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The German housing market cycle: Answers to FAQs

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Non-technical summary

Research Question

Frequently asked questions in the analysis of housing markets are: What are the effects of interest rates, income or housing supply on house prices? What is the impact of house price increases on the supply of housing? How much is housing inflation due to land price increases and what is the contribution of construction prices? How long do house price fluctuations last? This paper seeks to shed light on the joint price and supply responses on the German housing market to exogenous changes in macroeconomic determinants.

Contribution

Computing typical reactions of price and supply on the housing market across different episodes of the house price cycle requires a long time series for house prices. The paper presents a novel aggregate price index for housing in Germany, which goes back to 1993. The long house price series, which can be split into a land and a construction price component, is incorporated in an econometric model that takes into account the interaction between the price and supply of housing.

Results

Estimation results suggest that house prices in Germany mainly depend on current and expected income and on the level of interest rates. A decomposition suggests that land prices react more strongly to interest rate changes and to current income developments, whereas for construction prices expected income and the level of construction activity appear to play a larger role. While in the years before the Great Recession, construction prices contributed most to house price growth, land price growth was the main driver behind the recent strong house price increases. The estimates point to a moderate housing supply elasticity in international comparison. The house price dampening effect of additional housing supply is found to be small. This is the result of the combination of a positive price effect of additional construction via construction prices and a price dampening effect of additional building land. Finally, house prices and residential investment take several years to adjust to shocks.

Nichttechnische Zusammenfassung

Fragestellung

Häufig gestellte Fragen in der Analyse des Wohnimmobilienmarkts beziehen sich auf die Preiswirkungen von Zins-, Einkommens- oder Angebotsänderungen sowie die Effekte von Preissteigerungen auf die Angebotsausweitung. Interesse besteht auch an den relativen Beiträgen der Boden- und der Baupreiskomponente sowie der typischen Länge eines Immobilienmarktzyklus. Die Untersuchung zielt auf ein besseres Verständnis der Preis- und Angebotsreaktionen am deutschen Wohnimmobilienmarkt auf Änderungen des makroökonomischen Umfelds.

Beitrag

Die Berechnung typischer Verläufe der Preis- und Angebotsreaktionen am Wohnimmobilienmarkt über zyklische Phasen hinweg erfordert Preisangaben für eine hinreichend lange Zeitspanne. Daher wird ein neuer Preisindikator für Wohnimmobilien für Deutschland insgesamt vorgestellt, der zurück bis ins Jahr 1993 reicht. Der Preisindikator, der in eine Boden- und eine Gebäudepreiskomponente zerlegt werden kann, fließt in ein empirisches Modell ein, das die Anpassungskanäle über die Preis- von denjenigen über die Angebotsseite abgrenzen kann.

Ergebnisse

Den Ergebnissen zufolge hängen Wohnimmobilienpreise vor allem vom Zinsniveau sowie den aktuellen und erwarteten Einkommen ab. Eine Zerlegung der Wohnimmobilienpreise deutet darauf hin, dass die Bodenpreiskomponente stärker auf Änderungen der Zinsen und auf aktuelle Einkommensentwicklungen reagiert, während für die Baupreiskomponente das erwartete Einkommen und das Ausmaß der Bauaktivität eine größere Rolle zu spielen scheinen. Während vor der Großen Rezession die Baupreisänderungen den größeren Beitrag zu den Preisänderungen bei Wohnimmobilien lieferten, stand hinter den jüngeren Preiszuwächsen vor allem die Verteuerung von Baugrundstücken. Den Rechnungen zufolge reagiert das Wohnungsangebot in Deutschland im internationalen Vergleich moderat preiselastisch. Der preisdämpfende Effekt einer Angebotsausweitung fällt gering aus. Er setzt sich zusammen aus einem preisdämpfenden Effekt von Baulandausweitungen und der preissteigernden Wirkung erhöhter Bauaktivität. Die Anpassung von Preisen und Angebot an Schocks erstreckt sich über mehrere Jahre.

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Abstract

This paper analyses the behaviour of prices and supply on the German housing market taking into account the interaction between prices and quantities. A novel price index for residential property prices covering the whole country going back to 1993 is used in a macroeconomic model to estimate key housing market elasticities for Germany. A decomposition suggests that the land price component of house prices is relatively elastic with respect to income and interest rates, while the construction price component responds to income and the level of construction activity. The decomposition also highlights countervailing house price effects of a supply increase: A dampening effect via land prices and a stimulating effect via construction prices.

Keywords: Residential property prices, residential investment, housing market cycle

JEL-Classification: R21, R31, E32

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1 Introduction

Frequently asked questions in the analysis of housing markets are: What are the effects of changes in interest rates, income or housing supply on house prices? What is the impact of house price increases on the supply of housing? How much are house price changes due to land price changes, and what is the contribution of construction prices? How long do house price fluctuations last? When addressing these questions, the interaction between the price and supply of housing in response to shocks needs to be taken into account, as a housing boom or bust can be reflected in price changes, or a supply reaction, or a combination of both. This interaction channel may influence the direction, size and time profile of the price and supply responses to shocks, with a supply reaction potentially mitigating or exacerbating the price response. Macroeconomic models of the housing market featuring a feedback between prices and quantities exist for many advanced or emerging economies using different classes of models, such as traditional macroeconomic models (e.g. Antipa and Lecat, 2010; Grimes and Aitken, 2010; Nobili and Zollino, 2017; Steiner, 2010), DSGE models (e.g. Aspach-Bracons and Rabanal, 2010; Iacoviello and Neri, 2010) or structural vector autoregressions (e.g. Bian and Gete, 2015; Fry, Martin and Voukelatos, 2010; Jarocinski and Smets, 2008; Lastrapes, 2002; Musso, Neri and Stracca, 2011).

Against this background, it is striking that results on the characteristics of the German housing market hardly exist. Even as German house prices have been increasing strongly following the Great Recession, little is known about the characteristics of the German housing market cycle. An important reason might be the lack of a long series for aggregate house prices in Germany. While there are quality-adjusted transactions-based quarterly house price data for the period starting in 2003, a house price index for the whole country is not available prior to 2003.[1] At the same time, the period since 2003 might not be sufficient to cover a full housing cycle in Germany.[2]

This paper aims to fill these gaps by, first, proposing a novel aggregate price index for housing in Germany following Davis and Heathcote (2007), which goes back to 1993 and is based on official statistical data. This approach avoids both the limitations resulting from a short sample period for aggregate house prices, and those from a house price series with partial coverage of Germany. We use the novel house price index in a small

[1] The house price index by Destatis, the Federal Statistical Office, goes back to 2000, but is not representative for the whole country before 2014 (Destatis, 2018).

[2] House price data for a set of German cities going back to 1991, available at the Bank of International Settlements (BIS) or OECD, suggest that house prices in German cities exhibit fairly long cycles. In the cities, house prices reached their previous peak in the mid-1990s and their latest trough in 2007/2008.

macroeconomic model of the German housing market, following DiPasquale and Wheaton (1994) and McCarthy and Peach (2004). Through the lens of this model, we provide a quantification of typical dynamics on the German housing market.

Our paper contributes results for Germany to the literature on the macroeconomics of the housing market. In a structural model of aggregate household consumption in Germany, Geiger, Muellbauer and Rupprecht (2016), and Nocera and Roma (2017) investigate the interdependencies of economic activity, the mortgage market and house prices in Germany. The response of housing supply is not explicitly incorporated such that the joint behaviour of prices and supply of housing is not worked out. Lerbs (2014) estimates a single-equation panel model of building permits as a measure of housing supply change, without modelling potential feedback via house prices. The same applies to Gattini and Ganoulis (2012), who provide time-series panel estimates and single-equation regression results for the housing investment effect of house price changes. The feedback mechanism from housing investment to house prices is not estimated. Furthermore, a number of contributions seek to identify and quantify the degree of overvaluation by estimating a fundamental house price (Hertrich, 2019; Igan and Loungani, 2012; Kajuth, Knetsch and Pinkwart, 2016; Kholodilin and Ulbricht, 2015; Koetter and Poghosyan, 2010), or by deploying time-series methods (Chen and Funke, 2013; Kholodilin, Michelsen and Ulbricht, 2014). Their focus is more or less exclusively on the long-run determinants of German house prices without analysing the cyclical frequency.

In the remainder of the paper, section 2 introduces the regression model setup; section 3 presents the construction of the long series for aggregate house prices in Germany, section 4 discusses the estimation results, section 5 characterises the German housing cycle based on the estimation results, section 6 decomposes the house price responses to shocks into the effects on the land and those on the construction price component, and section 7 concludes.

2 Empirical model

The starting point for the empirical model is the conventional stock-flow model of the housing market (DiPasquale and Wheaton, 1994). In this model, the housing market equilibrium is characterised by a price level which balances housing demand and supply. An exogenous increase in demand, for example, leads to price increases. For an initial level of construction costs, this generates profit opportunities for builders, which results in additional housing construction. The new equilibrium after a positive demand shock is characterised by a higher price level and a larger housing stock. Note that new housing construction (i.e. net of replacement) increases only until the new equilibrium housing

stock is reached. This approach takes the developments in the wider economy as given from the perspective of the housing market and does not include feedback between the housing market and the wider economy.

