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# Determinants of residential property prices in Germany: Evidence from a structural approach

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## Abstract

We use a GMM approach to estimate the impact of standard macroeconomic variables on house prices in Germany. In order to avoid interpolation of house price data we use annual data and look separately at the demand and supply side. Our findings suggest that nominal and real house prices in Germany are reasonably well explained by disposable income, population growth, construction costs and to a lesser extent by nominal interest rates.

Keywords: Residential property prices, GMM, housing demand and supply

JEL classification: R21, R31, E21

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# 1 Introduction

While there has been a surge in papers analysing residential property prices over the last years, these studies naturally focus on developments in countries with large house price swings. In contrast relatively little attention has been paid to German house prices (exceptions are Belke, 2009; Demary, 2008). This has two reasons: First, until recently indicators for house prices in Germany were either of poor quality or contained only few observations. Of those indicators that attempt to control for quality changes in houses, the Bundesbank indicator<sup>1</sup> is available back to 1975 on an annual basis, while others<sup>2</sup> are of quarterly or even monthly frequency but go back to the year 2000 at most. Second, the movement in German house prices appears relatively unspectacular in an international comparison.

In time series analyses researchers have mostly dealt with the first problem by using the Bundesbank indicator interpolated to the desired frequency. While this might be acceptable in panel or cross-country regressions because it avoids throwing away information, it is less appropriate when focusing on the determinants of this variable in a single-country context. After all, three-quarters of the observations of the variable of interest would consist of fictitious data. Therefore we use annual data from 1975 to 2008 for German house prices and relate them to possible determinants.<sup>3</sup> To save on degrees of freedom we estimate demand and supply equations separately and back out the house price equation from the equilibrium condition. Moreover, to address potential simultaneity problems we apply a GMM estimation approach. The results from the GMM estimation are compared to simple OLS regression results.

Furthermore, we regard the rather moderate development of house prices

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<sup>1</sup>Calculated by the Deutsche Bundesbank based on data provided by BulwienGesa AG.

<sup>2</sup>These include indicators published by Hypoport AG and an experimental index compiled by the Federal Statistical Office (destatis).

<sup>3</sup>Due to limited regional coverage the indicators by destatis and Hypoport are less reliable. Moreover, they only go back to 2000 and 2005 respectively.

as rather favorable for an analysis of fundamental drivers. Precisely the absence of any obvious excess price changes allows to study the set and impact of fundamental determinants most clearly because their influence is unlikely to be blurred by non-fundamental factors.

The paper is structured as follows. In the following section we relate our paper to the existing literature, section 3 organises thoughts in a small theoretical framework from which the econometric model is derived, while section 4 discusses the data and some estimation issues. Section 5 presents the results and some discussion. Section 6 concludes.

## 2 Relation to the literature

Our paper is most closely related to a study by Case (1986), who looks at the prices for single-family homes in the Boston Area from 1976 to 1985 in a cross-section context. Demand and supply functions for houses are estimated using 2SLS and OLS and the results suggest that employment, income, interest rates, utility payments, taxes and construction costs explain a good fraction of house prices.

In addition there are papers that look at house prices and their determinants in a cross-country context. This review focusses on papers that include Germany in their analysis. Girouard et al. (2006) analyse fundamental determinants of house prices in a number of OECD countries by constructing various measures of the fundamental value such as the price-rent-ratio. Catte et al. (2004) examine the effect of house prices on wealth and consumption for a sample of OECD countries and estimate a range of consumption functions with housing and non-housing wealth as explanatory variables. Tsatsaronis and Zhu (2004) examine in a structural VAR framework determinants of house prices and find that inflation, real bank credit, real short- and long-term interest rates have a significant impact over time. In contrast real household income has little influence on house prices. In a paper by Egert

