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Fundamental determinants of real estate prices: A panel study of German regions

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Ansgar Belke and Jonas Keil[1]

Fundamental Determinants of Real Estate Prices: A Panel Study of German Regions

Abstract

This paper aims at establishing empirical facts on the fundamental determinants of real estate prices. It contributes to the literature by analysing a unique panel dataset covering a wide range of real estate market data and other economic variables for nearly 100 German cities. Several robust fundamental determinants are identified, among them the supply-side factors construction activity and housing stock as well as the demand-side factors apartment rents, market size, age structure, local infrastructure and rental prices. Results suggest that these factors are robustly linked to fundamental real estate prices and thus can be used to detect misalignments of market prices.

JEL Classification: R21, R31

Keywords: Real estate market; fundamental prices; regional data; panel study

December 2017

1 Ansgar Belke, UDE and IZA Bonn; Jonas Keil, UDE and DIE, Bonn. – *We are grateful to BulwienGesa AG for providing the real estate data analysed in this paper. Seminar participants at the Helmut-Schmidt-University, Hamburg, and the European Commission, Brussels, provided helpful comments.* –*All correspondence to: Ansgar Belke, University of Duisburg-Essen, Department of Economics, Chair for Macroeconomics, Universitätsstr. 12, 45117 Essen, Germany, e-mail: ansgar.belke@uni-due.de*

1. Introduction

In recent times, much discussion in economic research and economic policy has revolved around the question of the role of asset prices for macroeconomic policy. A particular asset class that has received a lot of attention is real estate. The market for real estate is widely regarded as being a very important market and especially real estate price developments have come under scrutiny. Up until the recent bust period with significant price corrections in a number of countries such as the USA or Spain beginning in 2008, many real estate markets around the globe have experienced considerable price increases since the late 1990s. Such periods of extended price increases can have numerous consequences. First, due to the wealth effect of rising house prices, private households have an increasing ability to borrow against their real estate as collateral (Sutton 2002). This effect is even stronger when credit markets are imperfect, as exemplified in the financial accelerator model by Bernanke et al. (2000). Such asset price increases that translate into increased borrowing and increased demand are a risk for price stability and thus pose a considerable problem for monetary policy (Bernanke and Gertler 2001). On the supply side, extended price increases can lead to misallocation of capital.

However, an important question in periods of extended price increases is whether the price developments can be regarded as fundamentally justified or not. If prices disconnect from fundamental factors and are mainly driven by speculation or by purely irrational factors, there is the danger of real estate price bubbles which can potentially have very detrimental effects for the macroeconomy. There are plenty of examples of house price bubbles, such as the experience of Japans asset and house price bubble that collapsed at the beginning of the 1990s and caused a long period of economic stagnation, or the recent developments on the US or Spanish housing markets. Indeed, the recent global financial crisis has been triggered by developments on the US house market and especially in the segment of subprime mortgages where a large overvaluation of real estate and a subsequent burst of prices could be observed.

In the literature, there is ample evidence of the negative welfare effects of bursting bubbles (e.g. Helbling 2005, Reinhart and Rogoff 2009). In their empirical study, Adalid and Detken (2007) identify boom/bust periods and classify these into low-cost and high-cost booms depending on the annualised drop in GDP in the years following the boom. They find that compared to low-cost boom/bust periods, the identified high-cost boom/bust periods were associated with a markedly higher real estate price increase during the boom phase and a larger decrease in real estate prices during the bust phase. Housing investment is found to be significantly higher during high-cost booms compared to low-cost

booms. Furthermore, they find that real estate price developments during the boom and in the post-boom phase are robustly linked to post-boom recessions. Such evidence gives credence to the notion that real estate markets play a key role for macroeconomic stability and that real estate bubbles seem to entail considerable macroeconomic costs. Potential policy options for reacting to real estate price bubbles include restrictive monetary policy, fiscal policy tools such as transaction or property taxes and macroprudential regulatory measures such as higher capital requirements for mortgage credit or limits to debt-to-income ratios (Igan 2012).

While it is important to identify deviations of real estate prices from fundamental values to guide economic policy, empirically it is no trivial task. Simply observing the development of realised prices on real estate markets is not sufficient in order to make a judgement about whether prices are fundamentally justified and therefore sustainable. Increasing prices might be fundamentally justified, but on the contrary, constant or even declining prices might still actually be overvalued when the fundamental value declines or declines faster than observed prices, respectively. Therefore, observed prices must be put into relation to underlying factors which determine fundamentally justified prices in order to make a judgement about the development of prices and to guide reasonable economic policy decisions.