In the empirical application an equation system is specified, which aims to capture the essence of the conceptual model. The first equation represents the long-run equilibrium relationship of house prices with macroeconomic demand and supply side variables. The aggregate house price can be viewed as reflecting, next to the expected path of interest rates, perceived future income growth, which is in turn closely tied to trend productivity growth (Hoffmann, Krause und Laubach, 2012). In a frictionless model, this link might arise via the effect of future aggregate income growth on the discounted sum of expected rents, or on future capital gains. Alternatively, under borrowing constraints the channel might arise if banks link their mortgage credit decisions to the expected future collateral value of homes (Iacoviello, 2005). On the supply side, construction costs and construction prices are in the long run related to the productivity of the construction sector.[3] In sum, the empirical specification of the long-run relationship

$$p_t = \beta_0 + \beta_1 y_t + \beta_2 r_t + \beta_3 y_t^{constr} + \beta_4 g_t^{exp} + \varepsilon_t \tag{1}$$

where p_t is the log of real house prices, comprises a constant, the log of real disposable income per household, y_t, the inflation-adjusted mortgage rate, r_t, (the log of) real productivity in the construction sector, y_t^{constr}, and long-run real GDP growth expectations, g_t^{exp}, as a proxy for expected future income growth; ε_t is an error term. House prices adjust in response to deviations from their long-run equilibrium relationship, according to a standard error-correction equation.

$$\Delta p_t = \gamma \varepsilon_{t-1} + \sum_{i=1}^{q} \alpha_i i_{t-q} + \boldsymbol{\Psi}' \Delta \boldsymbol{z} + \eta_t \tag{2}$$

where ε_t is now interpreted as an error-correction term, i_t denotes residential investment (relative to the existing real housing stock), and the vector $\Delta \boldsymbol{z}$ contains the lagged differences of the right-hand side variables in (1).

With regard to the supply side, consider the law of motion for the housing stock S_t.

$$S_t = (1 - \delta) S_{t-1} + I_{t-1|t} \tag{3}$$

where δ is the depreciation rate and $I_{t-1|t}$ new housing investment between *t-1* and *t*. The first term on the right summarizes past housing investment choices (net of depreciation).

[3] Long-run supply shifters of residential land are mainly costs which arise in the process of converting, e.g., agricultural land to residential areas, and which are due to frictions or legal prescriptions in land use regulation. Indicators for these types of costs are not available, however.

The second term on the right, housing investment, links the current value of housing stock to housing market drivers. A conventional assumption is that new housing investment, i_t, occurs if there are profit opportunities, which are measured by the relation between house prices and construction prices (Tobin's Q), controlling for other factors in $\Delta \boldsymbol{z}$.

$$i_t = \propto_0 + \propto_1 (p_t - cc_t) + \boldsymbol{\Gamma}' \Delta \boldsymbol{z} + \vartheta_t \quad (4)$$

Alternatively, Mayer and Somerville (2000) and Lerbs (2014) argue that housing investment should be modelled as depending on price changes (rather than the price level) and changes in construction prices, controlling for further relevant variables.

$$i_t = \delta_0 + \sum_{i=1}^{m} \delta_i \Delta p_{t-m} + \sum_{j=1}^{n} \mu_j \Delta cc_{t-n} + \boldsymbol{\Pi}' \Delta \boldsymbol{z} + \zeta_t \quad (5)$$

The intuition is that, after a permanent demand shock, for example a general rise in income, the house price and the housing stock are higher in the new equilibrium than previously. Going from the initial to the new equilibrium house prices and housing supply exhibit a positive growth rate, while the growth in of both variables fades once the new equilibrium is reached (except possibly replacement construction). In the empirical application, we test for the validity of specification Eq. (4) or Eq. (5).

3 Aggregate residential property prices in Germany 1993-2018

3.1 Methodology

To construct a long series for house prices in Germany, we start by defining the aggregate value of the housing stock, $p_t^h h_t$, as the sum of the value of housing structures, $p_t^s s_t$, and the value of land, $p_t^l l_t$, on which the structures sit (Davis and Heathcote, 2007).

$$p_t^h h_t = p_t^s s_t + p_t^l l_t \quad (6)$$

The value of the housing stock in *t+1* is the sum of the contribution of the price change and the value of the increment to the housing stock.

$$p_{t+1}^h h_{t+1} = \frac{p_{t+1}^h}{p_t^h} p_t^h h_t + p_{t+1}^h \Delta h_{t+1} \quad (7)$$

The value of the increments to the housing stock can be calculated as the sum of the net investment in structures and the value of the net increase in building land for housing.

$$p_{t+1}^h \Delta h_{t+1} = p_{t+1}^s \Delta s_{t+1} + p_{t+1}^l \Delta l_{t+1} \quad (8)$$

Eq. (7) and Eq. (8) can be combined and re-arranged to yield an expression for aggregate house price growth.

$$\frac{p_{t+1}^h}{p_t^h} = \frac{p_{t+1}^h h_{t+1} - p_{t+1}^s \Delta s_{t+1} - p_{t+1}^l \Delta l_{t+1}}{p_t^h h_t} \tag{9}$$

The terms on the right-hand side of Eq. (9) can be computed using official statistical data for Germany as explained in the following section. Consistency with Eq. (6) requires the assumption that the quantities of structures and residential land remain more or less unchanged between two periods, i.e. in practice change only very gradually. In this case, house price growth is a weighted average of the price growth rates of structures and land, where the weights refer to the housing stock value shares of structures, $1 - w_t$, and land, w_t, (Davis and Heathcote, 2007).

$$\frac{p_{t+1}^h}{p_t^h} = (1 - w_t)\frac{p_{t+1}^s}{p_t^s} + w_t \frac{p_{t+1}^l}{p_t^l} \tag{10}$$

3.2 Implementation

Data for the end-of-year value of the housing stock, the first term in the numerator and denominator of the right side of in Eq. (9), at replacement cost are available in the macroeconomic balance sheet statistics from the German Federal Statistical Office, broken down into the value of housing structures and of total building land. Building land is valued at current transactions prices, while structures are valued at current construction prices. We use data from official land use statistics on the share of residential area in total building area in Germany to calculate the value share of residential building land. Net investment in residential structures, the second term in the numerator of the right side of Eq. (9), is calculated as nominal residential investment less depreciation. Also, we subtract the value of public and private fees, commissions, property sales taxes, building connections and outdoor property installations, which are part of residential investment as published by the Federal Statistical Office. However, their prices should not be included in house price indices. These components made up 15.3 % of gross residential investment on average over the period 1991 to 2018. We include the amount of value-added tax, which is due on the purchase of residential investment for final consumption, as it is included in official price indices for new housing in Germany.

The value of the increment to residential building land, the third term in the numerator of the right side of Eq. (9), requires a more disaggregated approach. This is because there are neither aggregate data for this component nor mix-adjusted aggregate land prices prior to 2000 that could be used to convert aggregate increments to building land into nominal

values.[4] For the increases in residential building land, we use data on residential building area at a regionally disaggregated level, which is available in official land use statistics for all 401 administrative districts in Germany for the years starting in 2004. Prior to 2004, district-specific data are available for the years 2000 and 1996 and we interpolate linearly the values for the years in between. Prior to 1996, only an aggregate value for residential building land for the year 1992 is available and we interpolate the aggregate value for the years between 1992 and 1996. To convert the increments in building land into values we multiply them at the regional level with prices for building land, for which official data starting in 1995 is available. Computing the values of the increments to building land at the level of the 401 regions, and adding them up, helps to control for regional differences in the quality of building land, which are largely due to differences in location. The regional dataset for building land prices contains almost 10 % missing values. We impute those in a step-wise procedure. First, whenever available, we use official data on the price ratio of developed building land and total building land (including raw building land) in neighbouring cells to impute a missing value. This procedure reduces the share of missing values to 3.8 %. In these remaining cases, we interpolate linearly, whenever there is a gap between two filled cells, which reduces the share of missing values to 2.5 %. Finally, in the remaining empty cells at the beginning or the end of the sample period, we use data on the price dynamics of building land from other sources to extrapolate.[5] In a few cases, in which no data from other sources are available, which make up less than 0.5%, we extrapolate at the edges using average price dynamics over the adjacent period for which data are available.

Overall, this procedure yields a dataset of the value of the increment to residential building land at the regional level for the period starting in 1997, and a series for the aggregate value of increments to residential building land for the period 1993 to 1996. The aggregate increments to residential building land are thus available starting in 1993. However, for the period 1993 to 1996, the estimate for the value of the increment to building land is not mix-adjusted, and is therefore subject to larger price index measurement errors than the remainder of the sample. We calculate the empirical measures for the components in Eq. (9) for the market sector, i.e. excluding the government sector, except for the value of the increment of the residential building land, for which a sectoral breakdown is not available. Finally, where quarterly figures for the components in Eq. (9) were not available, i.e. for all components except residential investment, annual figures were converted to quarterly figures by linear interpolation for

