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A novel housing price misalignment indicator for Germany

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Non-technical summary

Research Question

This paper develops a composite housing price misalignment indicator (HPMI) to assess the vulnerability of the German housing market to a future realignment that may pose a threat to financial stability in "quasi real-time". By construction, the proposed measure also allows to decompose the determinants of potential imbalances in property markets, thereby facilitating the analysis of macroeconomic implications of future price adjustments.

Contribution

To the best of my knowledge, the proposed HPMI is the first composite indicator for Germany that is founded on both theoretical and recent empirical insights and that optimally uses the information of indicators with well-documented early warning characteristics, thereby facilitating a timely activation of macroprudential instruments. The metric itself is composed of several indicators that are associated with the fundamentals of housing markets and captures developments in the real economy, as well as in both the mortgage and the housing market.

Results

An empirical application to the most recent data suggests that the German real estate market exhibits an overvaluation of approximately 11% as of 2018:Q1, where interest rate risk and a relatively advanced stage of the housing cycle are identified as the main factors fueling these imbalances, while a solid debt-servicing capacity mitigates these imbalances since end-2009. However, by taking into account stylized facts about the German housing market and some of its particularities, the HPMI estimates suggest that concerns about an excessive overheating of the housing market are currently moderate.

Nichttechnische Zusammenfassung

Fragestellung

Das vorliegende Arbeitspapier entwickelt einen aus einzelnen Indikatoren zusammengesetzten Immobilienfehlbewertungsindikator (mit "HPMI" abgekürzt), der eine Beurteilung der Anfälligkeit des deutschen Immobilienmarkts gegenüber einer Neubewertung in Quasi-Echtzeit ermöglicht. Per Konstruktion ermöglicht der vorgeschlagene Indikator eine Zerlegung in die relevanten Preistreiber auf dem Immobilienmarkt, wodurch die Analyse potenzieller makroökonomischer Ungleichgewichte erleichtert wird.

Beitrag

Der vorgeschlagene HPMI ist nach bestem Wissen und Gewissen des Autors der erste Indikator für Deutschland, der auf theoretischen und neusten empirischen Erkenntnissen basiert und gleichzeitig die Information mehrerer Indikatoren mit hinlänglich bekannten Frühwarneigenschaften optimal nutzt, wodurch eine frühzeitige Aktivierung makroprudenzieller Instrumente möglich ist. Die Indikatoren selbst sind Größen, die mit dem fundamentalen Wert von Immobilien zusammenhängen und sowohl Entwicklungen in der Realwirtschaft, als auch auf den Immobilien- und Kreditmärkten erfassen.

Ergebnisse

Eine empirische Anwendung des HPMIs auf die neusten Daten deutet an, dass der deutsche Immobilienmarkt gegenwärtig (1. Quartal 2018) eine Überbewertung von ca. 11% aufweist, wobei das aktuelle Zinsumfeld und ein relativ fortgeschrittener Häuserpreiszyklus als wesentliche Treiber der Überbewertung identifziert werden können, während eine solide Schuldentragfähigkeit der positiven Preisdynamik seit Ende 2009 entgegenwirkt. Unter Berücksichtigung stilisierter Fakten und einiger Besonderheiten des deutschen Immobilienmarkts suggeriert die aktuellste Schätzung des HPMIs, dass Befürchtungen über die Entstehung einer Preisblase gegenwärtig noch moderat sind.

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Abstract

From 2014 until present, housing prices in Germany have been rising faster than consumer prices in all quarters except one, raising concerns about an excessive overheating of the housing market. To assess the vulnerability of the German housing market to a future realignment of prices or even a housing bust, this paper develops a housing price misalignment indicator that is composed of seven indicators, which are commonly associated with the fundamental value of residential property. An empirical application to the most recent data suggests that the German housing market exhibits an overvaluation of approximately 11%, where interest rate risk and a relatively advanced stage of the housing cycle are identified as the main factors fueling these imbalances, while a rather solid debt-servicing capacity mitigates these imbalances since end-2009.

JEL classification: C43, C51, E32, E37, E43, G12, R21, R28, R31.

Keywords: Composite indicator; fundamental value; housing market; imbalances; loose monetary policy; price misalignment.

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1 Introduction

In the aftermath of the Great Financial Crisis (GFC), the major monetary authorities around the world initiated a period of unconventional monetary policy measures, running e.g. quantitative easing programs. As a side-effect, housing markets in several countries have experienced considerable price increases in the past few years (see e.g. the housing price series for several OECD countries in the "OECD Affordable Housing Database"). To respond to emerging imbalances in domestic housing markets (e.g. housing price dynamics that are inconsistent with their underlying economic fundamentals) that may potentially pose a threat to macroeconomic or financial stability, several national designated authorities in different jurisdictions have activated macroprudential measures (see e.g. the overview provided by the European Systemic Risk Board). This contrasts with the experience in Germany to date, where no macroprudential instrument has been activated yet, despite an increasing number of commentaries in the media and from members of the German Financial Stability Committee on overheated housing markets in Germany (Deutsche Bundesbank, 2018). Given the prominent role of Germany as a "growth engine" for the economy in the European Union (EU) and strong empirical evidence showing that housing price corrections often have severe real economic effects, the question arises, whether house prices in Germany are misaligned.

In attempting to answer this question, this paper provides an assessment of potential imbalances in the German housing market and sheds light on potential sources of vulnerabilities in "quasi real-time" by combining the cyclical component of well-established housing valuation measures[1] into a composite misalignment indicator in the spirit of the multiple-indicator approach developed by UBS (2012) and Schneider (2013) for the Swiss and the Austrian housing market, respectively.[2] In order to reduce model risk[3] and to capture developments (and therefore the potential coexistence) of misalignments in both mortgage and housing markets and in the macroeconomy, this approach uses several indicators (called sub-indicators in the following) that are theoretically and/or empirically associated with the fundamental value of real estate assets. To weight and aggregate the sub-indicators into a composite housing price misalignment indicator (HPMI), such that non-zero values indicate the potential emergence of imbalances in the housing market, the proposed approach applies factor analysis (FA),[4] which is a well-established approach to

[1]Following the approach by the Bank for International Settlements (see e.g. Borio and Drehmann (2009)), the valuation measures are defined as the deviations from their smooth and time-varying long-term trend for two reasons. First, to take into account the stylized fact that vulnerabilities are mainly built up over an extended period (Borio and Lowe, 2002b). Second, to eliminate the otherwise misleading effect of structural changes (e.g. reflected in a slow-moving trend). This trend-extraction is also founded on economic grounds. For instance, the general equilibrium model in Iacoviello and Neri (2010) shows that real housing prices should exhibit a deterministic trend that is a function of technological progress in the non-housing sector, which implies that the trend is a proxy for the long-term fundamental value of housing (see also Hanschel and Monnin (2005)).

[2]This model has also been applied to the housing market in Slovenia and Malta by Lenarčič and Damjanovič (2015) and both Micallef (2016) and Micallef (2018), respectively.

[3]In the present setup, for instance, the risk of choosing inappropriate indicators to proxy for the fundamental value of housing markets.

[4]In general, it is unlikely that all the specific variances are equal in size. Therefore, given that we assume that the sub-indicators are linked to a smaller number of unobserved, latent variables (or common factors), that the variance of the sub-indicators can be decomposed into the variance accounted for by

construct composite indicators (e.g. financial stress indices).[5]

The advantages of the proposed approach are manyfold. First, contrary to the existing misalignment indicators in the spirit of UBS (2012) and Schneider (2013), the proposed HPMI is not contaminated by the otherwise misleading effect of benign, long-term changes in the sub-indicators (e.g. as an aftermath of beneficial financial deepening and financial innovations), as they enter the HPMI in "gap" form (i.e. measured as the deviation from a one-sided Hodrick and Prescott (1997) (HP) trend). By allowing for time-varying weights, the modified misalignment indicator also accounts for the fact that the correlation structure between the sub-indicators may change over time, thereby mitigating the potential risk of yielding erroneous or delayed information on the extent of vulnerabilities caused by non-stationary components.[6] Second, as opposed to alternative approaches (e.g. the univariate time series methods developed by Homm and Breitung (2012), Phillips, Shi, and Yu (2015a) and Phillips, Shi, and Yu (2015b)), the HPMI allows identifying[7] the factors that currently fuel deviations of housing prices from their fundamentals, which is relevant from a policymaker's and a financial stability perspective, as it facilitates the decision on how to address these imbalances (e.g. with tailor-made macroprudential policy actions). Third, the HPMI uses sub-indicators in "quasi real-time" that empirically exhibit well-documented early warning characteristics, thereby facilitating a timely activation of macroprudential instruments, which from both a supervisory and a financial stability perspective is a desirable feature of the HPMI, given that most macroprudential policies can only be implemented with a time lag and as there are relatively long lags in their transmission mechanism. Hence, with these two advantages the HPMI complements existing approaches that are based on data that are released with longer lags[8] or that use univariate time series methods (Kholodilin and Michelsen, 2017). Fourth, the HPMI summarizes complex, multi-dimensional sources of risk and only signals the emergence of a housing price misalignment when several sub-indicators coincidentally identify a misalignment. In view of the empirical evidence indicating that most countries with "twin booms" in housing and credit markets[9] subsequently went through a systemic banking

the common and the unique factors, respectively, and as the number of input variables is rather small, so that the solutions to factor analysis and principal component analysis will usually differ, it will be more convenient to proceed with factor analysis in the following (see Section 7.3 in Jolliffe (2002) for more details on the differences between both approaches).

[5]For instance, the St. Louis Fed's stress index or the Kansas City Fed's FSI are both widely used to assess the level of financial stress in the US (see e.g. Hakkio and R. Keeton (2009), Kliesen and Smith (2010) and Oet, Dooley, and Ong (2015)).

[6]As theoretically shown in Lansangan and Barrios (2009), applying principal component analysis to non-stationary data yields component loadings of equal or similar size and only one single linear combination of the input data capturing all the variability in the sample. Hence, any composite leading indicator with constant weights may react with a delay to rapidly and uniformly evolving sub-indicators.

[7]In this paper, the sub-indicators that compose the HPMI have been selected on a theoretical and/or an empirical basis, capturing factors related to the demand for and the supply of housing, as well as macroeconomic conditions. Sub-indicators that enter the misalignment indicator with a large weight are those that are highly correlated with the most relevant common factors, which are assumed to be associated with imbalances in the housing market. Hence, it is in this sense that the weighting scheme of the HPMI allows identifying those sub-indicators that are highly associated with the deviations of current housing prices from their fundamentals.

[8]For instance, the regional panel model of Kajuth, Knetsch, and Pinkwart (2016).