Against this background, this paper aims at contributing to the analysis of fundamental real estate prices by analysing a wide number of potential fundamental determinants of real estate prices in a panel study of German regions. The analysis is based on a panel dataset covering real estate prices and rents as well as a wide array of demographic, economic and infrastructural variables across a panel of up to 127 large German cities and regions. The dataset is unique in several aspects: With 127 regions, the cross-sectional dimension of the dataset is larger than the dimension of the datasets used in many other comparable studies. Typically, in cross-sectional or panel studies related to real estate prices, the dataset does not exceed the dimension of 10 or 20 cross-sectional units. What is more, many cross-country studies collect data from different national sources which can result in inconsistent datasets due to differing definitions of the variables used. Most of the data used in this paper have been collected and processed by a single source. Therefore, a higher degree of homogeneity regarding definition and construction of the data is achieved, which potentially minimises a bias of heterogeneity in the data.

Furthermore, given the large cross-sectional dimension, the dataset also has a considerable time dimension. Most variables used in our study are available at least for the period from 1995 to the most recent observation in the year 2010. Together, these panel dimensions allow applying panel estimation methods that are able to account for the heterogeneity across the regions analysed here. Given these

characteristics, the panel dataset employed here provides a unique opportunity for studying the fundamental determinants of real estate prices in Germany.

2. Related literature

This section reviews selected related literature dealing with recent developments of house prices on a global level and in Germany and discusses in more detail the consequences of bursting house price bubbles. The literature review then turns towards the fundamental determinants of house prices that have been analysed in previous research. By discussing the ways in which these fundamental factors affect house prices, this section gives a theoretical underpinning for the ensuing empirical analysis.

2.1 Literature on real estate price developments

Around the globe many real estate markets have experienced periods of considerable price increases over the last one or two decades. Girouard et al. (2006) document house price developments in OECD countries and conclude that price increases up to this point in time were unprecedented in size, duration and synchronicity across most OECD countries. Furthermore, price developments in these countries were largely detached from the business cycle at least from the year 2000 onwards. Girouard et al. (2006) argue that there has not been much evidence of overvaluation due to the low levels of long-term or mortgage interest rates. However, given the stickiness of nominal house prices, potential downward adjustments were forecasted to be large and protracted. Generally, Girouard et al. (2006) observed large ten-year house price cycles. As documented by Reinhart and Rogoff (2009), this widespread real estate boom period resulted in severe busts in many real estate markets around the globe. They quantitatively document the severe detrimental effects in the aftermath of housing crises by showing that house price declines after the burst of a bubble are both large in value (about 35% decline on average) and protracted (taking over six years on average) and go along with declining economic growth, higher unemployment and increasing government debt. One reason for recent real estate booms in countries such as the USA, United Kingdom, Ireland or Spain have been low financing costs which strongly drove housing demand in these countries (Dahl and Góralczyk 2017).

However, real estate market developments differ across advanced economies. Germany is an example of a country that has not experienced a comparable boom/bust period in its real estate market despite many such examples on a global scale. As for example documented by Gros (2007), in the 1990s and 2000s there has been a divergence of real estate market developments in Europe with a situation close to stagnation in Germany on the one hand and booms in countries such as Spain or Ireland. Gros (2007) documents declining or stagnating price-to-rent ratios in Germany and attributes this at least partially

to the reconstruction in East Germany that took place after the reunification and that led to a construction boom in the first half of the 1990s and consequently to a housing overhang that depressed demand.

Since around 2010, however, real estate price dynamics in Germany have picked up which has sparked discussion about a potential price bubble in urban real estate markets. As documented by Dahl and Góralczyk (2017), there have been strong real estate price increases mainly in larger cities, due to robust housing demand and insufficient and inelastic supply. This real estate price increase has outpaced consumer price inflation growth during the same period. There is no consensus about whether these developments are justified by fundamental determinants of real estate prices or whether there is reason for concerns about overheating and exuberance. (e.g. Chen and Funke 2013, Kajuth et al. 2013, Kholodilin et al. 2014, Dahl and Góralczyk 2017).