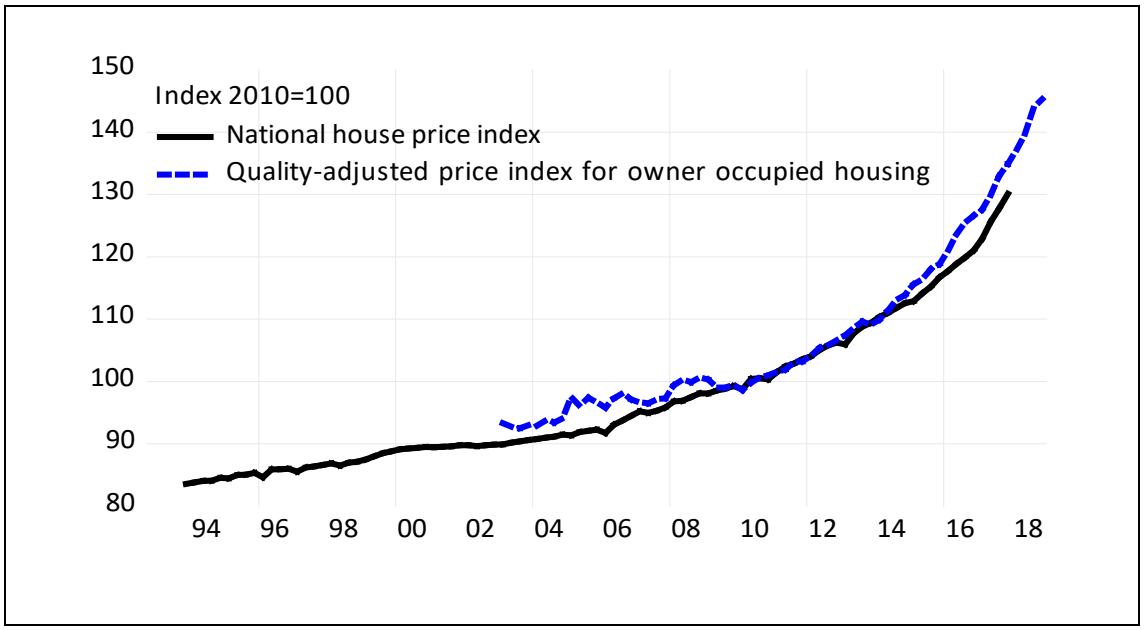
[4] A mix-adjusted land price index going back to 2000 is published by the Federal Statistical Office.
[5] Data sources in this case are a private property consulting firm, bulwiengesa AG, and the building society branch of regional mutual funds (*Sparkassen*).

each component before aggregating to a house price index, which we label national house price index.

3.3 Results

Fig. 1 compares the national house price index with the transactions-based, quality-adjusted quarterly aggregate price index for owner-occupied housing in Germany by the Association of German Pfandbriefbanks (vdp), which starts in 2003.

Figure 1: House prices in Germany 1993-2018



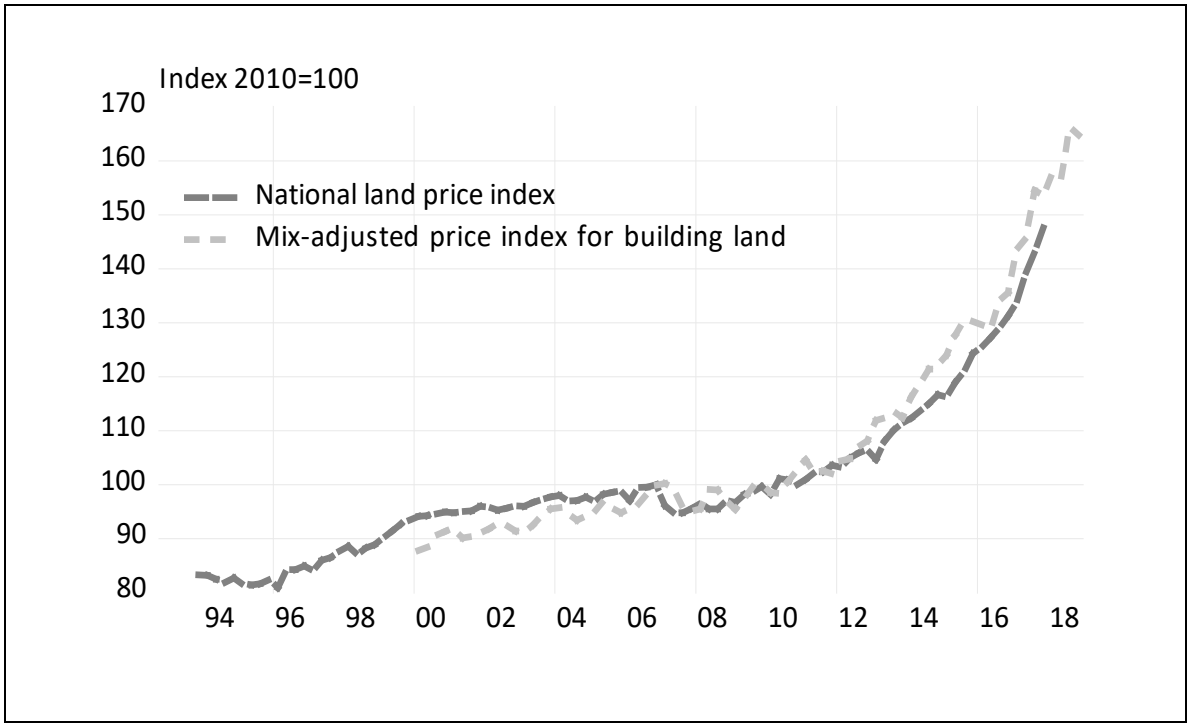
Source: Own calculations and Association of German Pfandbriefbanks (vdp).

Reassuringly, in the overlapping period both indicators track each other fairly closely. After a period of moderate house price growth since 2000, house prices started to pick up strongly around 2010 and kept on rising fast since then. The method also yields results for a price index for building land consistent with Eq. (6). The constructed series for land prices can be cross-checked with the mix-adjusted price index for building land by the Federal Statistical Office, which goes back to 2000 (Fig. 2). Again, both series exhibit a more or less identical development, which lends support to the method used to construct a house and land price index for Germany back to 1993.

Fig. 3 presents the house price index along with the price index for building land and construction prices for residential structures. Up to the recession in 2008/2009, rather moderate aggregate house price growth resulted from a combination of modest land price,

and virtually no construction price growth. Construction prices picked up in 2007.[6] Land prices show a more muted development around the recession than construction prices but started to grow again quickly. In the recent house price boom, house price growth resulted mainly from rather strong growth of land prices, with construction prices picking up strongly with a delay.

Figure 2: Prices for building land in Germany



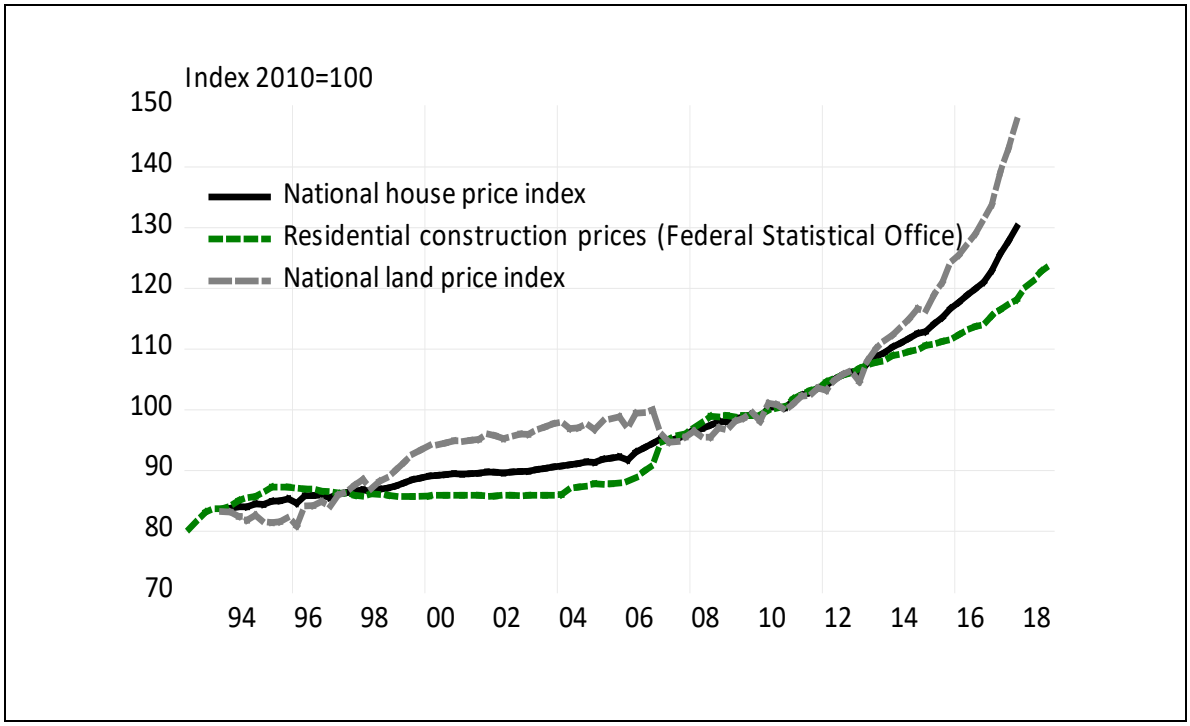
Source: Own calculations and Federal Statistical Office.

The main caveats of the approach are, first, that in contrast to official house and land price indices, the national indices are neither transactions-based nor explicitly quality-adjusted, but partially mix-adjusted. In the first years of the sample, mix-adjustment is not feasible at all with available data. Second, the data underlying the national house price index are mostly annual figures, while fluctuations at the quarterly frequency are not measured, except for residential investment. Therefore, the information content at quarterly frequency for estimation in the first part of the sample stems from the explanatory variables, while in the second part original quarterly data are used for house prices. From this perspective, the results on the long-run determinants of house prices are more reliable than those on the short-run dynamics. Third, aggregate regressions are bound to omit the information from the regional dispersion, which are a key feature of house price

[6] The construction price hike in 2007 also includes the contribution of a value-added tax increase from 16% to 19%. However, construction price growth net of VAT was higher in 2007 (3.9 %) and 2008 (2.9%) than in 2006 (1.9%), too.

developments in Germany since 2010. However, further regionally decomposing the constructed national house price index is beyond the scope of the paper.

