the 20th century, and on many measures the elevated house valuations of the 21st century appear to connect to deeper multi-century trends.

I go on to discuss drivers of real estate returns, where evidence supports the notion of deeper historical currents: reconstructed (real) mortgage rates (based on new German primary sources) display a secularly falling trend – and together with building costs their long-run fluctuations appear to play a more prominent role in housing dynamics than suggested in recent literature.

In the final part of the paper, I proceed with contextualizing real estate within the wider asset universe since the late Renaissance: the new multi-century data is at least consistent with the idea that the much-debated "low expected returns" environment of the early 21st century has very deep historical roots, with consistently lower *expected returns* and rising *ex post returns*. Fusing cross-asset data, hence, there is accumulating evidence now that falling yields and rising valuations appear to have begun much earlier in time, certainly relative to dominant post-1970s narratives. The evidence from real estate – in context with consistent related asset price evidence – adds to the proposition that a major turning point in asset markets took place around the year 1650 – an era that saw public assets first assume "safety status", and a time when rental yields followed trends in sovereign rates and originally assumed their secular downward trend. Since then, sovereign "safety premia" have evidently been secularly rising, with a remarkable degree of continuity and a paucity of structural breaks.

Regarding the outline – after discussing literature, part 3 will be mainly concerned with the construction of the new German multi-century primary source real house price index, including cost estimates, with section 4 then presenting machine learning reconstructions for full global series, on the basis of long-run historical covariates (such as building cost indices). Section 5 focuses on German and global total returns, their decomposition, and their respective trends. Afterwards, we will present comprehensive econometric analyses in section 6, where I formally try to establish structural breaks, stationarity, and adjustment speeds in real estate over the long-run – before turning, in section 7, to the holistic view of housing and "safe" asset dynamics – highlighting the deeper origins of the current "low expected return" environment, pinpointing the emergence of "safety premia" around the late 1600s, and presenting long-run measures of the cost of capital in real estate (mortgage rates), which is similarly trend stationary and downward trending, in lieu with rising valuations. Part 8 concludes.

2 Literature

The analysis of long-run housing market dynamics has been reinvigorated over recent years, though not only significant empirical drawbacks, but also key controversies remain over both basic trends in real estate itself – as well as its performance relative to other asset classes.

In a comprehensive paper, Knoll et al. (2017) reconstructed house price series for 14 advanced economies over the years 1870-2012, mostly using selected urban price data points for earlier half of their sample. The authors find that real house prices for residential properties in advanced economies were stagnant in the pre-1945 era, and afterwards began a long-run acceleration from the second half of the 20th century. Specifically, the authors concluded that:

- "From the last quarter of the nineteenth to the mid-twentieth century, house prices in most industrial economies were largely constant in real (CPI-deflated) terms. By the 1960s they were, on average, not much higher than they were on the eve of World War I. They have been on a long and pronounced ascent since then, giving rise to a hockey-stick pattern of house prices in the long run."

To reach this proposition, Knoll et al. (2017) undertake a structural break tests for the German and 13 other real house price indices and identify the years around 1964 as the key inflection point from which house prices began their secular acceleration. This German inflection point (1964) is close or even identical to the majority of other advanced economies the authors test.[4]

[4]Eight out of the 14 advanced economy real house price indices record the key structural break between 1952-1964 on their basis; the authors use a standard Bai and Perron (2003) set-up, allowing for up to three breaks.

In a subsequent extension of the work, Jorda et al. (2019) contextualize long-run real estate asset performance in the universe of asset returns and suggested that real total housing returns outperformed equities over the long-run, even when adjusting for the volatility of such returns.

Methodologically, the approach in Knoll et al. (2017) and Jorda et al. (2019) has been challenged by Chambers et al. (2021) on the basis of new U.K. data over 1901-1983, and by Eichholtz et al. (2021) for Dutch and French 1800-1970 data. Both studies suggest that once rental income and expenditure components are properly integrated into long-run residential housing return data, housing in fact performed much worse than suggested in Jorda et al. (2019), and in fact fails to outperform equities when adjusted for volatility.

In a recent study, Lyons et al. (2024) reconstruct U.S. house price and total return series over 1890-2006, using a hedonic index approach covering 30 cities on an annual basis using newspaper sources: their data revises several stylized facts in the Case-Shiller index, and proposes that the muted volatility for housing as an asset class suggested by Jorda et al. (2019) could be the result of the aggregation method on the national level: however, the authors also find stagnant real house price dynamics prior to the mid-20th century, and –like all related recent longer-run literature – exclude any econometric analyses. Focusing on contemporary dynamics, some recent contributions have questioned the econometric consensus assumptions related to residential real estate, including Giacoletti (2021), who emphasizes idiosyncratic risk components and rejects the existence of a random walk for this particular return component in U.S. data.

As for the drivers of housing boom and bust cycles, there continue to exist alternative emphases, many of which are not mutually exclusive. Demographic factors and personal beliefs, for instance, have recently been invoked (Landvoigt, 2017; Korevaar and Francke, 2024). But a substantial majority of studies stresses the role of credit markets, and here especially the credit supply side, prominently (Mian and Sufi, 2009). The fall in U.S. mortgage rates has been identified as a key variable capturing an array of lending constraints, the weakening of which promoted rising credit supply in the wake of the 2008 crisis (Justiniano et al., 2019). The latter in particular contend that:

- "Lending constraints are a simple modeling device to capture a combination of technological, institutional, and behavioral factors that restrain the flow of funds from savers to mortgage borrowers. Starting in the late 1990s, the explosion of securitization and of market-based financial intermediation, together with changes in the regulatory and economic environment, lowered many of these barriers...the associated shift in credit supply remains the only force pushing interest rates lower."

In this sense, credit supply factors lower the real mortgage interest rate and through additional mortgage lending, real house prices rise. These contemporary contributions are extended and broadly confirmed by historical case studies including Rajan and Ramcharan (2015).

The specific econometric literature that does exist and is concerned with forecastability of house prices (returns) deals virtually exclusively with post-1945 U.S. data: relevant contributions here include Campbell et al. (2009), who study U.S. data over 1975-2007, and the canonical Case and

Shiller (1989), who found forecastability in U.S. house price data over 1970-1986. An overview of recent real estate-specific econometric literature is provided in Ghysels et al. (2013).

Relevant for the final, cross-asset section, earlier research has associated historical time-variation in dividend yields as evidence of variation in "expected returns" (Golez and Koudjis, 2018), with related literature associating contemporary (21st century) high asset valuations with low expected returns (Ilmanen, 2022) – though in all cases there exists no clear fusion of long-run historical and contemporary asset pricing phenomena. And Korevaar (2021) demonstrates that investors in 18th century Holland actively shifted portfolio exposure from sovereign bonds to residential real estate conditional on expected returns: low sovereign yields in this environment boosted housing total returns, and it could be particularly fruitful therefore to contextualize these two variables over time.

3 Constructing a primary source long-run repeat-sales house price index (RHPI), Germany 1465-2024

Our basis for the construction of the new German housing price and total return indices are city level individual property records, known in German as *Häuserbücher* or *Hauschronik*. These are comprehensive compilations of cadaster and other official municipal records that allow a full chronological reconstruction of property level ownership, transactions, repeat sales prices, personal information on the occupants, and (occasionally) rental details. In effect, the data allows a construction of an index methodologically mirroring the widely used Case-Shiller repeat sales index for the U.S., which is still regarded as the most robust long-run approach controlling for quality changes and heterogeneous housing characteristics.

Major progress has been made in recent years in the digitization of methodologically sufficient housing records over very long periods of time. German archives have spearheaded some of these initiatives, which – combined with new multi-century granular data for related asset classes – makes this country especially suited for new efforts at a holistic and robust general asset market reconstruction. Figure 1 displays an example, an entry from the new "Topo N" project for the city of Nuremberg (one of the key early modern financial hubs of Europe), which as of 2023 has systematically linked close to 4,000 property level records via unit-identifiers, and merged this cadaster information with ownership histories, sales prices, and other notable events related to the property.[5] Such advancements mirror those in other cities and allow repeat-sales observations for thousands of properties over centuries for consistent individual housing units – for more than a dozen key German cities from the late medieval period.

These new sources have several advantages: perhaps most importantly, their level of detail on the property level allow a full repeat-sales index construction, in line with benchmark contemporary indices: such a methodology is considered the "gold standard" among various alternative ap-

[5]See methodological details in Razum et al. (2023).

proaches, since it allows a better control for quality changes in housing, a distinct concern for real estate as an asset class in existing literature. Second, as these records merge official with notary information, they contain *both* tax assessment values and market values of the property, with the latter being much preferred as a measure of actual price dynamics, though much literature (including the Case-Shiller index) has had to rely on assessment or self-reported values for earlier periods thus far, which contain problematic biases.[6] Third, the records are unusually consistent and complete: the average length for individual properties included in the index that is continuously documented stands at 201.5 years, with a maximum of 407 years, and more than one-third with over 300 years of continuous records. Typically, property related information is quite abundant in this source type, with a significant number of property level records reporting details such as building year of the property, underlying land values, incidences of significant material damages, and quality changes (significant renovations, additions, or mergers with other properties).

Figure 1: Example entry from the 2024 Nuremberg "Häuserbuch", *Unterer Bergauerplatz 10*.

Notes: The picture displays an example entry from the Nuremberg *Häuserbuch* ("Topo N" Project), for the modern address of the *Unterer Bergauerplatz No. 10*. Consistent cadaster units are traced here in their ownership history, sales transactions, sales prices, and other notable events associated with the house. In this case, we see the first ownership entry (category *Besitzer / Bewohner*) for the year 1479. Entry via: https://online-service2.nuernberg.de/stadtarchiv/zeig.FAU?sid=574BA1843dm=6ind=2ipos=4220332f34.

In the construction of the index, I focus solely on actual market transaction prices – ignoring tax assessment values of properties, which are often given, as these are noisy given variation in

[6] Not least, non-sales transactions (inheritances, transfers, or property swaps). The Case-Shiller index for U.S. pre-depression home values uses self-reported survey data points via – these drawbacks have been critiqued in White (2009) and elsewhere.

property tax rates, irregular assessment, and underreporting of actual property values by owners.

For the headline index, and all headline return figures, I arithmetically weight observations across all properties for the headline indices. However, a value-weighted version can also be constructed and is presented in the appendix, which rebalances index weights based on property values every single year (using interpolations for years where individual properties are not on the market). This value-weighted version suggests slower real price growth for higher-value properties over time, and slower real house price growth prior to the Thirty Years War, but otherwise comparable secular trends and inflection points.[7]

[7] See further discussion and data in Appendix section 4 and Figure A.2.

3.1 Summary Statistics

The German residential house sample covers eleven cities, spanning a heterogenous geographical and demographic range in the country over time. Three cities are in Northern Germany, eight in Southern Germany, and the size of cities ranges from 1,300 (Stengberg, as of 1500) to 538,000 (Munich, 1905). All the key financial hubs of Germany/the Holy Roman Empire over the early modern and modern period are part of the sample, including Nuremberg, Frankfurt, Munich, and Berlin. While such ex post successful cities may feature some degree of "superstar city" bias, the inclusion of smaller and relatively stagnant towns balances the aggregate sample regarding these possible factors.[8]

In total, we cover more than 200 individual properties at this point. The properties are exclusively single or multi-family residential objects, typically in the "old" parts of the respective cities. A significant share of the properties in the sample continues to exist as of 2024, based on a cursory survey – even though house numbers and other designations have repeatedly changed.[9]

The houses in our sample have a median value of 594 Rheinflorin (Rfl., or *Rheingulden*) in 1465, a figure that has risen to 2,025 Rfl by the year 1650, 4,537 Rfl. by the year 1750, followed by 18,131 Rfl. by the year 1850, and finally 33,753 Rfl. at the eve of World War One (1910). The small town of Stengberg records the lowest median house prices over the sample period at 224 Rfl., while Berlin records the highest median house price, at 14,392 Rfl.

The 202 properties between them account for 1,475 sales transactions, and together the repeat sales data allows a complete tracing of more than 44,000 property-years, with records starting as early as the 14th century for Nuremberg, Frankfurt, and Erfurt. The final property sale observation in our sample is for the year 1943, in Nuremberg. Of course, a sample of several hundred observations must still be considered "small" by the standards of the German housing stock, even in the early modern period. After all, more than 4,000 individual housing units existed in the early modern city of Nuremberg alone. Yet, our sample is designed to be highly representative of the German residential housing stock given its geographic composition; and even now, with its modest size, this sample presented here represents the most comprehensive one already for repeat sales at the individual property level. Our exercise does not embrace a "big data" approach – but it is easily scalable based on the new sources identified.

Tables 3 and 4 record some of the accompanying data from the Häuserbucher. For instance, we note that the average holding period – defined as the time between actual market sales transactions (thus excluding inheritance events or house swaps) fluctuated between 27-36 years, with a modest declining secular trend. In nominal terms, property owners recorded a gain of almost 94% over the previous sales price, with an upwards secular trend. We will return to such accompanying

[8]"Superstar cities" may exhibit faster house price growth, biasing the index upwards; however, other research suggests rental yields in these cities are generally lower.

[9]House numbers in any case are an innovation of the 18th century. In the pre-1700 era of our sample, the properties are typically designated by their owner, or by lengthy descriptions of their location relative to prominent buildings in the city (the church, city hall, or wells).

data and their interpretation.

3.2 A new repeat-sales house price index

Existing repeat sale indices typically use CPI data to adjust nominal house price series to real bases. Shiller (2015, chapter 3), for one, uses year-to-year U.S. CPI index changes to deflate respective nominal home price changes and create a U.S. "real home price index" over 1890-2014. Similarly, Knoll et al. (2017) deflate nominal house prices with a 5-year lagged realized CPI (that is, the average over t-5 to t-1, to deflate nominal price at t=0), to obtain real house price indices.

Such repeat-sales indices are regarded as "state of the art" indices, and not least they are widely considered the best methodology to control for quality improvements in homes, though alternative "hedonic indices" have been used recently for quality-adjusted U.S. series Lyons et al. (2024). Yet, while they can capture many of the quality-related changes in housing as a wider asset class – for instance, they are by design well equipped to deal with the land component of the home price, as they keep it constant at the property level – even repeat-sales indices are far from *perfectly* stripping out pure quality-related improvements. We note here that we follow existing approaches in incorporating quality-related adjustments to the best extent possible, and dedicate a subsection as well as an extensive chapter in the appendix that traces quality-related changes in our sample, together with better estimates on their effect on secular prices.[10] But importantly, we do by no means not rule out that much or most of the price index changes documented *do* in fact stem from quality-related improvements. The same quality changes are explicitly incorporated into all existing benchmark indices, without a definitive determination on their ultimate role in index changes. Even though, for instance, the long-run suggests that the median homeowner only possesses a 30-50% larger home in terms of living space, it might well be that representative homeowners are more and more willing to pay premia for other quality improvements, and that at least partly, construction cost variation incorporates quality-related variation (say, higher skilled construction labor inputs).

Figure 2 now displays our new long-run German house price index (RHPI), here in real terms, over the period 1465-1910. We observe that this index is quite sensitive to the price index basis one uses to adjust nominal house price growth, most strikingly related to the beginning of the Thirty Years War in 1618 when Germany experienced a dramatic inflation event (an issue we return to later).[11]

The two indices are closely tracking each other, however a major difference relates to the treatment of the Thirty Years War, the biggest historical inflation shock next to the German hyperinflation years of the 1920s. The contrast is most acute when we construct long-run real house price or total return indices. Over the full sample 1465-1910 period, the Schmelzing (2026) inflation basis

[10] See Section 3.4 and Appendix section 5.

[11] While the topic has not received much attention in recent evidence, the precise choice of the inflation adjustment basis also makes significant impact on more recent benchmark indices, including the choice whether to adopt a lagged inflation figure (as in Knoll et al. (2017)), or a raw year-on-year one (as in Shiller (2015)).

– which constructs a seven-year lagged realized CPI figure that is analogous to the approach in Knoll et al. (2017) and is concentrated on urban prices – suggests that house prices rose by just 2.1x in real terms; the Pfister (2022) basis on the other hand – which uses a year-on-year industrial and agricultural price index aimed to capture Germany as a whole –, primarily because it arrives at much lower inflation spikes during the 1620s, records a terminal increase at a level of 25x.[12] Since the majority of alternative independent price indices all agree with the drastic inflation spike during the Thirty Years War, our benchmark index accords with this approach.

Regardless of the specific inflation basis chosen, a key commonality of both indices displayed is the sharp acceleration of the index values from the late 18th century. In real terms, the index on the Pfister (2022) basis increases by a factor of 2.7 between the end of the Napoleonic Wars and 1910; on the Schmelzing (2026) inflation basis, the index value rises by a factor of 2.2 in real terms over the same period.

This suggests that real house prices – at least in one key geography where such returns can be measured granularly over time – did *not* begin to accelerate only from the mid-20th century, as key literature proposes (Shiller, 2015; Knoll et al., 2017). Instead, this consensus appears to be a function of the traditionally limited time horizon considered, one that begins observations in 1890 or 1870 respectively.

We visualize this result more strikingly in Figure 2, which now integrates the new long-run German real house price index with the previous index values in Knoll et al. (2017). This Figure shows more straightforwardly that the house price acceleration well precedes the proposed 20th century inflection. In a subsequent section, we can further test the idea and the timing of particular "inflection points" more systematically, with the help of econometric exercises (section 6).

While our benchmark approach in this section – to value-weight individual transaction observations – is consistent with contemporary state of the art indices (notably the Case-Shiller index for the U.S.), key sub-periods and absolute index levels are certainly sensitive to particular sales weightings and also the specific inflation adjustment approach: though none is inconsistent with the broader conclusions reached here (especially regarding the pre-1945 real price dynamics), the appendix reports a number of variations of the German benchmark index presented here, to illustrate these factors further.[13]

We stress that the new data does not rule out that there has indeed been a transitory slowdown in house price appreciation around the mid-20th century, in Germany and other advanced economies. Plausibly, this could be connected to the well-documented clampdown on the financial sector during the Bretton Woods era, including the subdued growth of mortgage credit.

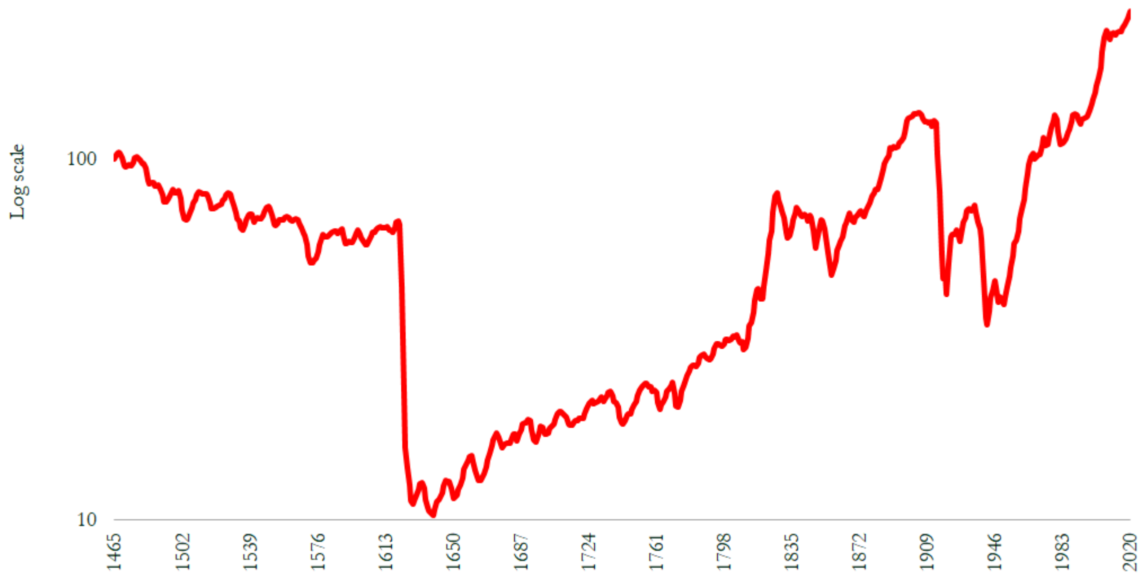
[12]See appendix Figure A.3 for details.

[13]Iterations of the city weighting, including a geometrically weighted German index and variations of the inflation adjustments, are to be found in the appendix, sections 4 and 5.

Table 1: Summary Statistics for Housing Index (RHPI), repeat sales				
	# properties	# transactions	Property-years	city size
Erfurt				
1300-1670	5	6	564	med
Stengberg				
1465-1860	17	91	4,240	sma
Mainz				
1604-1808	2	5	140	med
Frankfurt				
1358-1864	27	119	6,280	lar
Koblenz				
1408-1806	18	40	2,742	med
Berlin				
1658-1858	40	281	4,312	lar
Munich				
1391-1904	55	624	15,038	lar
Freiburg				
1572-1904	3	3	55	med
Dessau				
1693-1933	3	9	281	med
Nuremberg				
1387-1943	32	295	10,397	lar
Total				
1300-1943	202	1,473	44,052	—

Notes: The table reports the sample composition of the repeat-sales observations for residential real estate in Germany. Property-years reports the sum of all property level spans of years between first and final sales transaction. City sizes are grouped into three categories: ’"sma" (small cities averaging under 50,000 population across sample period), "med" (medium size cities averaging between 50,000 and 80,000 population across sample period), "lar" (large size cities averaging over 80,000 population across sample period).

Figure 2: Fused German real house price index (RHPI, log scale), 1465-2020.



Notes: The Figure displays a German real house price index running over 1465-2020 (1465=100, log scale), value-weighting German cities. Here we splice the new data introduced in this paper for 1465-1910 (using the "Schmelzing" inflation adjustment basis), with the existing German house price data in Knoll et al. (2017) over 1911-2020 (as updated in Jorda et al. (2019), and denoted "JST"). The gaps that JST record for selected German years are filled by taking the arithmetic average of the real house price change for Denmark, France, Switzerland, and Belgium.

Overall, one arguable drawback of the primary source approach might be that the sample size could be improved further – in principle, the sample could be further enlarged.

3.3 Renting and owner-occupation

According to Dirlmeier (1978), even lower middle and lower income households typically lived in their own single family home by the late 15th century – with around 30% of taxable citizens in German urban areas living in rented houses or apartments. Across the country, this figure appears relatively stable and suitable to assume as an average in the early modern era. For the year 1384, 23% is the equivalent figure for the town of Esslingen. In Rostock as of 1522, 57% of households live in rented real estate. In Nuremberg, the share is estimated at 29% in the year 1502.[14]

Overall, therefore, rental income constituted a clear investment motivation for buyers of real estate assets over the entire observation horizon, and to assess housing as an investment asset, the integration of rental yields is imperative to reach total return figures, and assess actual income

[14]Nuremberg data via Sachs (1915). Other data via Dirlmeier (1978).