[9]See Hott (2011) for a theoretical model that links housing prices to the creditworthiness of borrowers.

crisis[10] and evidence suggesting that recessions associated with credit crunches and housing busts are on average significantly deeper and longer than other type of recessions (Claessens, Kose, and Terrones, 2008),[11] this feature of the HPMI is another advantage compared to univariate early warning systems, as it reduces the uncertainty that is inherent in any periodical monitoring of the housing market and increases the reliability of the early warning signal.[12] The proposed approach is qualitatively also in line with the assessment of housing market risks by financial stability experts in central banks.[13] Fifth, given that the macroprudential toolkit in Germany does not include regionally-differentiated instruments,[14] using macroprudential instruments would have nation-wide effects. Consequently, from a macroprudential policy perspective, it is advisable to base any statistical assessment that is relevant for financial stability policies on aggregate economic conditions and developments rather than on their regional counterparts (Chen and Funke, 2014). The proposed HPMI therefore complements alternative approaches that focus on regional data. Sixth, the model can easily be calibrated for other countries and used as a starting point or benchmark for the country-specific (baseline/adverse) housing market shock in the EBA stress tests,[15] thereby ensuring consistent supervisory outcomes, which supports the supervisory convergence mandate that has characterized the actions of the major European and global supervisory bodies since the GFC. In addition, extending the use of the HPMI to stress testing would allow banking supervisory authorities to identify the drivers of potential losses in various stress test scenarios, thereby facilitating the supervisory dialogue with bank managers in cases where a supervisory action is mandated after a breach of the capital requirement in an adverse scenario.[16]

The paper proceeds as follows: Section 2 contains a description of the sub-indicators, their motivation and a brief overview of the estimation methodology. Section 3 presents the empirical results. Section 4 validates the quality of the HPMI early warning signal by benchmarking the empirical results against two well-established analytical approaches (i.e. frequency-based filters and turning-point analysis) that are commonly used to identify booms and busts in housing markets, thereby addressing concerns regarding data

[10]See e.g. chapter 13 in Kindleberger and Aliber (2005), Reinhart and Rogoff (2008), Schularick (2011) and Crowe, Dell'Ariccia, Igan, and Rabanal (2013).

[11]And therefore also costlier than other asset price busts. This fact is aggravated by the empirical finding that business cycles strongly co-move during recessions at higher frequencies (Yetman, 2011).

[12]See Borio and Lowe (2002b) for an early contribution that emphasizes the superior performance of combined early warning indicators (EWIs) and Aldasoro, Borio, and Drehmann (2018).

[13]For instance, the systematic analysis followed by the Swiss National Bank (2014) and the Deutsche Bundesbank (2017b) to assess the build-up of imbalances in mortgage and housing markets is based on a set of indicators, which are similar or identical to the seven sub-indicators that enter the HPMI.

[14]New Zealand and Korea, for instance, have experimented with regionally-differentiated debt caps (Igan and Kang (2011), Crowe et al. (2013) and Fáykiss, Nagy, and Szombati (2017)).

[15]For instance, a baseline could be calibrated in terms of the distance between the current size of the misalignment (i.e. the level of the HPMI) and the zero line. Similarly, an adverse scenario could be calibrated as the difference between the historical minimum level ever observed and the HPMI. The latter actual-to-through decline would also be in line with the definition of a severe housing bust in Helbling and Terrones (2003) and Claessens et al. (2008), whenever the actual level is interpreted as a local maximum. The dynamics of the housing prices after the negative shock could be proxied by e.g. the historical time series pattern in those EA countries that were seriously affected by the GFC (e.g. Ireland and Spain).

[16]For instance, banks that are exposed to a level of interest rate risk significantly above the level of their peers could be required to adjust their risk exposure accordingly or otherwise face higher capital requirements.

snooping. In this section, the implications of the current level of the HPMI for house price risks is assessed as well. Finally, in Section 4.5 the robustness of the HPMI is checked, while the final Section 5 concludes.

2 Data and Methodology

Motivated by the work of Ebrahim and Hussain (2010), showing within a general equilibrium framework how financial development permanently affects the banking sector and the housing market, the evidence in Borio and Lowe (2002a) and Borio and Lowe (2002b) indicating that e.g. the real property price gap (expressed in percentage points of the trend) or the investment gap both exhibit early warning properties and bearing in mind that vulnerabilities are mainly built up over a prolonged period (Borio and Lowe, 2002a), the sub-indicators enter the HPMI in gap form. Hence, by focusing on cumulative imbalances, the HPMI should capture most vulnerabilities and should not be contaminated by the otherwise misleading effect of long-term changes in the sub-indicators (e.g. the benign effect of a stable financial deepening process (Drehmann and Tsatsaronis, 2014)).

Specifically, as shown within a general equilibrium framework in Ebrahim and Hussain (2010), the three different dimensions of financial development (i.e. financial liberalization,[17] financial deepening[18] and financial innovation[19]) suggest the following impact on the banking sector and the housing market. All three dimensions should have a positive impact on housing prices, whereas financial liberalization and financial deepening should both lead to higher loan-to-value (LTV) ratios, while financial innovations should mitigate the underinvestment problem first described in Myers (1977). Hence, financial development should positively affect the housing price related sub-indicators and the housing investment measure, whereas the net effect on the affordability ∼, the loan-bearing capacity ∼ and the interest rate risk proxy is ambiguous in the recent past for the following two reasons. First, due to the tightening of banking regulation in the aftermath of the GFC (e.g. the introduction of surcharges for systemically important banks). Second, due to the significant increase of total credit (in terms of GDP) in the EA since 2008, which has been accompanied by an ultra-low interest rate environment affecting the interest rate transmission channel. Therefore, in view of all these complex, multi-faceted changes that have affected both the banking sector and the housing market in the period of interest, all the sub-indicators enter the HPMI in gap form, i.e. reflecting short-term deviations from a time-varying long-term trend that captures structural changes in the sub-indicators.

The trend-extraction is thereby performed using the well-established one-sided HP filter, as shifts in the level ("trend shocks") or breaks in the deterministic trend of any sub-indicator will be smoothed out by this filter (see the simulation and theoretical results in Phillips and Jin (2015)).[20] The findings in Phillips and Jin (2015), demonstrating that the HP filter in general will fail to remove stochastic trends, whereby any non-stationary

[17] Defined as a steadily ongoing deregulation of the financial system (Abiad, Oomes, and Ueda, 2008).

[18] Reflecting the positive effect of deeper financial markets on the volume of credit supplied (Abiad et al., 2008).

[19] Referring to the introduction of new financial instruments that enhance cross-sectional risk-sharing (see Allen and Gale (1997) and Ebrahim and Hussain (2010)).

[20] Hence, the HPMI in gap form should not be contaminated by this kind of structural changes in the sub-indicators.

and HP-filtered time series may exhibit spurious cylicality[21] is a minor concern for the HPMI, as the focus of the paper lies in quantifying the extent to which sources of potential vulnerabilities are becoming more unified over time and as we allow for time-varying factor loadings and incorporate the effect of non-stationarity in the weighting scheme of the HPMI (see Subsection 2.2), thereby capturing the impact of non-stationarity on the factor model.[22][23]

2.1 Sub-Indicators

Affordability Housing affordability reflects the purchasing power of a representative household,[24] which is largely determined by the mortgage component, as households finance their house purchases with a large fraction of debt (see e.g. Cerutti, Dagher, and Dell'Ariccia (2017) for an overview of the maximum observed LTV ratios in an international sample of countries). A readily available indicator that accounts for the current interest rate environment (i.e. reflecting the stance of monetary policy) relates the principal (or initial payout) of a hypothetical mortgage loan B_t of a representative household to the market price of housing P_t:[25]

$$\frac{B_t}{P_t} = \frac{\gamma Y_t}{P_t} \left[\frac{1 - (1 + R_t)^{-T}}{R_t} \right], \tag{1}$$

where γ denotes the fraction of annual disposable household income Y_t available for mortgage payments,[26] R_t is the effective mortgage rate and T equals the term of the mortgage. In Germany, mortgages are typically loans with an initial fixed-rate period of five up to ten years and with terms ranging from ten to thirty years (see also Deutsche Bundesbank (2017a)). In the empirical section, T is therefore set equal to 25 years, in accordance with previous academic contributions (Carstensen, Hülsewig, and Wollmershäuser, 2009). Figure 1 (upper panel) displays the resulting mean-centered and standardized ratio for Germany from 1991 onwards:

[21] The HP filter shares this shortcoming with other filter methods, see e.g. Osborn (1995) and Schüler (2018).

[22] It is well known how non-stationarity affects the factor loadings and the influence of the factors. With non-stationary sub-indicators, FA in general yields only one or very few factors, assigning similar loadings to all sub-indicators. Similarly, non-stationary sub-indicators will exhibit larger variation over time than the other stationary sub-indicators in the data sample of interest. Hence, the weighting scheme of the HPMI incorporates these two effects.

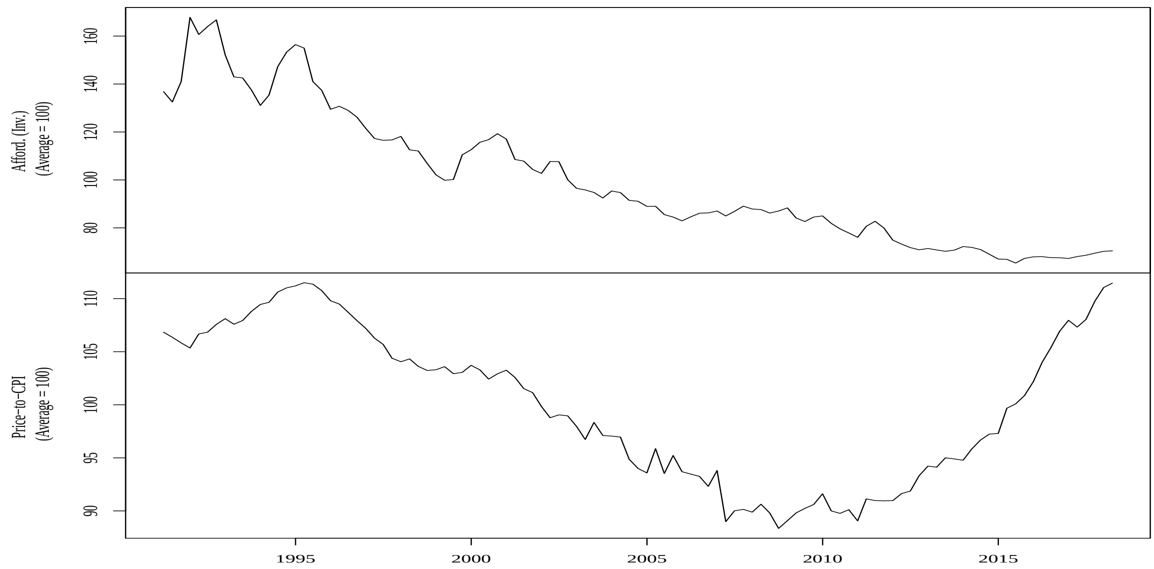
[23] Notice that the HPMI should not be contaminated by spurious interactions due to non-stationarity among the sub-indicators (Becker and Hall, 2012) for at least two reasons: first, as explained in footnote 7, the sub-indicators should be highly correlated. Second, as will become evident in the empirical section, the sub-indicators are highly cross-correlated.

[24] As evidenced in Poterba and Sinai (2008), homeowners typically exhibit different characteristics than renters. Hence, the term "representative" should refer to a representative homeowner. Moreover, since the disposable income metric usually used to run these calculations in Germany is based on the average household income, all these calculations may be biased, as the income of a representative owner may significantly exceed this level. In the US, for instance, household income refers to the median income.

[25] Notice that Schneider (2013) assumes that mortgage annuities are payments in advance, which is at odds with common market practice that in general agrees on mortgage payments in arrear. Hence, the present paper uses the "corrected" annuity formula.