Figure 3: Prices for residential property, building land and residential construction in Germany



Source: Own calculations and Federal Statistical Office. Construction prices incl. value-added tax increase from 16% to 19% in 2007. VAT not applicable in case of land prices.

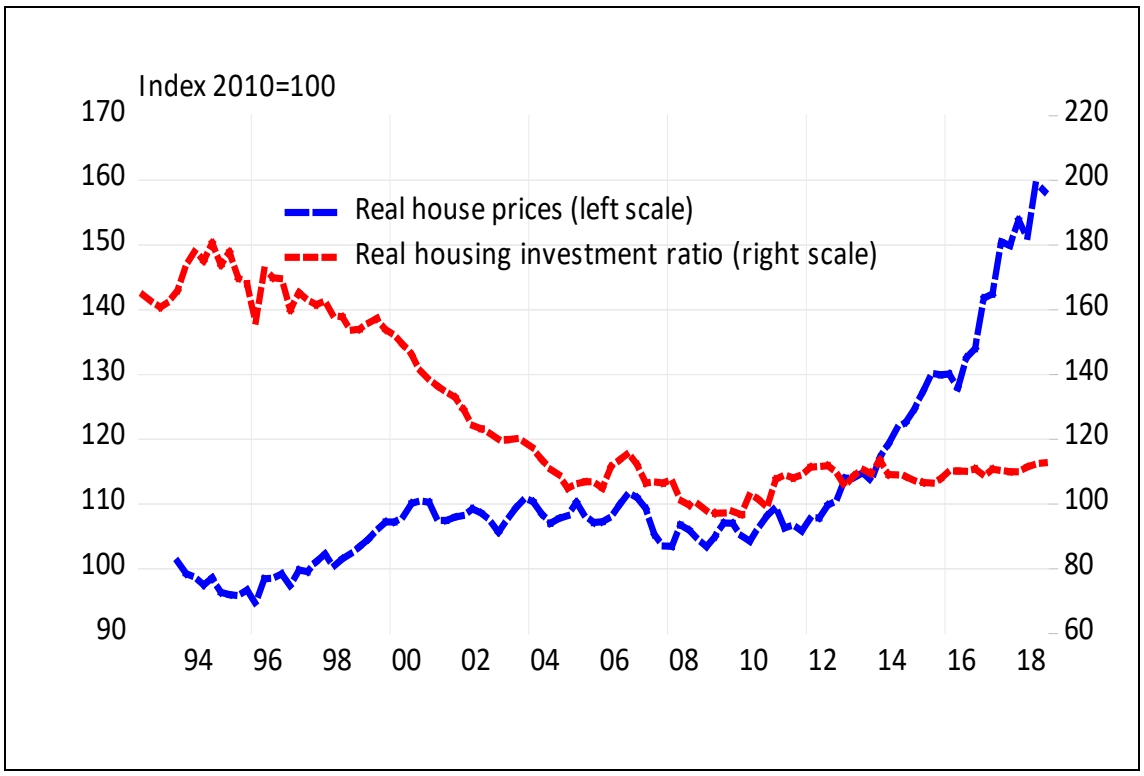
To prepare for estimation, we link the national house price index in 2003 Q4 to the quarterly price index for owner-occupied housing by the Association of German Pfandbriefbanks (vdp) in order to fully include genuine information at quarterly frequency from 2003 to 2018, and to include as much as possible of the current phase of strong house price growth. For the period before 2003 back to 1993, we use the national accounts based index, keeping in mind that the index is subject to higher uncertainty in the period 1993 to 1997, owing to possibly insufficient mix-adjustment in land prices.

Fig. 4 presents the real house price series along with real housing investment in relation to the real housing value, the main variables of interest in this paper. The housing investment ratio exhibits a pronounced decline after the mid-1990s, while fluctuating around the lower level since then.[7] Real house prices do not exhibit any pronounced boom-bust episodes until around the year 2012, after which they started to increase

[7] The number of building completions (also in relation to the number of households) shows a similar development, while real residential investment itself increased considerably during the recent housing boom mainly on account of investments for replacement and repairs,.

strongly. Since then, real house prices increased by around 30%, which is unprecedented in Germany since re-unification. The series for the remaining variables used in estimation are presented in the appendix.

Figure 4: Real house prices and real housing investment ratio in Germany



Notes: Own calculations for house price index before 2003, linked thereafter to price index for owner-occupied housing by Association of German Pfandbriefbanks; deflated using the private consumption deflator. Housing investment ratio calculated as ratio of real private residential investment to the real value of the gross private housing stock based on national accounts data.

4 Estimation results

The housing market model consists of three equations. The long-run house price Eq. (1) and the short-run price adjustment equation for house prices, Eq. (2), and Eq. (4) or Eq. (5) for residential investment.[8] The housing market model is estimated in this paper in the spirit of a traditional macroeconomic model. Potential reverse causality effects between house prices, residential investment and the explanatory factors are addressed in two ways. In a first variant, only lagged values of the right-hand side variables are included. This amounts to assuming a zero contemporaneous relationship between the

[8] In all cases, the empirical specifications contain lags of the dependent variable. Appendix 1 contains information about the data used for estimation including the deflators.

variables. In a second variant, we employ a two-stage least squares estimator instrumenting potentially endogenous right-hand side variables.

Table 1: Long-run relationship of house prices with macroeconomic determinants

	Specification:	
	I	II
Variable[1)]	(Semi-)Elasticities (in %)	
Income	0.5	0.5
	(0.2)	(0.2)
Income growth expectations	5.7	5.8
	(1.0)	(1.1)
Mortgage rate	-0.8	-0.8
	(0.4)	(0.4)
Construction productivity		0.0
		(0.1)
Year dummies	2015 to 2018	2015 to 2018
Sample:	1993Q4 2018Q4	

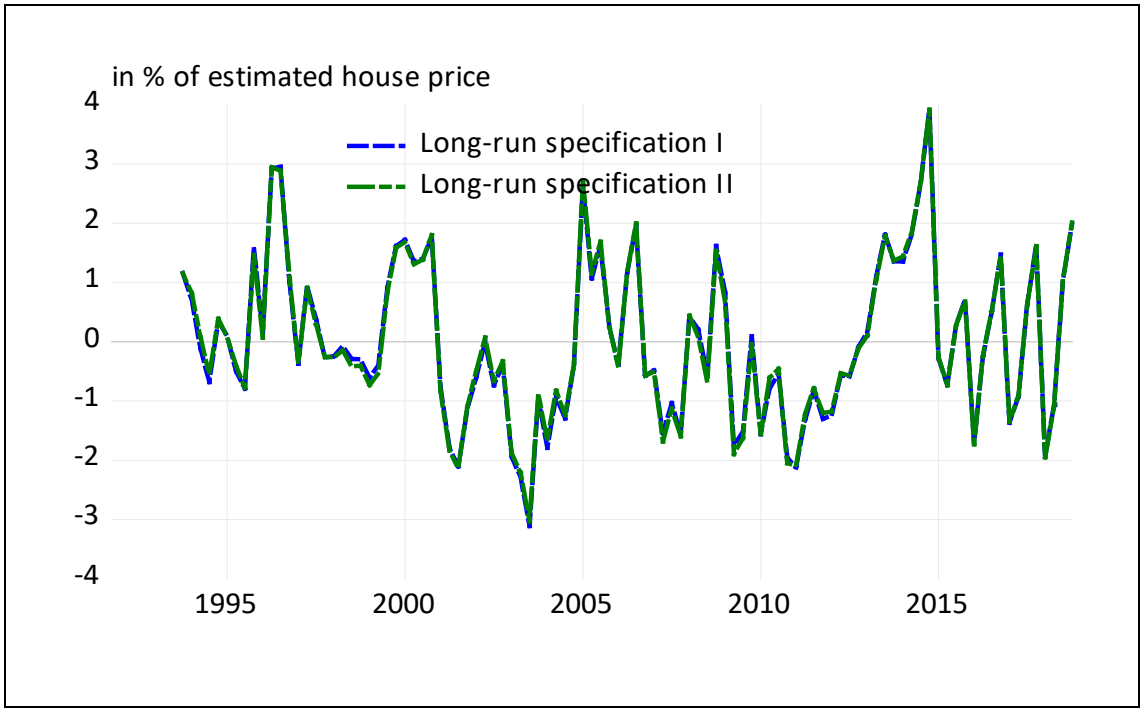
Notes: 1) ln logarithms, except income growth expectations and mortgage rate. Standard errors in parentheses.

According to the estimation results for the long-run relationship in Table 1, household disposable income, real income growth expectations and the inflation-adjusted mortgage rate clearly play a role, while real construction productivity is not economically relevant. Additionally, we included year dummies for the period 2015 to 2018 in the equation for overall house prices. The dummies take on the value one in the quarters of each year and zero in the remaining years. Preliminary estimates suggested a deterioration in the fit of both long-run equations after 2014. This could be due to at least two reasons. First, there are omitted variables in the long-run equation for which data are not available, such as long-run supply shifters of residential land.[9] Second, the fit of overall house prices might be poor if the individual elasticities of the construction prices and land prices, which constitute the components of the overall house price, with respect to explanatory factors differ. In Section 6 we present evidence that the elasticities indeed differ between the components of overall house prices and that modelling both components separately improves the fit of the long-run equations.