Table 2: Summary Statistics for rental yield observations

	# properties	# rental obs	Property-years	av yd
Basel				
1352-1566	5	6	215	7.1
Freiburg				
1407-1564	17	94	4,240	9.1
Konstanz				
1604-1808	2	5	140	6.5
Munich				
1401-1529	4	4	65	3.0
Warendorf				
1772-1863	7	100	186	7.9
Nuremberg				
1529-1659	5	6	14	7.2
Bremen				
1650-1765	2,435	2,438	38,960	2.9
Frankfurt				
1378-1902	28	31	37	10.9
Berlin				
1754-2019	>500	29	n/a	4.6
Total				
1352-1863	2,504	2,677	43,844	7.4

Notes: Rental yields are expressed as a percentage of sales price throughout, taking the price observation that is closest to the nominal rent observation in cases where no direct matching is available in the underlying source itself. Bremen data records city-wide averages across all rental properties assessed via Schwarz (1968). Munich also includes Strassburg and Augsburg data; Frankfurt includes Giessen data. Column 5 records the average gross rental yield in the respective sample, in nominal terms, as a percentage of the house market value (the total number being the arithmetic average of city levels). The modern Berlin data is based on census statistics via Bundesamt (2023), which does not provide the underlying sample size for the aggregate figures – hence we designated a "n/a" value to column 4 for Berlin.

risk.

As has been noted in related papers, historical rental data in primary sources is generally more elusive, hampered in part by the fact that rental contracts were privately negotiated and did not have to be registered with notaries or municipal authorities (unlike sales), in part by a convoluted nomenclature in early modern contracts. Housing contracts – besides mentioning the assessment or sales price – often refer to *Guelten*, or *Zins* ("interest") when denoting rental payments, with such terminology adding to confusion. All this especially complicates the construction of price and rental series featuring the *identical* housing properties: key recent literature has navigated this challenge in different ways, with some constructing separate housing and rental series (featuring different properties in each of the two samples) which are then merged to construct a rental yield series (e.g. Lyons et al. (2024)). However, our *Haeuserbuecher* contain a critical amount of detail, at least for multiple key cities, which allows a direct linking of rental and price series – and several hundreds of additional rental-only data points have been identified in related primary and secondary sources which allow the replication of existing approaches that construct a separate rental index series that is subsequently merged with price series to observe rental yields (all rental observations are summarized in Table 2). The level of detail in such rental sources allows the matching of identical property sizes (number of rooms) and within-city location.

3.4 Costs and net total returns

We have not comprehensively measured the cost component of residential real estate for our long-run sample thus far. Such costs mainly include taxes on the municipal and state level, maintenance costs, depreciation, and costs resulting from vacancy.

3.4.1 Taxes

Beginning with the first dimension, on the property and income tax side, the information is relatively comprehensive. Some of the German *Haueserbuecher* contain occasional unit-level tax information, most of which concur with our existing knowledge of aggregate city level rates.[15] For instance, among larger cities in our sample, we know that for Munich, an annual imposition of one Penny per Pound is levied from the mid-15th century, where it remains for centuries – a rate equivalent to 0.41% of the (self-assessed) value of the house. The city of Frankfurt charged 5/6 of one percent as real estate sales tax from the year 1613 onwards; the city of Augsburg charged 1/4 of one percent of the value of real estate and land in wealth taxes; the city of Leipzig charged 1 basis point of the (self-assessed) value of housing in irregular wealth tax impositions from 1481 onwards. It is to be stressed that these impositions occurred in irregular intervals – often connected to specific external threats for which cash was quickly needed and liquidity was

[15]For instance, in Nuremberg in 1500, we learn via TOPO N, B 6/5 that the house worth 190 Rfl was taxed at an annual 0.5 Rfl, that is, at 0.3%.

otherwise constrained.[16]

Afterwards, property tax rates are rather stable from the 15th century, with evidence of a moderate upwards trend. For Berlin, Voigt (1901) reports tax rates of 0.3% of the property value in the 17th and 18th centuries, which rise to 1.25% by the first half of the 19th century. Afterwards, Müller (1881) provides annual rate of 1.9% of the market value for rented residential housing in Berlin during the 1870s and 1880s. With much corresponding data for other cities in our sample in broad agreement, Eberstadt (1903) provides rates for representative Hessian cities, over 1890-1901, arriving at a lower 0.6% of property value for rental properties.

Against this backdrop, in the subsequent calculations, we operate with a constant 0.15% annual tax rate relative to the market house price prior to 1800, and increase this figure to 0.5% from the year 1800. Slight variations within the range of property rates provided in the literature, or the adoption of a more dynamic rate over time, do not alter any of our basic findings.

3.4.2 Non-tax costs

What are the resulting time series estimates for long-run total gross costs, as a percentage of value, over our German sample?

It would be methodologically ideal of course to match property level price, vacancy, and rent data with matching property level expenditures – however, such information is sporadic. For some cities in our sample, interesting internal cadaster calculations exist. For instance, the Berlin cadaster authorities during the 1870s apparently calculated with a 2% total gross expenditure figure relative to the current sales value of a rental residential property for total costs, including maintenance, labor, and fire insurance, but not adjusting for vacancy rates (Müller, 1881). A related official publication, also for Berlin, estimates an average vacancy rate for residential housing over the period 1880-1910 of 3% (Ascher, 1917). While providing some general reality checks, however, in line with existing literature, we will have to abstract from property and matched city level data and assume plausible aggregate figures. We will also have to abstract from some relevant city level provisions that are relevant on the margin, but cannot be generalized: for instance, Voigt (1901) reports that for Berlin in the early modern age, renovation costs are partially tax-exempt (up to 15% of total renovation costs) – lacking more specifics about the scope and duration of such provisions, we will disregard such details.

Given the less robust data situation across countries, recent long-run total return calculations thus have assumed time series based on general assumptions, rather than asset-level data. An example is Eichholtz et al. (2021), who estimate non-tax costs of 32% of rental yields as expenditure basis for Paris and Amsterdam, closely in line with the estimates in Chambers et al. (2021), who have actual property level data on expenditures for their U.K. sample. These estimates include maintenance, vacancy, insurance, and labor costs.

[16] For a systematic overview of tax rates, see Isenmann (2012). The Munich rates are via Solleder (1938, 208ff.). Further city level details in Mayr (1931) for Augsburg; Frankfurt data via Braeuer (1915).

With these cost approximations, we will return to our estimates of net total returns, in section 5 below. The appendix systematically compiles all expenditure share estimates and actual observations in secondary and historical literature that form the basis for these net return adjustments.[17]

4 Reconstructing Global House Prices – A Machine-Learning Approach

In a vibrant new literature, it has recently been argued that nonparametric machine learning (ML) approaches can clearly outperform traditional methods in empirical asset pricing applications: specifically, such "supervised learning" models that assume no functional form of the underlying training data have been applied to a broader range of financial forecasting debates, including U.S. equity prices (Gu et al., 2020), bond risk premia (Bianchi et al., 2021), as well as broader corporate finance and portfolio choice (Duarte et al., 2024).[18]

While the majority of financial applications are currently concerned with optimizing the prediction of future returns on the basis of a limited set of past realized data points, the financial historian faces a simpler problem: estimating *past realized returns (prices)* on the basis of a limited set of past realized known covariates (which are strictly already available for end of the t period). In other words, we are operating in an easier environment because instead of a look-ahead forecast, we are interested in a backcast target variable reconstruction – an environment where important covariates of the target variable for the given period are already known. In this sense, the approach can also be thought of as a simple computational optimization of a nonparametric regression exercise – with the advantage that the supervised ML environment can optimize the nonparametric environment for a large set of covariates, and determine the ideal statistical structure. However, it is important to note that this means the model setup as used here does not inform about actual *forward-looking* (that is, beyond the cutoff of the training data set, this being the year 2020) predictive conditions.[19]

Importantly, while advanced machine learning models have already been prominently used for similar time series reconstructions in related fields – notably long-run climate trend and demographic reconstructions – the full utilization for financial reconstructions has been rather underdeveloped, even though successful applications, for instance to backcast recent U.S. unemployment claims, have been presented.[20] Not least, backcasting approaches have been used to reconstruct historical per capita GDP series and improve over the benchmark "Maddison" data, via Koch et al. (2024).

While each methodology faces its own set of challenges, machine learning approaches could offer a powerful cross-check to, and extensions of, our primary source housing reconstruction approach that concentrated on Germany (as well as cross-checks to previous early modern price reconstructions in the literature, which we undertake more systematically in the appendix). The

[17] See Appendix Table A.2.

[18] For relevant surveys of finance and economics applications and their foundations, including the subset of "supervised learning" approaches used here, see Masini et al. (2023) and Kelly and Xiu (2023).

[19] For this approach, all forward-looking covariate data would not yet be available at the time of prediction, time t.

[20] Here see Bochow et al. (2025) and Borup et al. (2023).

situation is particularly promising given the availability – or available reconstructions – of large sets of (thus far unexploited) known covariates for key advanced economies over centuries (including GDP, interest rates, demographic data, and construction costs).

Specifically, we train several nonparametric machine-learning models on both modern nominal and real housing capital gains as their target variables. A plethora of available models exists – with our focus being on a subset of latest generation models optimized for multi horizon tabular fore- and backcasting applications.

Among the models we test are a Time-series Dense Encoder model (TiDE) (Das et al., 2024), a class of long-horizon forecasting models considered to be computationally more efficient than others, but more simplistic; a Seq2Seq+ model (Keneshloo et al., 2020), which utilizes deep reinforcement learning approaches; and a Temporal Fusion Transformer (TFT) model (Lim et al., 2021); both the Seq2Seq+ and TFT models incorporate Long Short-Term Memory (LSTM), a deep learning feature shown to be particularly potent at asset pricing applications such as predicting bond risk premia, for instance (Cong et al., 2021; Chen et al., 2024).

The advantage of these models is not just their optimization for long-horizon fore- and backcasting exercises – but their strictly nonparametric foundation: all models assume no particular functional form of the data, and batch predictions resulting from such training therefore contain no particular biases on the econometric features of time series properties that we are interested in.[21]

The first step consists of the training stage, to train the machine-learning model, with annual residential house price change (in both nominal and real terms) as its target variable. We train the model on housing capital gains on the basis of the most recent modern and early modern research datasets where a sufficient sample of additional covariates exists. Training and validation splits are undertaken in line with related previous finance literature: specifically, I use a 80:10:10 training:validation:test split.[22] The r-squared reported refers to the performance of the training data set on the validation and test data set – hence is an out-of-sample (OOS) measure. By design, the r-squared for backcasting environments will be higher than in classic forward-looking prediction environments.

The covariates importance across our specific ML models is detailed via Figure 3. Specifically, the thirteen covariates include the government deficit-ratio using Dincecco (2013), a financial crisis dummy using Metrick and Schmelzing (2025), population growth, 3-year lagged population growth, nominal interest rates, change in nominal interest rates, real interest rates, inflation, 7-year lagged inflation, change in real per capita income, a FX peg dummy, and national construction cost indices spanning 1871-2020 that are sourced from secondary literature and/or respective statistical agencies.

[21]Where such LSTM models struggle are environments with more meaningful data gaps in the training set – our environment uses the (comprehensive) JST environment where such data gaps are virtually absent (even though, as we argue for the case of Germany, the estimation procedures for given periods can be challenged).

[22]For instance, Bianchi et al. (2021) use a training:validation/test dataset split of 85:15. The backcasting p.c. GDP model in Koch et al. (2024) uses 80:20.

The source of the training dataset target values (year-on-year housing capital gains, 1871-2020) is primarily the "JST dataset" (Jorda et al., 2017) and sources therein – with the exception of U.S. data for which we utilize the superseding data in Lyons et al. (2024).[23] For nominal housing capital gains, the annual values are directly observable in "JST". To obtain observations for real year-on-year housing capital gains, we adjust the JST nominal capital gains with year-on-year CPI inflation rates in the same JST data set.

Using this set of time series for training, we report the model training performance in Table 3. The first three rows report nominal capital gain performance. Here we observe that a *Seq2seq+* model with specific tuning parameters performs best and achieves an OOS r-squared over the full training dataset of 0.544 when optimized for a 36-year forecast horizon, and a 115-year context window. The following three rows report results for real capital gains as the target variable. Here, we obtain an even better OOS r-squared of 0.572 when using *Seq2Seq+*.

It is important to note in this context that such r-squared (out of sample sample) may be expected to be even higher – adding 16 other annual macro-finance covariates for the 1870-2020 period delivers r-squared of over 80% in selected specifications – however, we have to strictly limit ourselves to the sample of covariates that are available to a sufficient degree for the early modern period as well.

The TiDe and the TFT models record slightly lower r-squared, up to 0.464 for nominal changes – with all models achieving a relatively tight range of MAE performance between .032 and .04. In general, we will note that all such performance measures obtained are comparable to recent influential machine learning standards in the finance literature, for instance those in Moreira and Manela (2017).

Via Figure 3, we provide the variable importance, by model, for the machine-learning methodologies. The importance refers to the training dataset that utilizes 1870-2020 data, across the three machine-learning models – Seq2Seq+, TFT, and TiDE. The former (Seq2Seq+) constitutes the "baseline" machine-learning model with the highest realized R-squared (for this the variable importance is called out in the Figure).

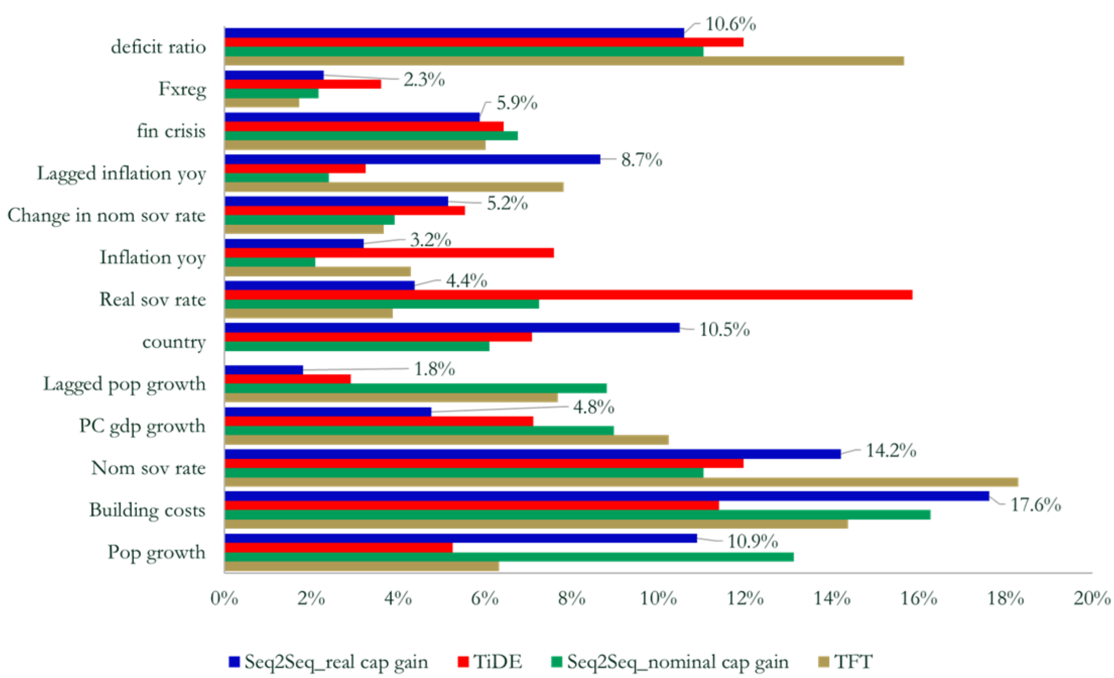
We generally note that variable importance can vary substantially across the four models, but that a handful of variables retain high important across approaches – including the nominal (long-maturity) sovereign interest rate, building costs, and population growth rates (lagged and unlagged). In the next step, we use the best-performing training model to generate a predictive backcasting house price growth series spanning 1502-1870: for Germany, the backcasted series runs to 1962, for the U.S. it runs from 1786 to 1889, and for the U.K. it runs from 1560 to 1844. This best-performing model for both nominal and real capital gains is the Seq2Seq+ model with a forecasting horizon of 36 years, and context windows of 110 and 115 years. TFT models perform only marginally worse across metrics, with the TiDE models being meaningfully lower than either two alternatives.

[23] One further addition is the inclusion of UK data over 1845-1870 on the basis of the Millennium Dataset, which is also reported in conceptually consistent annual residential house price change.

Table 3: Machine-learning model performance. Target: DM annual house price change				
	$r^2(OOS)$	MAE	forecast horizon	context window
Target: nominal y-o-y price change				
Seq2Seq+, 110-36	.544	.032	36	110
Temporal Fusion Transformer (TFT)	.464	.033	36	115
Time Series Dense Encoder (TiDE)	.184	.039	32	110
Target: real y-o-y price change				
Seq2Seq+, RHP, 115-36	.572	.035	36	115
Temporal Fusion Transformer (TFT)	.428	.040	36	115
Time Series Dense Encoder (TiDE)	.169	.040	36	115

Notes: The table reports training results from several machine-learning (ML) approaches, all with annual nominal (real) residential real estate price change as their target variable. The training data set consists of house price changes in addition to thirteen co-variant variables, annually over 1870-2020, primarily using "JST" (Jorda et al., 2017), except for Germany (excluded up to 1962 to prevent leakage) and the U.S. (where Lyons et al. (2024) is used). The training:validation:test split of the data in all models is 80:10:10.

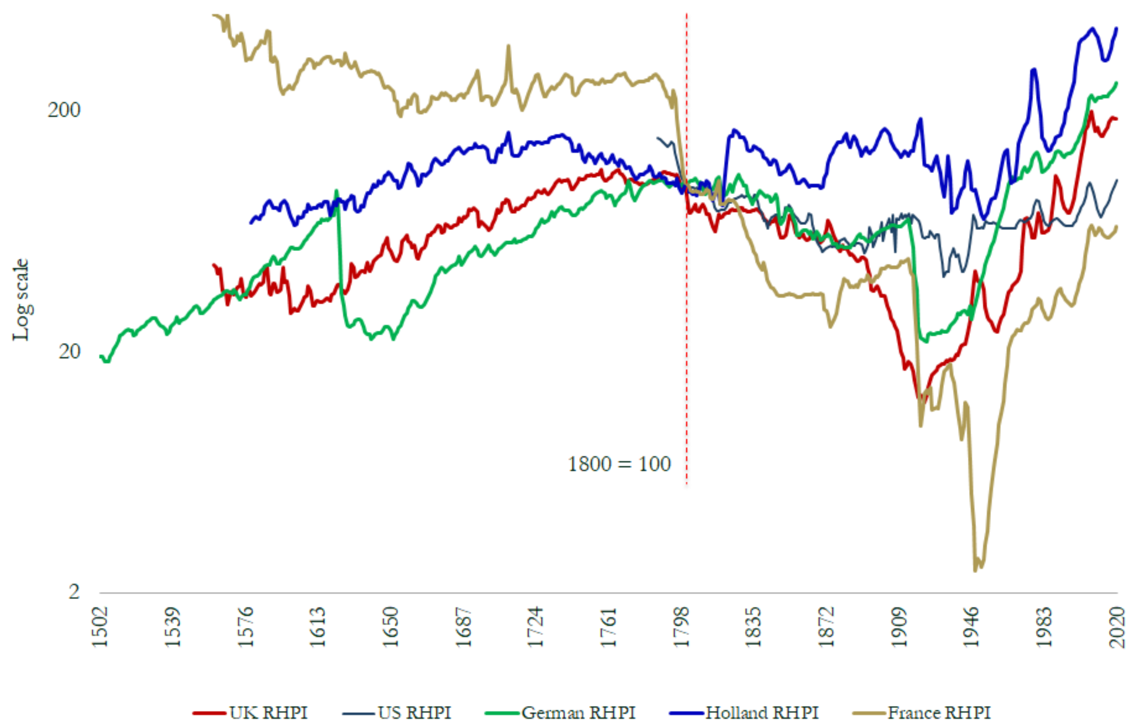
Figure 3: Variable importance, by ML model.



Notes: Variable importance for the top-13 most influential variables in each model. Variable importance within each model is normalized to sum to one, excluding "time". Called out with importance labels is our benchmark Seq2Seq+ model targeting real capital gains, in blue bars (cf Table 3).

In Figure 4, we display the benchmark Seq2Seq+ machine-learning reconstruction for nominal house price changes – with predicted nominal values then being adjusted by existing lagged inflation data to obtain real values. This is done for five key advanced economies since the early 16th century. All are indexed to 1800=100, and utilize the full set of sixteen covariates for the 1502-1869 period, to obtain the target value predictions. For these pre-1869 variables and data points I mainly rely on published GDP and population time series in the Maddison database (Bolt and van Zanden, 2020), as well as financial time series in Dincecco (2013), Rogoff et al. (2024), Schmelzing (2026), and Metrick and Schmelzing (2025). A key exception is that I hand collect and/or reconstruct building cost indices for the five key economies, which represents a variable with high variable importance across models (Figure 3). The appendix also displays "global" reconstructions on the other model bases, including for real capital gains as the direct target variable: the key structural results emphasized here hold for these alternative variations, though they at times differ on absolute house price levels.[24]

Figure 4: Seq2Seq+ Machine-Learning real house price index (LHS), 5 countries, 1800=100, 1502-2020.