and Mihaljek (2007) house prices and their determinants in 19 OECD and eight central and eastern European countries are examined in a panel setting. They find evidence of a significant influence on house prices of per capita real GDP, a real interest rate, private sector loans, unemployment and population. Hilbers et al. (2008) discuss features of housing markets across Europe and estimate panel regressions on real house prices, user costs, demographics and real per capita income. They find significant effects of all three variables, which however differ in strength across different groups of countries. Hiebert and Vansteenkiste (2009) estimate a global VAR of real house prices, real per capita gdp and real long-term interest rates for ten euro area countries including Germany and examine the transmission of shocks to house prices in one country to the others as well as the effect of shocks to the interest rate. German house prices appear fairly sensitive to house price shocks in Spain and Ireland, whereas they hardly respond to interest rate shocks. Carstensen et al. (2009) estimate pooled VARs of real GDP, the GDP deflator, the nominal short-term rate and real house prices on 13 European countries as well as on subgroups to gauge the reaction of macroeconomic variables to a monetary policy shock. House prices are found to react differently across subgroups. Goodhart and Hofmann (2008) use a panel VAR model to assess the relationship between key economic variables including house prices for 17 industrialised countries including Germany. The variables of interest are real GDP, the consumer price index, the nominal short-term rate, nominal house prices, nominal broad money and nominal bank credit. Shocks to GDP, the CPI and the interest rate are found to have a significant impact on house prices across countries. In a paper on booms and busts in housing markets Agnello and Schuknecht (2009) analyse determinants of strong increases and sharp decreases in house prices for 18 countries including Germany. According to their definition of bust phases Germany experienced a drawn out bust from the early 2000s onwards. However, they note that this bust was very mild and prices otherwise quite stable.

There are two recent single-country studies of German house prices. Demary (2008) estimates VARs separately for ten industrialised countries including Germany. The estimation includes GDP, a price index, house prices, nominal and real interest rates. German house prices are found to react positively to shocks to GDP and inflation, while these two variables themselves respond positively to house price shocks. Finally, Belke (2009) looks at the relationship between real monetary aggregates, real credit, real GDP, long-term interest rates and property prices for Germany. In a VECM he finds that for some specifications house prices react to deviations from the long-run relationship between house prices and real money and real credit respectively.

### 3 Conceptual framework and econometric model

We start from a very simple model of supply and demand for housing (cf. Case, 1986). Housing demand  $X^D$  depends on house prices  $P$ , disposable income per capita  $Y$ , the population  $N$  and the mortgage interest rate  $I^{mtg}$ .

$$X^D = X^D \underset{-}{(P,} \underset{+}{Y,} \underset{+}{N,} \underset{-}{I^{mtg}}) \quad (1)$$

The signs below the variables denote our priors on the direction of the effect on the demand for housing. As the price of housing gets more expensive demand falls c.p. Higher mortgage rates have qualitatively the same effect. Conversely, as income per capita or the population increases demand for housing should c.p. increase.

Supply of housing  $X^S$  is likely to be determined by the price  $P$ , construction costs  $C$  and some short-term refinancing rate  $I^{ref}$  to the extent that construction works are financed by short-term credit.

$$X^S = X^S \underset{+}{(P,} \underset{-}{C,} \underset{-}{I^{ref}}) \quad (2)$$

At higher sales prices more houses will be offered, while higher costs of construction should reduce supply for a given price. The same should hold for the short-term refinancing costs.

Of course, residential property prices are influenced by a variety of factors, especially institutional settings such as taxes and subsidies. This is even more true for the period in the early 1990s after German reunification, when property investment was heavily subsidised especially in Eastern Germany. Apart from that owner-occupied housing has been subsidised in Western and reunified Germany to varying degrees, however with a severe cut-back in 2006.<sup>4</sup> We experimented with a range of measures for subsidies for owner-occupied housing. Their effects on housing demand and supply, though, depend very much on more or less arbitrary combinations of indicators, which led us to drop this aspect completely from the analysis and focus on the influence of macroeconomic fundamentals. After all, these effects are likely to dominate from 2006 when subsidies to owner-occupied housing were largely phased out. Since property tax rates grew at a constant rate over the sample we leave the constant to pick up their effect, whereas the effect of VAT is included in the measure of construction costs.

Our econometric specifications of the demand and supply function are

$$x_t^D = \alpha_0 + \alpha_1 p_t + \alpha_2 y_t + \alpha_3 n_t + \alpha_4 i_t^{mtg} + \alpha_5 q_t + \epsilon_t \quad (3)$$

$$x_t^S = \beta_0 + \beta_1 p_t + \beta_2 c_t + \beta_3 i_t^{ref} + \eta_t \quad (4)$$

where lower case letters denote natural logarithms of upper case letters.  $q_t$  is the log of the oil price, which is included in some of the specifications to capture the effect of expectations on housing demand and prices. This variable is meant as a proxy for commodity price indexes, which are commonly used to proxy for expectations about future economic activity.