[26] Consequently, γ times Y_t equals the mortgage annuity.

Figure 1: (Inverted) Affordability and Price-to-Consumer Price Index (1991:Q1-2018:Q1)



Notes: The figure shows the two sub-indicators that reflect the demand side (i.e. the household perspective): the inverted affordability index ("Affordability (Inv.)"; in the upper panel) and the price-to-consumer price index ratio ("Price-to-CPI"; in the lower panel), respectively. Data source: see Table A.1 in the appendix.

Economic reasoning suggests that this indicator should be stationary in the long-run. The intuition is the following. Aggregate demand for housing depends on permanent (real) disposable household income, among other factors.[27] A rise in permanent disposable income then ceteris paribus increases B_t and thereby the demand for housing, putting upward pressure on housing prices[28] and making housing less affordable by the law of demand. On the contrary, a higher level of interest rates (and therefore mortgage rates) decreases the demand for housing due to e.g. higher borrowing costs and more pronounced credit constraints, thereby depressing housing prices and making housing more affordable.

The affordability index also closely matches the inverted price-to-income ratio that is often used in the strand of literature on real estate bubbles (Himmelberg, Mayer, and Sinai (2005), Black, Fraser, and Hoesli (2006)), especially in a low-interest environment. Specifically, if R_t approaches zero, it can be shown that the limit of the right-hand side of Equation 1 equals $\gamma T Y_t / P_t$ (see e.g. Kohn (1990)). Hence, in this case the affordability index and the inverted price-to-income ratio are numerically identical up to a constant γT. Moreover, the empirical evidence suggesting that the price-to-income ratio is stationary (Black et al., 2006) implies that the affordability index should be stationary too, at least in periods of low interest rates. To obtain a sub-indicator that signals a decrease in

[27]Aggregate housing demand also depends on the level of mortgage (interest) rates, the level of household wealth (i.e. equity), the price of housing services (i.e. the so-called user costs of housing), population growth, household preferences, the price of other goods and services, etc.

[28]See e.g. McQuinn and O'Reilly (2008) for a theoretical model of housing prices that explicitly translates changes in B_t to changes in housing prices P_t. Their empirical analysis shows that there is indeed a strong link between B_t and P_t.

affordability (and therefore higher risks to financial stability) whenever it increases, the affordability index is inverted. Accordingly, an unusual positive spike of the inverted ratio may signal the formation of a housing price misalignment.

In areas where building land is in limited supply, the price-to-income ratio and therefore also the inverted affordability index both are expected to be upward trending (Fox and Tulip, 2014). Figure 1 (upper panel), however, indicates that the inverted affordability index in Germany exhibits a downward trend, which may reflect the increase of building land by 20.9% between 1992 and 2015 (German Federal Statistical Office; in German abbreviated by "Destatis"), while the number of persons in employment increased by only 12.5%. A more granular analysis on a federal state level supports this view: the three federal city states (and labour market regions) Berlin, Bremen and Hamburg are among the employment areas with the largest increases in housing prices[29] and the number of persons in employment relative to the increase in building land between 2010-2015 (and 2012-2015). Therefore, in the empirical section the inverted affordability index enters the HPMI after extracting the corresponding one-sided HP trend.

Housing Investment-to-GDP This ratio reflects the role of housing markets in the real economy (e.g. with respect to the allocation of capital and labor) and the current stage of the housing cycle. Specifically, empirical evidence suggests that a prolonged period of excessive investments in housing relative to GDP by historical standards[30] (i.e. reflecting positive momentum in the construction sector[31]) often signals an overheating of the real estate market and therefore - from a macroeconomic perspective - a possible misallocation of capital with potentially substantial welfare losses. As an aftermath, risks to financial stability may rise, as housing is a highly leveraged investment and as there is evidence that banks frequently underestimate risks in boom periods. Consequently, a large number of households may become distressed in the event of a negative GDP shock (e.g. due to an amplification mechanism being activated by the shock),[32] resulting in a severe recession that may trigger a period of negative price momentum in the real estate market, raising the probability of asset price risk materialisation. This price effect would then again reduce housing investment relative to GDP, thereby triggering a period of dampened housing price dynamics. This ratio should therefore be mean-reverting in the long-run, see Figure 2 (upper panel):

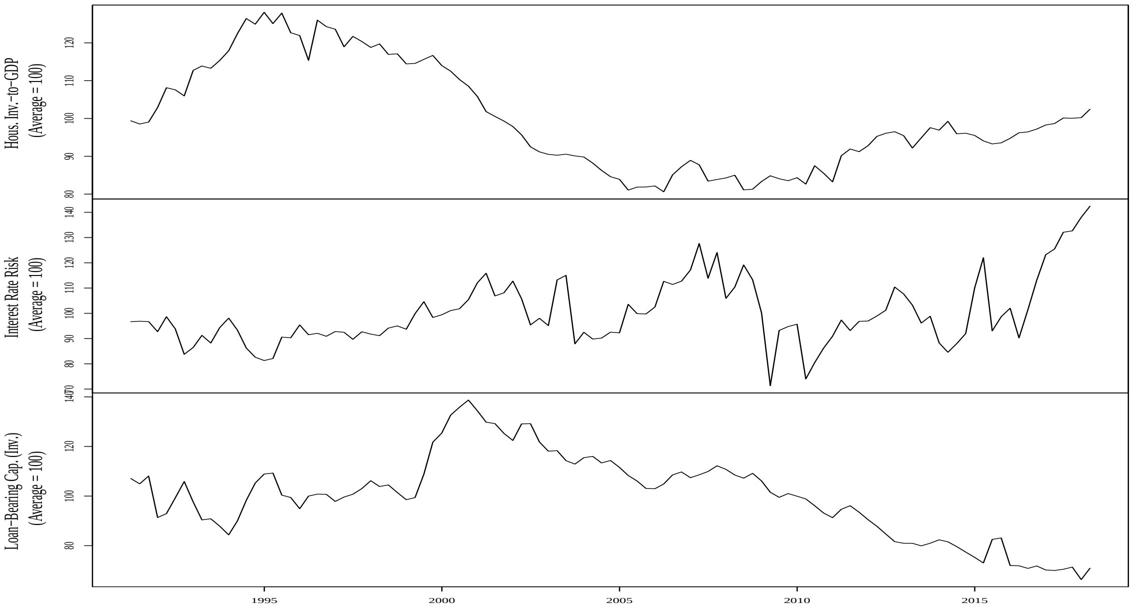
[29] According to the data available from Budde and Micheli (2017).

[30] Motivating the use of this sub-indicator in gap form.

[31] In line with the positive feedback theory in Shiller (1990) that postulates that when market prices rise substantially, many success stories of investors attract new investors; hence, real estate success stories may fuel housing investment and generate positive momentum in the construction sector. Moreover, there is empirical evidence in many OECD countries that speaks in favor of this theory in housing markets (see e.g. Caldera and Johansson (2013)).

[32] For instance, Boissay, Collard, and Smets (2016) propose a dynamic stochastic general equilibrium model to explain banking crises and find that when agents are highly leveraged, standard and mild negative productivity shocks may initiate an amplification mechanism (see e.g. the contributions by Caballero and Krishnamurthy (2008), Brunnermeier (2009), Krishnamurthy (2010), Brunnermeier and Oehmke (2013) for different mechanisms) that may aggravate the initial shock and lead to a severe recession that at the end may trigger a banking crisis. In line with this channel, early evidence from Japan shows that risks to financial stability materialized as an aftermath of a recession (Shiratsuka, 2005).

Figure 2: Housing Investment-to-GDP, Interest Rate Risk and Loan-Bearing Capacity (1991:Q1-2018:Q1)



Notes: The figure shows the three sub-indicators that connect macroeconomic conditions with property markets (i.e. the system-wide perspective): the housing investment-to-GDP ratio ("Housing Investment-to-GDP"; in the upper panel), the interest rate risk proxy ("Interest Rate Risk"; in the middle panel) and the inverted loan-bearing capacity index ("Loan-Bearing Capacity (Inv.)"; in the lower panel), respectively. Data source: see Table A.1 in the appendix.

The early warning properties of this ratio have been evidenced in Leamer (2007) who indicates that most recessions are preceded by an unusually large contribution of housing investments to GDP growth (i.e. reflecting positive momentum in the construction sector). In line with this evidence, the German recession in 2002-2003 was also preceded by a decade of unusually high investments in housing by historical standards, with quarterly housing investment-to-GDP ratios above six per cent from 1991:Q4 to 2001:Q3, fuelled by tax incentives in the early 1990s after the re-unification of Eastern and Western Germany.

Interest Rate Risk ("Taylor Rule Residuals") It is well established that periods of exceptionally low interest rates (e.g. in terms of current macroeconomic conditions and accounting for structural changes) may induce banks to take excessive risks by underpricing them[33] and increasing their credit exposure too much, which may then fuel the demand for housing (see e.g. McQuinn and O'Reilly (2008)). Consequently, interest

[33] See e.g. CGFC (2018).

rates that are "too low"[34] for "too long" may generate housing price misalignments[35] and financial imbalances that may pose a threat to financial stability. The role of interest rates that are too low for a prolonged period relative to e.g. the Taylor interest rate[36] in fueling housing bubbles has recently been analyzed in Hott and Jokipii (2012). Their analysis based on a sample of 14 OECD countries (incl. Germany) from 1981:Q1 to 2010:Q3 shows that there is indeed a strong link between the emergence of housing bubbles and short-term interest rates that are too low. Consequently, their empirical evidence supports the use of this sub-indicator.

To capture the effect of unsustainable affordability levels on mortgage and housing markets (i.e. interest rate risk in a broader sense), this paper takes advantage of the theoretical model of housing prices developed by McQuinn and O'Reilly (2008) that links the hypothetical borrowing volume B_t in Equation 1 (that depends on the interest rate level) to housing prices P_t. Their empirical results suggest that the link between these two variables is strong (i.e. a decrease of B_t by 1% is associated with a decrease in prices by at least 0.8%). Hence, an exogenous, unexpected increase in interest rates may translate into a significant decrease in the borrowing volume and a drop in housing prices (see, for instance, Sommer, Sullivan, and Verbrugge (2013)). This interest rate risk transmission channel is proxied by the ratio of the hypothetical borrowing volume B_t using the 3-month EUR EURIBOR rate vs. the same metric using the Taylor-rule implied interest rate (see Figure 2 (middle panel) for the resulting time series after mean-centering and standardizing this ratio):

$$\frac{B_t\,(R_t = \text{3m EURIBOR})}{B_t\,(R_t = \text{Taylor})}. \tag{2}$$

The use of the Taylor interest rate as a benchmark can be motivated by the following two academic contributions. First, Caputo and Díaz (2018) empirically demonstrate that the European Central Bank (ECB) has followed a forward-looking Taylor rule from 1991:Q1 to 2016:Q1. In addition, their results also indicate that both the magnitude and the sign of the ECB's policy responses are similar to the policy responses of a counterfactual Taylor rule for Germany.[37] Therefore, using one of the Taylor interest rates for the EA as calculated by the Deutsche Bundesbank (for more details see Table A.1 in the appendix), is a reasonable proxy for the latent neutral interest rate. Second, for the period before the introduction of the Euro, there is evidence that German money market rates closely followed the Taylor interest rate for Germany (Deutsche Bundesbank, 1999). Hence. both papers suggest that the stance of monetary policy in Germany is largely in line with the rates implied by a Taylor rule. Therefore, in the empirical section, Taylor implied interest

[34]In the sense of interest rates on loans and mortgages that are below the natural rate of interest, i.e. the real key interest rate of the European Central Bank that is consistent with stable inflation in the absence of transitory shocks to both demand and supply.