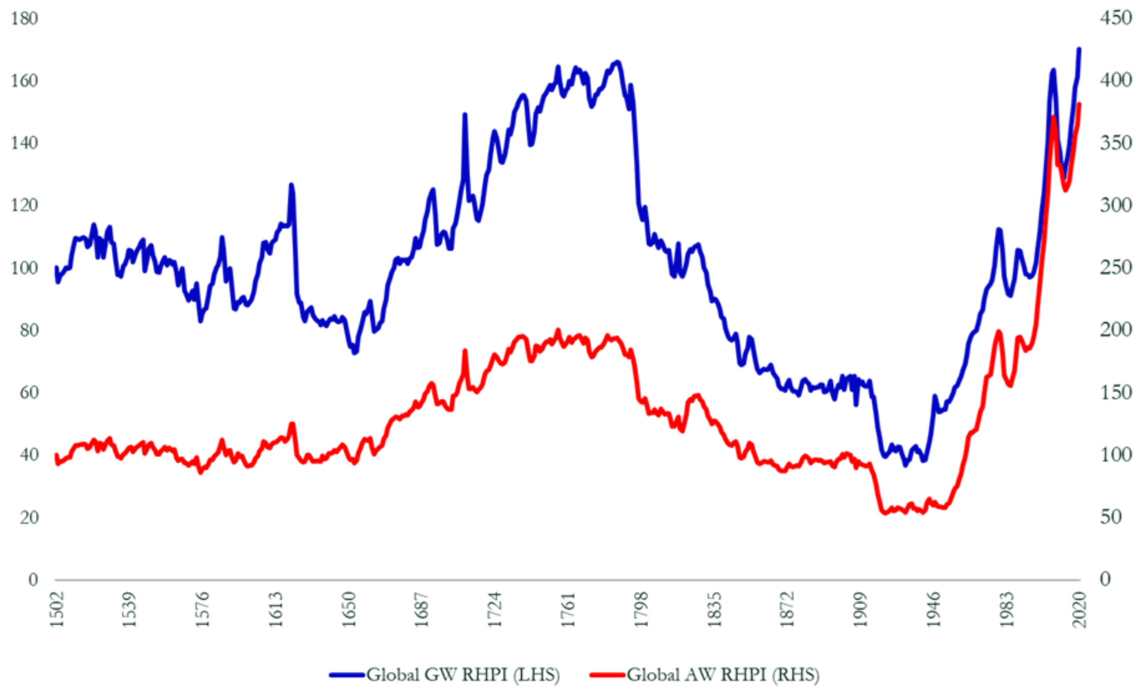


Notes: The Figure displays real house price indices based on the Seq2Seq machine-learning model, for five advanced economies, all based to 1800=100 (log scale). U.S. data is ML-backcasted over 1786-1889, U.K. data over 1560-1844, German data over 1502-1962, French data over 1503-1869, and Holland data over 1578-1869: we then switch to the respective existing price series.

What secular patterns do we observe on the country-level? First, the period of circa 1500-1650 is marked by moderate but consistent declines in real house prices, interrupted by a sharp volatility

[24]See appendix section 7.3 and discussion there.

Figure 5: Global Real House Price Index (RHPI), Seq2Seq+ bases, 1502=100.



Notes: The Figure displays Global Real House Price Indices, on the arithmetically-weighted (AW), and GDP-weighted (GW) bases, indexed to 1502=100. The sample spans France, Germany, U.K., U.S., and the Netherlands, and all backcasted periods per Figure 4. Post-1870 values (post-1962 for Germany) are based on "JST" data points – and on Lyons et al. (2024) for U.S. data points from 1890.

around the outbreak of the Thirty Years War. After the conclusion of hostilities and the Treaty of Westphalia (1648), house prices in the Holy Roman Empire significantly rebound secularly, a turnaround also visible in French and Dutch data, with both of them being traditionally considered key beneficiaries of the geopolitical distress. France's own secular appreciation cycle comes to a dramatic reversal with the French Revolution. For most countries, real house prices through the 19th century appear in fact to remain below pre-Revolution peaks. It is during the first quarter of the 20th century that French, German, U.S., and British real house prices bottom out, with the Netherlands being a key exception.

Generally, therefore, country-level inflections appear to reflect major political-financial breaks well documented in related literature – with a variety of anecdotal evidence in support of the housing-specific inflections[25] – and subsequent econometric tests (section 7 below) being able to validate such initial narrative evidence.

Next, Figure 5 allows a holistic analysis of the "long cycles" in global house prices over centuries,

[25]For instance Ambrose et al. (2013), who documented a "market implosion" in Amsterdam real house prices between 1781 and 1814. Our new Netherlands RHPI peaks in 1782 and bottoms in 1819. Note that the Ambrose et al. (2013) data (like all other pre-1870) data is not part of the ML training data set, so our Dutch RHPI represents an independent validation.

using aggregation methods recently undertaken for related financial variables[26]. A GDP-weighted aggregation (GW) and an arithmetically weighted (AW) aggregation of country-level series are presented here, covering a substantial share of "advanced economy" GDP over centuries. Particularly on the GDP-weighted basis, the contextualization of "recent", 20th century performance of housing markets, is highly revealing.

Most notably, perhaps, our reconstructions suggest that on a GDP-weighted basis only most recently, as of the early 2000s, did global real house prices surpass all-time peaks previously reached in the immediate years prior to the French Revolution. All-time lows, on the other hand, were reached on both aggregation bases in the interwar period of the 20th century, with the two world wars dragging real house prices down to all earlier local bear markets, including the post-Thirty Years War bottom. This latter observation also holds for arithmetically weighted real house prices – though here we note that the surpassing of all-time peaks in real house prices occurs earlier, specifically in the late 1990s.[27] The appendix contains robustness exercises for these global ML indices, including the full reconstructions for using real capital gains as the target variable.[28]

5 Nominal and real total ex post returns, and their decomposition, Germany and "Global"

5.1 Decomposition: rental yields, real estate capital gains, and the cost of capital

Recent debates have made much of the precise decomposition of residential real estate total returns: while Knoll et al. (2017) have suggested a decisive role for rental returns – one that plays the main role in accounting for superior returns of housing over equities – Chambers et al. (2021) have questioned this decomposition and posited much lower rental yields for residential estate over time.[29] Our new data may illuminate therefore the precise contribution of different return elements, and assess whether recent declines in rental yields – and corresponding large housing capital gains – represent historical outliers, or should rather be expected to continue. More importantly, perhaps, it also allows us to assess more comprehensively than in existing literature the economic properties of rental yields and other return components.

First, Figure 6 displays our secular evolution of rental yields.[30] Visually, it already appears

[26]See Rogoff et al. (2024), where an identical weighting approach is presented for global interest rate time series, on the basis of annual-level aggregate GDP series.

[27]On the AW basis, a local peak is reached in the year 1756 (index level 200.4), with this level being surpassed in 1998 (index level 204.7). On the GW basis, the local peak occurs in 1786, at the eve of the French Revolution (index level 165.9), and is first surpassed again in 2020 (index level 170.1).

[28]See appendix Figure A.9 and associated discussion there.

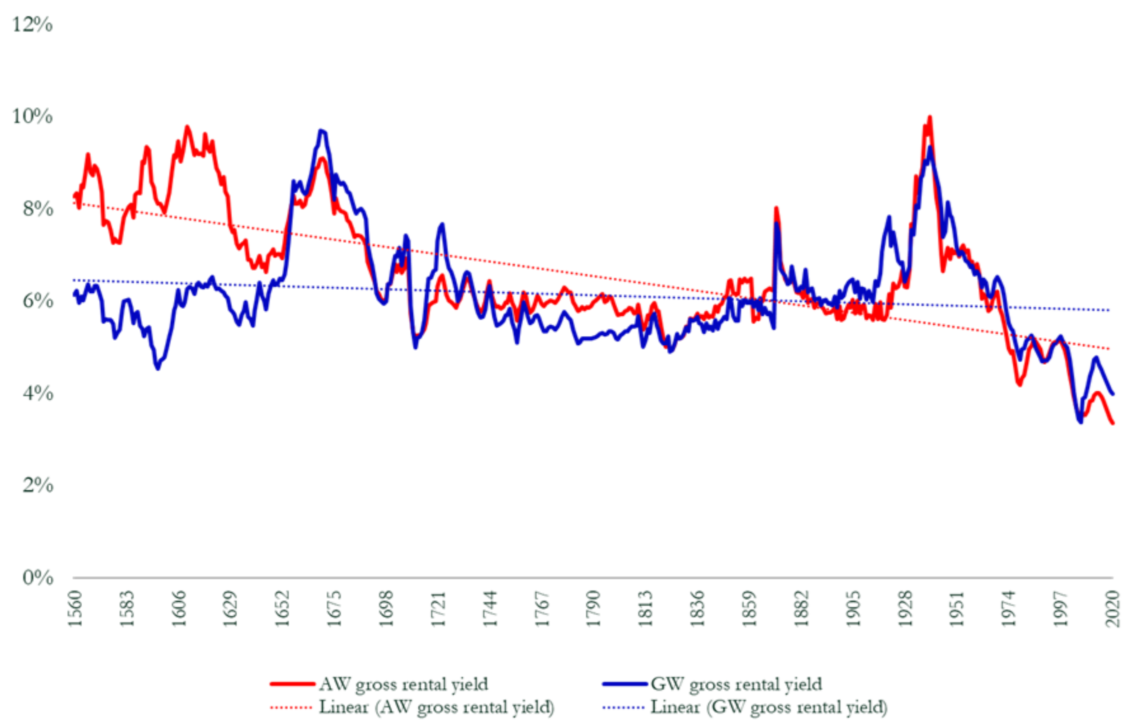
[29]Specifically, Chambers et al. (2021) find rental returns that are just three-quarters the Knoll et al. (2017) estimate (3.0% p.a. vs 4.0% p.a.), but they also revise downwards real capital gains contributions for U.K. data over 1901-1983 (-0.7% p.a. vs 0.7% p.a.); rental growth rates are close to zero.

[30]The reconstruction of rental yields is covered in detail in the appendix. We mainly derive rental yields from existing

that rental yields constructed thus are downward trending over time – in other words, that the contemporary high valuation environment of residential real estate has deep historical roots.

Specifically, the AW series declines by an average of 0.7 basis points per annum (0.7% per century), and the GW basis declines by an average of 0.1 basis points per annum. These are moderate downward slopes – not least compared to the 2-3 basis point p.a. declines recorded for sovereign bond yields in the same countries (Schmelzing, 2022). Yet, these relatively moderate rental yield slopes can be confirmed to be trend stationary over the 1560-2020 period, and equally display few if any structural breaks. Taken together, such observations (which are detailed on the econometric side further in the appendix) strongly suggest that the "low expected return" environment (in real estate and elsewhere) (Ilmanen, 2022) has deep asset pricing roots.

Figure 6: Rental yields, GW and AW, 1560-2020.



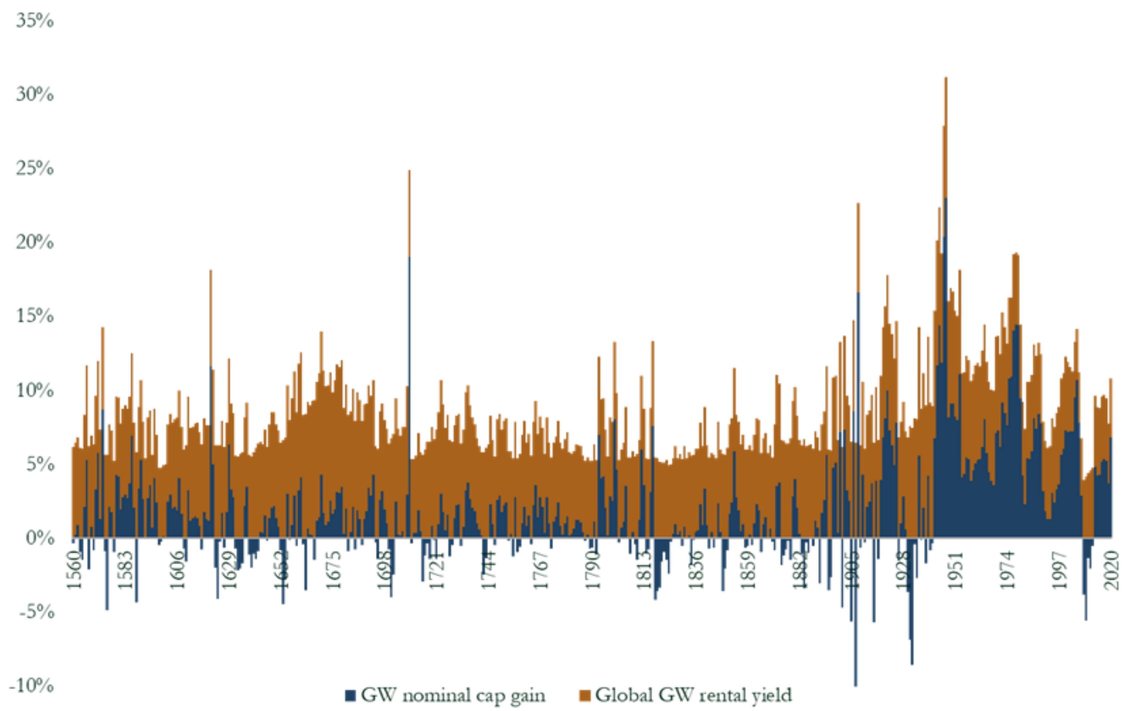
Notes: The Figure displays global gross rental yields, both on the arithmetically weighted (AW) and the GDP-weighted (GW) basis, on the five-country basis. The dashed lines represent simple linear trends.

Next, Figure 7 displays the contribution of capital gains and rental yields, respectively, to residential housing total returns, on the Global GW basis, over 1560-2020. Here, too, a key observation stands out visually already: historically, the majority of residential real estate total returns was accounted

secondary source rent indices (such as Lesger (1986)), and then reconstruct the rental yield annual observations in "JST", by combining our ML-derived house price change with changes in the rent indices in secondary literature (and primary sources, per section above, for Germany). Recently, Eichholtz et al. (2023) also focused on European rent changes over centuries, using partly overlapping data to the secondary sources I utilize for total return series.

for by rental yields. Indeed, nominal capital gains over 1560-1914 stand at 1.05% p.a. – but *real* capital gains stand at a negative -0.07% p.a. over the same horizon. Meanwhile, GW rental yields average 6.1% over 1560-1914, and thus historically used to account for the bulk of real estate total returns.

Figure 7: Decomposition of housing total returns, capital gains and rental yields, 1560-2020.



Notes: The Figure displays the decomposition of nominal total returns for the Global GW (GDP-weighted) total return series, across the rental yield and the capital gains components.

5.2 Total ex post nominal returns

The separate consideration of house price changes, rental yields, and expenditure components now allows the fusion into a total gross return series for German residential real estate since 1466.

We follow the total return definition in Jorda et al. (2019), specifically defining housing total return R as:

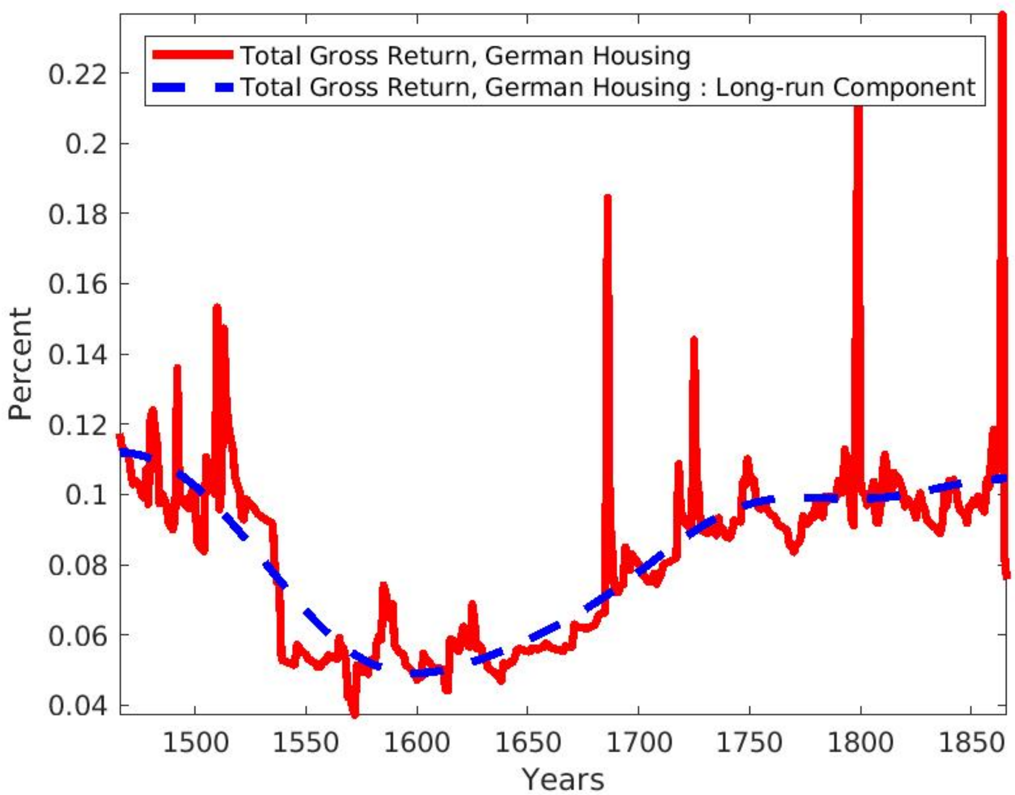
$$R_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}} + Y_{i,t} \tag{1}$$

with P denoting the nominal price change year-on-year for housing index in country i, at time t, and Y representing the rental yield.

Figure 8 first displays this time series on German nominal total gross returns. What are the main takeaways? We observe that the series over four centuries displays a "U-shape", initially at levels around 12%, but declining trendwise, and reaching all-time lows around the mid- and late 1500s, at levels just over 4%. From then onwards, total gross returns recover secularly, and return to double-digit levels by the mid-1700s. From then onwards, returns appear quite stable, trending around 10% for the remainder of the sample, despite occasional sharp spikes.

The all-time average nominal total return stands at 5.9% p.a. on our basis, after taxes and all expenditures.

Figure 8: Total Gross Returns, nominal, German housing, 1466-1866.



Notes: The picture displays the housing total return series, in nominal terms. Pre-expenditures, pre-taxes. The blue line displays the long-run trend component following the methodology of Müller and Watson (2018).

5.3 Total ex post real returns, and excess returns (EX)

Inflation has evolved dynamically in the early modern and modern periods, and therefore real total returns might represent a more accurate measure of actual asset performance. We once more follow Jorda et al. (2019), by defining housing real total returns r. Let π denote the seven-year lagged CPI price change as measured by Rogoff et al. (2024) for the respective country. Then r:

$$r_{i,t} = \frac{1 + R_{i,t}}{1 + \pi_{i,t}} - 1 \quad (2)$$

Given multi-year holding periods in residential real estate, the lagged indices appear more suitable than year-on-year inflation adjustments, and also makes results more consistent with existing long-run real asset price series including sovereign yields.[31] For our German primary source series, we can use the Schmelzing (2026) inflation basis – and when that is done, this results in a real total return figure for 1700-1877 of 6.2%, and an all-time (1465-1877) figure of 4.6% – with the same long-run "U-shape" total return pattern emerging. Figure 9 displays the net total return series for Germany, spanning 1466-1866, incorporating our cost and tax estimates (as per section 3.4).[32]

In any case, what is clear is that these German primary source figures appear generally close to modern day estimates of residential real estate returns. For instance Ilmanen (2022) calculates a real total return (net of costs) for U.S. housing over the period 1960-2020 of 6.1% real p.a. – a Figure that is lower than Jorda et al. (2019), who record an arithmetically weighted (AW) real total return (net of costs) of 7.3%, and a GDP-weighted real total return of 6.7%.

We next turn to housing "excess returns" – a key measure of interest in the literature, not least in the Case-Shiller canon (Case and Shiller, 1990). In this section, we display outright our "global" samples, this time combining the ML and secondary source methodologies?

My excess return definition follows previous literature, including Case and Shiller (1990), defining non-leveraged gross excess returns EX for year t as:

$$EX_{i,t} = R_{i,t} - i_{i,t} \quad (3)$$

With i representing the nominal long-maturity interest rate for the respective country (global), sourced per Rogoff et al. (2024).[33]

On this basis, Figure 10 displays global residential real estate excess returns (gross) for the Global GW real estate sample, spanning 1560-2020. It is visually highly suggestive that this series (like its counterparts on the country level) are secularly upwards trending. We will investigate all these visual "trend" and related properties more formally in the next econometric section now.

6 Econometrics: regressions and structural breaks

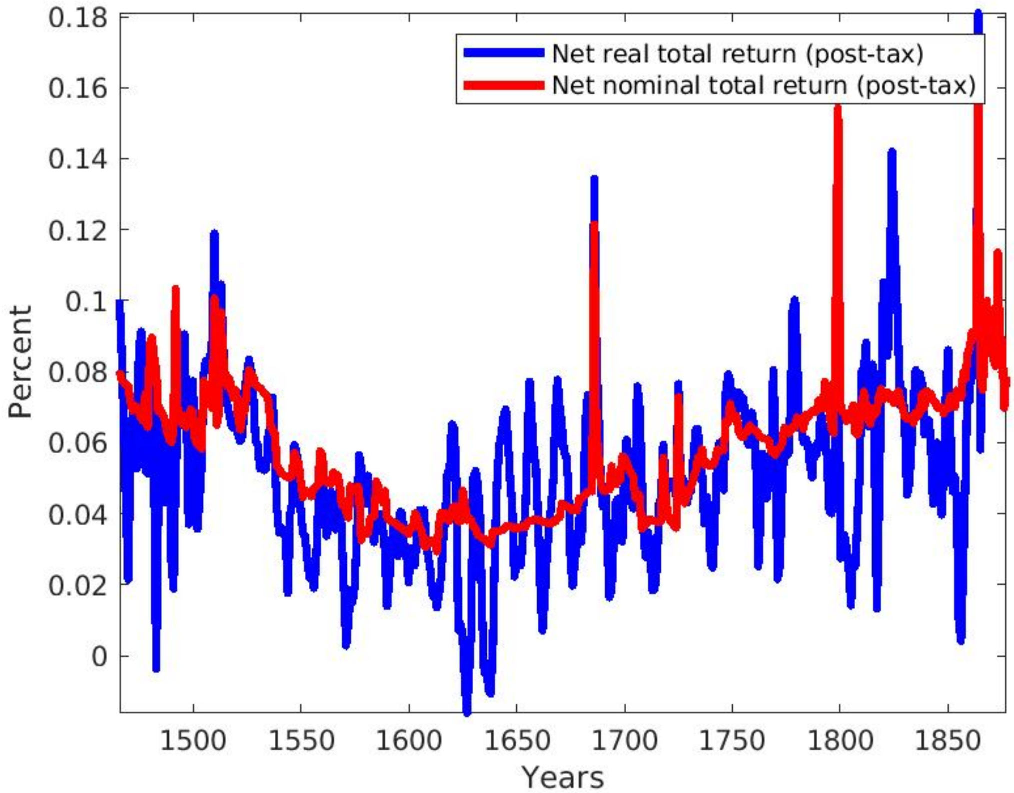
We turn to econometrics, an investigation of "turning points" in housing markets over time, and the question whether our visual impression of a long-run upwards trend in housing total returns

[31] For instance, Schmelzing (2026) and Rogoff et al. (2024) use the same seven-year lagged adjustments, series that we will return to in section 9.

[32] It should be noted that this net real return figure does not yet include depreciation and vacancy cost estimates. We noted before that Berlin tax authorities in the 19th century calculated with depreciation rates of 0.5% p.a. for residential real estate. However, the true depreciation rates were evidently meaningfully higher.