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<sup>4</sup>For a detailed discussion of the various subsidies to owner-occupied housing in Germany see Bach and Bartholomai (1995).

The fitted demand and supply equations are combined via the equilibrium condition  $\hat{x}_t^D = \hat{x}_t^S$  to yield an expression for new and existing house prices respectively. This implies that we regard all observations of prices and quantities as equilibrium values. The correlations of prices for new and existing houses with the explanatory variables are given by expressions involving the estimated parameters. One advantage of this approach is that it reduces the number of coefficients to be estimated in each equation. Furthermore, it has a structural interpretation.

## 4 Data and methodological issues

Residential property prices as published by the Bundesbank are available for new homes,  $p_t^N$ , and resale homes,  $p_t^{RS}$ , so we carry out separate regressions for both types.<sup>5</sup> The series are based on data compiled by a private sector firm and are derived from expert judgements of the price for a typical object. As such there is only an informal and not controllable quality-adjustment. Also, the data are not purely transactions data. The demand for new houses as well as their supply is proxied by building permissions measured in  $m^3$ .<sup>6</sup> In addition, building permissions are taken as a measure for the demand for existing homes for lack of a better proxy. A priori the effect of prices for existing houses on building permissions could be positive if buyers switch from more expensive existing houses to newly built. On the other hand, to the extent that suppliers of new homes raise their price as well there might be a drop in the demand for building permissions. It turns out that the data support the latter case. Income per capita refers to the whole economy and captures spending power by private households as well as the overall business

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<sup>5</sup>Before 1990 the house price data do not distinguish between new and existing dwelling. Therefore the same series for both types are used.

<sup>6</sup>Completions might be used alternatively to account for not completed starts. However, the correlation between permissions and completions is quite high (0.87) and permissions are an earlier measure of demand and supply. More technically, completions are only available as pure numbers whereas permissions are available as a volume measure.



cycle stance. Mortgage rates are interest rates on loans to private households for house purchases. Refinancing rates are interest rates on loans to non-financial firms. Construction costs refer to residential properties including VAT. Since house prices are available on an annual basis we use annual averages of the remaining variables from 1975 to 2008. As stated in the beginning this is to avoid interpolating the house price series, which are the focus of the analysis. More details on some of the data can be found in the appendix.

As it is likely that prices and quantities are simultaneously determined a GMM approach is applied. As instruments we use lags of explanatory variables, the order of which is determined by their correlation with the endogenous right-hand side variable of interest.

A second issue to decide is whether to specify demand and supply equations in nominal terms of prices, income, interest rates and costs or to deflate nominal variables. We carry out all analyses for both cases on the grounds that a real specification is theoretically more appealing, while a nominal specification might be of interest for short term forecasting purposes. In the real specification, however, we use nominal interest rates for two reasons. First, with sticky prices nominal rates are expected to have an impact on real variables and second, inflation expectations are not available over the chosen sample period. This would require an approximate solution to generating ex-ante real rates e.g. by using the core inflation rate, which is likely to introduce more noise into the estimation. To deflate nominal house prices we use the consumer price index (CPI) less owner-occupied housing in order to get a relative price.<sup>7</sup> Income per capita and construction costs were deflated using the headline CPI.

Even though we are dealing with a very limited number of observations such that unit root tests might have low power, preliminary unit root tests

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<sup>7</sup>The German CPI uses the rental equivalence approach to account for owner-occupied housing.

were carried out. Table 1 presents the results of standard ADF-tests on the log-levels and first differences of nominal variables, while table 2 contains the results for real variables ( $rx$  denotes a deflated nominal variable  $x$ ).

Nominal variables	$p_t^N$	$p_t^{RS}$	$y_t$	$i_t^{mtg}$	$i_t^{ref}$	$c_t$	$q_t$
Sample	1975 to 2008						
	<i>Levels</i>						
Lag length	1	1	0	1	1	1	0
Constant	yes	yes	yes	yes	yes	yes	no
Trend	yes	no	yes	yes	no	yes	no
ADF test statistic	-3.97**	-3.03**	-3.12	-3.05	-4.33***	-3.18*	0.69
	<i>First differences</i>						
Lag length	-	-	0	0	-	-	0
Constant	-	-	yes	no	-	-	no
Trend	-	-	yes	no	-	-	no
ADF test statistic	-	-	-5.07***	-4.11***	-	-	-4.73***

Table 1: ADF-test results for the null of a unit root. Note: p-values in parentheses. \* / \*\* / \*\*\* denote significance on the 10 / 5 / 1%-level according to MacKinnon's (1996) critical values. A constant and /or trend was included on the basis of individual significance in the ADF-regressions.