Regarding institutional factors, Maclennan et al. (1998) show that Germany is a country with fixed interest mortgage rates, relatively low loan-to-value ratios, high transaction costs and smaller owner-occupied sector. According to Dahl and Góralczyk (2017), the home ownership share in Germany was only 52% in 2015 compared to 67% in the other Euro area countries. For much of recent decades, the German real estate market generally tends to exhibit lower house price volatility and therefore generate less pronounced consumption effects. Nevertheless, housing is still a major component of consumption and investment expenditures. In Germany, rents are around 17% of total private consumption, 30% of total investment and 67% of construction investment (Dahl and Góralczyk 2017).

Using an autoregressive distributed lag (ARDL) analysis framework based on aggregated German data, Belke (2010) shows that the rather poor performance of the German real estate market in the 1990s and in the recent decade does not support the idea that asset price bubbles were prevalent in the German real estate market. However, this does not exclude the possibility that speculative exaggerations or even exuberance has taken place in individual cities or metropolitan areas. Belke (2010) is able to corroborate empirically for some specifications that the expansion of the euro area money stock allotted to Germany has contributed to a boom of West German real estate prices.

Since Germany has experienced a real estate market development different from many of the countries that have been in the focus of recent empirical research, a dedicated analysis of the German real estate market seems promising as an addition to existing research on other countries. There is evidence for the notion that there is considerable variation on a more disaggregated level within Germany such as differences between the East and the West or differences across cities and regions. Also, regarding potential problems of aggregated nation-wide real estate price indicators such as the

important role of local characteristics of the real estate market (Deutsche Bundesbank 2003), one might argue that analyses on a more disaggregated regional level do not suffer from such problems.

2.2 Literature on the determinants of real estate prices

In the empirical literature on the determinants of real estate prices, there are several general approaches depending on the specific research questions and the available data. First, there is an asset pricing approach that relates real estate prices to expected future discounted earnings derived from owning real estate. An example is the application by Hott and Monnin (2008) who derive fundamental house prices from the user cost model and show that prices are a function of future discounted imputed rents or user costs. Factors such as mortgage rates, depreciation, maintenance costs, taxes or capital gains, determine the imputed rents and thereby fundamental prices. Other applications of the asset pricing approach can be found in Himmelberg et al. (2005), Weeken (2004) and Girouard et al. (2006). A second approach focuses on the affordability and sustainability of house prices or the indebtedness of private households by analysing price-to-income ratios, loan-to-value ratios or an affordability index such as the ratio of the actual monthly mortgage cost to income. This approach is applied in Girouard et al. (2006) or Hlaváček and Komárek (2011), among others.

Third, there are empirical studies which apply the hedonic pricing method to the analysis of real estate prices. The basic idea of hedonic price modelling is that individual object-specific or neighbourhood-specific characteristics each contribute to the overall value of real estate objects. The basic theory of hedonic pricing of goods has been developed and formulated by Lancaster (1966), Griliches (1971) and Rosen (1974). In the context of real estate price analysis, empirical studies applying the hedonic pricing method use data on individual real estate objects, their respective characteristics and corresponding prices in individual transactions. Early applications of hedonic regressions to the analysis of real estate prices are provided by Grether and Mieszkowski (1974), Linneman (1980), Li and Brown (1980) or Can (1992) who show that house prices can robustly be explained by a number of structural characteristics and neighbourhood characteristics. Authors such as Goodman (1978) or Ong et al. (2003) apply hedonic price modelling to real estate price indices. Other studies have extended the hedonic house price regression model by incorporating additional factors such as a house's view (Benson et al. 1998) or environmental influences (Dickes and Crouch 2015) or by methodological aspects such as analysing heteroscedasticity in hedonic models (Stevenson 2004). In the literature, alternative approaches to hedonic-based regression analysis of real estate price determinants have been proposed, among them artificial neural network modelling (Nguyen and Cripps 2001) or the decision tree approach (Fan et al. 2006), but hedonic-type regressions have remained one of the workhorse models for house price analysis in science and for practitioners (Bao and Wan 2007).