[35]See e.g. Taylor (2007), Ahrend, Cournède, and Price (2008), Assenmacher-Wesche and Gerlach (2008), Taylor (2009), White (2009), Kahn (2010), Obstfeld and Rogoff (2010), Hott and Jokipii (2012), Crowe et al. (2013) and O'Meara (2015).

[36]Which depends on current inflationary and cyclical developments.

[37]In addition, Molodtsova and Papell (2012) document that the Taylor rule has been a valid predictor for the EUR-USD exchange rate even during the GFC, which reinforces the use of the Taylor interest rate as a benchmark to assess the time path of interest rate risk, as exchange rate changes are largely determined by the interest rate differential between two currency areas according to interest parity.

rates for the EA are used. For the years before the introduction of the Euro currency, a Taylor rule for the Economic and Monetary Union (EMU) is used.

Loan-Bearing Capacity A sub-indicator that captures unsustainable[38] developments in mortgage markets has been proposed by Schneider (2013). It relates the hypothetical borrowing volume of a representative household B_t in Equation 1 to the volume of new mortgages actually granted (see Figure 2 (lower panel) for the corresponding sub-indicator), reflecting the ability of the household to repay its outstanding mortgages. A lower ratio indicates a worsening of a household's debt-servicing capacity, e.g. reflecting a lower household income and/or a higher interest rate environment. If this deterioration is deemed to be permanent, a bank's exposure to aggregate credit risk and systemic risk ceteris paribus rises. For the loan-bearing capacity measure to be consistent with the other six sub-indicators, the ratio is inverted, such that the sub-indicator signals a potential overvaluation of the German housing market, whenever it rises above its long-term trend.

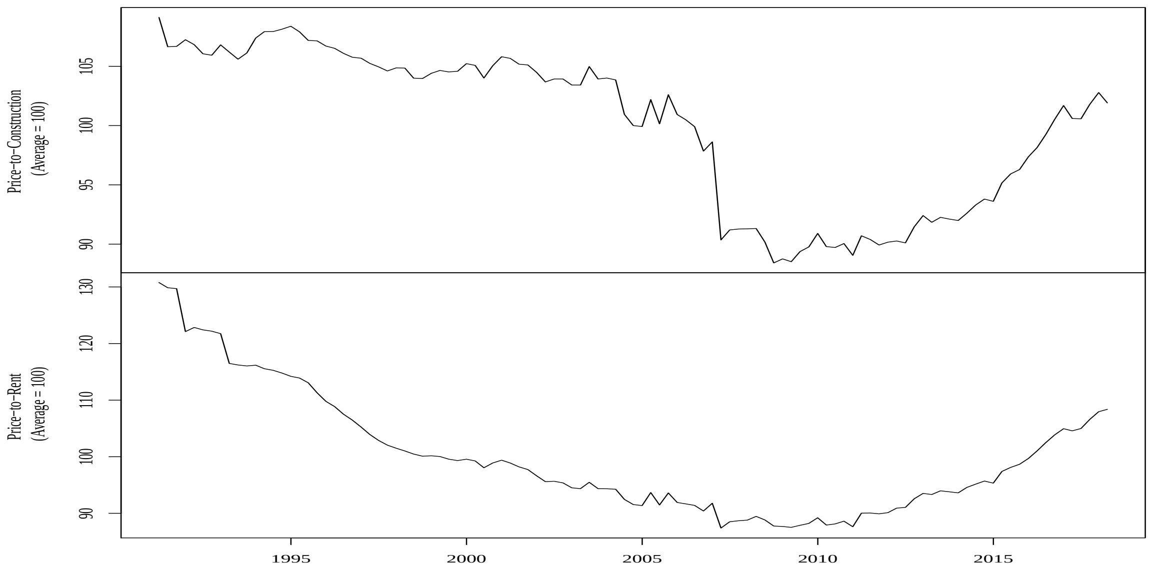
Price-to-Construction Costs ("Tobin's Q") Similar to Tobin's Q (i.e. the market value-to-replacement costs ratio), this ratio relates the price of housing to the corresponding construction costs, where the latter is associated with the fundamental value of housing. Specifically, a commonly used rule of thumb in the building industry assumes that construction costs on average amount to 80% of the price of new housing (Glaeser, Gyourko, and Saíz, 2008).[39] In line with this rule of thumb, the list of country-specific upper limits of observed LTV ratios in Cerutti et al. (2017) evidences that advanced economies typically exhibit a maximum-observed LTV of 80% for new lending, which in view of the previous sentence is a prudent way to manage the mortgage business of a bank. In addition, the stylized fact that house price changes are largely determined by land price changes (see Davis and Heathcote (2007) and Knoll et al. (2017)) and evidence of bubbles only for residential land, but not for housing structures (Kocherlakota, 2010), are further reasons why this indicator is relevant for assessing potential imbalances in housing markets, as an unusual spike of the price-to-construction costs ratio may be an indication of the emergence of a housing price misalignment. Last but not least, the use of this ratio is further motivated by its significant predictive power for one-year-ahead housing price changes, as evidenced in Case and Shiller (1990) and Case and Shiller (2003).

The dynamics of the price-to-construction costs ratio over longer periods can be rationalized as follows. A level of this ratio that is large compared to its own history may incentivize construction companies to increase their supply of housing, thereby fueling construction costs. In the medium-term, the increased supply of housing abates housing price dynamics and prices tend to move back towards construction costs (Glaeser et al., 2008). Consequently, the price-to-construction costs ratio should be mean-reverting over longer horizons. Figure 3 (upper panel) shows the corresponding indicator for Germany.

[38] For instance, a prolonged period with aggregate credit growth rates that are unusually high in terms of both the stance of monetary policy and current macroeconomic fundamentals (e.g. GDP growth). Therefore, this paper focuses on cumulative imbalances, motivating the use of the loan-bearing capacity indicator in gap form.

[39] See also Table 2 in Knoll, Schularick, and Steger (2017) who show that the share of land in housing value has been close to 20% in Germany during most of the 20th century.

Figure 3: Price-to-Construction Costs and Price-to-Rent (1991:Q1-2018:Q1)



Notes: The figure shows the two sub-indicators that reflect the supply side (i.e. the investor's perspective): the price-to-construction costs ratio ("Price-to-Construction"; in the upper panel) and the price-to-rent ratio ("Price-to-Rent"; in the lower panel), respectively. Data source: see Table A.1 in the appendix.

Price-to-Consumer Price Index (Real Housing Price Index) The ratio of a real estate price index to the consumer price index (CPI) expresses the price of housing in terms of the price of the consumption goods of a representative household, reflecting the level and the dynamics of inflation-adjusted housing prices.[40] If the total effect of the positive substitution ∼, endowment ∼ and collateral effect exceeds the negative income effect,[41] an above-average level indicates that real estate assets are overvalued by historical standards, which may subsequently reduce the demand for this asset class, thereby triggering a period of decreasing housing prices. Similarly, a below-average level indicates that housing property may be undervalued, which may then increase the demand for housing, thereby fueling its price. Hence, based on theoretical grounds, this ratio should be mean-reverting

[40]This ratio can alternatively be calculated using the GDP deflator (i.e. the implicit price deflator). The time series pattern of this alternative metric, however, indicates that both ratios exhibit similar dynamics. Therefore, this paper only presents the results obtained with the price-to-CPI ratio as a proxy for the real housing price index.

[41]The substitution effect captures the elasticity of substitution between non-durable consumption and housing and is close to unity (see the references in Berger, Guerrieri, Lorenzoni, and Vavra (2017)). The positive "endowment effect" reflects the increased demand for consumption from homeowners after a permanent rise in the price of housing, the negative "income effect" is related to the user costs of housing concept and implies that higher imputed rents for renters will lead to a lower demand for consumption goods (here the net effect will depend on the fraction of renters vs. the fraction of landlords), while the positive "collateral effect" reflects the effect of higher collateral value on consumption for given housing choices, see Berger et al. (2017) for more details.

over longer horizons, whenever the positive effects dominate the negative "income effect". International empirical evidence indeed suggests that the time series pattern of this ratio exhibits persistence in the short-run and mean-reversion in the long-run (see Figure 3 in Black et al. (2006) and (Gyourko, 2009)). In line with this "stylized fact", Figure 1 (lower panel) reveals that this sub-indicator has only limited predictive power for short-term corrections in the German housing market. One factor that may explain periods of marked price momentum in housing markets is the limited scope to arbitrage away price deviations from the fundamentally justified prices, e.g. due to the heterogeneity of real estate assets, large transactions costs (going hand in hand with lower liquidity (Bracke, 2013)), short-selling constraints or relatively large information costs (see e.g. Glaeser and Gyourko (2009)).

There is also strong evidence suggesting that the price-to-CPI ratio in levels and in gap form (Borio and Lowe (2002a), Borio and McGuire (2004), Borio and Lowe (2004) and Borio and White (2004)) serves as an EWI of banking crises, especially if the ratio coincides with a rapid credit expansion (Crowe et al., 2013). Similarly, Reinhart and Rogoff (2008) qualitatively show that both large-scale as well as other rich country financial crises are typically characterized by a prolonged period of significantly rising real housing prices prior to the year of the eruption of the crisis. This qualitative observation is also in line with the results reported in Barrell, Davis, Karim, and Liadze (2010), who quantitatively analyze the suitability of the real housing price growth rate as an EWI for banking crises. According to their results, a rise in the real housing price growth rate by one percentage point is associated with a subsequent rise in the probability of a banking crisis by 0.07-0.74 percentage points. For Germany, the estimated impact is equal to 0.22 percentage points. Hence, a marked positive spike of the real housing price index signals the potential formation of imbalances in housing markets, increasing the likelihood and potential severity of a future banking crisis. Last but not least, recent contributions in the strand of literature on business cycles indicate that the real housing price growth rate has predictive power for future recessions in the G-7 countries (Bluedorn, Decressin, and Terrones, 2016), motivating the use of this sub-indicator, as recessions often go hand in hand with subsequent banking crises (see also footnote 32).

Price-to-Rent Under the assumption of arbitrage-free housing markets, in the sense of not offering predictable excess returns for owning compared to renting (Glaeser and Gyourko, 2009),[42] comparing the current price-to-rent ratio to its long-term average is a popular approach to assess potential imbalances in residential housing markets (Case and Shiller, 2003).[43] The OECD, for instance, uses this approach in its academic contributions

[42]However, the fact that there are both major differences in rental versus owner-occupied units with respect to their attributes and that owners and renters are a different type of people (with mainly unobserved characteristics) is something that cannot be solved empirically (Glaeser and Gyourko, 2009). The former matters, since comparing rents and housing prices is only meaningful when controlling for these differences. The latter matters as well, since people with different characteristics may affect aggregate expectations about future housing price dynamics differently (Glaeser and Gyourko, 2009). This drawback of the price-to-rent ratio is another reason why it is preferable to base the assessment of potential misalignment on multiple sub-indicators instead of relying on only one sub-indicator.