[33] As a difference to my definition, note that Case and Shiller (1989) focus on net (after tax) excess returns, and use T-bill rates, rather than long-maturity rates.

Figure 9: Total Net Returns, nominal and real (ex post), German housing, 1466-1866.



Notes: The picture displays the German housing total return series, net of taxes and maintenance costs (per estimates detailed in the text and the appendix), in nominal and real terms, all ex post, over 1465-1866.

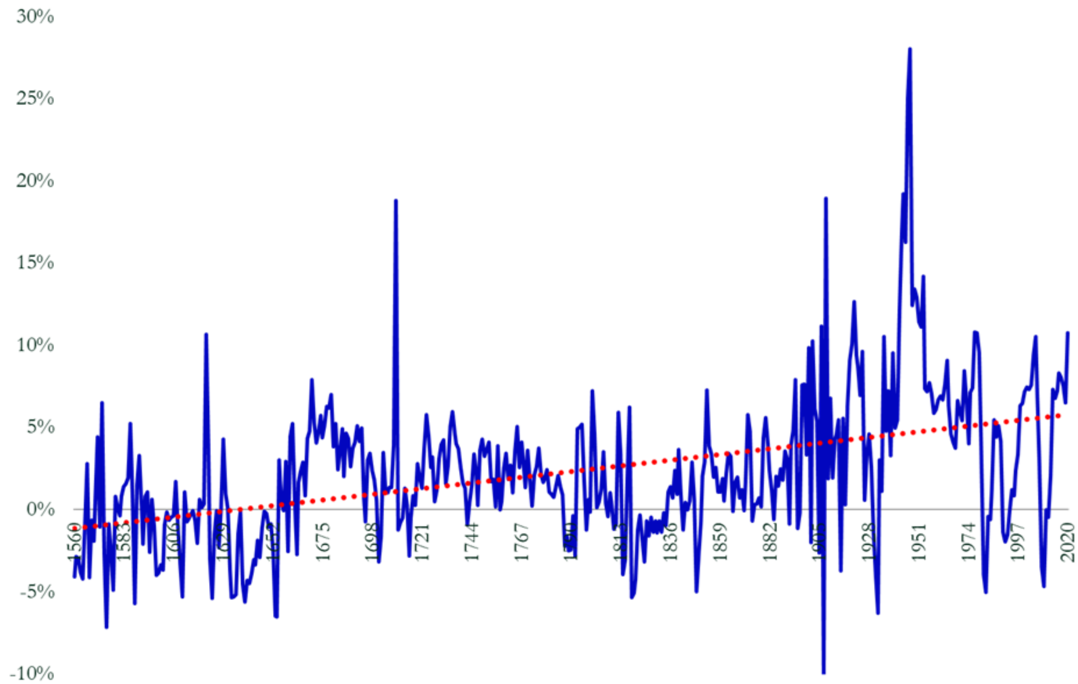
can be confirmed through formal tests.

As a summary of the state of the literature, a weak form of market inefficiency is generally accepted for real estate markets – but virtually all such literature focuses on post-1945 data, and lacks consensus on the existence of any trading strategies that might be able to exploit inefficiencies.[34] In this sense, at the very least we would expect our data to be able to confirm current consensus on real estate return forecastability on a much more general, multi-century level, exploiting the well-known statistical power from long horizon time series. And in terms of return drivers, we should expect both supply (credit supply, technological advances, regulatory easing) and demand (demographics, growth in "superstar cities") factors to influence secular trends, and the data availability allows testing both channels for Germany.[35]

[34]For a summary of econometric literature related to real estate markets and returns, see Ghysels et al. (2013).

[35]On the "regulatory" side, we note for one that some early modern cities required the approval of the city council if a non-citizen wished to purchase property within their walls. On long-run rent controls, a useful survey is Kholodilin (2024).

Figure 10: Excess Returns (EX), ex post, Residential Real Estate, Global GW basis, 1560-2020.



Notes: The Figure displays the GW excess return series using the residential real estate gross total return definition per formula (2), weighting the five constituent countries by their rolling GDP-share ("GW"). From gross ex post residential real estate returns, the sovereign GW rate (also pre-tax) is subtracted using identical five country weights, with rates via Rogoff et al. (2024). The dashed red line represents the simple linear trendline.

Table 5 presents a simple OLS regression with housing gross total returns as the dependent variable. Independent variables include real GDP growth, population growth, the inflation rate, and German real and nominal sovereign long-maturity interest rates.[36] We observe in the regression that PUB-PRI and population growth rate both correlate significantly with total gross returns. Inflation rates, real GDP growth (aggregate or per capita) and real interest rates are never significant.

It appears therefore that both supply and demand side factors may play a determining role in long-run housing total return dynamics. Higher population growth spurred demand for additional housing, and the rebound in population growth (in Germany and other advanced economies) from the late 17th century thus provides a plausible backdrop to the supra-secular housing boom.

On the supply side, the finding of significance for real sovereign interest rates is intriguing. This confirmation of credit availability seems to underpin literature emphasizing the role of credit for the 2000s U.S. housing boom (Justiniano et al., 2019), as well as contributions that emphasized credit availability as a driver of other historical housing price boom episodes (Rajan and Ramcharan, 2015).

[36] GDP growth and population growth data is via Pfister (2022). All financial variables are via Schmelzing (2026).

Table 5: OLS Regression, log excess housing returns (er)				
	log er	log er	log er	log er
German inflation	-0.0992	-0.0992	-0.0714	-0.0714
	(-1.36)	(-1.36)	(-1.25)	(-1.25)
Real aggregate GDP growth	0.0307		-0.00961	
	(0.62)		(-0.25)	
Real per capita GDP growth		0.0315		-0.00903
		(0.64)		(-0.23)
Population growth	1.216***	1.247***	0.981***	0.971***
	(7.38)	(7.87)	(7.55)	(7.74)
German real rates	-0.144***	-0.144***	-0.0895***	-0.0896***
	(-5.38)	(-5.38)	(-4.20)	(-4.20)
PUB-PRI spread	-0.0632	-0.0632	0.0198	0.0198
	(-1.58)	(-1.58)	(0.62)	(0.62)
year			0.000138***	0.000138***
			(14.86)	(14.85)
constant	0.000791	0.000788	-0.236***	-0.236***
	(-0.42)	(-0.42)	(-14.84)	(-14.84)
observations	355	355	355	355
Adj. R-squared	0.197	0.197	0.507	0.507

Notes: t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Columns 1 and 2 are not controlling for a year trend, while Columns 3 and 4 do. Real total gross return is not included as a variable given that it is mechanical. Columns 1 and 3 use German real aggregate GDP growth and Columns 2 and 4 use German real per capita GDP growth, as both measures are highly correlated and therefore cause multicollinearity issues. "PUB-PRI" spread here uses German mortgage rates for PRI basis. All data for the period 1466-1910.

Overall, we note that the r-square obtained when including all regressors (columns 4 and 5) is quite high relative to existing standards for comparable analyses.[37] In addition, we present a number of variations of this regression in the Appendix, to test the strength of these results – the main result is that population and real rates remain significant, including for a setup that uses gross total returns instead of log excess returns as the independent variable.[38]

6.1 Stationarity and forecastability

In their seminal paper, Case and Shiller (1989) analyzed U.S. city-level real house price index changes and excess returns, and rejected random walks in both variables. In representative fashion, the authors use post-1945 U.S. residential real estate data, as did virtually all subsequent work that tended to generally confirm forecastability, at least over the horizon of a few years, e.g. Mankiw and Weil (1989), and the literature associates such evidence with the existence of weak market inefficiency: for a summary see Ghysels et al. (2013). However, I am unaware of similar exercises being applied to proper long-run data, or at least horizons well beyond 100 years: existing research suggests that only at such horizons, unit roots can confidently be rejected.[39] At the very least, therefore, one would expect that our data can confirm existing consensus on a much more general level. Perhaps most importantly, though, we might be able to shed light on the question of a *trend* over the long horizon that our Figures visually suggested.

First, via Table 6 we can confirm forecastability for all German total return (gross and net) as well as real price series – with clear stationarity being confirmed when using the conventional ADF-GLS test via Elliott et al. (1996). The stationarity holds for variations of the test without a time trend, always at the 1% significance level. Table 6 reports all results, with the appendix reporting all additional results.[40]

Next, we observe that the confirmation of trend stationarity extends to our non-German, non-primary source price and return time series – as well as our "global" constructions that incorporate both methodologies. Table 6 confirms stationarity on the 1% level for all Global AW and GW varieties, as well as country-level indices (countries not shown in Table 6 are in the appendix, including country-level total returns). Once more, these results also hold when not assuming a time trend.

[37] For instance, the classic Mankiw and Weil (1989), in their most encompassing regression for U.S. real excess housing returns over 1947-1985 obtain an r-squared of 0.32.

[38] See Appendix Section 5, and Table A.5.

[39] See Rogoff et al. (2024) for interest rates: here, the true positive share for the ADF-GLS test falls off when samples of "only" 100 years of annual observations are used (to 68.8%), and drops even lower for 50 years (29.8%).

[40] See Tables A.7-A.8, along with discussion in appendix section 7. There, I also test stationarity on the German city level – where trend stationarity also holds, though with weaker significance. It has long been posited that national house price indices that fuse city level observations by design mask the house price volatility on the city level: indeed, the average individual city level real y-o-y price volatility, at 2.8%, is higher than the aggregate index volatility, at 2.1%. The appendix contains full tables and results, using different set-ups of the test. Yet, the greater volatility on the city level still appears to retain a meaningful level of forecastability. See appendix table A.10.

Existing (post-1945) econometrics in housing disproportionately focus on price changes. Using our decompositions, we can state that trend stationarity appears to be stronger for total return and price changes than rental yields. In the appendix, I detail ADF-GLS results for rental yields, and both country- and global-level rental yield series indicate a weaker confirmation of stationarity.[41]

6.2 Bai-Perron

Next, we test the long-run series via the standard structural break test of Bai and Perron (1998). The Bai-Perron methodology tests time series for up to five structural breaks, has been widely used in the financial and economic literature, and has in particular been employed to identify "turning points" in the canonical housing literature. Specifically, Knoll et al. (2017) use Bai and Perron (1998) as their basis to suggest the 1960s as the inflection point in advanced economy housing markets.

The test is however sensitive to the sample length used, and meaningfully improved sample length in particular have been shown to revise canonical structural break narratives in recent macro-finance literature (Rogoff et al., 2024).

I report the results from our long-run series in Table 7, which employs a standard set-up of the test.[42] I test both nominal return series introduced in section 5 (gross and net bases), as well as the benchmark real housing price index. For the former pair, we observe that several breaks are revealed: in particular, both gross and net returns share the years 1537 and 1640 as break dates. The gross return series shows an additional break for the year 1742.

Meanwhile, both global real price indices (GW and AW) record no breaks for the full sample length – in particular no break in the 20th century is revealed.

How do we interpret this structural break evidence, and is it plausible against independent studies? Generally, the results put doubts on the idea that a relevant housing inflection point occurred in the 20th century post-war era, as suggested by Knoll et al. (2017). Similar artificial periodizations as in Lyons et al. (2024) for U.S. markets (1940, 1970) are not confirmed by actual U.S. structural break tests. The more striking emphasis is that housing market dynamics are characterized by a significant degree of long-run continuity: the acceleration in housing returns, and real housing prices echo dynamics in other asset classes, including real interest rates – for which new long-run series recently revealed that 20th century breaks by and large disappear when longer sample lengths are considered.

On the other hand, is the major global inflection point around the late 18th century (ca. 1780) echoed in other historical evidence? Clearly such a generational turnaround should leave imprints: indeed, we note that Ambrose et al. (2013) for one detected a "market implosion" in Amsterdam real house prices between 1781 and 1814; for France, Hoffmann et al. (2000) document a well-aligned epic credit boom prevailing throughout ca. 1720-1780 – followed by a unprecedented crash that

[41]See appendix table A.9 – the results hold when tested without a time trend.

[42]As is conventional in the literature, the Bai-Perron is run with a maximum of five structural breaks allowed, and a trimming parameter of 5% of the sample.

Table 6: ADF-GLS, housing and credit variables, with time trend			
	no of lags	t statistic	optimal lag
Germany primary source, 1465-1910 (2020)			
Real gross housing return, 1465-1910	3	-3.396	
	2	-3.556	Seq, SIC, MAIC
	1	-4.262	
Real net housing return, 1465-1910	3	-4.037	
	2	-4.216	Seq, SIC, MAIC
	1	-5.027	
RHPI change, 1465-2020	3	-7.519	MAIC
	2	-8.616	Seq, SIC
	1	-11.111	
ML generated, real price y-o-y change, 1560-2020			
U.K. RHPI change	3	-3.396	
	2	-3.556	Seq, SIC, MAIC
	1	-4.262	
U.S. RHPI change	3	-4.037	
	2	-4.216	Seq, SIC, MAIC
	1	-5.027	
France RHPI change	3	-6.031	
	2	-6.178	Seq, MAIC
	1	-7.158	SIC
Global GW RHPI change	3	-7.019	Seq, MAIC
	2	-8.139	
	1	-8.985	SIC
Global AW RHPI change	3	-7.019	Seq, MAIC
	2	-8.139	
	1	-8.985	SIC
Total gross real returns, 1560-2020			
Global GW	3	-3.396	
	2	-3.556	Seq, SIC, MAIC
	1	-4.262	
Global AW	3	-4.037	
	2	-4.216	Seq, SIC, MAIC
	1	-5.027	

Notes: The table reports the ADF-GLS test statistic for several choices of the number of lags k (with a maximum of three lags). The regression includes a constant. The test assumes a time trend (see appendix for ADF-GLS results without time trend). The critical values at the 1, 5, and 10 percent significance levels are the following: -2.58 (1 percent); -1.95 (5 percent); -1.62 (10 percent). "Optimal lag" indicates the optimal number of lags according to the sequential procedure ("Seq"), the Bayesian Information Criterion (SIC), or the Modified Information Criterion (MAIC). The test rejects when the test statistic is negative and larger (in absolute value) than the critical value.

leads to subdued credit volumes well into the 19th century. And in Germany, covering residential housing markets in Berlin under Frederick William (r. 1713-40) and Frederick the Great (r. 1740-86), Voigt (1901, 76) reports that:

- "The completely new observation of house speculation, a rapid speculative change of ownership of the land, a shortage of rental units and a sharp increase in rental prices, must have made a fundamental impression on the Berliners of the time; time and again, the local sources and writers keep coming back to this puzzling phenomenon..."[43]

By 1765, specific edits were passed in Prussia to reign in on house speculation, though apparently with limited effect, at least until the death of Frederick the Great.[44] These documentary echoes must remain anecdotal, but they are consistent with our empirical reconstructions, and back up the general idea of a major housing boom during the 1700s, followed by a late-century bust.

6.3 Half-lives and adjustment speeds

A variety of asset classes have been analyzed with regards to their adjustment speeds – but curiously, real estate as the largest asset class has not been one of them. We can try to fill this gap, and now ask – how long does it take for real estate returns to mean-revert? The finding of trend stationarity over time could be a relevant theoretical insight – but it only assumes practical relevance if its adjustment speed is sufficiently low. Below, via Table 8, we deploy a half-live test to measure the adjustment speeds for real estate total returns – using the approach recently detailed for sovereign bond yields in Rogoff et al. (2024): we also choose matching subsamples for these adjustment speeds that allow a direct comparison for our real estate market dynamics to those in sovereign bond yields over time. We observe half-lives generally around 1-3 years for our "global" total return series across different weighting methods – and also observe that these figures appear to be moderately rising over time. These adjustment speeds are *economically meaningful*, as I will elaborate on below.

How do these real estate adjustment speeds compare to other asset classes for which data exists? Compared to sovereign real rates – where half-lives have recently been found to average between two and eight years over the long-run – real estate returns thus show slightly faster adjustment speeds (Rogoff et al., 2024). Both asset classes show a moderate upwards trend over time in these adjustment speeds. For modern U.S. stock prices, Balvers et al. (2000) found adjustment speeds (half-lives) of 3.1-3.5 years. The appendix reports further half-life results for primary source series, where all general long-run results also hold.[45]

[43]Translated from the original: "Die vollständig neue Erscheinung einer Häuserspekulation, eines raschen spekulativen Besitzwechsels der Grundstücke, einer Wohnungsnot und einer schellen Steigerung der Mietpreise muß auf die damaligen Berliner einer ungeheuren Eindruck genmacht haben; immer wieder kommen die Berliner Lokalschriftsteller auf das merkwürdige Phänomen zurück. . . "

[44]Prussian edict against "Housing Excesses" of April 15, 1765, via Voigt (1901, 77).

[45]See appendix table A.11 and associated discussion, for the German primary source results: the time trend towards

Table 7: Structural break tests, Bai-Perron basis

	no of breaks	break years
Primary source series, Germany, 1465-1910/2020		
Real gross total return yoy	3	1537, 1640, 1742
Real net total return yoy	2	1537, 1640
Real price index change (AW)	0	–
Real price index change (VW)	3	1518, 1573, 1878
Real price index, 1465-2020, fused S-JST	0	–
Mortgage rates, nominal, 1465-2020	1	1685
Mortgage rates, real, 1465-2020	2	1666 1799
Machine-Learning real house price index (RHPI) series, 1560-2020		
Global GW RHPI	0	–
Global AW RHPI	0	–
U.K. RHPI	3	1713, 1882, 1966
U.S. RHPI, 1786-2020	0	–
Netherlands RHPI, 1578-2020	3	1768, 1921, 1975
Germany RHPI	0	–
Total gross return (TR) series, 1560-2020		
Global GW real TR	0	–
Global GW nominal TR	0	–
Global AW real TR	3	1713, 1882, 1966
Global AW nominal TR	0	–
Germany real TR	3	1768, 1921, 1975
Germany nominal TR	0	–

Notes: The table reports the results of the sequential Bai and Perron's test (Bai and Perron, 1998). The test is implemented in Matlab using the Matlab function "pbreak" from Pierre Perron's website. The test is applied to linearly detrended series using a trimming parameter of 5 percent and a heteroskedasticity and autocorrelation consistent variance estimator. The significance level is 5 percent, and the maximum number of allowed break points is 5 for all series. When the test rejects the hypothesis of no breaks, the estimated number of breaks and the break dates are reported in the second and third columns, respectively. "AW" denotes the arithmetically weighted index basis, "VW" the value-weighted basis, and "GW" the GDP-weighted bases. The series "Real price index, 1465-2020, fused S-JST" splices the newly introduced German primary series from this paper over 1465-1910 with the "JST" data series for Germany over 1911-2020: corresponding to the series shown in Figure 3.

Table 8: Half-Lives of Total Returns, Full Sample and Subsamples				
	α	Confid. Interv. α	h	Confid. Interv. h
		GW real total returns		
1560–2020	0.50	(0.41; 0.60)	0.77	(0.69; 0.88)
1750–2020	0.43	(0.34; 0.56)	0.71	(0.63; 0.83)
1914–2020	0.62	(0.48; 0.78)	2.13	(0.96; 3.03)
		GW nominal total returns		
1578–2020	0.72	(0.63; 0.79)	0.79	(0.71; 0.93)
1750–2020	0.74	(0.63; 0.83)	2.02	(0.69; 2.34)
1914–2020	0.81	(0.67; 0.94)	3.28	(1.79; 9.08)
		AW real total returns		
1560–2020	0.28	(0.49; 0.67)	1.07	(0.90; 1.30)
1750–2020	0.62	(0.52; 0.73)	1.24	(0.91; 1.74)
1914–2020	0.74	(0.60; 0.91)	1.82	(1.24; 4.73)
		AW nominal total returns		
1560–2020	0.84	(0.76; .90)	0.99	(0.87; 1.45)
1750–2020	0.83	(0.72; 0.92)	1.14	(0.86; 2.07)
1914–2020	0.87	(0.70; 1)	1.60	(1; 1000)

Notes: This table reports median unbiased estimates and 90 percent confidence intervals of α based on Hansen's (1999) grid-bootstrap as well as median unbiased estimates and 90 percent confidence intervals of the half-life (h) based on Steinsson (2008). The regression is $y_t = \mu_0 + \mu_1 t + \alpha y_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta y_{t-j} + \varepsilon_t$, where α is the largest root. The row with the country name reports the full sample estimates, while the rows with subsamples report the subsample estimates.

7 The cost of capital, real estate premia, and the 17th century safe asset inflection

The regression results in Table 5 motivate a closer look at a key underlying financial variable associated with house price variation: private credit through the ages, in the form of mortgage rates. This factor is of course of key contemporary relevance given the discussion about the "mortgage credit channel" of the 2008 financial crisis (Mian and Sufi, 2009). And not least Case and Shiller (1989) already speculated in their seminal paper that the forecastability of housing prices and housing excess returns could primarily be a function of the forecastability either of real sovereign interest rates, or mortgage rates.[46]

Mortgage debt has deep historical roots in advanced economies – it is older than sovereign debt and thus likely constitutes the oldest financial asset in continuous existence – and a subset of the German *Häuserbücher* even report direct information on the mortgage loans associated with the respective real estate sales.[47]

This prominence allows us to measure this key variable over time and exploit a comprehensive new dataset for German long-run consistent (real and nominal) mortgage rates – including data for the exact subset of cities that constitute the repeat sale price index. This mortgage dataset features more than 1,100 individual observations and is described further in Schmelzing (2026). A representative archival mortgage contract from this sample is shown via Figure 11, where we see a mortgage involving the South German monastery of Pfullendorf (South-West Germany) on the creditor side, dated April 30, 1624.[48]

German mortgage interest rates represent a trend stationary series displaying a general downward trend, and per Table 7 record a structural break on the nominal basis in the year 1685. This break in 1685 is echoed when testing the real mortgage basis, where breaks are revealed for 1666 and 1799.[49] We visualize German real mortgage rates via Figure 12, showing this secular downward trend. Over the period of 1666-1799, real German mortgage rates fall by 7.7 basis points per annum,

longer half-lives is absent in this series, though the absolute adjustment speeds are closely comparable to results in table 8.

[46]See in particular their Table 3 and associated discussion. Meanwhile, in the appendix (Section 5), we will consider another key variable for which our regressions suggest some plausibility, and our primary sources provide new detail: housing supply estimates through the ages.

[47]Principally, of course, that means that it would also be possible to estimate relatively well German *leveraged* excess returns. Currently, this is beyond the scope of the paper – but I leave this for future discussion.