Fourth, there are econometric models that directly estimate the effect of real estate price determinants based on some form of aggregate national, regional or local-level real estate price index in time-series or panel setups. While hedonic pricing models use individual object characteristics as determinants of the prices of individual real estate objects, these studies are not based on individual object level data but rather use economic variables on national, regional or local level as determinants. In a VAR model, Sutton (2002) studies the response of house prices in six advanced economies to shocks in income, real interest rated and equity prices for the period 1970–2002. He finds that positive shocks to income or equity prices and negative shocks to long-term or short-term interest rates lead to house price increases after three years. Also estimating a VAR model of house prices and different determinants, Tsatsaronis and Zhu (2004) conclude that monetary policy decisions in response to inflation may result in real estate price misalignments from fundamentals. Gallin (2006) conducts aggregate and city-level cointegration analyses of house prices and their determinants, but does not find evidence for cointegration of the level of house prices and the level of the determinants. Other comparable cointegration studies analysing house prices and their determinants are surveyed by Girouard et al. (2006).

Annett (2005) analyses short-run house price dynamics in the context of a fixed effects (FE) panel model including house prices and real disposable income per capita, real long-term interest rate, real credit, broad money. Results show that lagged house prices have explanatory power in the overall sample, but notably not in Germany. Real income is not a significant determinant of short-term house price dynamics in most specifications. Real interest rates exhibit a negative and significant relation with house prices in the overall panel. Real credit and money are no significant determinants of house prices in most specifications. Schnure (2005) analyses fundamental determinants of house prices using a panel of nine US regions. Both stand-alone estimations for each region and fixed-effects panel estimations for the whole sample of regions are conducted. The analysed determinants are regional values of income, unemployment and the labour force and national values of interest rates, CPI and GDP. Results show the positive effect of income growth and the negative effect of unemployment and interest rates on house prices. Furthermore, the labour force is found to be a relevant determinant with a positive sign, but neither is CPI or GDP. Schnure (2005) also finds that pricing errors, i.e. the residuals of the house price regressions, decline in more recent times.

Hlaváček and Komárek (2011) perform ordinary least squares (OLS) and FE panel regressions of apartment prices in Czech regions on a set of demographic and economic explanatory variables. Results show that mostly, demographic and demand factors are significant determinants of apartment prices. These include population growth, net migration, the divorce rate, the unemployment rate and wage growth. Hlaváček and Komárek (2011) also include apartment rents as a potential determinant

of apartment prices. Since rents turn out to be a determinant of prices, they conclude that there seems to be a substitution relationship between renting and owning.

Kajuth et al. (2013) estimate the effects of fundamental determinants of German regional house prices using an instrumental variables estimator based on a random effects setup. They find several important determinants. House prices are robustly linked to the housing stock per capita, income per capita, the unemployment rate, the age structure, the population density, and economic growth expectations. The analysis of Kajuth et al. (2013) is most comparable to our analysis and is based on similar data.

Summing up the literature on the determinants in econometric models of house prices results in the following potential determinants which can broadly be divided in to demand-side factors (factors related to the demand for housing) and supply-side factors (factors related to the supply of housing). Potential supply-side factors are as follows: Rents could be argued to be a demand-side factor of house prices. On the demand side, rents are expected to be in a positive relation to house prices due to the substitutive relationship of buying or renting a house or apartment. If rents are high, demand would shift towards buying real estate and vice versa. Furthermore, high rents potentially increase demand for buying real estate due to “buy-to-let” arrangements. Demographic variables such as population size or growth, the age structure of the population, migration to and from the region, the number of households, overall changes in household size and household formation shape demand for housing. Even characteristics such as the marriage or divorce rates might affect household formation and thus demand for housing. Girouard et al. (2006) link an observed decline in German house prices to a comparably low number of single households, among other factors.

Disposable household income is theoretically an important factor shaping demand for housing. Related to disposable household income are taxes and subsidies. Taxation or, on the contrary, specific subsidies such as social housing provision influence disposable income and thus housing demand. Household wealth which could be measured in a variety of ways such as with equity market price indices (Sutton 2002) can affect demand for housing. Since unemployment has a direct negative effect on disposable household income, the unemployment rate potentially also affects housing demand. Equally, the labour force could affect housing demand in a region. Furthermore, the economics structure of a region as measured by the number of workers in the different economic sectors might have an influence. Infrastructure factors such as roads, schools or hospitals in the area around the property increase the utility that can be derived from real estate and thus might increase demand for housing. Long-term interest rates or mortgage rates in theory affect the affordability of a long-term investment such as real estate and thus should have an effect on housing demand. Generally, credit and loan

availability determines the conditions under which households can obtain real estate financing. Related to this are institutional factors such as credit or mortgage regulations.