[43]Hott and Monnin (2008), Lai and Van Order (2010), Ambrose, Eichholtz, and Lindenthal (2013), Chen and Funke (2014) and Engsted, Hviid, and Pedersen (2016), among others, are recent academic contributions that use the price-to-rent ratio to assess the fundamental value of housing markets.

(OECD, 2005) and in its global economic outlook (OECD, 2017). The price-to-rent ratio for Germany is displayed in the lower panel in Figure 3.

The theoretical basis of this ratio is the present value model of asset prices and therefore reflects the supply-side from an investor's perspective (e.g. also capturing the effect of fixed-income investors in search of higher yields).[44] Specifically, housing prices are interpreted as the present value of a series of periodical rent payments, motivated by the concept of the dividend yield in finance and empirical evidence finding support for the widespread perception that decreases in the lagged dividend yield are typically followed by subdued future stock returns.[45] Similarly, empirical analyses of housing markets find that the rent-to-price ratio predicts price changes in housing markets.[46]

In the long-term, this ratio should be mean-reverting, since an extended period of above-average housing prices[47] should increase the demand for renting and lower the demand for housing, thereby dampening the dynamics of housing prices.[48] A marked positive ratio may then signal an overvaluation of real estate assets that is at odds with fundamentals. As a consequence, the probability of a significant price correction may increase. In the opposite case, an unusually low ratio may signal that housing prices are too low (i.e. that housing markets are undervalued). Households may then increase their demand for homeownership, thereby pushing housing prices and this ratio upwards.

Resuming this subsection, the proposed HPMI includes sub-indicators that capture both the demand side (the inverted affordability index and the price-to-CPI ratio) and the supply side (the price-to-construction costs ratio and the price-to-rent ratio), as well as sub-indicators that relate macroeconomic conditions with property markets (i.e. the housing investment-to-GDP ratio, the interest rate risk proxy and the inverted loan-bearing capacity indicator). Detailed information on the specific sub-indicators can be found in Table A.1 in the appendix.

2.2 Methodology

Aggregation Assigning an equal weight to each sub-indicator would in general be inefficient, as it can be expected that the contribution of a given sub-indicator to the covariance (or correlation) matrix of the analyzed data will not be uniform.[49] To attach a weight to each sub-indicator that is consistent with its historical importance in explaining cyclical fluctuations in the German housing market, the HPMI therefore applies the FA technique. Specifically, it is assumed that each de-trended and scaled sub-indicator $Z(X_{it})$ linearly depends on (at most) seven latent, orthogonal factors F_{jt}:

$$Z(X_{it}) = \frac{X_{it} - T_{it}}{T_{it}} = \sum_{j=1}^{7} \alpha_{ij,t} F_{jt} + u_{it}, \qquad (3)$$

[44] Given that most apartments are held as a form of capital investment (Petkova and Weichenrieder, 2017), it is important to capture the investor's perspective to shield against omitted variable bias.

[45] See e.g. Campbell and Shiller (1988), Goetzmann and Jorion (1993), Campbell and Shiller (2001), Goyal and Welch (2003) and Ang and Bekaert (2007).

[46] See e.g. Davis, Lehnert, and Martin (2008), Gallin (2008), Hott and Monnin (2008) and Campbell, Davis, Gallin, and Martin (2009).

[47] Reflected in a high price-to-rent ratio.

[48] See, for instance, the empirical evidence in Piazzesi, Schneider, and Tuzel (2007) for the US.

[49] Equal weighting implies that all sub-indicators are perfectly correlated with each other.

where T_{it} represents the smooth long-term trend of the original sub-indicator X_{it} (see Equation 5), $\alpha_{ij,t}$ the factor loading of variable i on the jth factor F_{jt}, reflecting the correlation between the transformed sub-indicator i and the latent factor j, and where u_{it} equals the residual term.

Centering by the long-term trend is a standard approach when the interest lies in the distance to a reference (Nardo, Saisana, Saltelli, Tarantola, Hoffmann, and Giovannini, 2005). In the present case, the reference is the one-sided HP filter (Stock and Watson, 1999), which in the absence of transitory shocks reflects the long-term equilibrium value of real estate property in Germany, with a large smoothing parameter value ($\lambda = 400'000$) to capture the gradual and cumulative build-up of vulnerabilities:

$$\begin{aligned} x_{it} &= \ln(X_{it}) = \tau_{it} + c_{it}, \\ \Delta^2 \tau_{it} &= \epsilon_{it}, \end{aligned} \tag{4}$$

where x_{it} denotes the logarithm of the original sub-indicator X_{it}, τ_{it} and c_{it} are the latent trend and cyclical component, respectively, and where it is assumed that c_{it} and ϵ_{it} are uncorrelated white noise components that are also uncorrelated with the vector of starting values (y_0, y_1) (Hamilton, 2018). The smooth long-term trend T_{it} is then obtained after subtracting the Kalman filter estimate of the cyclical component $\hat{c}_{it}$ from x_{it} (first summand) and taking the exponential of this difference plus a correction term (second summand):[50]

$$T_{it} = \exp^{\tau_{it} + \sigma_c^2/2}, \tag{5}$$

where the correction term is set equal to 0.5 times the sample variance of the cyclical component $\hat{c}_t$, following the recommendation in Verbeek (2005).

The HPMI is then calculated as a weighted average of the seven transformed sub-indicators $Z(x_{it})$:

$$\begin{aligned} \text{HPMI}_t &= \sum_{i=1}^{7} w_{it} Z(x_{it}), \forall t, \\ w_{it} &= v_{it} / \sum_{j=1}^{7} v_{jt}, \\ v_{it} &= \alpha_{ij,t}^2 \phi_{jt}, 1 \le i \le 7, \\ \phi_{jt} &= \frac{\sigma_{jt}^2}{\sum_{i=1}^{J} \sigma_{it}^2}, j \in \{1, 2, \ldots, 7\}, \\ j &= \arg\max(|\alpha_{ij,t}|), \end{aligned} \tag{6}$$

where the weight w_{it} assigned to $Z(x_{it})$ is equal to the normalized weight of $\alpha_{ij,t}^2$ times the proportion of the sample variance among the retained J factors that is explained by the jth factor ϕ_{jt}, where the factor j represents the factor on which variable i has the highest loading in absolute terms.

[50] This step is done for ease of comparison with the non-logarithmized HPMI.

Number of retained Factors J and Empirical Implementation In a preliminary step, the degree of correlation among the transformed (i.e. de-trended and scaled) sub-indicators is estimated, since a low degree of correlation among the data is an indication that it is unlikely that the data share common latent factors. This assessment can be done either qualitatively by analyzing the correlation matrix (i.e. focusing on pair-wise correlations) or quantitatively by performing a statistical test of sphericity.[51] After assessing the degree of pairwise correlation, the lowest necessary number of factors to retain for the calculation of the HPMI is determined using principal component analysis (PCA), such that the variation in the set of transformed sub-indicators can be explained to a sufficiently large degree. As explained in Jolliffe (2002), the number of factors for an adequate factor model is equal to or strictly smaller than the number of principal components (PCs) in PCA. Nevertheless, overestimating the number of factors is preferred to underestimating it, since it is only in the former case that the factors can still be consistently estimated (Stock and Watson, 2002). Hence, the number of common factors is set equal to the optimal number of PCs in PCA.

To assess the degree of sufficiency under PCA, the Jolliffe criterion[52] and the scree test are applied, which are two commonly used rules of thumb to determine the "optimal" number of extracted PCs.[53] According to the Jolliffe criterion, all PCs with an eigenvalue larger than 0.7 are retained. The scree test consist of the following two steps. First, the extracted eigenvalues are sorted in descending order and plotted against the index number of the corresponding PC. Second, a straight line is included to identify those points in the figure where the eigenvalues begin to asymptotically approach the x-axis with a flat and steady decrease (Breitung and Eickmeier, 2006). The point closest to the y-axis that strongly deviates from this line then determines the total number of PCs to be extracted.[54]

In a final step, maximum-likelihood factor analysis is performed with the statistical software package `R` using the `factanal` function. To obtain a sparse factor loading matrix that facilitates the interpretation of the factors, the initial factor solutions are rotated by applying the "varimax" method, which is the most common rotation technique for orthogonal rotations.[55]

Identification of a Boom/Overvaluation The proposed methodology assumes that the long-term trend of each sub-indicator accords with a level when the German real estate market is in equilibrium. Hence, any deviation of one of the sub-indicators from its trend signals a potential misalignment of residential property with its fundamentals. To increase the reliability of the early warning signal (see also Section 1), the HPMI aggregates the

[51] For this purpose, the Bartlett test of sphericity can be used, as recommended in Nicoletti, Scarpetta, and Boylaud (2000) and Nardo et al. (2005). This test assumes that the analyzed data is uncorrelated under the null hypothesis, i.e. that the correlation matrix is equal to the identity matrix.

[52] The other commonly used Kaiser criterion, whereby all PCs with an eigenvalue below one are excluded, is too conservative, as shown in Jolliffe (1972).

[53] Notice that the optimal number of factors is not determined by the Bai and Ng (2002) criterion, as this criterion is only valid for samples with large cross-sectional dimension.

[54] The motivation for this test is the observation that when carrying out these two steps, uncorrelated data is characterized by a straight line with a slope close to zero (Breitung and Eickmeier, 2006).

[55] The rotated factors are then characterized by large correlations with a small set of sub-indicators and small or no correlations with the remaining sub-indicators (see chapter 4 in Everitt (2005)).

Table 1: Explained Portion of Total Variation

Factor Component	Sum of Squared Loadings (Rotation)	Explained Variance (in %)	Cum. Explained Variance (in %)
F_1	2.688	38.4	38.4
F_2	1.880	26.9	65.3
F_3	1.323	18.9	84.2
F_1	2.787	39.8	39.8
F_2	1.958	28.0	67.8
F_3	1.352	19.3	87.1

Notes: In the upper panel, the second up to the fourth column exhibits the sum of squared factor loadings (in descending order) after applying the "varimax" rotation method, the explained portion of total variance (in per cent) and the cumulated explained portion of total variance (in per cent) for the corresponding factor F_i as of 2018:Q1. The lower panel displays the average of all these measures for the sequence of rolling six-year windows.

signals from the seven sub-indicators, such that an increased vulnerability of the German real estate market to a future realignment is only identified, when several sub-indicators coincidentally point to a misalignment, i.e. when the sources of vulnerability have become more uniform. In the present paper, specifically, any positive (negative) value of the HPMI indicates an overvaluation (undervaluation).