[48]The overall mortgage sample covers 18 different cities and areas (both urban and rural areas), with observations spread relatively evenly across the current geographic borders of the Holy Roman Empire from the inception of the dataset: on the creditor side, the sample features a mix of private and institutional creditors (monasteries), on the debtor side exclusively private individuals and households: virtually all contracts are secured by the underlying residential real estate asset.

[49]The real basis uses the seven-year progressively lagged German inflation rates in Rogoff et al. (2024) which follows constructions in related literature. See Appendix tables A.6 and A.7 for ADF-GLS tests on German mortgage rates, as well as sovereign rate-mortgage rate spreads over time.

over the period 1799-2022 real German mortgage rates moderate their decline slightly, and display an average 7.3 basis point decline. In general, however, these results confirm recent evidence from sovereign real interest rates: over longer horizons, sovereign real interest rates have been shown to be trend stationarity around a downward trend, with relatively few breaks over centuries and relatively short half-lives. The same appears to be the case for (real and nominal) mortgage rates, at least on the German data basis. The concurrent decline of mortgage rates (the cost of capital in housing) and the rise in house prices constitutes a plausible interplay, in light of the strong causal links established in existing literature, though on the basis of much shorter time series (Case and Shiller, 1989; Piazzesi and Schneider, 2016).

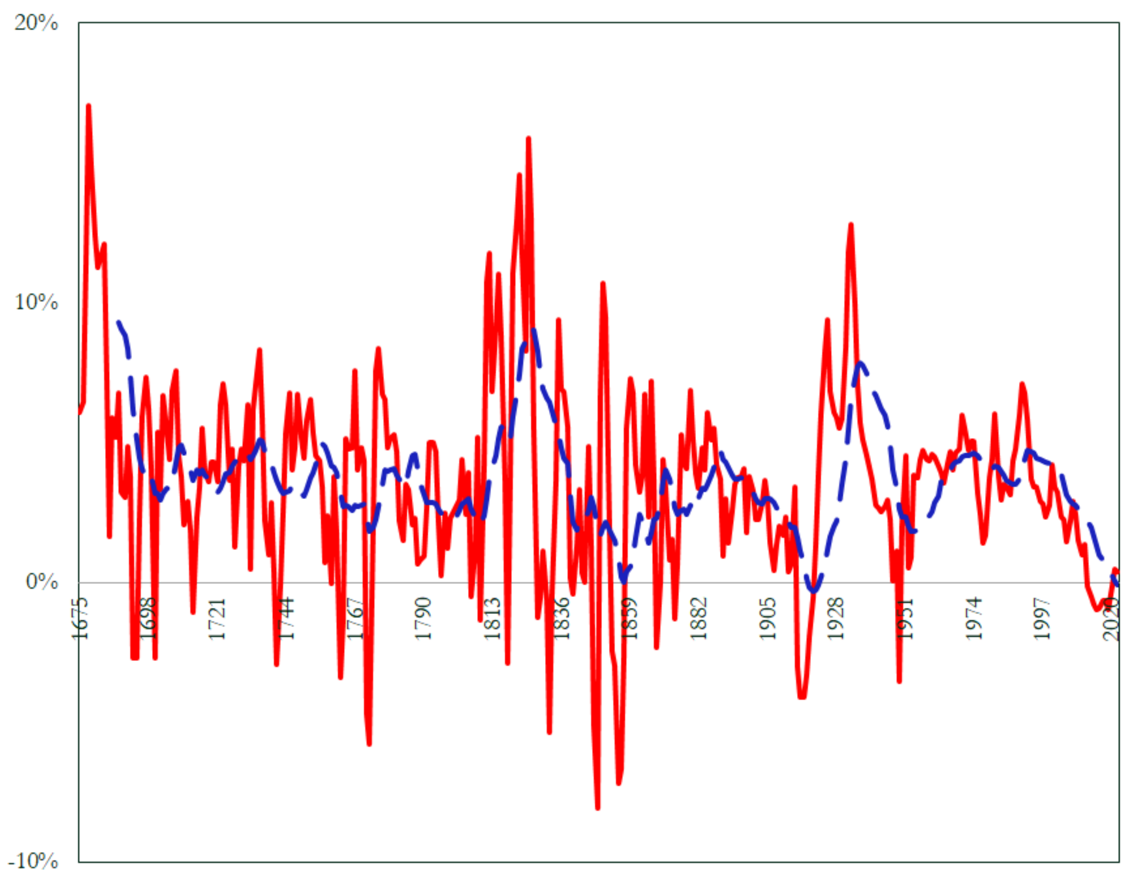
Figure 11 displays a representative mortgage contract used in the real mortgage rate series, dated April 30, 1624, with additional discussions also in Schmelzing (2026). Here the stated nominal interest rate is 5% p.a.

Figure 11: Representative mortgage contract, April 30, 1624, Freiburg region.

Notes: The image displays a mortgage contract dated April 30, 1624. It is part of the mortgage rate sample over 1311-2024 in Schmelzing (2026). The contracting parties in this case are Cleopha Mayerin zu Pfullendorf on the debtor side, and the monastery of Pfullendorf on the creditor side. Contract held in the archives of the Archbishopric Freiburg, Erzbischöfliches Archiv Freiburg, Urkundensammlung Haid UH095, in: Monasterium.net, URL </mom/DE-EAF/Haid/UH095/charter>, accessed November 11, 2024.

Overall, what the evidence from credit markets appears to show is that the "recent" fall in mortgage rates that has been put at the core of explanations of the 2000s housing boom and its subsequent crash (Justiniano et al., 2019) has in fact deep historical origins. That is, our structural break analyses did not reveal some point during the 1980s or 1990s as constituting a relevant inflection point in real mortgage rates (table 7). Instead – echoing new evidence from sovereign credit markets – it appears that significant continuities exist in fixed income markets, with continuous downward trends and trend stationarity features being confirmed for all of them. To be clear, while our mortgage results are confined to Germany only, the literature has generally posited strong correlations between advanced economies, and therefore future research could strengthen our basic observation of a positive correlation in German data for other advanced economies constructions.[50]

Figure 12: Real mortgage rates, Germany, 1685-2020.

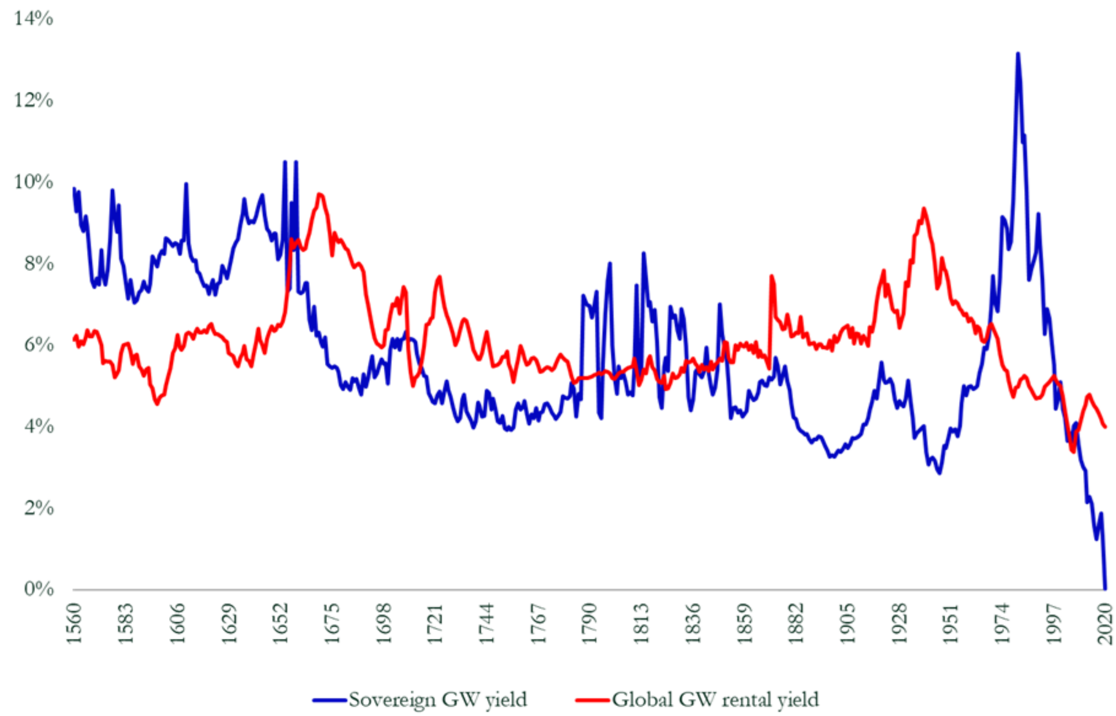


Notes: The Figure displays German real long-maturity mortgage rates on a consistent concept basis, as reported by Schmelzing (2026), using more than 1,100 primary mortgage contracts. The inflation adjustment approach follows Rogoff et al. (2024), using a seven-year progressively lagged German inflation rate. The blue line displays the Müller and Watson (2018) trend component.

The structural break evidence from housing over the very long run raises intriguing long-run questions, regarding both asset pricing and also political-economic ones. Importantly, the idea of a

[50]For instance Eichholtz et al. (2021) show high degrees of correlation (.75) on the gross yield side between Paris and Amsterdam, over 1900-1943.

Figure 13: Global GW rental yields versus GW sovereign debt yields, 1560-2020.



Notes: The plot depicts Global GW rental yields, as well as Global GW sovereign nominal bond yields. The rental yield data is constructed as per this paper, and the sovereign yields are sourced via Rogoff et al. (2024). Identical country samples and GDP-weightings are applied, for the five key advanced economies. Both series are pre-tax.

small handful of structural breaks over centuries – breaks that are particularly concentrated over the era of ca. 1537-1685 – accumulates from new research across different asset classes.

As we saw, breaks in our new real total gross and net returns for housing are clustered over 1537-1685; in addition, mortgage rates inflect over 1666-1685 (Table 7).

Meanwhile, Rogoff et al. (2024) showed recently that long-maturity sovereign real interest rates inflect in the year 1557, and show strong trend stationarity.[51]

We can fuse such evidence and now contextualize real estate in the broader asset universe. It is often taken as a given that European sovereign bonds constituted the market "safe asset" from at least 1700 – and that such sovereign assets commanded valuation premia from that time: at times referred to as "convenience yield" or "safety premium", with a variety of precise preferred empirical approximations.[52]

[51]This 1557 date was the result of a Chow test, which tests the significance of specific imputed break dates, unlike the open-ended Bai-Perron.

[52]While sharing the same conceptual basis, the precise definition of the "safety premium" in the literature varies: some prefer to use the TIPS-Treasury premium (Acharya and Laarits, 2024), others use long-maturity sovereign interest rate differentials (Lustig et al., 2023), yet others Aaa corporate-Treasury spreads (Krishnamurthy and Vissing-Jorgensen,

Constituting the two largest asset classes for early modern and modern portfolio holdings which households demonstrably viewed as substitute marketable assets (Korevaar, 2021), a direct comparison of real estate with sovereign interest rates is therefore instructive, and now visualized in Figure 13: fusing the evidence on sovereign nominal bond yields and our new rental yield series, and applying identical country and GDP-weights to both, we can reconstruct these two valuation variables next to each other over 500 years.

We see that initially – in the final decades of the 16th century and into the mid-17th century – sovereign bond yields showed positive premia over rental yields in advanced economies. However, the signs invert around the year 1650, and for the first time sovereign bond yields *structurally* fall below rental yields. In our sample, for the first time in the year 1655, GW sovereign nominal yields yields fall below rental yields. Afterwards, over 1655-2020, sovereign yields record a "safety premium" over rental yields for 78% of the time. Except for these 80 annual observations since the mid-17th century, this safety premium in advanced economies is not just positive in absolute terms –it also appears to be sloping upwards over time.[53]

I follow the definition of "expected returns" as in Cochrane (2011), and elsewhere in the relevant literature, where it is still acknowledged that current price variation does contain information unrelated to expected future cash flows (for real estate specifically, see Fama and French (2025)).[54] If adequate, then the additional evidence I presented for rental and sovereign yields is clearly at least consistent with the idea of a much deeper cross-asset trend spanning wide parts of the asset universe, and spanning all relevant advanced economies, towards the "low expected return" environment widely debated for the contemporary era Ilmanen (2022).[55]

To summarize, the long-run absolute and relative trends analyzed in this section can empirically underpin two new stylized facts:

- First, the "low expected return" environment of the early 21st century – as ever more prominently highlighted in asset pricing (Ilmanen, 2022) – appears to be both a multi-century and a cross-asset phenomenon. Valuations have risen, and yields have continuously fallen for two of the main items of the asset universe, with the observation of few structural breaks underpinning this continuity.

- Second, based on the consistent measurement of yield differentials, enabling a first very long-run relative asset pricing perspective, we can pinpoint the emergence of a "safety premium" on advanced economy debt with unparalleled general precision. Namely, I suggest that the

2012).

[53]The linear trend of the GW "safety premium" (here defined as the slope of the spread between the red line and the blue line in Figure 13): +0.62 basis points p.a.

[54]In Cochrane (2011), "discount rate', 'risk premium' and 'expected return' are all the same thing". Fluctuations in equity valuations over the long-run have also been interpreted as evidence of time-varying expected returns in (Golez and Koudjis, 2018), who – like I do in this paper – lack any true measure of early modern "expectations" as surveys are virtually absent.

[55]Why there has been such a fundamental trend is a question beyond the scope of this paper.

period between 1550-1650 can be regarded as the era witnessing the "birth" of sovereign debt as the safe asset in the universe.

8 Conclusion

Real estate constitutes perhaps the biggest asset class over time, and arguably new stylized facts on its performance therefore matter also for our understanding of the broader long-horizon asset universe. This paper argued that recent leaps in both primary source availability and machine learning models now allow us to do exactly this. In this paper, I first took advantage of the German primary data situation in particular, which allows a granular "bottom up" reconstruction of house prices and total returns: using Haeuserbuecher and newly digitized data, we can construct a new repeat sales index. Combining such data with machine learning models in a second step – for which I utilize long-run covariates reconstructions, including sourcing new building cost indices –, I provided the first housing price and total (ex post and excess) return series for housing markets covering a substantial share of global aggregate GDP over centuries. On this new empirical basis, I attempted to establish a number of new stylized facts for this asset class, break down return components over centuries, and contextualize the performance of real estate within the broader asset universe where recent literature highlighted the importance of long-horizon analyses.

And indeed, as this paper attempted to show, we can establish new key asset class properties for residential real estate over time. On the basis of a new granular house price index – one that projects modern "state of the art" indices into the past and thus overcomes key source obstacles that have prevented comprehensive constructions – we for the first time assessed the truly "long cycles" in global housing and first established that the well-documented real and nominal house price appreciation over the past years in fact appears to have deep secular roots. Importantly, both "bottom up" and "top down" (ML) approaches agree that the idea of a "hockey stick" evolution of global house prices (and returns) appears tenuous. Sharp fluctuations and "booms and busts" in housing appeared to have taken place regularly in the past – though generally, the degree of continuity is perhaps most striking, as we fail to consistently identify structural breaks in the mid-20th century using conventional tests.

On the question of forecastability in real estate, the canonical literature has dealt almost exclusively with recent, 20th century evidence – typically focusing on the U.S. Using the same two very different methodological approaches, in this context this paper argued that a key consistency relates to housing total returns (real, nominal, and "excess") appearing to increase consistently if moderately, exhibiting a moderate positive slope, with clear rejections of unit roots across approaches, and relatively fast mean reversals (in the context of other assets and literature). In terms of return decompositions, rental yields have remained more stable in the early modern period but tended to decline moderately over time, with capital gains assuming a greater importance.

And indeed, the combination of falling rental yields and rising capital gains is plausible not least in light of the long-run reconstruction of a prime driver: (real) mortgage rates. We presented a new long-run real mortgage rate series for Germany, and observed that real mortgage rates began to secularly decline since the 17th century: the post-1980s "secular" decline in mortgage rates, often invoked as causally attributable for the 2000s housing "boom and bust" appears to have far deeper origins.

Notably, these headline results are not dependent on specific alternative specifications of the ML approaches, nor on variations in inflation-adjustments, or weighting methods on the country- or global levels (even though such changes will bear on, say, the precise reported absolute return averages on which there are related debates). They gain independent validity from the reconstructions of construction cost indices and (real) mortgage rates, as well as historical narrative sources.

I then sought to locate the performance of real estate more holistically in the broader asset universe over time – contextualizing our new data with related recent empirical advanced, including for sovereign interest rates. We found that, initially, in the early modern period sovereign interest rates were higher than rental yields for the same set of key countries, but then dropped more aggressively with time, with rental yields exhibiting more stability generally. Mechanically, this results in a "safety premium" (as defined in this paper) emerging for sovereign assets, first towards the early 17th century. We observed that this safety premium is secularly increasing, but with both rental yields and sovereign yields hitting new all time lows in the early 21st century. Therefore, the long-run trends in both assets – which together account for a decisive share of total net worth over time – not just point towards commonalities regarding their economic properties (trend stationarity, coupled with economically relevant degrees of half-lives) but importantly allows to suggest for the first time that the "low expected returns" environment of the early 21st century constitutes a multi-century, cross-asset phenomenon that apparently began far earlier than consensual narratives, which predominantly trace this investing regime back into the 1970s and 1980s.

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APPENDIX

1. Details on data sources, and *Häuserbücher*

In Table A.1, I provide full details on the underlying sources used for the repeat sales observations across the ten municipalities in our German sample.

I also provide contextual details for each city – whether accompanying information such as house transfers and inheritances, details on tax assessment values (as opposed to sales prices), and quality improvements on the property level are available in each case.

Next, while I have displayed examples in the main text from the new primary source basis utilized in this study (the Topo N database for Nuremberg), the other major source type are the secondary source compilations in the *Häuserbücher*. Figure A.1 displays sample pages from secondary literature that is utilized – specifically sample pages from the *Häuserbücher* for Berlin and Munich. The left handside displays an entry for the "Stralauerstrasse 17", an address still in existence in the Berlin district of Friedrichshain as of 2024. This property documentation begins in the year 1700, and chronologically lists all associated transactions, including non-sale transactions such as inheritances (here in May 1762). Also indicated explicitly are foreclosure sales (here in June 1744), often denoted with the legal phrasing of a "*sub hasta* sale" in historical sources.

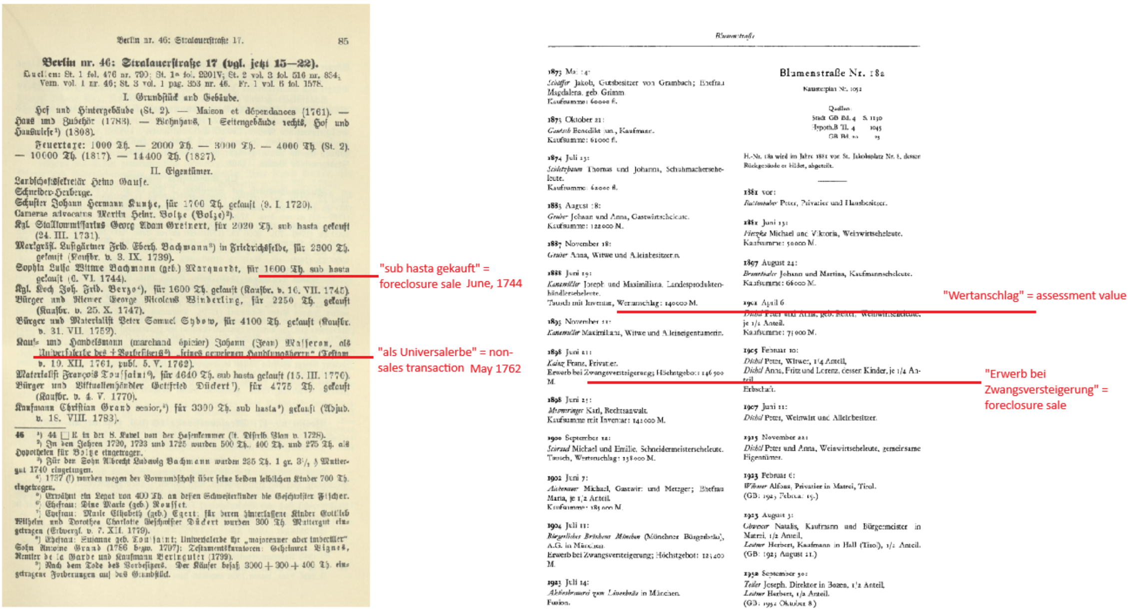
Table A.1: Overview of sources for Housing Index, repeat sales

	# Source	period	Source type	information
Erfurt	Hartung (1861)	1300-1700	Secondary, cadaster	F
Stengberg	Scheiber (1948)	1465-1860	Secondary	F, N
Mainz	Schaab (1841)	1604-1808	Secondary	
Frankfurt	ISG	1378-1845	Primary, archival	F, N
Koblenz	Gillissen (2016)	1408-1792	Primary, archival	
Berlin	Lüdicke (1933)	1681-1850	Secondary, cadaster	
Coburg	Wolter (2010)	1400-1945	Primary, archival	N, A
Munich	Stahleder (2006)	1368-1571	Secondary, cadaster	F, N, Q
	Burgmaier and Schneider (1966)	1572-1904	Secondary, cadaster	F, N, A, Q
Freiburg	Flamm (1905)	1572-1904	Secondary	
Dessau	Brückner (1989)	1693-1933	Secondary, cadaster	Q
Nuremberg	Topo N	1492-1910	Primary, archival	F, N, A, Q

Notes: The table reports underlying sources for repeat sales observations. For column 5, the following codes are used: F = contains explicit foreclosure events; N = contains additional information on non-sale transactions (such as inheritances or transfers within families); A = contains details on assessment values; Q = contains details on quality improvements.

On the right handside, we display an entry from the Munich counterpart, here for the Blumenstrasse 18a, an address also in continuous existence as of 2024, in the Munich district of Altstadt-Lehel. In this case, I also highlighted an example of a *Wertanschlag* – an official assessment value of the property, as opposed to a sales price. Such assessment values are documented frequently in the *Häuserbücher*, but I do not use them for the construction of price indices, given a rage of potential (and well-documented) biases arising from such assessments. As in the Berlin case, the Munich sources also explicitly identify foreclosure sales, highlighted here for the Blumenstrasse in 1898.

Figure A.1: Example entries from the Berlin (LHS) and Munich (RHS) "House Books".



Notes: The picture displays an extract from the Berlin house book (Lüdicke, 1933) on the left handside (LHS), and an extract from the Munich counterpart (Burgmaier and Schneider, 1966) on the right handside (RHS), together with representative examples on the details these sources provide. In particular, I highlighted inheritance events, and foreclosure sales ("sub hasta") in both cases.