Potential supply factors include the following: The availability of land/property as a largely fixed characteristic of a region affects the supply of housing. The available housing stock could be regarded as one of the most important factors shaping supply with the existing stock of housing being inelastic (Poterba 1984). Construction activity determines new housing, i.e. additions to the existing housing stock. The construction of new houses depends highly on the profitability of supplying new homes and thus is affected by construction costs. Institutional factors that affect the supply side of the real estate market include building regulations and administrative processes etc., as these directly affect profitability.

3. Empirical strategy

After having discussed the potential determinants of real estate prices in general terms above, in the following the panel dataset and the construction of the specific variables employed in the analysis are presented. Afterwards, the empirical model and the applied estimation methods are described.

3.1 Data

We use annual data on regional real estate market characteristics and other economic variables in order to explain real estate prices. The main source for data used in the empirical analysis of this paper is the RIWIS Regional Property Market Information System database supplied by BulwienGesa, a commercial real estate research institute (BulwienGesa 1995-2010). This database provides several annual aggregated real estate price indices for 127 of the largest German cities from all parts of the country selected on the basis of the population size. Cities with a population below 100.000 inhabitants are not included in the sample. This sample selection criterion based on population size results in the cross-sectional sample spanning about 100 West German cities and about 25 East German cities.

The price indices provided by BulwienGesa are constructed in such a way to allow meaningful comparison of real estate prices across regions and over time. The price indices represent standardised “typical cases” of real estate objects with comparable characteristics regarding object size, quality of the object or quality of the surrounding location. BulwienGesa compiles the real estate dataset using a wide range of own data collections, expert assessments, market surveys and analyses and test transactions. Due to the way the indices are constructed, the data unaffected by biases or distortions due to differences in the characteristics across different real estate objects and changes in the

characteristics of objects over time. The database provides individual data for different classes of real estate object (e.g. single-family detached houses, apartments, row houses) and differentiates between medium, good and very good quality of the property or the surrounding area. Additionally, there is data on minimum, maximum and average prices observed in the market transactions. In our paper, we analyse average price data. An extensive explanation of the methodology applied by BulwienGesa in calculating the time series of the different indices is given by Kauffmann and Nastansky (2006). This dataset allows us to use aggregate real estate data while at the same time controlling for the characteristics of real estate objects without using data on individual real estate objects and their respective characteristics as with hedonic studies.

BulwienGesa maintains indices on different segments of the real estate market (residential property, commercial property, offices, retail property). However, the empirical analysis here is restricted to the segment of residential real estate in order to obtain results that are comparable with previous literature which mainly focuses on residential real estate, and in order to avoid several additional methodological problems associated with the analysis of, say, commercial property. The causal link between prices and fundamental determinants is often regarded as being closer and more clear-cut for residential property than for other segments of the real estate market. The market for commercial property, office buildings, industrial property and retail stores is to a larger extent than residential housing driven by factors other than regional demand and supply since demand is also determined by international corporations and franchises. This is especially relevant in large cities which a make up a large fraction of the cross-section in our sample. Restricting the analysis to residential real estate data avoids these problems.

The two dependent variables of main interest in our analysis are house prices and apartment prices. House prices are defined as the purchasing prices of single family houses. For apartments, two different types of price indices are available: a price index for newly built apartments and one for existing re-sold existing apartments. This owes to the supply-side differentiation between the market segments for newly built housing and those for existing housing (Poterba 1984). In our estimations, we use the data referring to newly built apartments. Both house price and apartment price series are denoted in thousands of Euros. We deflate the series using the consumer price index series taken from the German Federal Statistical Office. In the estimations, we use the log of real house prices and real apartment prices as the dependent variables.

The following list gives an overview of the variables capturing the fundamental determinants included in our empirical analysis based on the literature review. Source of the data is the RIWIS database (BulwienGesa 1995-2010) if not noted otherwise.