As building permissions, the real price of existing houses, disposable income, mortgage rates, real costs and the oil price seem to be integrated of order 1, whereas the remaining variables to be stationary a model in first differences of all variables was chosen. With a p-value of 0.12 the first differences of population can be regarded as marginally stationary.

## 5 Estimation results

### 5.1 Demand and supply regressions

As a preliminary estimation we run regressions of building permissions on the full set of pre-selected variables for the demand and supply of houses separately. Table 3 presents the results for new and existing house prices

Real variables	$x_t^{D/S}$	$rp_t^N$	$rp_t^{RS}$	$ry_t$	$rc_t$	$n_t$	$rq_t$
Sample	1975 to 2008						
	Levels						
Lag length	0	1	1	2	3	1	0
Constant	no	yes	yes	yes	yes	yes	no
Trend	no	yes	yes	yes	no	yes	no
ADF test statistic	-1.21	-3.89**	-2.29	-2.28	-2.14	-2.69	0.19
	First differences						
Lag length	0	-	0	0	0	0	0
Constant	no	-	no	yes	no	no	no
Trend	no	-	no	no	no	no	no
ADF test statistic	-4.63***	-	-2.57**	-3.95***	-2.82***	-1.52	-4.86***

Table 2: ADF-test results for the null of a unit root. Note: p-values in parentheses. \* / \*\* / \*\*\* denote significance on the 10 / 5 / 1%-level according to MacKinnon's (1996) critical values. A constant and /or trend was included on the basis of individual significance in the ADF-regressions.

with prices, income, construction costs and interest rates in nominal terms. The upper panel of table 3 contains the coefficient estimates for the demand and supply equations, separately using the prices for new and existing homes as one of the explanatory variables. The lower panel presents the statistics for an F-test of joint significance of the instruments in the first stage regressions for the endogenous right hand variables along with the p-values for the overidentifying restrictions test.

In the demand equations for new houses the price and income variables don't come out significant and neither does the oil price. For existing houses all variables have the expected signs and some explanatory power. The p-values for joint significance of the instruments as well as the overidentifying restrictions test are satisfactory. In the supply equations none of the pre-selected variables are significant, while the diagnostics of the first stage regressions and the overidentifying restrictions tests are acceptable.

In the real specification, the real price and real income don't carry the

Dependent variable	log-change in building permissions			
	<i>Demand equation (3)</i>		<i>Supply equation (4)</i>	
	<i>Price variable</i>			
	$\Delta p_t^N$	$\Delta p_t^{RS}$	$\Delta p_t^N$	$\Delta p_t^{RS}$
	<i>Coefficients</i>			
constant	-0.13***	-0.20***	-0.07***	-0.05
$\Delta p_t$	0.56	-1.77*	-0.26	0.27
$\Delta y_t$	1.29	3.68***		
$\Delta i_t^{mtg}$	-0.77*	-0.37*		
$\Delta n_t$	16.32***	19.76***		
$\Delta q_t$	0.07	0.01***		
$\Delta c_t$			1.02	0.65
$\Delta i_t^{ref}$			-0.21	-0.11
	<i>Instruments</i>			
	3 lags of each variable	3 lags of each variable	3 lags of each variable	2 lags of each variable
	<i>p-values F-test</i>			
$\Delta p_t$	0.000	0.000	0.000	0.000
$\Delta y_t$	0.029	0.033		
$\Delta i_t^{mtg}$	0.009	0.020		
$\Delta n_t$	0.000	0.000		
$\Delta i_t^{ref}$			0.002	0.009
$\Delta c_t$			0.000	0.000
	<i>p-value J-statistic</i>			
	0.77	0.95	0.86	0.99

Table 3: Preliminary estimates of the demand and supply equation with nominal prices, income, construction costs and interest rates. Note: \* / \*\* / \*\*\* denote significance on the 10 / 5 / 1%-level.