2. Details on input estimates: expenditures, taxes, rents

Here I provide details about key inputs in the housing total return series, in particular the non-price components, on which even recent literature relies more on unobservables and generated informed estimates, as opposed to relying on direct property level data.

Table A.2 begins by presenting estimates of total expenditures associated with residential housing, as a share of gross rent. We observe that literature dealing with 19th and 20th century data has operated with relatively similar assumptions on this expenditure component across advanced economy cities, with shares ranging from 21-35% of rental income.

3. Profits from sale, idiosyncratic risk, and fire sales

The real estate literature – with recourse almost exclusively to post-1945 data – generally posits weak market efficiency in real estate prices: in other words, (real) price changes are predictable at least over the horizon of a few years, but that it is not likely that profitable investment strategies can in practice exploit this phenomenon. Summarizing the literature, per Ghysels et al. (2013),

- "Transaction costs and other frictions are too large for the serial correlation to translate into economic gains for the non-REIT and REIT data."

Table A.2: Overview of housing expenditure share estimates				
	Source	period	EXP share	coverage
Paris	Eichholtz et al. (2021)	1809-1943	25%	
Amsterdam	Eichholtz et al. (2021)	1900-1979	31.8%	M+C
U.K.	Chambers et al. (2021)	1901-1983	32%	M+C+T
U.S.	Eisfeldt and Demers (2022)	1986-2014	35%	
DMs	Jorda et al. (2019)	1870-2018	"About one-third"	
Elberfeld	Eberstadt (1903)	1891-1901	32.6%	M+C+I
Berlin	Müller (1881)	1870s	20.7%	M+C+I+T

Notes: The table reports estimates for the non-tax housing expenditure share for various geographies and historical periods in secondary literature, together with details. The EXP share in column 4 is expressed as a percentage of the property income, excluding taxes and vacancy adjustments, unless otherwise noted in column 5. Column 5 denotes the components included in the expenditure share by the respective authors: "M" = Maintenance; "I" = Insurance; "T" = Taxes.

As our German repeat-sales observations come (by design) with a large body of actual transaction and profit data, it appears potentially very fruitful to examine the idea of actual economic gains from housing transactions over long spans. Our transaction data usually reports the persons involved in the transaction, allows the inference of holding periods, and given the availability of inflation data, allows real and nominal profits from sales. Only transaction costs are difficult to obtain, and therefore all such profits are gross ones.

But not least, the sample also allows the identification of "fire sales" that are not related to general market conditions – in other words, idiosyncratic heavy discounting of housing objects against the backdrop of non-distressed aggregate housing markets.

.1 Price gains, holding periods, and fire sales frequency

First, table 2.2 displays summary statistics on the transactions for the full German repeat sales sample, including average and median sales price changes (relative to the previous sales price for identical properties), and the average holding period of houses spanning individual (open market) sales transactions.

We observe that the average and median sales price gains (in nominal terms) are strongly positive. Across the entire sample, over 1300-1933, a median nominal price gain of 33.3% is observed. This median is relatively stable over sub-periods, ranging from 33-37%. In average terms, there appears to be an increase in prices, from levels in the mid-80% range, to levels above 100% in the post-1800 subsample. That is, home sales have on average doubled over their previous purchase price in nominal terms from the 19th century onwards.

Broadly the same picture emerges when we measure such sales gains in real terms. On such a basis, all-time median (1300-1943) stands at 13.5%, with a secular upwards trend reaching a sub-period record of 20.6% over 1800-1943.[56]

At the same time, holding periods appear to have seen a slight decline over time – while the 16th, 17th, and 18th centuries saw average holding periods above 35 years, this figure dropped to around 27 years by the 19th century. This process could be related to improved liquidity, or trends in migration patterns, or

[56] For details see Table A.2.3.

other demographic factors. Much modern data is not directly comparable to such statistics, but those that are indicate that as of the 21st century, typical holding periods in real estate have declined further.[57] In any case, this apparent (moderate) downward trend in holding periods mirrors evidence from other asset classes, including the secular downward trend in average effective sovereign debt maturities.[58]

.2 Fire sales

Recent literature has engaged with these two "crash" dimensions, on the market and individual housing level, and suggested stylized facts. For instance, recently in a study focusing on the U.S. market over 1987-2009, Campbell et al. (2011) have suggested that "forced sales" of housing – including foreclosures – come with an average -26% price discount compared to "non-forced" transactions.[59] However, for long-run historical series, similar definitions are not extant thus far.

We build off this literature and measure aggregate and individual housing distress over the German sample. We take existing numbers as a benchmark for the definition of "fire sales" in German housing over the centuries. For individual transactions, we first start by measuring frequencies where the sales price is at least 25% below the previous sales price in nominal terms.

The advantage of our underlying *Häuserbücher* as sources is that typically, foreclosure events are explicitly mentioned, therefore providing a cross-check that indeed, our threshold is capturing actual distress situations by the sellers.

On this first fire sale definition (-25% and more discount to previous sales price), however, we appear to observe more variation over time. Out of a total of 1,468 transactions, the full-sample frequency of fire sales stands at 7.6%.

Figure A.2 displays the long-run trend visually, and reveals several distinct rapid spikes in this distress variable. In particular, the two greatest surges in fire sales appear to have been recorded, first, during between 1495-1505 – when fire sale frequency jumps to an all-time record of just under 30%; and second, during the 1640s, just following the formal conclusion of the Thirty Years War, with an all-time peak of 32.9% over 1648-9: the war period of 1618-1648 itself saw a severe intensification of material destruction in German cities – and it appears that in line with evidence from sovereign debt markets, the recognition of formal default events only got underway when hostilities ended. Consistent with our severe drop after 1618 in the RHPI (-83.9% peak-to-trough),[60] the Thirty Years War in general appears to constitute the most intense real estate market correction ever recorded – it certainly outranks the 2008 crash both in terms of peak to trough real price correction, as well as in fire sale frequency using modern definitions: on the Shiller

[57]Neither current official German data or U.S. census statistics are directly comparable given that transfers, sales, and non-sale transactions are not distinguished in aggregate holding period statistics. For modern U.S. commercial real estate, Sagi (2021) records 8.2 years of holding periods on an identical methodological basis as ours. Private data from the provider ATTOM (2024) for the U.S. allow a closer comparison for residential real estate, suggesting that comparable U.S. holding periods as of 2024 stand at 7.8 years, again with a slight secular trend over the past 20 years.

[58]For secular trends in average maturities of sovereign debt assets, see Schmelzing (2026).

[59]The authors focus on residential single- and multi-family home transactions in Massachusetts. "Distress sales" are classified here in two main categories, encompass (a) a sudden death of the owner triggering a sale; (b) a formal foreclosure event. In our historical sample, the focus is on category (b), though in practice the explicitly recorded (b) events include (a) events as a trigger.

[60]This figure takes the Schmelzing (2026) lagged inflation adjustment, as per our earlier discussion: the peak in real house prices is recorded in 1620 (167 with 1465=100), the bottom in 1627 (26.9).

Table 2.2: German repeat sale housing transactions, price gains, and holding periods

	# of transactions	avg. price %	median price %	Avg holding period
Total				
1300-1943	1,468	105.4	32.9	32.7
1500-1850	1,192	106.7	31.1	34.5
1700-1850	792	101.0	30.7	34.6
1800-1943	595	102.1	34.9	26.9

Notes: The table reports summary statistics for market sales transactions of houses in the sample. Average and median price columns record price increase (decrease) relative to most recent previous recorded sales price, in nominal terms. Average holding period in years.

(2015) basis, 2008-9 saw a 38.9% real house price drop in U.S. data; and per Campbell et al. (2011), the 2008-9 housing bust saw a peak in fire sale frequencies (for MA) at 28.5%.

In this sense, it appears that major geopolitical shocks constituted one of the biggest property-level risk factor in the early modern period, but only to the extent that they were associated with severe material damage – consistent with recent granular material damage statistics (Zwierlein, 2021), war events over 1648-1910 were no less damaging in terms of human costs, but far less so in terms of raw physical (and housing) damage.[61]

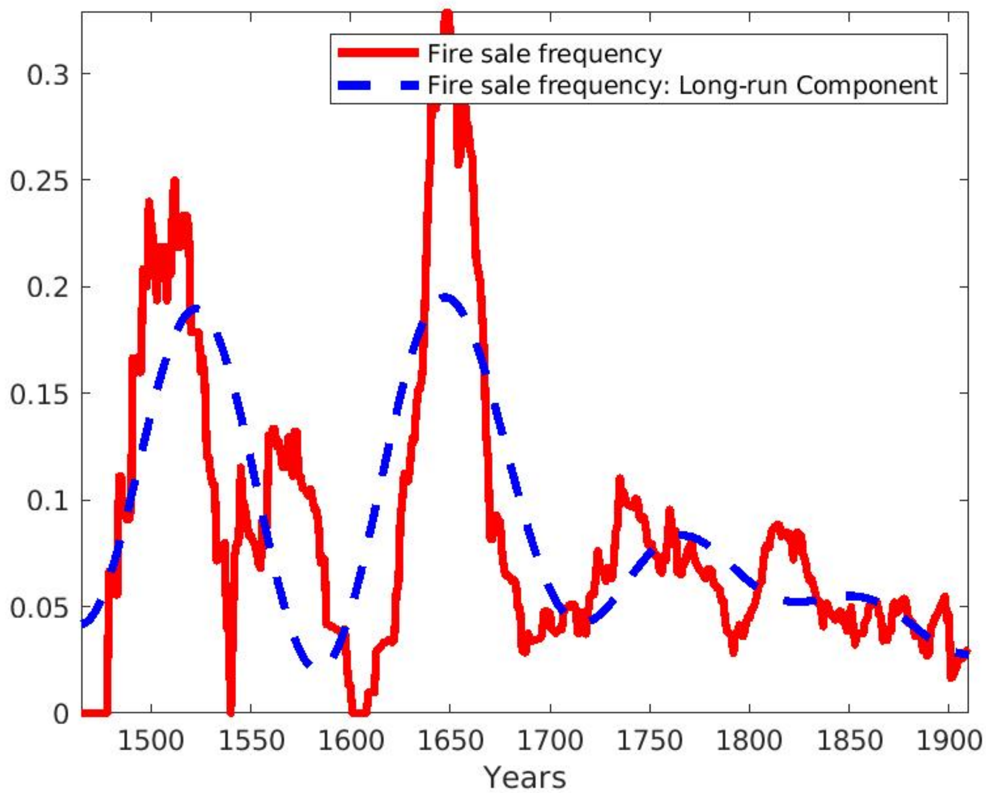
In this sense, the 1648 surge in itself marks an epochal asset market inflection point. The most important item in the capital stock over time – real estate – assumed its contemporary, modern "risk profile" after the Westphalian Peace. For if we take the 1650-1910 average in fire sale frequency – recorded at 6.9% p.a. – this average comes extremely close to "normal" levels in U.S. residential housing markets over the full sample period reconstructed by Campbell et al. (2011) for Massachusetts housing markets, for which they record 7.1% along the same definitions.

Overall, therefore, the fire sale data over time is a key reflection of the idiosyncratic risk of residential real estate as an asset class. It has long been recognized that this idiosyncratic risk for housing as an asset class is higher than for other asset classes, including sovereign bonds or equities – with housing risk much more difficult to diversify (Piazzesi and Schneider, 2016). In a relative sense, it might still be true that such risks are higher than other asset classes even centuries ago – however, the remarkable fact from our data appears to be that outside of war events, idiosyncratic risk within housing as an asset class – as measured by adopting modern fire sale definitions (Campbell et al., 2011) to German data – by the late 17th century dropped to levels directly comparable to recent U.S. housing data from the 1980s. On this basis, idiosyncratic housing market risk appears to have changed relatively little over the past three and a half centuries.

Secularly, it appears that at least over the period of 1466-1910, the fire sales frequency is trending downwards. But importantly, however, over the period of 1700-1910, the fire sale frequency, at 5.4% is already highly comparable to the fire sale frequency that Campbell et al. (2011) calculated for U.S. homes over 1987-2009, at 6.1%. Second, the *peak* fire sales frequencies that we observe in the very long-run sample are also intriguingly close to the 2009 fire sale peak as recorded by Campbell et al. (2011) – who record a peak of 28.5% fire sales

[61] Meanwhile, the causes of the 1490s and 1740s surges are not immediately apparent: for the former, fire sales are especially concentrated in the cities of Nuremberg and Stengberg, and the regional "War of the Succession of Landshut" (1503-5) may have played a role; in the latter episode, Munich and Berlin show particularly sharp increases.

Figure A.2: German housing fire sale frequency, 1465-1910.



Notes: The plot depicts the rolling share of German housing transactions in our sample that record at least a -25% nominal sales price discount relative to the most recent previous sales price. We use a rolling 28-year centered window. The blue line depicts the long-run component of the series using the methodology of Müller and Watson (2018).

by 2Q:2009 in their sample.

In general, the fire sale evidence indicates a secularly falling risk of housing as an asset class. However, that fire sale risk appears to have levelled off around the year 1700, when frequencies are for the first time closely comparable to some existing modern estimates on comparable measures. Importantly, the well known destruction events of World War I and II are not included in this fire sale sample – with existing literature equally excluding such events from 20th century return and index chronologies.[62]

4. Comparisons with existing housing indices, and variations of inflation bases

First, we will compare our German house price index directly with the index in Knoll et al. (2017). The latter index is representative for the authors' claim, made for Germany and the advanced economy sample as a

[62]Including Knoll et al. (2017) and Jorda et al. (2019).

Table 2.3: Sales at loss and fire sales

	Share sale at loss	Share fire sales nom.	Share fire sales real
Total			
1300-1943	20.7	7.6	25.3
1500-1850	25.2	8.9	27.3
1700-1850	24.5	7.2	23.6
1800-1943	16.3	6.4	17.9

Notes: The table reports summary statistics for housing sales at losses, including two "fire sale" definitions. All columns refer to transaction values in nominal values, spanning the entire transaction sample summarized in Table 3.

Table A.3: Repeat sale housing transactions, prices, real

	# of transactions	avg. price %	median price %	Avg holding period
Total				
1300-1943	841	25.1	13.5	33.8
1500-1850	679	12.6	12.6	36.4
1700-1850	426	38.8	17.8	37.0
1800-1943	320	73.8	20.6	27.2

Notes: The table reports summary statistics for market sales transactions of houses in the sample. Average and median price columns record price increase (decrease) relative to most recent previous recorded sales price, in real terms. The nominal price change is adjusted with the cumulative change in the price index over the holding period between the sales transactions, taking the closing index value in the year prior to the sales year. Average holding period in years.

whole, that (real) house prices inflected around the middle of the 20th century, after having been "stagnant" in the decades since 1870.

The empirical basis of German house prices in Knoll et al. (2017), however, is less than satisfying for several reasons. Not least, the pre-1914 data is based on only two cities, Berlin and Hamburg. Indeed, prior to 1903, only selected years only for Berlin are used, using the statistical yearbook of Berlin (1892).

Next, we are presenting transaction prices in real terms via Table A.3. Afterwards, via Table A.4, I report correlation statistics for the new German House Price index (in nominal y-o-y change) as compared to other historical house price indices in recent literature. It is of course not to be expected that high degrees of correlation should exist – but such measures at least provide a first indication to what extent our results could be representative for broader samples of advanced economies over longer periods of time. Per the table, we generally observe low but positive correlation values when comparing the GHPI nominal changes to historical indices for Paris, Amsterdam, and Germany.

5. AW versus VW indices, and inflation variations

Prominent repeat sales house price indices are constructed on a price-weighted basis, including the prominent Case-Shiller index for U.S. cities (Corelogic, 2024). For the Case-Shiller index, in the words of the creators follows the following approach (Corelogic, 2024): "The composite home price indices are analogous to a cap-weighted equity index, where the aggregate value of housing stock represents the total

Table A.4: Correlations new German house price index (GHPI) and returns, other indices

	period	correlation	source
Total			
GHPI – Amsterdam, annual index change	1689-1748	.181	Korevaar (2021)
GHPI – Paris, annual index change	1810-1910	.093	Eichholtz et al. (2021)
GHPI – Germany, annual index change	1871-1910	.014	Knoll et al. (2017)
GHPI – U.S., annual index change	1891-1910	.099	Lyons et al. (2024)
GHPI – Paris, log total returns	1810-1910	.109	Korevaar (2021)

Notes: The table reports correlation statistics between the new German House Price Index (GHPI) introduced in this paper, with several existing historical indices. All index correlations in nominal terms, except U.S. correlation in real terms.

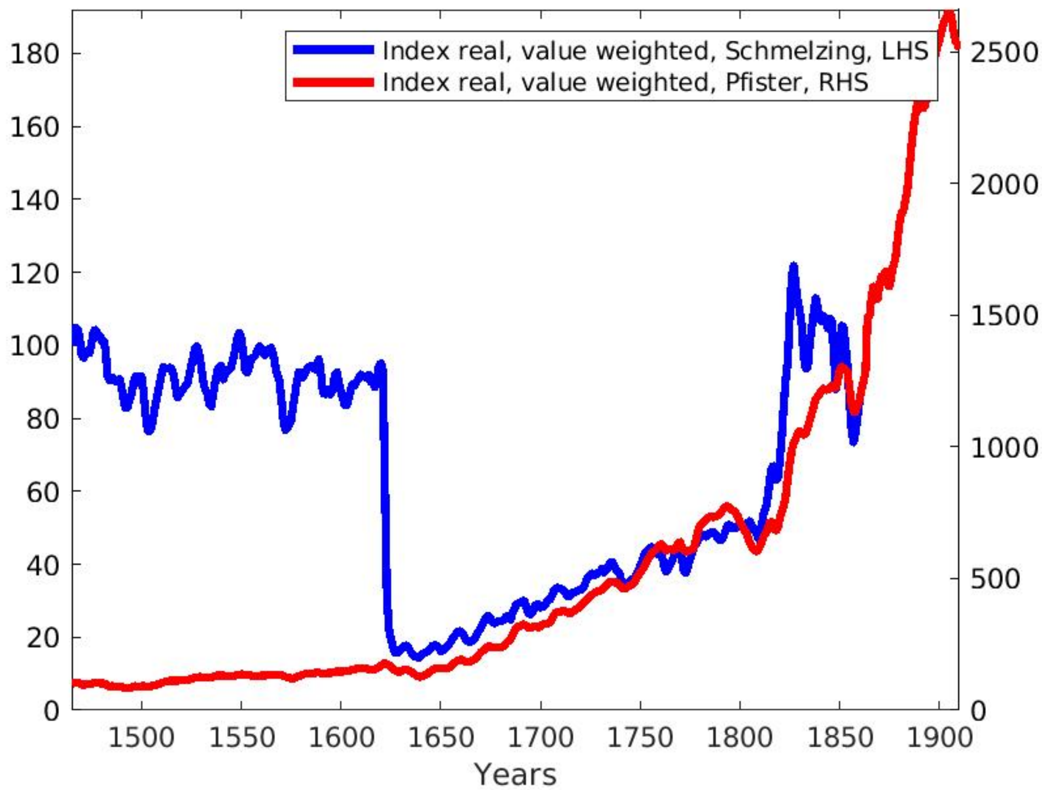
capitalization of all of the metro areas included in the composite. The numerator of the previous formula is an estimate of the aggregate value of housing stock for all metro areas in a composite index".

While such a methodology has a different set of potential drawbacks, it could be relevant to test whether high level differences exist to the arithmetically weighted index presented in the main part of the paper. In this subsection, therefore, I present the main German index on such a comparable price-weighted basis – with an index rebasing every year based on shifting value weights. Each individual home enters the aggregate index sample with its own weight – that is, there is no arithmetic weighting on the city level – thus also analogous to the Case-Shiller methodology. Interpolated home values are used for all annual observations in between actual transactions.

Figure A.3 displays this value-weighted version, for the two inflation adjustment approaches. When comparing this value-weighted version to the arithmetically weighted version in the main part of the paper, we observe that once more, the index adjusted with the lagged inflation figures in Schmelzing (2026) for Germany (blue line), a steep dropoff in real housing prices is observable at the time of the outbreak of the Thirty Years War and the associated "Kipper- and Wipper" inflation shock (here from a 1620 index value peak of 95.1 down to a bottom of 15.6 for the year 1628). The general secular trends before and after this inflection point, meanwhile, are comparable across both weighting approaches, but they suggest that the arithmetically weighted version could lead to an over-representation of lower value housing, for which price growth appears to be higher over time. Indeed, for both inflation approaches. For instance, in the period of 1466-1617, the arithmetically weighted versions suggest a real house price index increase of 50-150% (Schmelzing and Pfister inflation bases, respectively) – while the value-weighted versions suggest cumulative real price growth over the period of -7 to +46%. We reach a terminal value for the Schmelzing (2026) inflation adjusted basis in the year 1910 of 197.8 compared to 375.5 for the arithmetically weighted version; the Pfister (2022) inflation adjusted version (red line) on the other hand records a terminal value of 5,226 for the arithmetically weighted version, compared to 2,746 for the value-weighted version. In all cases across all versions, we take the index inception as 1465=100.

Figure A.4 meanwhile compares the value-weighted to the arithmetically weighted German RHPI, log scale. Here, value-weighted ("VW") refers to weighting the price change of each house in the sample by the absolute value of each house in the total house sample, while "AW" takes the same weight for each house in each year. We observe that the main differences in the two bases are apparent during the pre-1618 era – when the AW basis shows a moderate *upwards* trends, as opposed to the moderate downward trend of

Figure A.3: Inflation variations for value-weighted German RHPI, 1465-1910.