[9] In additional regressions, the long-run effect of mortgage credit supply on real house prices was checked. As an indicator of mortgage supply, the mortgage credit conditions index by Geiger, Muellbauer and Murphy (2016) was used. It exhibits a positive long-run relationship with real house prices suggesting that standards tended to get stricter in times of house price increases and vice versa. As this does not support the view of credit supply standards driving house prices, and its estimated impact is negligible, the mortgage credit conditions index was eventually not included in the long-run relationship.

For a comparison with the literature, a classic reference for the income elasticity is Meen (2001), who reports a mean value of 2.6 across estimates for the UK. More recent estimates of the income elasticity derived from a cross-country panel model for 20 OECD countries including Germany turn out to be a little lower of around 1.6 (Geng, 2018). Both studies, however, do not differentiate between current and expected future income as a variable. Note that a linear combination of the elasticities of both current and expected income in Table 1 might yield an overall income elasticity of similar magnitude. Cross-country panel estimates for the interest rate elasticity result in a value of around - 2.3, which is higher in absolute value than our estimate, but also reflects the effect across countries.

Figure 5: Error-correction terms from long-run house price equations



The error-correction terms relating to the specifications with and without construction productivity are virtually identical (Fig. 5), which suggests that construction productivity can be omitted from the long-run equation. According to Fig. 5 real house prices fluctuated more or less tightly around their long-run trend as specified in Table 1. The adjustment coefficient of house prices to the lagged error-correction term suggests that there is a tendency of house prices to revert to their equilibrium relationship (Table 2).

Table 2: OLS estimation results for short-run adjustment equations

	Dependent variable:	
	House price growth	Residential investment[2)]
Variable	Coefficients[1)]	
Error-correction term(-1)	-0.20 [0.02]	
Income growth	0.01 [0.31]	
Mortgage rate change	0.74 [0.05]	
Residential investment[2)]	0.0003 [0.00]	
Construction price growth		-0.63 [0.25]
House price growth		0.77 [0.01]
Construction productivity growth		-0.14 [0.20]
Adj. R^2	0.29	0.98
Durbin-Watson statistic	2.1	2.1
Sample period	1995Q3 2018Q4	1995Q3 2018Q4

Notes: Specifications include constant and lagged values of dependent variable (not reported). Specification of house price growth contains dummies for the first quarters of 2015 to 2018 in line with year dummies of long-run equation (not reported). 1) Sum of coefficient on current and lagged values of regressors. p-values in brackets next to coefficients refer to LR-test of joint significance of lagged values of regressors (in case of error-correction term, value refers to t-test). 2) ln logarithm.

Table 2 also reports the sums of coefficients on the short-term determinants of house price growth.[10] Residential investment, one of the measures for the expansion of housing supply, has a negligible impact.[11] Additionally, the change in available building land was included in a further specification because new housing construction tends to go hand in hand with an expansion of the supply of building land for residential purposes. However, the change in building land supply did not turn out to have a significant effect at any lag. Changes in the mortgage credit conditions index did not turn out significant, either.

Turning to the supply side, note that Eq. (4) as well as Eq. (5) can be obtained as restricted specifications of

$$i_t = \varphi_0 + \sum_{i=1}^{m+1} \varphi_i p_{t-m} + \sum_{j=1}^{n+1} \phi_j cc_{t-n} + \boldsymbol{\Gamma}'\Delta \boldsymbol{z} + \vartheta_t \qquad (11)$$

[10] The lag length for each variable was determined by successively eliminating insignificant lags, starting from a high lag number

[11] Note that in the estimation real residential investment is measured relative to the real value of the housing stock.

where house prices and construction prices are included in log-levels. We estimate Eq. (11) and test for the validity of the restrictions required to obtain Eq. (4) or Eq. (5). Table 3 reports the test results, which indicate whether the data support the Tobin's Q view (Eq. (4)) or the stock-flow view (Eq. (5)) of residential investment in Germany. The statistical test results favour neither Eq. (4) nor Eq. (5). However, the coefficient estimates on the Tobin's Q term in Eq. (4) sum to a negative value (- 0.08), while from an economic point of view the value should be positive. Therefore, the data do not appear to support an economically meaningful Tobin's Q relationship for German residential construction. In contrast, the sum of estimated coefficients on the lagged differences of real house price growth is positive, and the one of construction price growth negative, as expected.

Table 3: Tobin's Q vs. stock-flow view of residential investment

LR test results of restrictions on Eq. (11)			
Restriction	LR statistic	df	p-value
$\varphi_i=\phi_j$ (Eq. (4))	4.02	7	[0.78]
$\varphi_i=\varphi_{i-1}$ & $\phi_j=\phi_{j-1}$ (Eq. (5))	1.05	2	[0.59]

Estimates of Eq. (5) in Table 2 suggest that residential investment in Germany can be explained by the dynamics of house prices and by construction prices, whose effects go in the expected direction, while only the lags of house price growth are jointly statistically significant. The negative sign on real productivity growth in the construction sector reflects the protracted adjustment in the German construction sector during the period from the mid-1990s to the beginning of the 2000s. The German construction sector shrank against the background of overcapacities that had arisen in the re-unification construction boom. Real hourly productivity increased during the adjustment phase owing to the shrinking construction sector, while real residential investment decreased, too.

To evaluate potential reverse causality issues we also ran two-stage least squares instrumental variables estimations of the short-run specifications. As instruments, further lags of each right-hand variable were used. Some of the contemporaneous variables have a statistically significant effect, while the contemporaneous and lagged values of other variables become insignificant altogether. However, the instruments do not have sufficient predictive power for the endogenous variables as indicated by values of less than 10 of the F-statistic of the exclusion tests of the instruments in the first stage regression (Table 6 in the Appendix). In sum, these results caution against relying on the

instruments owing to a potential weak instruments problem, and we proceed using the specification subject to exclusion restrictions in Table 2.[12]

5 The German housing cycle through the lens of the model

5.1 Impulse responses

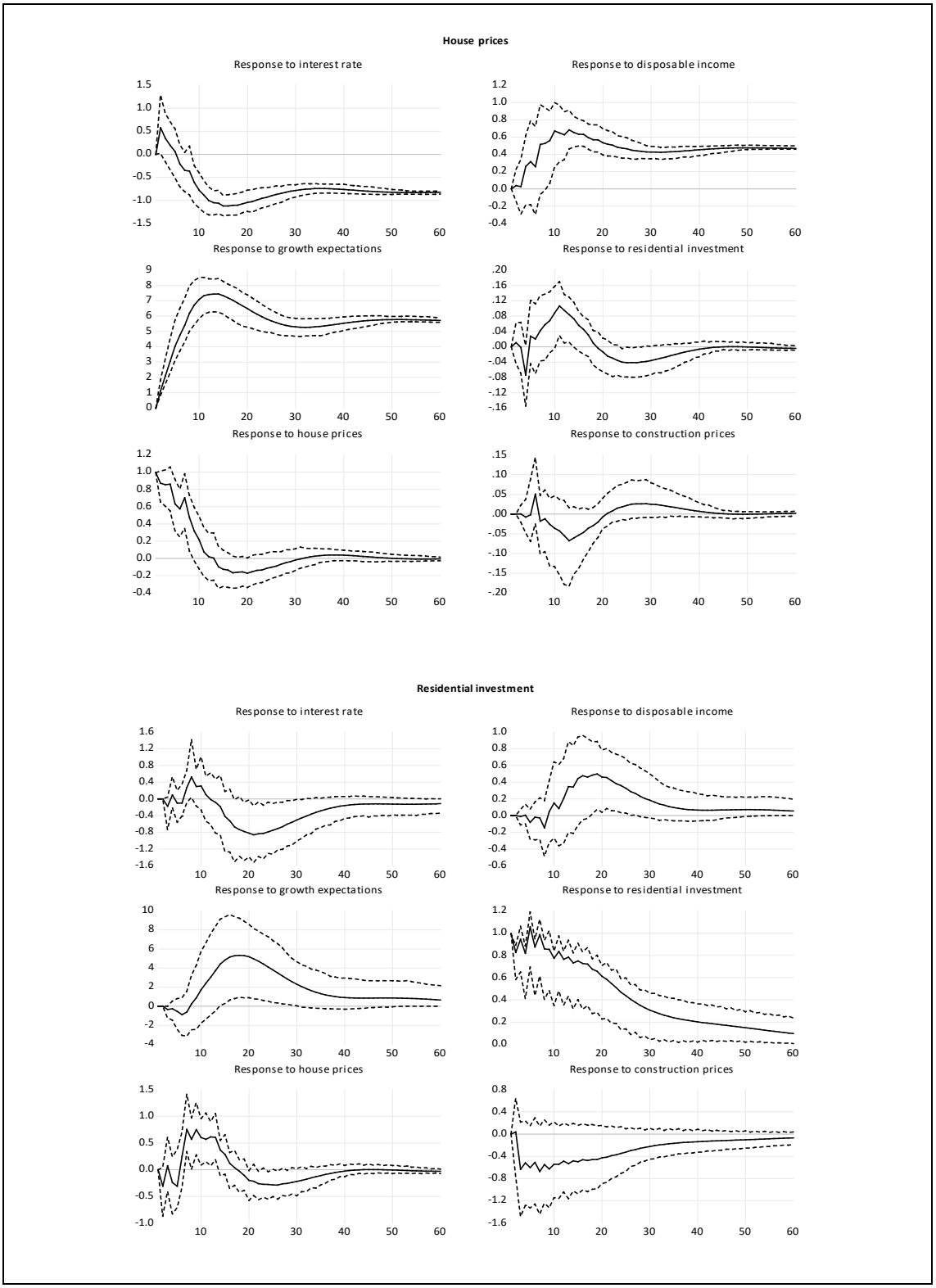
Fig. 6 presents the responses of house prices and residential construction to exogenous changes in income, income growth expectations, interest rates, and construction prices. In addition, it contains the reactions of both variables to price and quantity shocks. The shocks are the regression residuals or changes to the exogenous variables and refer to a one-off 1%-increase of the shock variable. House prices react significantly and persistently to interest rates, current income and income growth expectations, while shocks to residential investment or construction prices have only a temporary effect. In particular, the price growth dampening effect of an increase in residential investment reaches a maximum in absolute value of 0.04 percent after around seven years. This effect is statistically marginally significant and comes after a period of upward pressure on house price growth. On balance, the effect of residential investment on house price growth appears small. We explore the role of housing supply in more detail in Section 6.[13] The responses of house prices are in all cases fairly protracted. Residential investment reacts most strongly to expected income developments and to interest rate changes, while the effect of current income is smaller. Note that the responses of residential investment exhibit wider confidence intervals than in case of house prices.