Dependent variable	log-change of building permissions			
	<i>Demand equation (3)</i>		<i>Supply equation (4)</i>	
	<i>Price variable</i>			
	$\Delta rp_t^N$	$\Delta rp_t^{RS}$	$\Delta rp_t^N$	$\Delta rp_t^{RS}$
	<i>Coefficients</i>			
constant	0.19*	-0.02	0.03*	-0.01
$\Delta rp_t$	11.31**	2.85**	6.73****	3.53***
$\Delta ry_t$	-7.79**	-1.58**		
$\Delta i_t^{mtg}$	-2.53**	-0.78****		
$\Delta n_t$	-11.03	2.60		
$\Delta rq_t$	0.02	0.02		
$\Delta rc_t$			0.13	-1.72***
$\Delta i_t^{ref}$			-0.79***	-0.40***
	<i>Instruments</i>			
	3 lags of each variable	3 lags of each variable	3 lags of each variable	3 lags of each variable
	<i>p-values F-test</i>			
$\Delta rp_t$	0.017	0.027	0.008	0.024
$\Delta ry_t$	0.005	0.009		
$\Delta i_t^{mtg}$	0.000	0.067		
$\Delta n_t$	0.000	0.000		
$\Delta i_t^{ref}$			0.007	0.009
$\Delta rc_t$			0.003	0.003
	<i>p-value J-statistic</i>			
	0.94	0.87	0.92	0.93

Table 4: Preliminary estimates of the demand and supply equation in real terms, except interest rates. Note: \* /\*\* /\*\*\* denote significance on the 10 /5 /1%-level.

expected signs. If the oil price controls for expectations it would be hard to argue that the demand for houses increases with their price.<sup>8</sup> Mortgage rates are significant with the right sign, while population growth is not significant. Again, the test statistics on the instruments appear reasonable. The choice of including nominal interest rates in the real specification was made on the grounds that a suitable measure of expected inflation is missing over the relevant period and that under price stickiness nominal interest rates should have an effect on real variables.

<sup>8</sup>We also tried including the nominal oil price as control variable, which didn't change the results.

To further investigate the determinants of demand and supply for housing we ran a number of alternative specifications. The inclusion of individual explanatory variables and the choice of the lag length for the instruments was based on significance levels of individual coefficients as well as the F-test results for joint significance of the instruments. E.g. we started by dropping insignificant variables from the estimations. However, since house prices are the focus of our analysis we keep them during the specification search regardless of their individual significance. Following the rule of dropping individually insignificant variables often resulted in implausible specifications (i.e. the coefficients carried the wrong signs). Also the significance of individual coefficients seemed to depend on the inclusion of other variables. As such there is some degree of arbitrariness as to which variables should be included in the regressions. These observations led us to rely on judgement in deciding on the appropriate specification, which is guided by our small theoretical model. However, the diagnostic test statistics as well as the comparison with simple OLS estimates lend some support to our choices. Tables 5 and 6 present the results of our preferred specifications. Note that the equation for the demand for existing houses is identical to our preliminary specification. The demand for housing depends negatively on new and existing house prices, positively on disposable income and population growth. The oil price and nominal mortgage rates have a significant effect only when existing house prices are used. Housing supply depends positively on the prices for new and existing homes and negatively on construction costs. Note that these specifications omit any influence via short-term interest rates. Including interest rates on loans to firms often led to insignificant or implausibly signed coefficients. Running the regressions in real terms (except interest rates) delivered qualitatively the same results. In addition, however, the nominal interest rate on loans to firms impacts negatively on the supply of housing, while the nominal mortgage rate has no significant effect on the demand for housing anymore.

Dependent variable	log-change in building permissions			
	<i>Demand equation (3)</i>		<i>Supply equation (4)</i>	
	<i>Price variable</i>			
	$\Delta p_t^N$	$\Delta p_t^{RS}$	$\Delta p_t^N$	$\Delta p_t^{RS}$
	<i>Coefficients</i>			
constant	-0.12***	-0.20***		
$\Delta p_t$	-1.72***	-1.77*	3.71*	3.44**
$\Delta y_t$	2.31**	3.68***		
$\Delta n_t$	15.81***	19.76***		
$\Delta q_t$		0.10***		
$\Delta i_t^{mtg}$		-0.37*		
$\Delta c_t$			-3.01*	-3.14*
	<i>Instruments</i>			
	3 lags of each variable	3 lags of each variable	2 lags of each variable	2 lags of each variable
	<i>p-values F-test</i>			
$\Delta p_t$	0.000	0.000	0.000	0.000
$\Delta y_t$	0.026	0.033		
$\Delta n_t$	0.000	0.000		
$\Delta i_t^{mtg}$		0.020		
$\Delta c_t$			0.000	0.000
	<i>p-value J-statistic</i>			
	0.85	0.95	0.74	0.94

Table 5: Preferred specification of the demand and supply equation including nominal disposable income and the nominal oil price. Note: \* /\*\* /\*\*\* denote significance on the 10 /5 /1%-level.