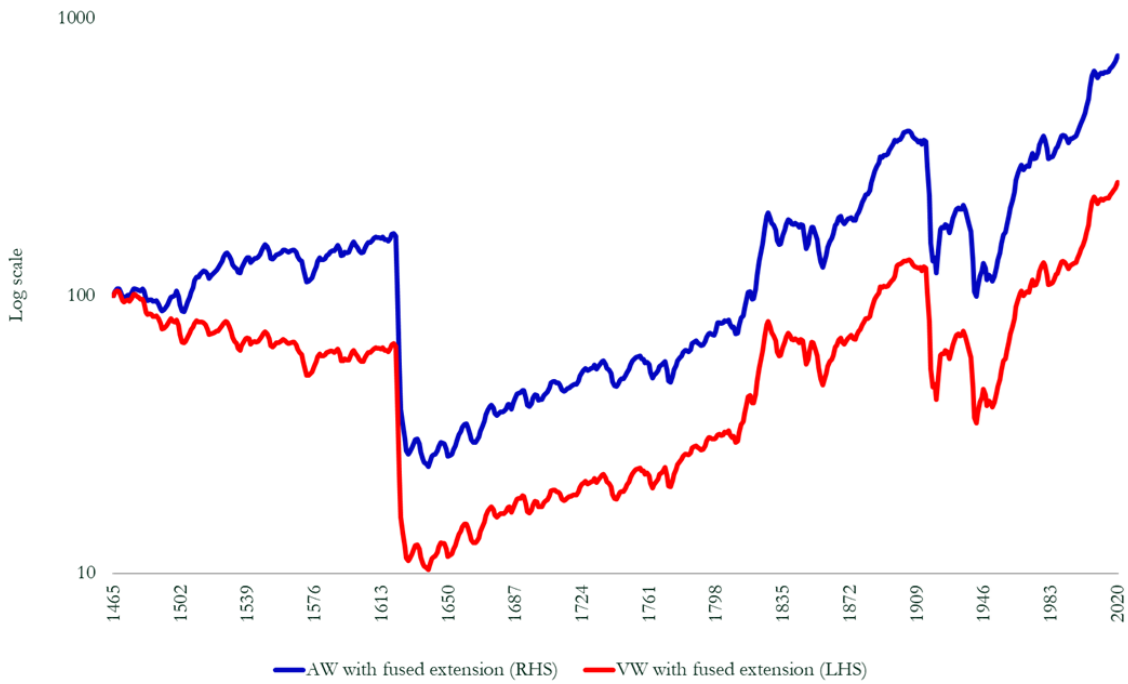
Notes: The Figure displays value-weighted real housing index, taking 1465=100. Two inflation bases are shown, the Pfister (2022) basis (in red, RHS), and the Schmelzing (2026) basis (in blue, LHS). Rebasings are every year, with interpolated housing values for each house in the sample outside of transaction years. Figure is non-logged.

the baseline VW basis; and secondly, we note that the terminal index value for AW is moderately higher, standing at 2020=699, versus 2020=257 for VW. The post-1618 shape and average real price gains y-o-y, however, are closely aligned on both indices.

Figure A.5 compares the ML-generated real house price index for the Netherlands to a benchmark real house price index for Amsterdam presented by Eichholtz (1997), the "Herengracht Index" spanning 1628-1972. As we are training our post-1870 models on national house price gains – in this case for JST's Netherlands index – we should not expect to see any perfect overlap between the two indices, even with optimal training outcomes. However, the exercise reveals that our ML-generated real house price index in fact mirrors the Herengracht Index in numerous regards: it is more volatile overall – an observation consistent with Piazzesi and Schneider (2016), who document a house price volatility on the city level roughly double that of aggregate national volatility. However, at multiple key inflections, the two indices are closely aligned, including the downturn after 1740, the bottom around 1816, and comparable terminal values in 1972 of 199 (ML) and 218 (Herengracht). The overall correlation between the two indices stands at 0.36.

Overall, these exercises illustrate that the ML process generates time series within plausible ranges, as benchmarked against existing primary source approaches in the literature. Of course, there are multiple

Figure A.4: AW versus VW German RHPI, 1465-2020.



Notes: The Figure displays value-weighted (VW) versus the arithmetically weighted (AW) German RHPI, on log scale, and both indexed to 1465=100, and both adjusted with the same seven-year progressively lagged realized inflation figure for Germany.

conceptual reasons why we should not expect any significant overlap in these indices: for instance, the Herengracht index measures a street-specific repeat sales sample – while the ML index is based off the country-wide "JST" reconstruction for Holland. In any case, the moderately positive correlation to existing city- and street-specific data is a plausible observation, especially in light of agreement on key (visual) inflection points.

6. Housing quality – and residential housing supply estimates

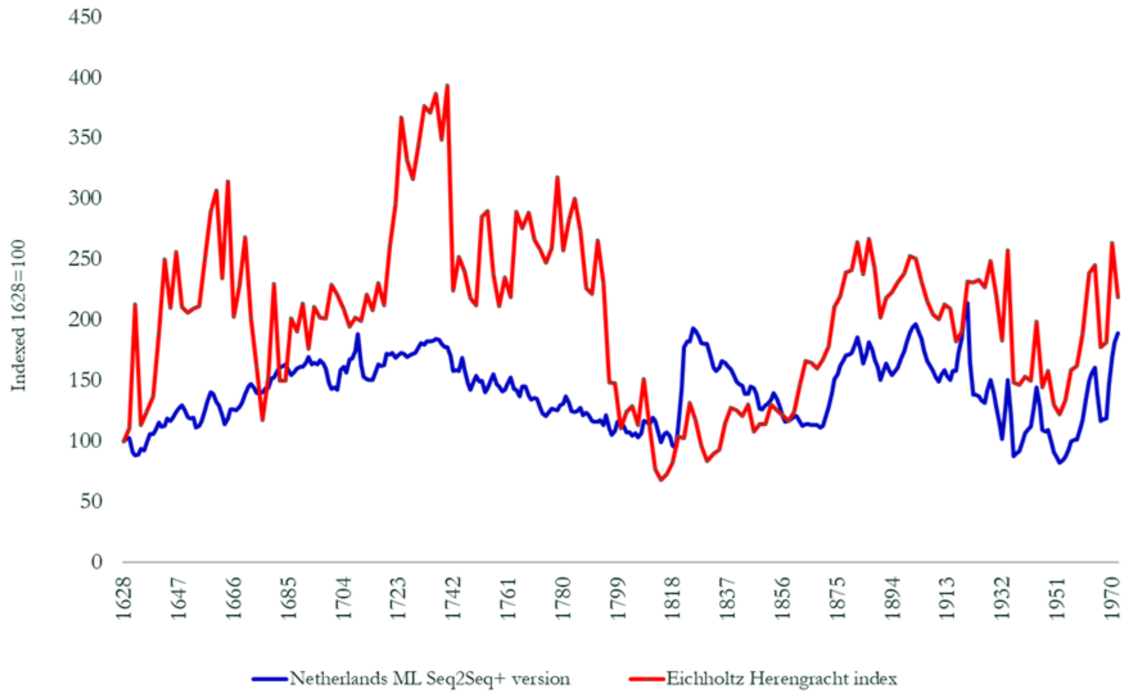
As we mentioned briefly in a preceding section, it is crucial to note that all existing housing indices of relevance here are agnostic regarding the role of quality-related improvements in the housing sample being measured. That is, it might well be that much if not most of the residual positive index changes over time could be capturing representative house improvements.

Characteristically, Knoll et al. (2017) state that:

- "researchers using our dataset in the future should take into account that accurate measurement of quality-adjustments remains a challenge."

These authors – in line with preceding work – make no quality adjustments for price indices in the early part of their sample, but splice early observations with quality adjusted series in the second half of the sample. Our basis is therefore consistent in that no principal quality adjustment is made: conceptually, that

Figure A.5: Machine-learning (ML) Netherlands RHPI index, versus Eichholtz Herengracht index, 1628-1973, with 1628=100.



Notes: The Figure compares the machine learning-generated Netherlands real house price index, compared to the Herengracht Amsterdam real house price index presented by Eichholtz (1997).

is of no concern for any of the preceding or subsequent discussions, though of course it would be *desirable* to know precisely the underlying decomposition in quality-related price changes and the residual components.

Yet, we can at least sketch the general contours and focus on two recognized major quality measures for which long-run analyses are feasible: specifically, floor space per capita, and heating.

Key contributions decomposing the "quality" input into residential housing have posited that the floor area per capita and the number of rooms constitute major ingredients for housing quality, for both renters and owner-occupiers – and indeed a statistically more significant one compared to factors such as neighborhood, schooling, or crime indicators (Kain and Quigley, 1970). This is in particular true for existing long-run studies which try to devise constant-quality indices, and which emphasized floor space per capita as a dominant input (Clark, 2002; Eichholtz et al., 2023).[63] Given that the *Häuserbücher* frequently inform us about house level parcel and floor sizing, we can derive some long-run statistics on representative quality changes on this key indicator: we know, for instance, that the Berlin houses in our sample run at an

[63]As Eichholtz et al. (2023) state, "housing quality per capita [is] most relevant when discussing the evolution of the standard of living. Such concerns are relevant: Adam Smith explains the relative affordability of London housing as the result of mass-scale sub-letting of parts of dwelling homes (Smith, 1776). Smith's observation suggests that the number of people per house may have varied substantially across cities (and potentially over time). To address these concerns, we need to look at housing space per capita." And similarly, via Clark (2002), "to estimate housing rental values while controlling for quality, I have used the subset...of the observations where there are multiple observations on the same property at different times, and no indications of change in size or quality of the structure, or of change in lot".

average 417 square meter parcel size, and know that in the two districts from which our houses are drawn (Dorotheenstadt and Friedrichstadt), persons per house are calculated at 14.9 for the year 1711, yielding a square meter living space figure of 28 per capita. The appendix more systematically lists sources and chronological estimates for all cities.[64] Overall, however, the data suggests that it is not implausible to assume an increase of representative floor space per person in German urban areas by a factor of 2-2.5x between the early 1500s and the early 21st century – from levels between 15-20 square meters in the era prior to the Thirty Years War, to contemporary averages of 38-40 square meters based on most recent census data for key German cities. That is an increase that falls far short of the increases in real property level house prices over the same period when using arithmetically weighted indices – however, interestingly, value-weighted indices suggest that living space growth could account for a not insignificant share of overall real price growth. Specifically, our value-weighted RHPI that fuses JST data post-1910 records a full-sample increase in real house prices of 3.9x over 1465-2020. To the extent that the sample over time captures "representative" housing samples, this suggests that living-space adjusted real house price growth on such a basis would only account for the residual 1-1.5x in real price growth.

Another approach leverages advanced artificial intelligence models to estimate changes in living space. For a variety of our housing units, more or less professional imagery exists that documents the evolution of (exterior) housing characteristics over long periods of time. An example is the situation for Munich, which can utilize the architectural drawings by Gustav Schneider printed in the Munich *Haeuserbuch* that reconstructs the exact visual appearance of same housing blocks over centuries.

Repeat-sales housing indices are considered as the best construction method to incorporate quality changes in housing assets – but they still remain subject to potential quality-related distortions. In general, the literature has settled on preferring repeat-sales indices to control for many quality-related changes in housing, but acknowledges that no perfect methodology exists to fully separate "true" housing index changes from housing quality changes. Indeed, some key literature dealing with long-run construction has resorted to simply acknowledging the potentially distorting role of quality changes, but gone ahead with splicing quality-controlled with non-quality controlled sub-indices (Knoll et al., 2017).[65]

For even longer time series, the potential role of quality adjustment of course rises further. As in previous literature, I therefore emphasize that even in our repeat-sales basis, the pre-1910 trend in rising real house prices in Germany could still be driven mainly by quality improvements within the same homes; subperiods of falling prices could be driven by a drop in housing quality within the same homes. But it is important to get a sense of the potential size of the quality effect, to the best extent possible. For this purpose, the following Table A.5 begins by systematically compiling available data for living space in early modern and modern German cities, converted to a per capita basis. I only include data points where authors refer to "typical" or "representative" housing units in the respective city, and have included precise space data.

Here we observe that there appears to have been a clear upwards trend in living space per capita in German urban areas over the very long run – perhaps an intuitive general observation. Our earliest data points indicate typical living space of around 15 square meter – a figure which then rises over the course of the early modern period, and by the eve of the Thirty Years War rose above 20 square meters for the first time.

[64]Earlier house and parcel sizes in Germany are typically measured in "Ruten" (1 Quadratrute = 14.1846 square meters) or "Fuss" (1 Fuss = 0.313 meters). See Table A.5 and associated discussion in Appendix section 5.

[65]Knoll et al. (2017) acknowledge the fact that their indices may insufficiently control for quality dynamics, especially in the pre-1945 era, and write that "researchers using our dataset in the future should take into account that accurate measurement of quality-adjustments remains a challenge." For Germany, the paper claims that the pre-1945 data is non-quality controlled, while from 1962, their nationwide index controls for quality changes.

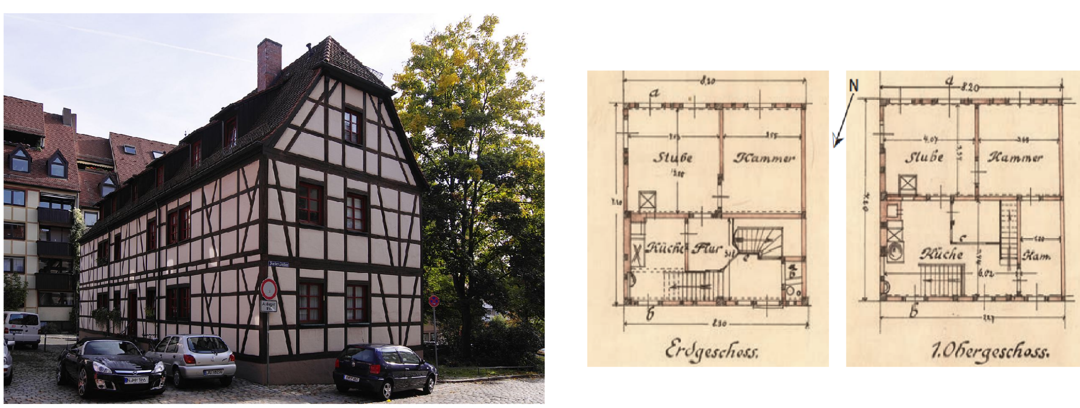
From there, another doubling of average living space takes place by the early 21st century, where current official city surveys for Berlin and Munich indicate living spaces per capita of 38-40 square meters.

This means that some of our housing price appreciation is likely driven by house quality improvements related to size: given homes can be enlarged, either by adding "attached houses" on the same address, or through adding additional stories, say. That both effects took place is confirmed by anecdotal evidence in our cities. At the same time, at least on the basis of the limited number of concrete data points, it is not clear that such space dynamics themselves had any decisive role per se: assuming a doubling of living space for a representative housing inhabitant in our sample over half a millennium would translate into an annual increase of living space of just 0.2%.

But perhaps additional nuance to quality improvements can be gleaned from representative micro-level evidence. Figures A.6 and A.8 actually display the evolution of representative residential housing units that are featured in our sample. These are typical units behind our numbers over time and space. In the first, we exhibit a artisan building in Nuremberg, originally built in the year 1489 for newly arriving weavers from the Nuremberg region. The buildings have undergone an eventful history, but are still located at the same place in Nuremberg today, keeping the same address at the *Sieben Zeilen*. Thanks to in-depth studies by the Nuremberg Historical Association (Taschner, 2013) we have extensive detail about the precise quality adjustments and architectural details of the buildings.

The building contains two stories, with an additional roof area used for storage purposes, as well as a cellar containing work areas. Two households lived in such a building from the inception date. Per the architectural drawing displayed on the right handside of Figure A.6 – itself produced for a renovation project in the year 1912 – we know that the living space per story stands at 59 square meters (8.2 meters width, 7.2 meters depth, including staircases). Such dimensions are comparable with corresponding information from other German urban areas in our sample and beyond. Adjusting the living space for household size developments for urban middle class households yields several relevant data points for living space per capita.

Figure A.6: Representative middle class residential house, built 1489, Nuremberg.



Notes: The Figure's left handside displays the exterior of a representative Nuremberg middle class home, located at the *Sieben Zeilen*; the left handside displays the corresponding architectural drawing, sourced via Taschner (2013).

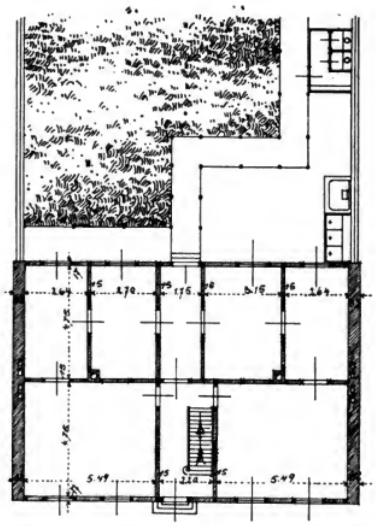
Next, Figure A.8 displays a representative residential street in Munich, shown in its condition in the year 1939. We observe that by the 20th century, residential houses in larger German cities feature four to

Table A.5: Average or representative living space estimates, German cities

	Source	period	sqm per capita	type detail
		Early Modern Era		
Nuremberg	Dirlmeier (1978)	1488	15	representative M and LM
Augsburg	Weidenbacher (1926)	1516	16	representative LM
Lemgo	Kaspar (1985)	1400-1650	17.6	
Cologne	Eberstadt (1903)	ca. 1620	20.3	"typical three-window house"
Berlin	Voigt (1901)	1711	28.1	representative UM and M
Frankfurt		1855	25.1	representative M
Vienna	Lichtenberger (1977)	1856	16.8	weighted avg, inner city
		Modern Era		
Berlin	Berlin (1897)	1890-5	31.4	all-city average
Wolfen	Wilde (1999)	1872-1908	27.5	representative M and LM
Munich	Renaud (1904)	1903	9.3	all-city average
Giessen	Meyer (1903)	1900	20.4	representative M and LM
Frankfurt	Schuette (1930)	1930	37.0	Housing office Frankfurt
Berlin	Grundstuecks-MB	1946	11.8	all-city, census data
Berlin	Grundstuecks-MB	1996	34.8	all-city, census data
Berlin	Grundstuecks-MB	2000	37.9	all-city, census data
Berlin	Landesamt (2022)	2022	40.7	all-city, census data
Munich	SAM (2022)	2022	38.4	all-city, census data

Notes: The table reports data for the residential living space per capita in contemporary and historical sources. Data prior to 1700 operates with average household size of 3.3 persons. um = upper middle class; M = middle class ; LM = lower middle class. The Vienna figure takes midpoints of the range in Lichtenberger (1977), and inner city population figure of 1834.

Figure A.7: Representative lower middle class residential house, Rhineland, ca. 1848.



Erdgeschoss.
Fig. 10.
Aelteres Arbeitermietshaus (1848).

Notes: The architectural drawing from Eberstadt (1903) displays two representative middle class house types in the Rhineland, 1848. The house contains three storys, with two units per story. Displayed is the ground story, with the added backyard. The measurements per unit are 5.48 meters by 9.52 meters = 52.3 square meters of living space per unit.

five stories, including attics. At this time, one can assume three to four households per residential unit, that is 12-20 persons in a representative residential building, per Burgmaier and Schneider (1966). These residential units again contain unit-level heating, hot water, and kitchens. In the ground floors, we often find commercial real estate, and shared cellars are typically included below ground floors. The street length is about 80 metres, and the depth is 11 metres.

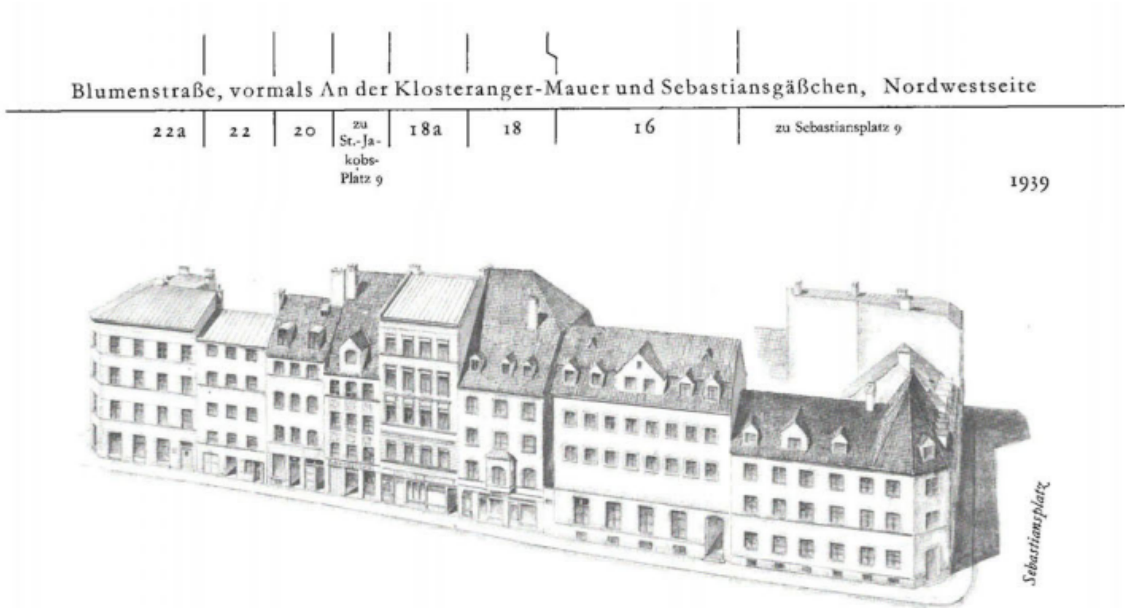
Today, the buildings in the *Blumenstrasse* remain in place, and can be located at geoportal.muenchen.de/portal/plan – coordinates 11° 34 16 | 48° 07 55.

Over the (very) long-run, the precise evolution of housing supply and the connection to secular price and return trends remains virtually unexplored. Even influential recent contributions (Knoll et al., 2017) made no attempt to understand better the *drivers*, including supply side drivers, of housing boom episodes – or to incorporate supply trends. But such an exercise can provide a first glimpse into the evolution of housing quality, specifically the component of living space per capita.

Of course, such a broader aggregation of urban residential housing stocks does not reflect potentially decisive dynamics in housing *size*. Single-family units could have been replaced by spacious multi-family units, and the typical single family unit could have substantially grown in size, de facto increasing living space. There is no systematic study on the evolution of housing unit size over the long run – but there is a panoply of individual information in city level contributions, which can be aggregated. To address the size evolution, we therefore utilize such historical sources. Detailed urban building histories exist for a sufficient number of representative – and at times directly overlapping – cities that can inform us on such trends, and enable a merger with the housing stock figures.

The general contours of housing size are known in urban history literature. For instance, prior to the 17th

Figure A.8: Representative middle class residential street, 1939, Munich.



Notes: The architectural drawing from displays a typical street of residential houses in Munich, shown in their condition as of 1939 (*Blumenstrasse 16-22a*). Architectural drawing by Gustav Schneider in Burgmaier and Schneider (1966).

century, lower and middle income residential houses rarely featured more than two living floors (first and second floor). High income units on the other hand, featured up to three floors – and in addition occasionally featured additional attached rental housing on the same land parcel.[66] Multi-story buildings, featuring five and more floors, emerge in the second half of the 19th century in our city sample. The appendix systematically displays "typical" residential buildings from urban histories that lie behind the bare numbers in our subsequent statistics, and which allow precise adjustments on the number of units, household size, and square meter footage per capita over time.