3 Empirical Results

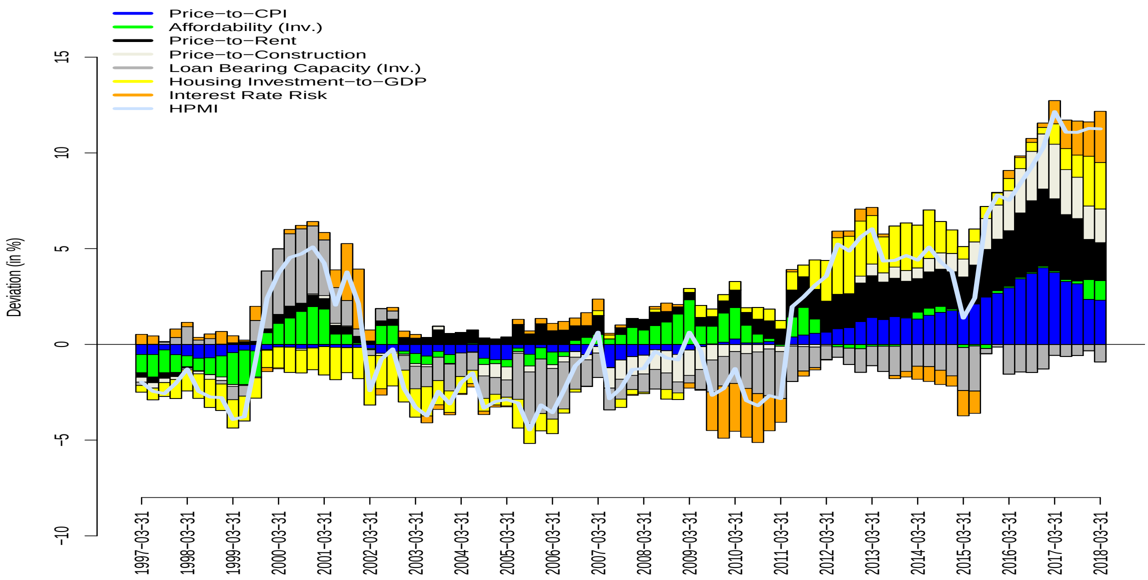
3.1 Preliminary Steps

After running the Bartlett test of sphericity that strongly rejects the null of uncorrelated sub-indicators, the number of retained factors J is determined. The Jolliffe criterion and the scree test both identify three relevant common factors for the six-year rolling windows, in the sense of explaining a sufficiently large portion of the common variation in the transformed data set (e.g. as of the first quarter 2018, 84.2% of the total shared sample variance is explained by the first three factors, see Table 1). Hence, in the following J is set equal to three in Equation 6 and the HPMI is calculated as described in Subsection 2.2.

3.2 Housing Price Misalignment Indicator

Current Level and Periods of Over-/Undervaluation According to the HPMI, real estate property was undervalued from 1997:Q1 to 1999:Q3, when housing prices were between 0.8% and 3.9% below their fundamentals. This situation changed in the fourth

Figure 4: Housing Price Misalignment Indicator (1997:Q1-2018:Q1)



Notes: The figure shows the housing price misalignment indicator ("HPMI") that reflects the percentage deviation of housing prices from their fundamentals and subsumes the amount that each of the seven sub-indicators contributes to this misalignment: the price-to-consumer price index ratio ("Price-to-CPI"), the inverted affordability index ("Affordability (Inv.)"), the price-to-rent ratio ("Price-to-Rent"), the price-to-construction costs ratio ("Price-to-Construction"), the housing investment-to-GDP ratio ("Housing Investment-to-GDP"), the inverted loan-bearing capacity index ("Loan-Bearing Capacity (Inv.)") and the interest rate risk proxy ("Interest Rate Risk"), respectively. Data source: see Table A.1 in the appendix.

quarter 1999 (+ 2.4%), when property markets initiated a period of positive price momentum relative to fundamentals that peaked in the fourth quarter 2000 (+5.1%), when this momentum was finally reverted. This episode of negative momentum continued until 2003:Q2 (-3.7%), when the misalignment entered a short period of stagnating relative housing prices that lasted more than two years. From 2006:Q1 (-3.6%) to 2007:Q1 (+0.6%), the misalignment steadily narrowed, to enter again a period of a sideways movement from 2007:Q4 (-1.3%) to 2009:Q2 (-0.4%) after a drop in 2007:Q2 (-2.8%). Relative housing prices modestly decreased in the subsequent quarters, leading to a maximum undervaluation of 3.2%. In 2011:Q2, German housing markets gained renewed positive momentum, leading to a misalignment of real estate property that peaked in 2017:Q4 (+11.3%) and as of 2018:Q1 amounts to slightly less than 11.3%, which is more than two sigmas from the zero line.

To assess whether the current imbalances can be classified as a boom, the approach in Goodhart and Hofmann (2008) is used, who define a boom as a persistent positive deviation of the cyclical component of more than 5% lasting for at least 12 quarters. Applying this definition to the HPMI signals a period of positive momentum that started eleven quarters ago. Consequently, the current episode may potentially be classified as a boom in the next quarter.

Major Risk Factors A granular view on the major factors fueling these developments suggests that interest rate risk is the major risk factor, contributing by 2.7 percentage points (pp) to these imbalances. The second and third major potential vulnerability is associated with housing investments ($\sim$ 2.4 pp) and the real housing price index ($\sim$ 2.3 pp), reflecting a relatively advanced stage of the housing cycle, while the (inverted) loan-bearing capacity indicator dampens the overvaluation by 0.9 pp, respectively.

A closer look at the dynamics of the sub-indicators that compose the HPMI reveals that interest rate risk has become steadily more relevant in aggravating the imbalances in housing markets since end 2015 and is now the predominant factor, contributing by 22.0% to the overvaluation. To assess the role of the low interest rate environment in explaining the most recent housing price dynamics, the time path of the short-term rate actually used for the interest rate risk sub-indicator is compared to the path of the average of the Taylor interest rates among differently calibrated and modelled rules. The results reveal that the duration of interest rates that are too low, given overall business conditions (i.e. given the prevailing output and inflation gap), amounts to three years as of March 31, 2018. Hence, the greater role of interest rate risk in the past few years, as suggested by the HPMI, is in line with this finding.

The housing investment-to-GDP sub-indicator is the second major factor (currently contributing by 20% to the overvaluation). It has been one of the major factors in driving the imbalances in the German housing market from 2010:Q3 to 2014:Q4 and since the last two quarters. Another important factor is the real housing price index, which has become more relevant over time since the third quarter 2009. Its impact currently amounts to 19.0%. By contrast, the contribution of the price-to-rent ratio to these imbalances has remained relatively stable from 2009:Q3 to 2016:Q4 (contributing by 32.6% on average) and has recently become less relevant (currently: 16.3%), while the dampening effect of the (inverted) loan-bearing capacity has continuously gained importance since the fourth quarter 2009.

To summarize this subsection, the aforementioned findings suggest that after a prolonged period of misalignment levels between ± 5%, lasting from 1997:Q1 up to mid-2015, the imbalances in the German housing market have increased in the last quarters. This development must however be assessed bearing in mind the general role of house price risks in Germany, which will be explained in the following subsection. Before concluding and as a word of caution, it is nevertheless important to bear in mind that any assessment of mispricing is subject to the second statement of Roll's critique (Roll, 1977), as the misalignment component is inferred from the difference between market-based data and the estimated fundamental value, where the latter is unobservable. Its price dynamics must therefore be modelled, which contributes to model risk.

4 Validation and Robustness Checks

As the German housing market has never experienced a severe housing bust at a nation-wide level, it is not possible to statistically assess the power of the HPMI in correctly identifying a housing market "crash". Nevertheless, the fact that the sub-indicators exhibit well-documented early warning characteristics suggests that the HPMI might "inherit" this property by construction. Moreover, to account for concerns about data snooping (Guharay, Thakur, Goodman, Rosen, and Houser, 2016), the time path and the level of the HPMI are both benchmarked against two well-established analytical approaches that are commonly used to identify booms and busts in housing markets (i.e. frequency-based filters and turning-point analysis). To this end, the following paragraphs shed light on different aspects that are important for a suitable EWI and demonstrate the value-added of the HPMI as a complement to existing early warning tools. This section ends with a brief discussion on the implications of the current level of the HPMI for house price risks in Germany.

4.1 Frequency-Based Filters: Dating, Duration and Size of Misalignment Episodes

To assess the adequacy of the HPMI in correctly identifying episodes of housing booms and turning points of the housing cycle, as well as in providing accurate estimates of the housing price misalignment, the widely used approach of decomposing a time series into its trend and its cyclical component is applied to the logarithm of the real housing price index y_t provided by the OECD, imposing a phase-in-period of 10 years.

The first filter applied is the one-sided HP filter in Equation 4 with a large smoothing parameter value of $\lambda = 400'000$, in line with Goodhart and Hofmann (2008) and Micallef (2018), respectively. The assessment is complemented with a second filter that has been proposed by Hamilton (2018) to overcome the end-point problem of the HP filter (denoted by HM filter, in the following) and that consists of a regression of y_t on its four most recent values as of date $t - h$, where a length of $h = 5$ years is used for the housing price cycle, in accordance with the assumption in Borio and McGuire (2004) and André (2010):[56]

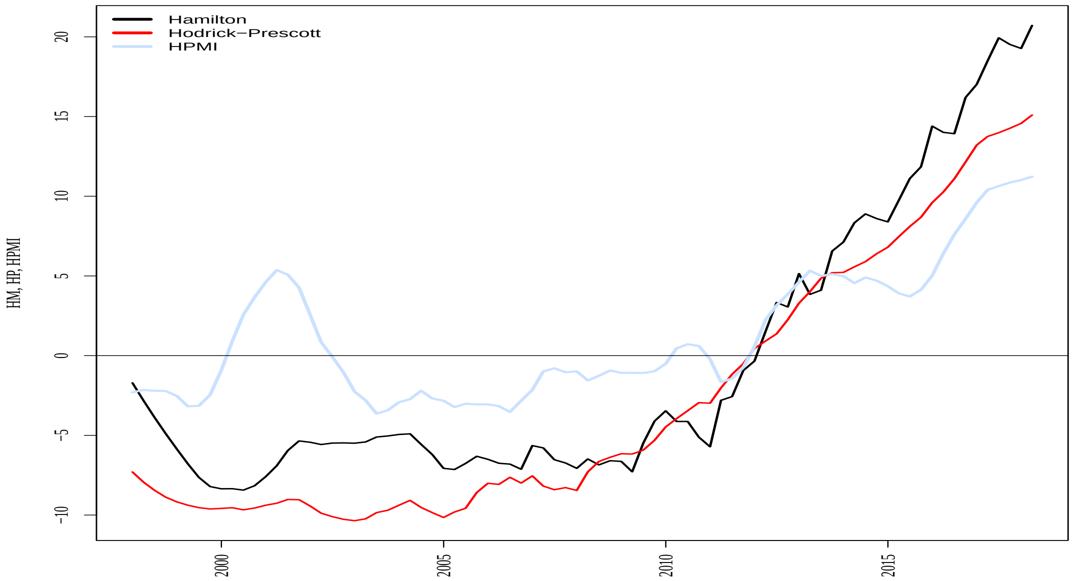
$$y_t = \beta_0 + \beta_1 y_{t-20} + \beta_2 y_{t-21} + \beta_3 y_{t-22} + \beta_4 y_{t-23} + v_t. \quad (7)$$

The resulting residuals $\hat{v}_t$ provide an estimate of the cyclical component of the real housing price index, as $\hat{\beta}_1$ converges to 1 for large samples, while the other OLS estimates of the lagged values of y converge to 0.

The smoothed version of the extracted two cycles are displayed in the following figure, together with the smoothed HPMI:

[56] As the statistical properties of the HM filter are not yet well understood, this paper prefers applying the well-established HP filter to extract the trend from the seven sub-indicators instead of using the former filter.