## 5.2 The implicit house price equation

In this section we present evidence on the determinants of house prices derived from the estimated demand and supply equations in the previous section. Setting the fitted demand and supply equations,  $\hat{x}_t^D$  and  $\hat{x}_t^S$ , equal results in the "fitted" equations for new and existing house prices in table 7. The second and fourth columns report the implicit coefficients from the structural GMM estimation for the prices of new and existing houses, respectively. The third and fifth column contain the coefficients that result from a simple OLS regression of both types of house prices on the same determinants.

Dependent variable	log-change in building permissions			
	<i>Demand equation (3)</i>		<i>Supply equation (4)</i>	
	<i>Price variable</i>			
	$\Delta rp_t^N$	$\Delta rp_t^{RS}$	$\Delta rp_t^N$	$\Delta rp_t^{RS}$
	<i>Coefficients</i>			
constant	-0.09***	-0.10***		
$\Delta rp_t$	-1.77***	-2.04***	5.73***	3.88***
$\Delta ry_t$	1.83***	3.22***		
$\Delta n_t$	15.31***	16.40***		
$\Delta rc_t$			-3.33*	-1.57**
$\Delta i_t^{ref}$			-0.37*	-0.43***
	<i>Instruments</i>			
	3 lags of each variable	3 lags of each variable	2 lags of each variable	3 lags of each variable
	<i>p-values F-test</i>			
$\Delta rp_t$	0.009	0.006	0.016	0.024
$\Delta ry_t$	0.017	0.026		
$\Delta n_t$	0.000	0.000		
$\Delta i_t^{ref}$			0.020	0.009
$\Delta rc_t$			0.000	0.003
	<i>p-value J-statistic</i>			
	0.66	0.43	0.81	0.82

Table 6: Preferred specification of the demand and supply equation in real terms, except interest rates. Note: \* /\*\* /\*\*\* denote significance on the 10 /5 /1%-level. As an additional instrument in the equation for the demand for existing houses the 10-year German government bond yield was included.

Dependent variable	log-change in nominal prices of			
	new houses		existing houses	
	<i>Coefficients</i>			
	GMM	OLS	GMM	OLS
Constant	-0.02	-0.02**	-0.04	-0.03***
$\Delta y_t$	0.42	0.30*	0.71	0.42***
$\Delta n_t$	2.91	1.04	3.80	2.11**
$\Delta c_t$	0.66	0.71***	0.60	0.77***
$\Delta q_t$			0.02	0.02
$\Delta i_t^{mtg}$			-0.07	-0.04
quasi-adjR <sup>2</sup>	0.94		0.98	
adjR <sup>2</sup>		0.66		0.78

Table 7: Implicitly and directly estimated coefficients in the house price equation. Note: \* /\*\* /\*\*\* denote significance on the 10 /5 /1%-level. OLS estimates are heteroskedasticity and autocorrelation consistent.



Note that the (implicit) GMM estimates are of similar order of magnitude as the OLS estimates, while the individual figures often do differ quite a bit. E.g. OLS estimates the impact of disposable income on existing house price growth as roughly half the one derived from the GMM estimation. The same holds for the effect of population growth. The signs of the estimated coefficients match the implicit ones throughout. Moreover the effects are of roughly the same order of magnitude for new and existing homes. Quantitatively, population growth has the biggest impact on nominal house price changes. Construction costs have a slightly larger impact on new house prices than disposable income. This comparison is less clear for existing house prices. Including interest rates and the oil price in the OLS estimation virtually didn't change the results with interest rates and the oil price being insignificant. For the implied coefficients we calculated a quasi-adjusted  $R^2$ , which measures how much of the deviation from the implicitly derived constant can be explained by the explanatory variables. This is in contrast to the standard adjusted  $R^2$ , which measures how much of the deviation from the mean can be explained. Since the indirectly estimated constants are based on the structural demand and supply equations, they don't necessarily correspond to the sample mean of house prices. The implicitly derived coefficients seem to increase the explanatory power relative to the directly estimated ones, since the quasi-adjusted  $R^2$  for the GMM estimation are higher than the ones for the OLS regression.