7. ML and source details – building costs, and rental yields

.3 Alternative ML index – real cap gains as target variable

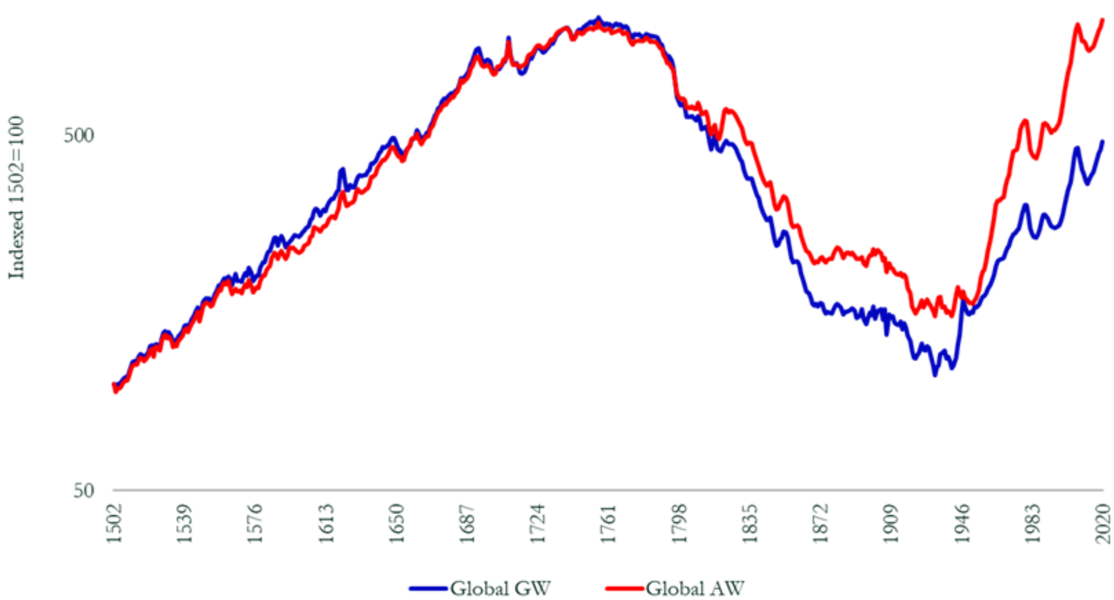
Here I present the alternative construction of ML-based "global" indices, paralleling Figure 5 from the main text. While I used nominal capital gains as the target variable in the main part of the paper – Table 3 above indicated that treating real capital gains as the target variable itself might on some models yield at least comparable, if not superior, results – though it imposes more immediate assumptions on the variable construction approach.

Figure A.9 displays this alternative index basis (log terms), for AW and GW global aggregations. We observe that in terms of the general contours, there is actually a great degree of consistency between the nominal

[66] For instance, for early modern Lemgo, Kaspar (1985) estimates that 15% of all residential housing included such attached smaller units, almost exclusively for high income owners. Also occasionally, in the case of merchant and business occupants, high income houses featured additional commercial space within the same unit.

and real-derived RHPI indices: our real-derived RHPI also records the major turnaround point in the final years of the 18th century – and equally agrees with the generational reversal around the 1930s. A major difference is that on the GW basis here, real house price levels by the year 2020 remain *lower* than the previous high watermark: this is not the case for our benchmark basis (nominal cap gains as target variable) in the main part of the paper, where GW RHPI by 2020 are 3% higher than the previous high watermark in 1786, and at new all-time peaks.

Figure A.9: Global RHPI, AW and GW, 1502-2020.



Notes: The indices display AW and GW weighted global real price indices based on the Seq2Seq+ prediction model – analogous to Figure 4 in the main text – but this time taking "real capital gains" as the target variable. In log terms.

.4 Source details

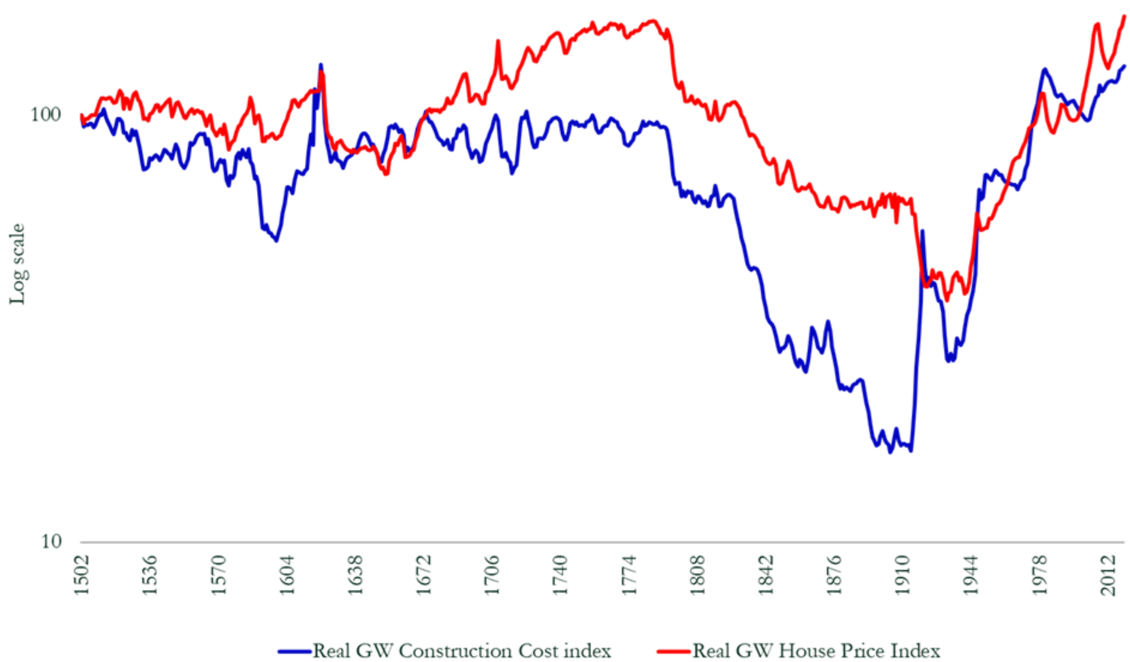
Next, I list the sources and methodology for our building cost indices, by country. As per the prior exercise, in terms of variable importance, these building cost indices – several of which we newly construct in consistent ways from raw commodity data – exhibit key relevance for the machine-learning approaches presented.

- Germany: we use the building cost index constructed by Pfister (2022), who reports index values on a quinquennial basis over 1500-1860 – we linearly interpolate annual frequencies.
- U.S.: we use the U.S. construction cost index in Adams (1975), "Variant B", reported with annual frequency over 1785-1860. The author's "Variant B" is one of several indices created for the same period – we choose this particular variant as it allows for index weight changes from substitution effects over time, rather than operating with fixed base weights ("Variant A").

- U.K.: Spanning 1661-1820, O'Brien (1985) constructs a building cost index for Britain by weighting equally (50:50) material cost changes, and construction wages. We replicate this approach for the pre-1661 data using the price components in Rogers (1902): Rogers records annual price changes for timber, bricks, lime, board, laths, crests, and slates – these seven components are arithmetically weighted to constitute the materials component; for construction wages pre-1661, we use the building craftsmen and building laborer wage data in Allen (2001).
- Holland: we use wood prices in Middelhoven (1981) for 1717-1865. To these, we add building labor costs obtained via Allen (2001) for Amsterdam. Commodities and labor costs are weighted arithmetically (50:50), identical to the approach in O'Brien (1985) for the U.K.
- France: we use Hanauer (1878), who records building material prices in Alsace over 1407 to 1875, covering categories including bricks, tiles, lime, and wood.

Below we directly compare our new building cost indices to the aggregate global real house price indices – both on the identical sample and weightings on the GW (Figure A.10), and the AW (Figure A.11) bases.

Figure A.10: Building Cost Index versus RHPI on GW basis, with 1502=100.

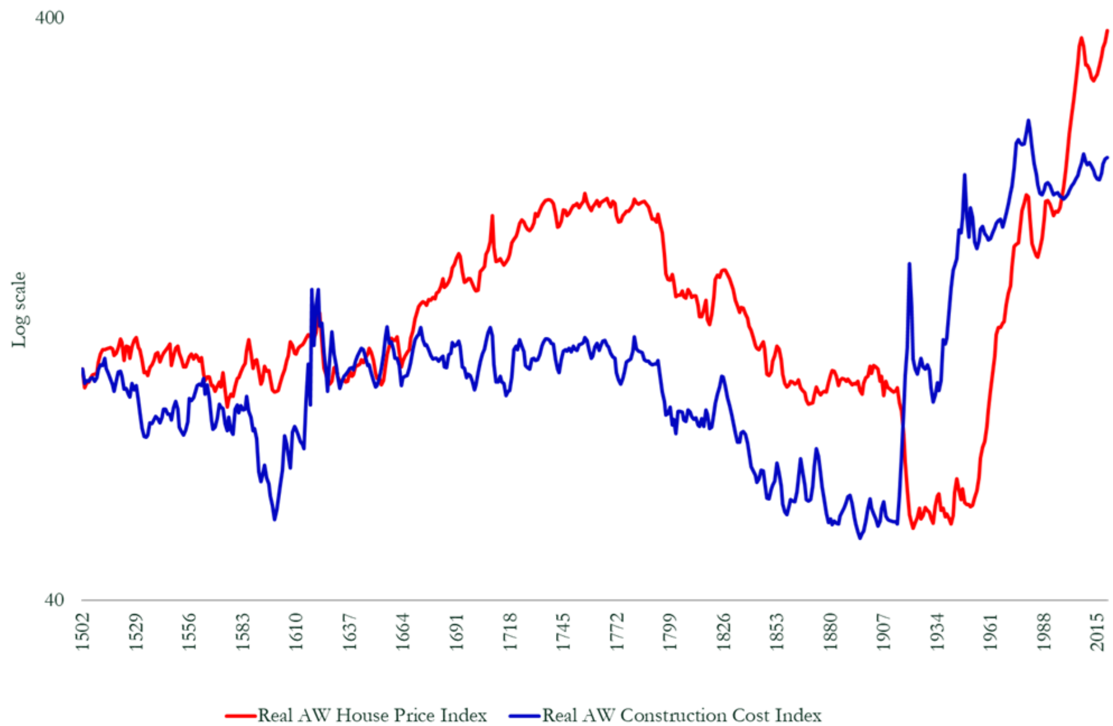


Notes: The Figure compares the building cost index less the general (seven-year progressively lagged) inflation rate (the latter as sourced by Rogoff et al. (2024)) relative to the Real House Price Index - both on the identical weighting basis (GW = GDP-weighted) covering the same five countries.

.5 Rental yield sources

Here I detail the sources for rental yield series.

Figure A.11: Building Cost Index versus RHPI on AW basis, with 1502=100.



Notes: The Figure compares the building cost index less the general (seven-year progressively lagged) inflation rate (the latter as sourced by Rogoff et al. (2024)) relative to the Real House Price Index - both on the identical weighting basis (AW = arithmetically weighted) covering the same five countries.

- Germany: I use the primary source series as detailed in this paper. The underlying sources are per Table 2 of the main text.
- U.S.: For 1830-1860, I use Margo (1996) who covers rental yields for New York. Afterwards, I use Hoover (1960) to 1880, and then I use Lyons et al. (2024) rental yield series from 1890. The 1881-1890 annual data points are linearly interpolated, and from 2007 I rely on "JST".
- U.K.: I use Clark (2002), who reports decadal-frequency rental indices for "London" and "outside London", starting in 1550. We focus on the "outside London" series given longer coverage, and linearly interpolate annual observations. From 1890, I switch to "JST" rental yield observations.
- Holland: I use Lesger (1986)'s composite index from 1578. Index values are reported in the source on an annual level, and run through 1850. Afterwards, I use the Amsterdam data in Eichholtz (1997), and from 1974, I switch to "JST".
- France: I use Couperie and Ladurie (1970), who construct Parisian rental prices from 1402 in tri-annual frequency, to 1788, for which I linearly interpolate annual observations. From 1809, I use Parisian data from Eichholtz et al. (2021), who report annual-level data.

Table A.6: OLS Regression, German Gross Housing Total Returns				
	Gross TR	Gross TR	Gross TR	Gross TR
German inflation	0.0238	0.0238	-0.0236	-0.0236
	(0.34)	(0.34)	(-0.35)	(-0.35)
Real aggregate GDP growth	-0.00154		-0.0170	
	(-0.03)		(-0.38)	
Real per capita GDP growth		-0.00134		-0.0167
		(-0.03)		(-0.38)
Population growth	0.981***	0.980***	0.974***	0.957***
	(6.24)	(6.45)	(6.52)	(6.63)
German nominal rates	-0.676***	-0.676***	-0.175	-0.175
	(-7.78)	(-7.78)	(-1.52)	(-1.52)
German real rates	0.0122	0.0121	-0.0098	-0.0098
	(0.45)	(0.45)	(-0.38)	(-0.38)
PUB-PRI spread	0.217***	0.217***	0.197***	0.197***
	(5.42)	(5.42)	(5.18)	(5.18)
year			0.000093***	0.000093***
			(6.29)	(6.29)
constant	0.111***	0.111***	-0.0727*	0.0726*
	(23.10)	(23.10)	(-2.46)	(-2.46)
observations	355	355	355	355
Adj. R-squared	0.254	0.254	0.329	0.329

Notes: t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Columns 1 and 2 are not controlling for a year trend, while Columns 3 and 4 do. Real total gross return is not included as a variable given that it is mechanical. Columns 1 and 3 use German real aggregate GDP growth and Columns 2 and 4 use German real per capita GDP growth, as both measures are highly correlated and therefore cause multicollinearity issues. "PUB-PRI" spread here uses German mortgage rates for PRI basis.

8. Econometrics, further details

Here we undertake additional tests to analyze the main paper results with regards to robustness, especially the main regressions and time series properties of the housing and associated variables.

.6 Regression variations

First, we assess variations of the German excess return variation. We begin by showing variations of the main excess return regression shown in the main part of the paper, via Table 5.

In Table A.6, we replace German log excess returns with gross total returns, to test whether the arithmetic basis influences results, and whether the excess spread is a result driven by the specific excess return definition.

Table A.7: ADF-GLS, housing and credit variables, no time trend			
	no of lags	t statistic	optimal lag
German primary sources			
German mortgage rates, nominal, 1311-2022	3	-6.803	Seq, MAIC
	2	-7.662	
	1	-8.940	SIC
Real gross housing return, 1495-1910	3	-2.244	
	2	-2.375	Seq, MAIC, SIC
	1	-2.884	
Real net housing return, 1495-1910	3	-2.676	MAIC
	2	-2.832	Seq, SIC
	1	-3.429	
Real house price change, 1495-1910	3	-4.286	
	2	-4.480	Seq, MAIC, SIC
	1	-5.328	
German PUB-PRI, 1311-2022	3	-3.671	Seq, MAIC, SIC
	2	-4.393	
	1	-5.018	
ML variables, 1578-2020			
Holland RHPI	3	-10.163	
	2	-11.105	MAIC
	1	-13.865	Seq, SIC

Notes: The table applies the methodology of Elliott et al. (1996) and reports the ADF-GLS test statistic for several choices of the number of lags k (with a maximum of three lags). The regression includes a constant. The test assumes no time trend. The critical values at the 1, 5, and 10 percent significance levels are the following: -2.58 (1 percent); -1.95 (5 percent); -1.62 (10 percent). "Optimal lag" indicates the optimal number of lags according to the sequential procedure ("Seq"), the Bayesian Information Criterion (SIC), or the Modified Information Criterion (MAIC). The test rejects when the test statistic is negative and larger (in absolute value) than the critical value.

.7 Mortgage rate and housing variable stationarity

Next, we assess the time series properties of key variables that we have introduced and discussed in the main part of the paper (section 7). Table A.7 reports results for a standard ADF-GLS trend stationarity test, via Elliott et al. (1996), this time *not* assuming a time trend. Table A.8 repeats this exercise, this time assuming a time trend.

Across all these variations, we observe that German mortgage rates, as well as excess returns (PUB-PRI), are all recording clear trend stationarity, all at the 1% significance level.

.8 City level ADF-GLS

Below we report the result for city level trend stationarity. In general, it can be observed that trend stationarity is broadly confirmed once more – however, with slightly weaker significance than the aggregate

Table A.8: ADF-GLS, housing and credit variables, with time trend			
	no of lags	t statistic	optimal lag
German primary source			
German mortgage rates, nominal, 1311-2022	3	-7.835	MAIC
	2	-8.709	Seq
	1	-10.022	SIC
German PUB-PRI, 1311-2022	3	-7.019	Seq, MAIC
	2	-8.139	
	1	-8.985	SIC
ML variables			
Holland RHPI	3	-10.061	
	2	-11.016	MAIC
	1	-13.599	Seq, SIC

Notes: The table reports the ADF-GLS test statistic for several choices of the number of lags k (with a maximum of three lags). The regression includes a constant. The test assumes a time trend. The critical values at the 1, 5, and 10 percent significance levels are the following: -2.58 (1 percent); -1.95 (5 percent); -1.62 (10 percent). "Optimal lag" indicates the optimal number of lags according to the sequential procedure ("Seq"), the Bayesian Information Criterion (SIC), or the Modified Information Criterion (MAIC). The test rejects when the test statistic is negative and larger (in absolute value) than the critical value.

national index we constructed. Cities with fewer property units and/or short observation spans record weaker (if any) significance, including Dessau and Freiburg. This appears in line with existing results for modern city level aggregations that have found meaningfully higher volatility and noise on city level, as compared to national aggregations (Piazzesi and Schneider, 2016).

.9 Half-lives, primary source basis

In the main part of the paper, we observed half-lives of approximately 1-3 years for our global total return series. Table A.11 now displays further results for our half-live exercise: here we report half-lives for the primary source series covering Germany – once more nominal and real gross total return bases. We observe a somewhat tighter range of these half-lives, standing between 1.3 and 1.9 years overall. In addition, the observation of a gradually rising adjustment speed over time is not visible on this basis.

Overall, however, half-lives and confidence intervals are all well within the general results on the global basis. Not least, the German-specific adjustment speeds for real estate can be directly compared to the German sovereign real rate adjustment speeds for the same subperiods as reported by Rogoff et al. (2024): here, the authors found adjustment speeds ranging from 2.4-5.2 years over the same horizon. Once more, it is suggested therefore that real estate total returns show faster adjustment speeds compared to sovereign real rates.

Table A.9: ADF-GLS, rental yields, with time trend

	no of lags	t statistic	optimal lag
France	3	-1.687	Seq, SIC, MAIC
	2	-1.981	
	1	-1.686	
Holland	3	-2.515	
	2	-2.584	
	1	-2.693	Seq, SIC, MAIC
U.K.	3	-1.129	Seq, MAIC
	2	-1.004	
	1	-1.077	SIC
GER	3	-2.430	
	2	-2.346	Seq, MAIC
	1	-2.659	SIC
U.S.	3	-1.231	
	2	-1.197	
	1	-1.143	Seq, SIC, MAIC
Global GW	3	-2.658	
	2	-2.763	
	1	-2.610	Seq, SIC, MAIC
Global AW	3	-3.151	
	2	-3.162	Seq, SIC, MAIC
	1	-2.686	

Notes: The table reports the ADF-GLS test statistic for several choices of the number of lags k (with a maximum of three lags). The regression includes a constant. The test assumes a time trend. The critical values at the 1, 5, and 10 percent significance levels are the following: -3.48 (1 percent); -2.89 (5 percent); -2.57 (10 percent). "Optimal lag" indicates the optimal number of lags according to the sequential procedure ("Seq"), the Bayesian Information Criterion (SIC), or the Modified Information Criterion (MAIC). The test rejects when the test statistic is negative and larger (in absolute value) than the critical value.

Table A.10: ADF-GLS, city level, with time trend			
	no of lags	t statistic	optimal lag
Erfurt	3	-5.360	
	2	-5.456	Seq, SIC
	1	-4.819	MAIC
Stengberg	3	-4.505	Seq, MAIC
	2	-5.151	SIC
	1	-6.528	
Frankfurt	3	-2.936	
	2	-3.066	Seq, SIC, MAIC
	1	-4.276	
Koblenz	3	-6.119	Seq
	2	-6.445	MAIC, SIC
	1	-8.740	
Berlin	3	-4.859	MAIC
	2	-5.580	
	1	-6.561	SIC
Munich	3	-6.829	MAIC
	2	-7.381	Seq
	1	-8.656	SIC
Freiburg	3	28.818	Seq
	2	28.716	SIC
	1	-4.499	MAIC
Dessau	3	-0.899	Seq, MAIC
	2	-0.763	SIC
	1	-0.994	
Nuremberg	3	-6.323	
	2	-6.171	Seq, MAIC, SIC
	1	-7.491	

Notes: The table reports the ADF-GLS test statistic for several choices of the number of lags k (with a maximum of three lags). The regression includes a constant and a deterministic time trend. The critical values at the 1, 5, and 10 percent significance levels are the following: -3.48 (1 percent); -2.89 (5 percent); -2.57 (10 percent). Except for Erfurt where its -3.54 (1 percent); -3.00 (5 percent); -2.71 (10 percent) , Berlin where its -3.49 (1 percent); -2.96 (5 percent); -2.67 (10 percent) and Freiburg where its -3.77 (1 percent); -2.19 (5 percent); -2.89 (10 percent). "Optimal lag" indicates the optimal number of lags according to the sequential procedure ("Seq"), the Bayesian Information Criterion (SIC), or the Modified Information Criterion (MAIC). The test rejects when the test statistic is negative and larger (in absolute value) than the critical value.

Table A.11: Half-Lives of Real Rates, Germany primary source, Full Sample and Subsample				
	α	Confid. Interv. α	h	Confid. Interv. h
		Nominal total returns		
1560–2020	0.63	(0.55; 0.70)	1.36	(1.19; 1.55)
1750–2020	0.58	(0.49; 0.68)	1.30	(1.07; 1.52)
1914–2020	0.59	(0.46; 0.75)	1.32	(0.98; 1.75)
		Real total returns		
1578–2020	0.66	(0.59; 0.73)	1.90	(1.71; 2.24)
1750–2020	0.61	(0.52; 0.69)	1.62	(1.39; 1.89)
1914–2020	0.65	(0.52; 0.79)	1.57	(1.21; 2.24)

Notes: This table reports median unbiased estimates and 90 percent confidence intervals of α based on Hansen's (1999) grid-bootstrap as well as median unbiased estimates and 90 percent confidence intervals of the half-life (h) based on Steinsson (2008). The regression is $y_t = \mu_0 + \mu_1 t + \alpha y_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta y_{t-j} + \varepsilon_t$, where α is the largest root. The row with the country name reports the full sample estimates, while the rows with subsamples report the subsample estimates.