Figure 5: Housing Price Cycle and the HPMI (1997:Q1-2018:Q1)



Notes: The figure shows the smoothed two extracted housing prices cycles (black and red line) and the smoothed HPMI (lightblue line). Data source: see Table Appendix A.1.

The figure shows that the two extracted cycles and HPMI differ in levels, but broadly coincide with respect to their dynamics and their local optima (i.e. minima and maxima), suggesting that the duration of the identified expansion and contraction phases are similar (see also the next paragraph on this issue), except from 1999:Q4 to 2001:Q4. The overvaluation in the latter period is, nevertheless, in line with the findings of the International Monetary Fund (Geng, 2018). In line with the former qualitative finding, the HPMI and the two housing price cycles both started in 2011-2012 a period of gradual recovery from the trough in 2009:Q3 that still endures.

To assess whether the extracted cycles are positively synchronized, the phase synchronization test that is also used in Meller and Metiu (2017) is applied. In the present case, this test consists of a regression of the business cycle synchronicity measure proposed by Mink, Jacobs, and de Haan (2012) that equals the product of the sign of the HPMI and the sign of the corresponding cycle on a constant. The test results indicate that the HM and the HP filter are both positively synchronized with the HPMI, lending support to the usefulness of the HPMI.

To conclude this subsection, the comparison of the HPMI with the frequency-based filters reveals that the HPMI captures well the housing price cycle. Compared to simply using frequency-based misalignment estimates, however, the HPMI offers the advantage of identifying the factors that currently fuel deviations of housing prices from their fundamentals, among others (see also the introductory Section 1).

4.2 Turning Point Analysis: Housing Boom and Bubble Episodes

To benchmark the results of subsection 3.2, suggesting that the ongoing period of overvaluation cannot be classified as a boom as of 2018:Q1, four different definitions and/or approaches are considered in the following.

Boom - Persistence in the Cyclical Component The first approach applies the aforementioned definition of a boom in Goodhart and Hofmann (2008) that requires a minimum duration of 12 quarters for the expansion phase (see Subsection 3.2) to the two extracted cycles. Both the HM and the HP filter identify a boom that starts in 2013:Q2 and still endures. This episode is also identified by the HPMI from 2015:Q3 onwards.

The second approach applies the definition of a housing boom in André (2010), whereby a minimum cumulative increase of the real housing price index of 25% over a period of at least five years (20 quarters) is categorized as a boom phase, to the longest available price series from the OECD (starting in 1970:Q1). Accordingly, Germany would not be exposed to a boom phase to date, as the current expansion phase implies a cumulative increase of 17.3% (as of 2018:Q1). Indeed, this approach suggests that Germany has not experienced any boom episode to date, since the maximum 5-year price increase ever recorded amounts to only 18.0% (from 2013:Q1 to 2017:Q4). These results are also robust to the use of alternative real housing price indices and alternative definitions (e.g. in Helbling (2005) and OECD (2005) who define major boom and bust periods as those episodes where cumulative peak-to-peak real price changes exceed 15%).

Bubble - Explosive Time Series Dynamics When applying the definition of a bubble in Kindleberger and Aliber (2005) to the German real estate market, who classify a period of steadily rising prices over an extended period of at least 5 quarters (p. 29, l. 30ff.) as a bubble, Figure 1 (lower panel) suggests that housing markets currently do not exhibit a bubble, since real housing prices have steadily been rising for the last 4 quarters only.

A third and compared to the first and second also stricter approach (as it identifies periods of explosive time series patterns) shows that the starting date of the current episode of positive momentum in the German real estate market (i.e. the 2nd quarter 2011) is prior to the turning point in 2014:Q1 detected by the Backward Sup Augmented Dickey-Fuller (BSADF) test of Phillips et al. (2015a) and Phillips et al. (2015b) that allows date-stamping[57] bubble periods by systematically testing sub-samples of e.g. the real housing price index for explosive time series behavior, where the specific test results[58] can be downloaded from the international housing price database[59] that is maintained by the Federal Reserve Bank of Dallas.[60] Restricting the minimum duration of the expansion phase to last for at least two quarters as in Harding and Pagan (2002) and Brunnermeier, Rother, and Schnabel (2017) and using a lag length of one,[61] three real estate bubbles can

[57]Notice that the actual size of the bubble cannot be identified by the BSADF test. Hence, the HPMI adds value to this methodology.

[58]The parameters of the BSADF test statistic are set to 36 observations (= minimum window size) as in Phillips et al. (2015b) and Pavlidis et al. (2016) and two different lag lengths are used in the ADF regression $k = 1$ and $k = 4$ (the autoregressive lag length). The test is applied to both the German real housing price index and the German price-to-income ratio with a 95% confidence level.

[59]See Mack, Martínez-García, and Grossman (2018) for more details on the time series actually used for Germany.

[60]https://www.dallasfed.org/institute/houseprice#tab2 and is also available from the author upon request.

[61]The results with four lags coincides with the reported results, except that the BSADF test now does

be detected in total: from 2007:Q1 to 2008:Q4, from 2016:Q1 to 2016:Q4 and from 2017:Q2 onwards.[62] The relatively short duration of these episodes of "irrational exuberance", however, suggests that housing prices are rather anchored by fundamentals, as empirical evidence suggests that the length of a boom-bust cycle typically exceeds the imposed minimum length of the boom phase.

Extending the minimum duration of the expansion phase to five quarters, thereby following the recommendation in Phillips, Wu, and Yu (2011), whereby the minimum length should at least be as large as the log of the number of observations (in the present case: 170), the BSADF only detects the first bubble episode, although in this case the BSADF test result is at odds with expert judgment and other empirical findings suggesting that real estate markets were rather anchored by their fundamentals in 2007-2008 (see e.g. Figure 6 in Kajuth et al. (2016) and Otto and Schmid (2018)). Similarly, Chen and Funke (2014) and Engsted et al. (2016) both applying the BSADF test to the price-to-rent ratio and analyzing the German real estate market from 1970:Q1 to 2013:Q4 find no evidence of a real estate bubble in Germany.

4.3 The Role of Interest Rate Risk

The last "benchmark exercise" sheds light on how well the HPMI captures the role of interest rates that are deemed too low[63] for an extended period in fueling deviations of housing prices from their fundamentals. This transmission channel has previously been analyzed in Hott and Jokipii (2012) for an international sample using data from 1981:Q1 to 2010:Q3. Their results imply that the relation between a prolonged low-interest environment and the risk of overvalued real estate assets is in general strong, except in Germany, where on average only 20% of the imbalances can be attributed to interest rates that are deemed too low,[64] whereas both historical and recent evidence speaks in favor of a stronger impact of low interest rates on housing prices in Germany (Chen and Funke, 2014). In line with this observation, the HPMI suggests that from 1997:Q1 to 2010:Q3 interest rate risk accounted for 29.2% of the misalignment.[65]

The larger role of "unsustainable" interest rates in affecting deviations of housing prices

not identify any bubble in the first and second quarter 2008.

[62]Similar results are documented in Figure 2(b) in Brunnermeier et al. (2017) using the real price index provided by the OECD.

[63]E.g. interest rates that are temporary below the rate associated with the fundamental value of real estate property as in Kajuth et al. (2016).

[64]This empirical finding is in line with the cross-country empirical results in Kuttner (2014), who develops a dynamic user cost model to show that even large housing price increases (e.g. as a reaction to small and unexpected interest rate reductions) can be in line with fundamentals. As Kuttner (2014) emphasizes, most studies that find a strong link between interest rate reductions and fundamentally unjustified housing price increases are often upward biased, as they wrongly interpret part of the impact of interest rate changes on housing prices as being disentangled from fundamentals. This conclusion can easily be exemplified. For instance, within the dynamic equilibrium framework of housing tenure in Sommer et al. (2013), the decrease of the real risk-free rate by 200 basis points that was observed between 1995 and 2006 in the US implies a fundamentally-justified rise in housing prices by 16.4%. For the same period, the aforementioned dynamic user cost model by Kuttner (2014) would similarly imply a fundamental price increase of 26.3%. Hence, a large fraction of interest rate changes in actual fact feeds into the fundamental value of real estate assets.

[65]Part of the differences may be due to the shorter time period compared to the period that is analyzed in Hott and Jokipii (2012).

from their fundamentals (especially for apartments) is also evidenced in Kajuth et al. (2016). They find that in 2014, 9.1 percentage points of an overvaluation of around 12.5% (see their Figure 6) for apartments were associated with the low-interest environment in the aftermath of the GFC, which in part may reflect the search for yield behavior that characterizes the investment strategies of professional investors since that episode.[66] Both numbers are, however, smaller for single family houses (1.3 percentage points of an overvaluation of 4.8% in 2014).[67] Using the latest available data on the number of single-family houses (defined as a property with just one housing unit) and apartments from the Federal Statistical Office in Germany as of end 2014 to determine the fraction of housing price misalignment for all types of dwellings that can be attributed to the low-interest environment, implies that around 59.1% of the overvaluation is related to interest rates that are "low" by historical standards. The corresponding number is lower for the HPMI, where only 34.3% of the misalignment in 2014 is related to the low-interest environment.

To conclude this subsection: most studies that investigate the role of interest rates that are deemed too low for the German housing market suggest that "unsustainable" interest rates indeed have a major effect on property price misalignments. In the next subsection, the impact and the probability of risk materialization is discussed for the German housing market.

4.4 Implications of Current Indicator Levels for House Price Risks in Germany

Impact of Risk Materialization Assuming that the maximum observed LTV in Germany amounts to 80% (see e.g. Goodhart and Hofmann (2008) and Cerutti et al. (2017)), the current level of the HPMI (i.e. 11.3% as of 2018:Q1) suggests that the potential impact of risk materialisation is currently rather moderate, as a realignment would most likely only lead to a limited number of homeowners with negative equity of a rather small magnitude. In this regard, the empirical evidence on the negative effect of forced sales of apartments and single-houses on their prices might suggest that a significant overvaluation of the housing market could generate a prolonged period of continuously decreasing prices. However, although empirical research documents that foreclosed properties are generally sold at a discount of at least 20% to market value after controlling for differences in property characteristics and for spatial price interdependence,[68] empirical evidence indicates that spillovers are in general small in size (-2.6%) and limited to last for at most one year (Gerardi, Rosenblatt, Willen, and Yao, 2015), thereby limiting the risk of triggering an extended period of negative price momentum in the German housing market, assuming that the experience in other countries is also valid for Germany.

In view of the fact that most residential buildings in Germany are relatively old and recent academic contributions suggesting that there are foreclosure externalities for res-

[66] See e.g Just, Voigtländer, Eisfeld, Henger, Hesse, and Toschka (2017) who in their Figure 4-6 show that foreign investors (often professional investors) are heavily investing in the German real estate market since 2010.

[67] Notice that Budde and Micheli (2014) obtain a more balanced result with respect to the overvaluation of single family houses vs. apartments as of 2014, using the prices in 2011 as the base year.