Analogously the results using real variables (except interest rates) are displayed in table 8.

Dependent variable	log-change in real prices of			
	new houses		existing houses	
	<i>Coefficients</i>			
	GMM	OLS	GMM	OLS
Constant	-0.01	-0.01***	-0.02	-0.02***
$\Delta r y_t$	0.24	0.26**	0.54	0.24*
$\Delta n_t$	2.04	1.15	2.77	2.00**
$\Delta i_t^{ref}$	0.05	0.03**	0.07	0.01
$\Delta r c_t$	0.44	0.49*	0.26	0.68**
quasi-adjR <sup>2</sup>	0.39		0.42	
adjR <sup>2</sup>		0.49		0.58

Table 8: Implicitly and directly estimated coefficients in the house price equation. Note: \* /\*\* /\*\*\* denote significance on the 10 /5 /1%-level. OLS estimates are heteroskedasticity and autocorrelation consistent.

Again the order of magnitude of the implicitly and directly estimated coefficients is apparently similar and the signs of the coefficient pairs match well. Population growth is the main driver of real house prices, too, while real construction costs have a larger effect on new house prices than real disposable income. For existing home prices this balance is less clear again. In contrast to the nominal specification, interest rates on loans to firms have a small impact on real new house prices. This time the goodness-of-fit of the OLS estimation is higher. Again, including the mortgage rate and the real oil price doesn't qualitatively change the OLS results, however, making the estimates somewhat less precise.

Comparing the implicit GMM estimates with the OLS estimates there are differences with respect to the size of the coefficients as well as their significance. As it cannot be ruled out that the OLS estimates are biased and inconsistent due to a potential simultaneity bias we conclude that our structural approach yields more reliable insights than a simple OLS regression. Consider population growth which the OLS approach would not have identified as a significant driver of new house prices. Moreover, the size of its effect is about two to three times larger in the structural approach.

Figures (1) to (4) in the appendix show the actual and fitted changes

in nominal and real house prices along with the  $\pm 2$  standard deviations. While the estimated house prices track actuals quite well, the estimation uncertainty remains in all cases quite high. As such actual house price changes barely deviate significantly on the upside from the estimated ones. This is in line with conventional wisdom that house prices in Germany have not shown any major risk of over- or undervaluation.

## 6 Conclusion

A simple model of demand for and supply of housing yields estimates of the determinants of house prices in Germany. They are to a large extent driven by population growth, followed by construction costs and disposable income. Comparing the results to simple OLS regressions some coefficients don't come out significant in the OLS estimation and there are sometimes quite large differences in the size of the coefficient estimates. We interpret this as support for using GMM to account for a potential simultaneity problem. This arises mostly because the longest series for German house prices is only available on an annual basis. Over time it is likely that indicators with a higher frequency will be published such that other time-series techniques might be preferred. So far however, this has not been the case.

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## **7 Appendix**

### **7.A Data**

House price data for West Germany run from 1975 to 2008, and for Eastern Germany from 1995 onwards. The long series used in this paper are constructed by chain-linking West German and German data in the year 1995. West German data up to 1990 doesn't distinguish between new and existing buildings (with the vast majority of observations referring to new buildings) such that the house prices series is the same for both types of buildings before 1990 and split up into new and existing dwellings from thereon (Hoffmann and Lorenz, 2006). We use data for the remaining variables for West Germany up to 1995 and for Germany from 1995 to 2008. Disposable income for the total economy of West Germany is only available until 1991, which is why we use data for Germany from 1992 onwards and for West Germany before that. The constant maturity 10-year German government bond yield is the yearly average of month-end interest rates.

### **7.B Figures**



Figure 1: New houses: actual vs. fitted nominal house price changes (implicitly estimated coefficients).