Particularly interesting is the response of residential construction to house price shocks, which increases by around 0.6 % after two to three years. Estimates in the literature report values for the supply elasticity of 0.4 % to 1.5 % for Germany (Caldera and Johansson, 2013; Cournède, Ziemann and Cavalleri, 2019; Gattini and Ganoulis, 2012; Geng, 2018; Lerbs, 2014). Differences in the estimates are due to sample length (some of these are based on samples excluding the recent upswing in residential investment), model specification or the definition of housing supply. Compared to those cases where housing supply is defined in terms of real residential investment, as in this specification, our estimates fall into the range of previously reported values.

[12] As a cross check estimation was carried out using the national house price index up to 2017 linked to the vdp-index in 2017 Q4. The results remained virtually the same, while the precision of the estimates did not improve.

[13] The responses to construction productivity shocks are not presented as they mostly reflect the reduction of overcapacities in the construction sector in the mid-1990s, which is not representative looking ahead.

Figure 6: Impulse responses of house prices and residential investment (percentage deviations from baseline)

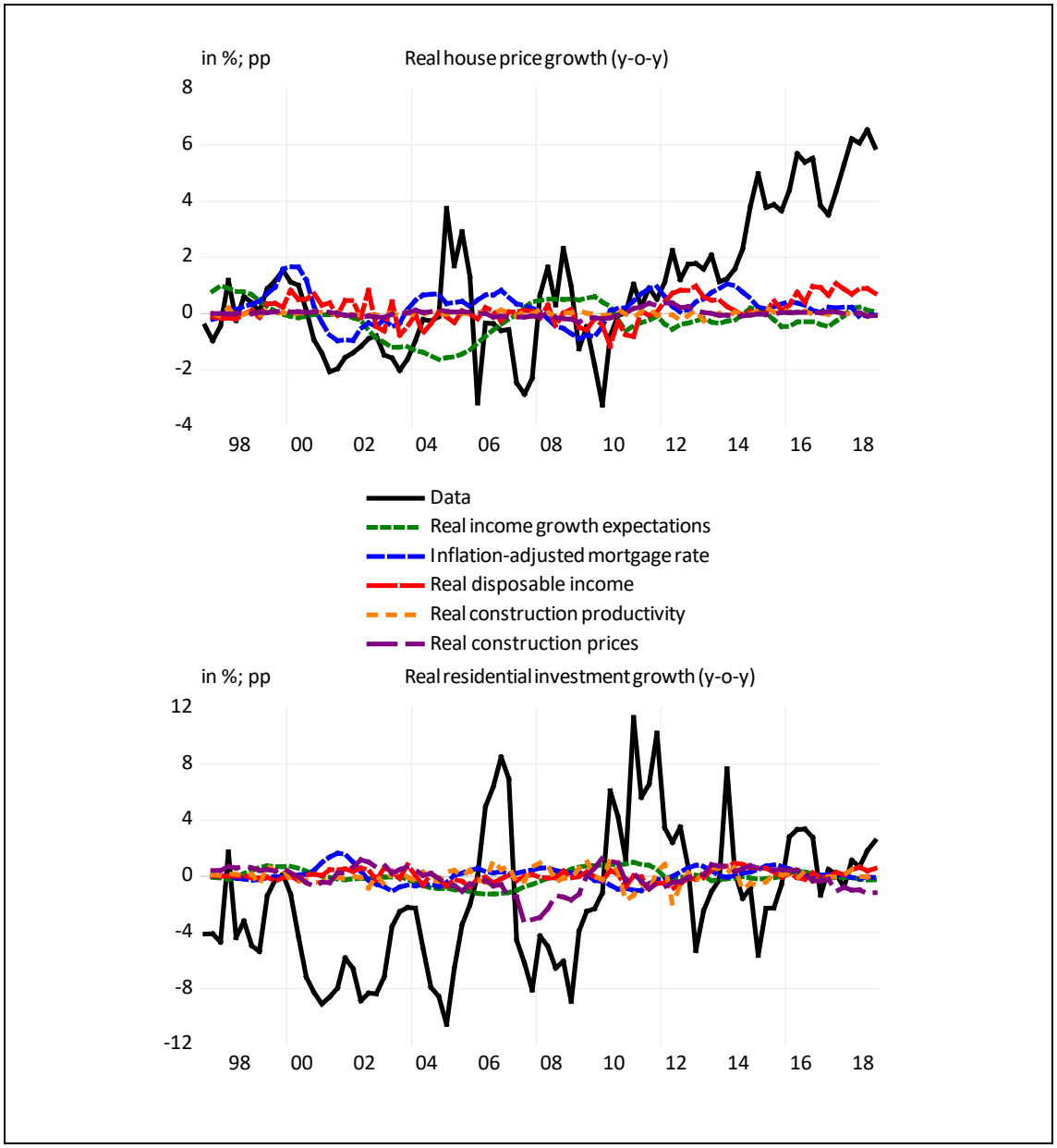


Notes: Solid lines: Impulse responses. Dashed lines: Bounds of 90%-confidence intervals.

5.2 Historical decomposition

Through the lens of the model, the recent house price boom was mainly the result of increasing income gains by private households and by the extraordinary decline of mortgage rates (Fig. 7). At the sample end a large part is explained by the year dummies or by other factors not included in the regression. The decline of long-term growth expectations, which held back house price growth in the past, gradually faded more recently. Real residential investment growth was mainly driven by the contribution of construction price growth, and more recently by disposable income gains.

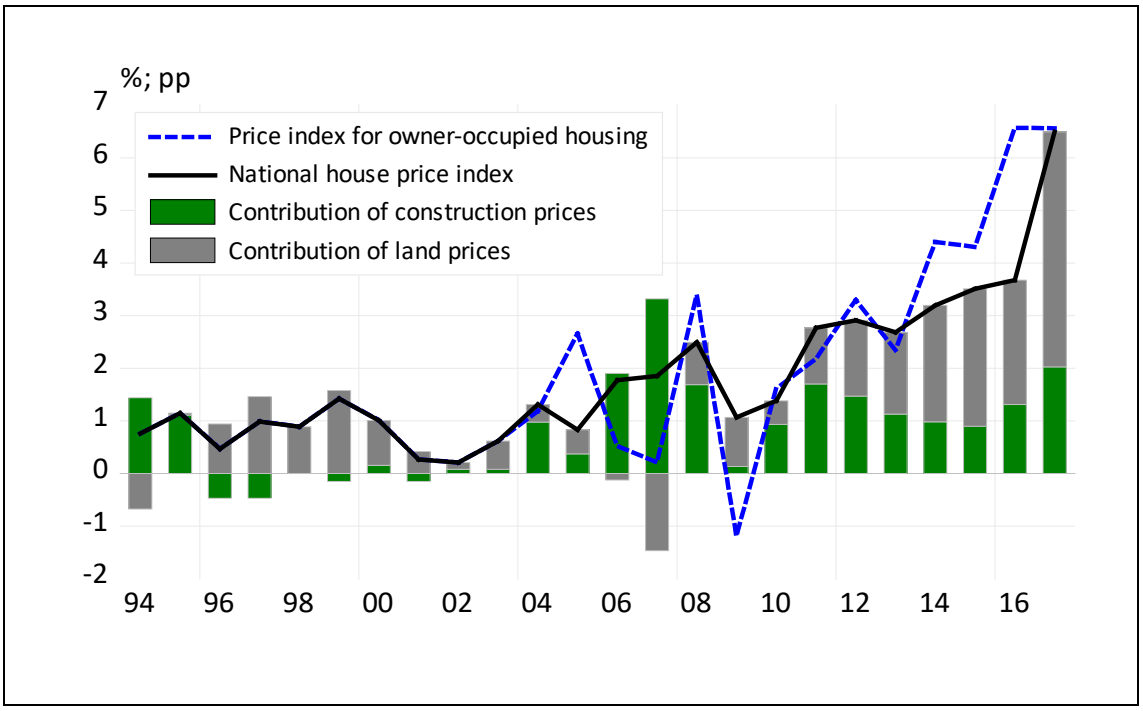
Figure 7: Contributions to house price and residential investment growth



6 Decomposition into land and structures prices

The decomposition of the value of the housing stock into a land and structures component in Section 3.1 implies that the estimated house price elasticities reflect a combination of the responses of the land price and the structures price component (Eq. (11)). Fig. 8 shows the contributions of construction and land price growth to overall house price growth. While in the years before the Great Recession, construction prices contributed most, land price growth was the main driver behind the recent strong house price increases.