[68] See Clauretie and Daneshvary (2009) and Donner, Song, and Wilhelmsson (2016) who both provide a summary of previous research results.

idential property in poor condition (Gerardi et al., 2015), it is important to take this risk transmission channel into account when assessing the vulnerability of the German real estate market to a future realignment. Assuming that all the aforecited empirical evidence from other countries is also valid for Germany, however, concerns related to this spillover channel seem to be unwarranted too, given that nearby transactions are only modestly negatively affected by foreclosed properties in the closest neighborhood (as already mentioned).

Probability of Risk Materialization The assessment of misaligned housing markets and therefore a potentially higher impact of risk materialization is in line with the current favourable financing conditions in the EA and Germany's above-average real wage growth (see e.g. the most recent data from the European Commission), which increases the purchasing power of households. As both factors are related to the fundamentals of housing, they may partially explain the latest price increases (OECD, 2017), except in periods where these explanatory factors mainly reflect temporary deviations from those levels that are associated with the fundamental value of housing (Kajuth et al., 2016). Assuming that these temporary deviations are rather small in size, these two factors indicate that the probability of risk materialization (i.e. the default risk of households) is currently rather small. This conclusion is reinforced by the observation that the largest housing price increases for both single-houses and apartments are concentrated in those large cities that are experiencing strong economic and population growth (e.g. Frankfurt or Munich, see e.g. Schier and Voigtländer (2015), Budde and Micheli (2016) and Deutsche Bundesbank (2017b)).

Similarly, the latest available information from the new OECD affordable housing database reveals that 19.0% of the homeowners in Germany have a mortgage outstanding and that 26.0% of them that belong to the bottom quintile of the income distribution spend an unsustainable large fraction of their disposable income for mortgage payments (i.e. more than 40%). These numbers are low compared to other OECD countries,[69] suggesting that it is less likely that a critically large number of households may default in the case of a housing bust, as the debt servicing costs of these households may still be affordable even in case of one household member becoming unemployed. This conclusion is supported by the information in Figure 2 in Andrews and Sánchez (2011), indicating that nearly 60% of the homeowners in Germany belong to the upper third quartile of the disposable income distribution and that this number is large compared to other advanced economies (e.g. Australia, Austria, the Netherlands and the USA). In addition, the Bank Lending Survey of the ECB and the low-interest environment survey 2017 conducted by the Deutsche Bundesbank (Deutsche Bundesbank, 2017a) both indicate that banks have not significantly loosened their credit standards in mortgage lending in the past few years. Hence, the current numbers may still be in line with the cited numbers.

4.5 Additional Robustness Checks

To assess the validity of the empirical results against a range of benchmarks, several alternative specifications and calibrations have been tested. First, alternative time series assumptions concerning the trend of the sub-indicators have been imposed (e.g. using

[69] Compared to 23.4% and 37.9%, respectively.

other filters, linear or higher-order polynomial time trends). The (undocumented) results reveal that the time series pattern of the sub-indicators is both qualitatively and quantitatively robust with respect to the trend-assumption. Second, the robustness of the HPMI with respect to the selected sub-indicators has been assessed by using alternative sub-indicators (e.g. alternative housing price indices, the user costs of housing relative to the rental yield) or based on empirical evidence suggesting that the sub-indicators that enter the HPMI are highly correlated with alternative well-established indicators. For instance, Kholodilin, Michelsen, and Ulbricht (2014) show in their Figure 2 that other measures than the used housing investment-to-GDP ratio, which are also associated with construction activity (e.g. investment in new dwellings and housing permits), exhibit similar time series dynamics, thereby supporting the use of the housing investment-to-GDP ratio both as a robust and valid sub-indicator and as a mirror image of the stage of the construction sector in the housing investment cycle. Third, other factors that are also related to the fundamental value are indirectly captured by the used price-related ratios (e.g. the degree of urbanization). Similarly, regional income variation should be relatively low in Germany compared to other countries due to the progressive tax system and very high tax rates by international standards, which reduces regional differences in disposable income. In addition, the Germany solidarity surcharge (in German: "Solidaritätszuschlag"), a tax transfer created with the purpose of funding investments in Eastern Germany, contributes to upgrade differences in infrastructures between federal states, thereby reducing the degree of heterogeneity in Germany's property markets (e.g. hedonic housing prices should have become less dissimilar after re-unification). In this vein, Piazzesi et al. (2007) show how changes in the expenditure share on housing affects asset prices. They also show that these changes are not affected by inflation-adjusted income and interpret this empirical evidence as supportive to the assumption of homogenous consumer preferences. Hence, regional heterogeneity with respect to housing demand should play a minor role (e.g. the trade-off between consumption goods and property should be rather homogenous).

5 Conclusion

This paper proposes a composite housing price misalignment indicator to assess the vulnerability of the German housing market to a future realignment. The proposed metric is composed of seven indicators that are associated with the fundamentals of housing markets and captures developments in the real economy (e.g. the stance of monetary policy, the current stage of the housing cycle), as well as in both the mortgage (e.g. mortgage rates) and the housing market (e.g. housing price dynamics, rental rates, construction costs), which are among the most relevant group of housing market-related indicators used as early warning indicators for systemic banking crisis by central banks, financial market participants and policymakers. In order to account for the stylized fact that vulnerabilities are built up over a prolonged period and to remove the otherwise misleading effect of benign, long-term changes in the sub-indicators (e.g. as an aftermath of mortgage market development), they enter the HPMI in gap form (i.e. measured as the deviation from a one-sided Hodrick-Prescott trend).

An empirical analysis to the most recent housing price developments in Germany suggests that the housing market is currently overvalued by approximately 11%. The main economic factors fueling this misalignment are interest rate risk and a relatively advanced stage of the housing investment cycle, whereas a rather solid debt-servicing capacity has a dampening effect. By taking into account the stylized facts about the German housing market and some of its peculiarities, this paper concludes that to date, concerns about a significant realignment are rather low.

Before concluding, it is worth mentioning that there are at least two arguments why in the future it may be less likely to observe large housing price misalignments. First, research on experimental asset markets shows that it requires only a relatively small number of experienced traders to eliminate (or at least abate) the dynamics of bubbles (e.g. Dufwenberg, Lindqvist, and Moore (2005)). Given that the number of professional investors in the German housing market has increased during the last decade (e.g. financial investment firms and residential property companies like Vonovia and Deutsche Wohnen that have both aggressively gained market share in the recent past), the housing market should now be more resilient to negative housing price shocks than before the Great Financial Crisis. It might, however, become necessary to regulate these real estate companies if they continue buying more and more real estate assets in Germany, as the risk that they may be forced to fire sale part of their asset portfolio may rise accordingly, which may then initiate a cascade of decreasing housing prices. Second, the increasing number of online portals offering market prices and characteristics that are relevant inputs in standard hedonic regressions (e.g. ImmobilienScout24) should lead to lower information costs and therefore to lower transaction costs (e.g. lower margins due to lower risk premia).[70]

[70]See Krainer (2001) for a theory of liquidity in real estate markets.

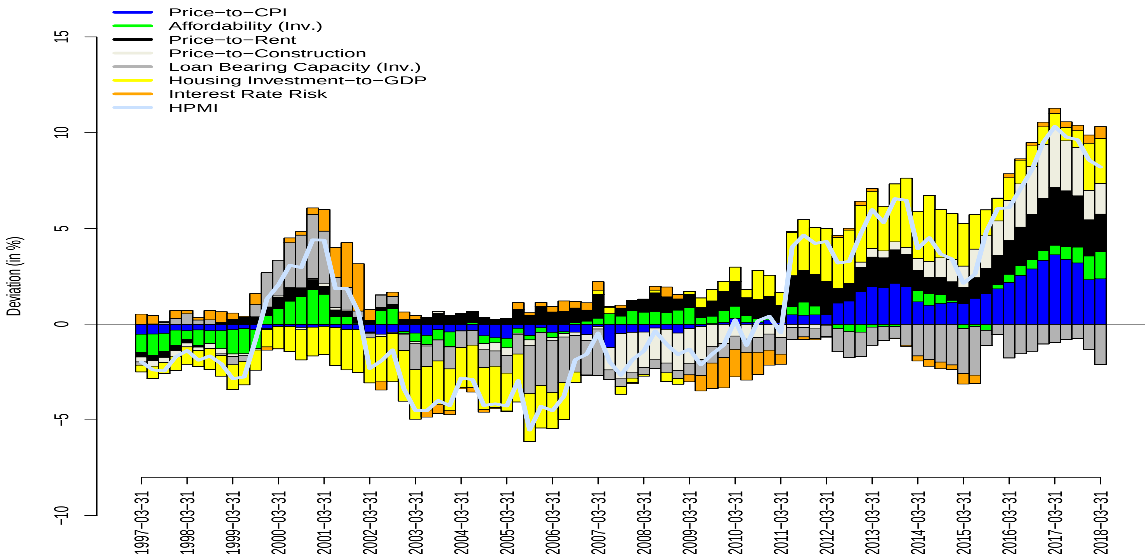
Appendix

Table A.1: Data

Variable	Source	Start	End
Construction price index	Deutsche Bundesbank (data from Destatis)	31.03.1968	30.06.2018
Disposable household income	Deutsche Bundesbank (data from Destatis)	31.03.1991	30.06.2018
Effective mortgage rate (new business)	Deutsche Bundesbank (MFI statistics)	31.03.2003	30.06.2018
Effective mortgage rate (estimated new business)	Deutsche Bundesbank	30.06.1982	31.12.2002
Consumer price index (overall index)	Deutsche Bundesbank (data from Destatis)	31.01.1991	30.09.2018
Housing construction investment-to-GDP (in %)	Deutsche Bundesbank (data from Destatis)	31.03.1991	30.06.2018
Lending for house purchase (new business)	Deutsche Bundesbank (MFI statistics)	31.12.2014	30.06.2018
Housing loans	Deutsche Bundesbank	31.12.1968	30.06.2018
Nominal house price index	OECD	31.03.1970	31.03.2018
Number of private households	Destatis	31.12.1961	31.12.2017
Rent index	OECD	31.03.1970	31.03.2018
Real house price index	OECD	31.03.1970	31.03.2018
Taylor interest rate EA (average; with $\alpha_{\hat{\pi}} = 1.5$)	Deutsche Bundesbank	31.01.1999	31.08.2018
Taylor interest rate EMU	Deutsche Bundesbank	31.03.1991	31.12.1998
3-month EURIBOR	Reuters	31.12.1998	27.09.2018

Notes: The first column displays the variables that are used in the empirical section, while the second up to the fourth column exhibits the source of the data, as well as both the starting and the end date of the corresponding variable, respectively.

Figure A.1: Housing Price Misalignment Indicator with an Expanding Window (1997:Q1-2018:Q1)



Notes: The figure shows the housing price misalignment indicator ("HPMI") that reflects the percentage deviation of housing prices from their fundamentals and subsumes the amount that each of the seven sub-indicators contributes to this misalignment for an expanding window with a minimum size of 24 quarters: the price-to-consumer price index ratio ("Price-to-CPI"), the inverted affordability index ("Affordability (Inv.)"), the price-to-rent ratio ("Price-to-Rent"), the price-to-construction costs ratio ("Price-to-Construction"), the housing investment-to-GDP ratio ("Housing Investment-to-GDP"), the inverted loan-bearing capacity index ("Loan-Bearing Capacity (Inv.)") and the interest rate risk proxy ("Interest Rate Risk"), respectively. Data source: see Table A.1.

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