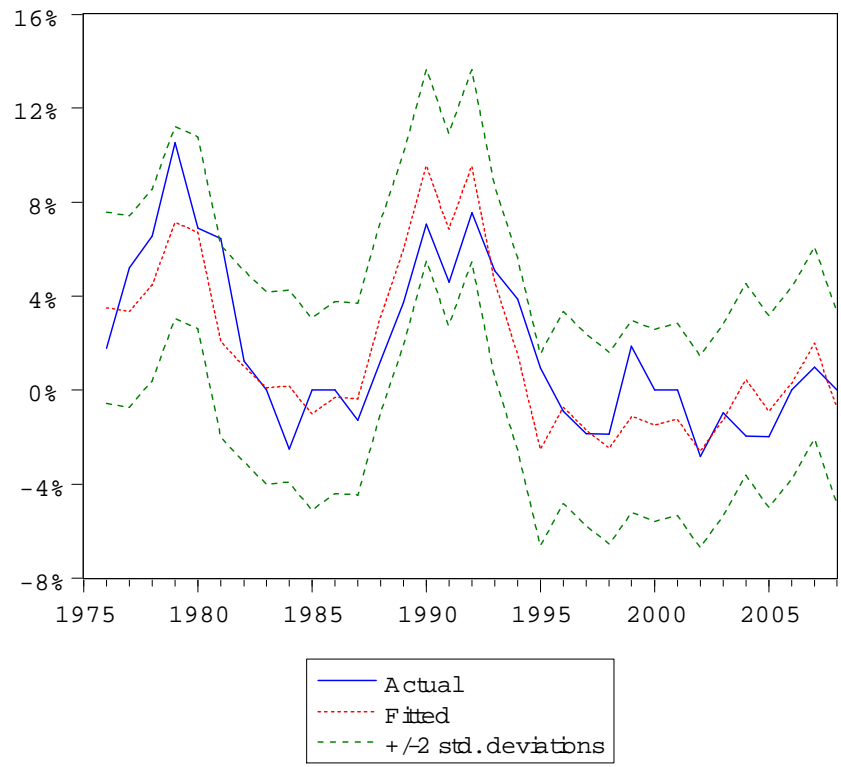


Figure 2: Existing houses: actual vs. fitted nominal house price changes (implicitly estimated coefficients).



Figure 3: New houses: actual vs. fitted real house price changes (implicitly estimated coefficients).



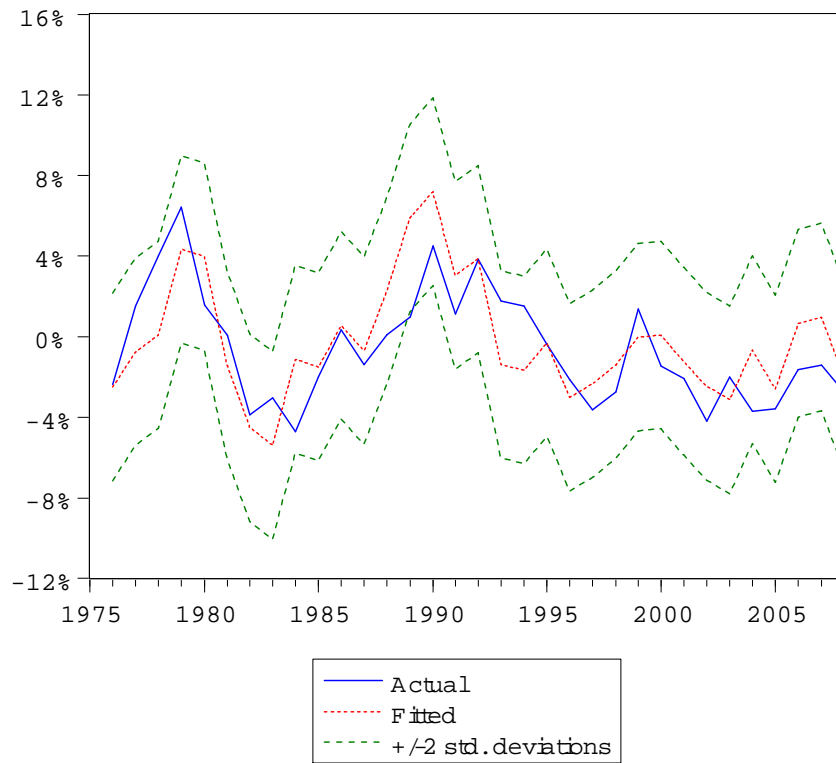


Figure 4: Existing houses: actual vs. fitted real house price changes (implicitly estimated coefficients).