Figure 8: Decomposition of house price growth



In order to take a closer look at the roles of construction and land prices, we estimate two additional systems of equations. They correspond to the estimation equations for overall house prices in the previous section, where house prices are replaced in each case with construction and land prices, respectively. This way, the responses of overall house prices to shocks can be traced to the responses of construction and land prices. Table 4 reports estimates of the relationship of construction and land prices, respectively, with the long-run macroeconomic determinants of overall house prices. The elasticities of land prices with respect to income and interest rates are larger than for construction prices.[14] In

[14] Hourly labour construction productivity did not turn out to be an economically or statistically relevant factor for construction prices.

contrast, income growth expectations have a larger coefficient in the equation for construction prices than in the one for land prices.

Table 4: Long-run relationship of construction and land prices with macroeconomic determinants

Estimation results for Eq. (1)		
	Price variable:	
	Construction prices	**Land prices**
Variable[1)]	(Semi-)Elasticities (in %)	
Income	0.6	3.8
	(0.2)	(0.5)
Income growth expectations	5.3	0.9
	(1.2)	(2.5)
Mortgage rate	-0.5	-3.1
	(0.4)	(0.6)
Sample:	1992Q4 2018Q4	1993Q4 2018Q4

Notes: 1) In logarithms, except income growth expectations and mortgage rate. Equation for construction prices contains a step dummy for the VAT increase from 2007Q1 on (not reported). Standard errors in parentheses.

In the short run, land prices respond to deviations from their idiosyncratic long-run trend in line with the error-correction mechanism as reflected by the negative adjustment coefficient (Table 5). Construction prices also respond to deviations from their long-run trend. Note that no dummies were used to obtain these results. In these specifications, the land supply growth effect turned out negative and highly significant for both construction and land price growth. This way, the price effects of a housing supply increase can be split-up into the effect of construction added and of additional building land.

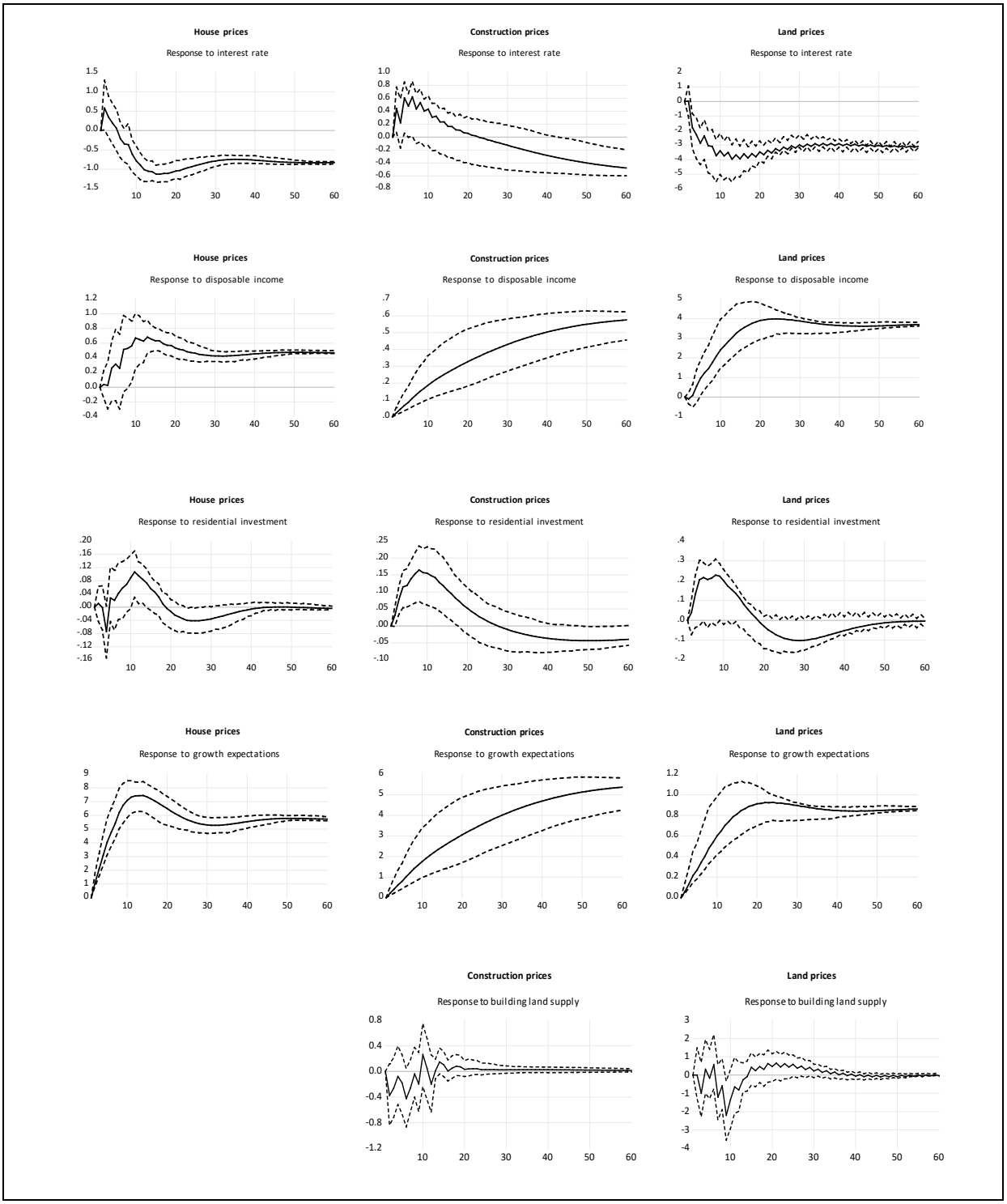
Table 5: Short-run adjustment of construction and land prices

Estimation results for house price components		
	Dependent variable:	
	Construction price growth	Land price growth
Variable	Coefficients[1)]	
Error-correction term(-1)	-0.04 [0.11]	-0.07 [0.10]
Income growth	--	-0.23 [0.28]
Mortgage rate change	0.67 [0.03]	-1.36 [0.03]
Residential investment[2)]	0.0003 [0.12]	0.0007 [0.21]
Construction productivity growth	0.05 [0.23]	--
Building land growth	-0.51 [0.00]	-1.71 [0.00]
Adj. R^2	0.38	0.33
Durbin-Watson statistic	1.9	2.0
Sample period	1995Q1 2018Q4	1995Q1 2018Q4

Notes: Specifications include constant and lagged values of dependent variable (not reported). Equation for construction price growth includes a dummy in 2007 Q1 for the VAT increase and for 2018 Q1 in line with year dummy in the long-run equation (not reported). (not reported). 1) Sum of coefficient on current and lagged values of regressors. p-values in brackets next to coefficients refer to LR-test of joint significance of lagged values of regressors (in case of error-correction term, value refers to t-test). 2) ln logarithm.

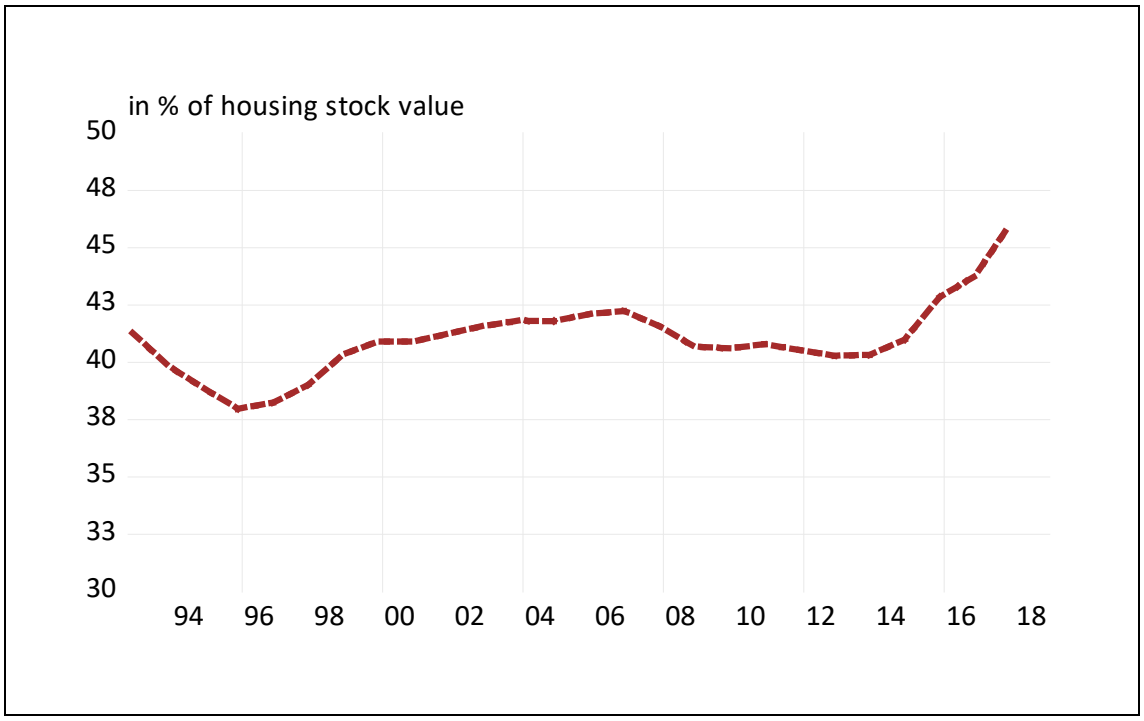
Fig. 9 shows a comparison of the impulse responses of overall house prices, construction and land prices. First, the negative interest rate response of house prices is more or less entirely due to the large negative reaction of land prices. This makes sense when viewing land as an asset whose price depends negatively on interest rates. In contrast, interest rates increases tend to increase construction price growth in the short run, which might reflect the role of interest rates as a cost component of construction firms. Second, the price effect of disposable income also works mainly via land prices, while it is smaller in the case of construction prices. Conversely, growth expectations have a large effect on construction prices, while their effect on land prices is much smaller. Third, while land prices do not respond significantly to residential investment, the reaction of construction prices is significantly positive reflecting the increase in building activity. It is plausible that, at times of rising construction capacity utilisation, costs and prices in the construction sector increase. Finally, additional building land supply dampens land price and therefore overall house price growth, all else equal. In sum, the construction price pressure due to residential investment works against the price dampening effect of additional building land, mitigating the overall price effect of additional housing supply.

Figure 9: Impulse responses of house, construction and land prices (percentage deviations from baseline)



Notes: Solid lines: Impulse responses. Dashed lines: Bounds of 90%-confidence intervals.

Figure 10: Land's share of housing value



Notes: Value of residential building land, calculated as described in Section 3.

Taken together with land's increasing share over the sample (Fig. 10), these results point to changing cyclical behaviour of overall house prices. Depending on the land share in housing value, house prices respond more to land-related factors or more to structures-related factors. Land's share reached a trough in the mid-1990s before trending upwards on balance, and reaching its highest value at the end of the dataset in 2017. This suggests that, on net over the sample period, the response of the land price to shocks has gained importance for the cyclical behaviour of overall house prices. In the first half of the sample, supply-side factors like interest costs for construction firms and the increasing construction activity were the main drivers of overall house price growth as they led to price increases for residential construction against the background of a below-average land's share of housing value.[15] More recently, at a higher share of land in housing value, disposable income and interest rates contributed most to house price growth via their effect on land prices.

7 Conclusions

A novel national house price index for the period starting in 1993 based on official statistical data allows estimating German housing market responses to shocks. Our results

[15] Additionally, subsidies to housing investment in East Germany in the period following reunification might have led to increasing mark-ups on construction costs.

suggest that, house prices in Germany react significantly to current and expected income and interest rate developments.

Estimates for the price elasticity of housing supply in Germany confirm values found in previous studies, which point to a moderate housing supply elasticity in international comparison. Conversely, the sensitivity of house prices with respect to an increase in housing supply, in terms of construction added and additional building land, is small. This is the result of the combination of a positive price effect of additional construction via construction prices and a price dampening effect of additional building land via the land price component in overall house prices.

The increasing trend in land's share in housing value suggests that the contributions of construction and land price growth to overall house price growth vary over time. While in the years before the Great Recession, construction prices contributed most, land price growth was the main driver behind the recent strong house price increases.

The results in this paper were derived within a standard framework allowing the model to be incorporated as a housing market module in larger macro-econometric models of the Germany economy. This would allow analysing feedback mechanisms between the German housing market and the wider economy, an issue for future research.

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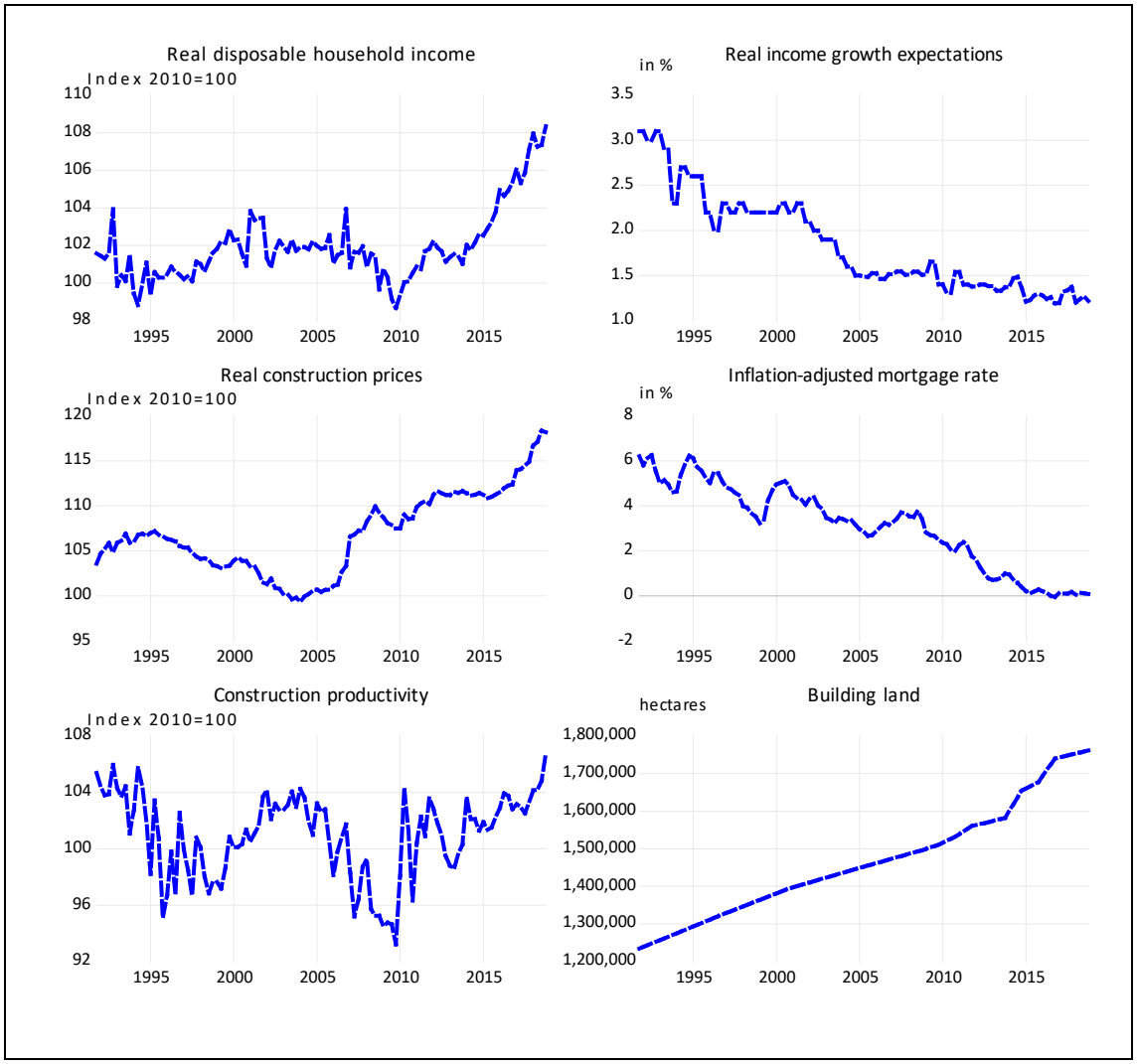
Appendix

1 Data

Figure 11: Variables used in the estimation



Notes: Real construction price data including value added tax increase in Q1 2007.

Fig. 11 shows the variables used in estimation. Residential property prices were inflation adjusted using the private consumption deflator. Residential investment in the estimations refers to real residential investment in relation to real gross fixed capital in residential buildings taken from national accounts. Disposable household income was taken from national accounts and price-adjusted also using the private consumption deflator and normalised by the number of private households. Income growth expectations are proxied by real GDP growth expectations, which were taken from Consensus Economics survey results. Mortgage rates are effective interest rates on new bank loans to households for house purchases adjusted for expected average annual inflation over the following ten

years provided by Consensus Economics. Construction prices are provided by the Federal Statistical Office and were set in relation to the GDP deflator. Construction productivity is measured by real gross value added in the construction sector divided by hours worked in construction. Data on building land (commercial and residential) are also provided by the Federal Statistical Office.

2 Additional results

Table 6: Short-run adjustment equations (2SLS estimates)

	Dependent variable:	
	House price growth	Residential investment[2)]
Variable	Coefficients[1)]	
Error-correction term(-1)	-0.2 [0.07]	
Income growth	-0.8 [0.44]	
Mortgage rate change	0.7 [0.26]	
Residential investment[2)]	0.0003 [0.30]	
Construction productivity growth		-5.2 [1.00]
Construction price growth		38.6 [1.00]
House price growth		-1.0 [1.00]
F-statistic in first stage regressions		
Income growth	1.1	
Mortgage rate change	2.5	
Residential investment[2)]	1.7	
Construction productivity growth		0.2
Construction price growth		0.2
House price growth		1.5
Sample period	1995Q3 2018Q4	1995Q4 2018Q4

Notes: Specifications include constant and lagged values of dependent variable (not reported). Specification of house price growth contains dummies for the first quarters of 2015 to 2018 in line with year dummies of long-run equation (not reported). Instruments: Lagged values of endogenous right-hand side variables. 1) Sum of coefficient on current and lagged values of regressors. p-values in brackets next to coefficients refer to LR-test of joint significance of current and lagged values of regressors (except for error-term, where p-value refers to t-test). 2) ln logarithm.