- *Rent*: For apartments, there is data on monthly rental prices are available in addition to the purchasing price data. Rents are denoted in Euros per square meter. We deflate the series using the consumer price index series taken from the German Federal Statistical Office and use the log of real rental prices as a regressor in the regressions with apartment price as the dependent variable. However, rents are not included as an explanatory variable for the regressions with house prices as dependent variable, as there is no data on rental prices for houses/single family homes and there is no direct link between prices in the house segment and rents in the apartment segment. We expect a positive relationship between rents and prices since increasing rents increase the profitability of owning real estate assets. Rental price data are measured in Euro per square meter.
- *Transactions* is defined as the recorded number of real estate market transactions per 1000 inhabitants of each city. This variable is a measure of general real estate market activity in the specific region. We expect a positive relationship between transactions and real estate prices since a higher number of transaction reflects stronger demand for housing.
- *Construction* is defined as the number of newly constructed apartments per 1000 inhabitants of each city. This variable is a measure of construction activity. The expected sign of the relationship between construction and real estate prices is unclear. There could either be a negative sign reflecting increase of supply relative to demand to new construction, or a positive sign due to new construction as a supply side reaction to increased demand for housing.
- *Stock* is defined as the stock of existing apartments per 1000 inhabitants of each city. We expect a negative relationship between the stock of housing and prices since a higher supply of housing reduces the relative demand pressure in the real estate market.
- *Age structure* is defined as the dependency ratio, i.e. the number of persons aged under 15 or above 65 divided by number of persons aged 15 to 65 expressed in percentage points. This variable captures differences in the age structures across cities with a higher value reflecting a lower share of working-age population. We expect cities with higher dependency ratios to exhibit lower prices due to weaker demand in cities with lower working-age population share.
- *Households* is defined as the number of households expressed in units of thousand for each city. This variable can be interpreted as an indicator of the size of the regional real estate markets. We expect the number of households to be positively related to real estate prices as a higher number of households means stronger demand for housing.
- *Unemployment* is defined as the unemployment rate of dependent civil employees of each city expressed in percentage points. We expect a negative relationship between unemployment and real estate prices due to weaker demand in cities with a higher unemployment rate.

- *Economic structure* is defined as the number of persons working in the services sector divided by sum of persons working in the manufacturing and agriculture sectors. We expect a negative relationship between a higher share of the services sector (i.e. lower share of manufacturing sector) and real estate prices due to weaker demand.
- *Income* is defined as the average annual disposable income per capita measured in real terms. In the estimations, we use the log of this variable. We expect a positive relationship of income and real estate prices to stronger demand for housing in cities with higher income.
- *Purchasing power index (PPI):* As an alternative variable capturing the purchasing power of income in the regions we use an index of purchasing power. It refers to net incomes of households after taxes and social contributions, including received transfer payments such as pensions, unemployment benefits, benefit payments and other transfers. This variable is a broader indicator of purchasing power in the different regions than disposable income.
- *Hospitals* is defined as the number of hospitals per 1000 inhabitants of each city. The number of hospitals is included as a proxy for the quality of available public infrastructure, or in the terminology of hedonic pricing, the neighbourhood amenities. It is defined as the number of hospitals per 1000 inhabitants. We expect a positive relationship to real estate prices as proximity to such non-residential neighbourhood factors is shown to have a positive effect on real estate prices (Li and Brown 1980).
- *Interest* is defined as the yield rate on 10-year German government bond measured in real terms. Data is taken from Eurostat (1995-2010). This variable is used as a proxy for real long-term interest rate environment in the economy and thereby the mortgage financing costs occurred when financing a real estate purchase (Himmelberg et al. 2005, Campbell et al. 2009). A priori, the sign of the relationship between interest rates and real estate prices. While higher financing costs are expected to reduce demand for housing and thereby real estate prices, interest rates are determined by the monetary policy stance and the business cycle. According to this second view, higher interest rates would coincide with higher demand for housing and higher real estate prices.

We do not include institutional factors related to real estate markets (e.g. building regulations) or financial markets (e.g. regulations on bank loans) since it can be reasonably assumed that there is neither significant variation in such factors across German regions.

In a study of regional real estate prices, the issue of potential cross-regional differences in price levels and the cost of living needs attention since differences in cost of living across regions could distort the results. As discussed by Linz (2010), German statistical authorities do not provide meaningful data on regional price levels or cost of living differences for German regions that could be used in panel

analyses. Roos (2006) shows that regional average income or population size can be regarded as important explanatory variables for regional price differences. By including these variables as regressors in our study, we account for these factors which determine potential differences in cost of living across regions. Furthermore, any existing significant differences in cost of living across German regions can be expected to be largely determined by differences in real estate prices as there is no significant variation across regions in other factors such as food prices in Germany. Therefore, we argue that our results to a large extent capture and account for any cost of living differences. To further explore this issue, we provide additional estimations of our model using a purchasing power index as a robustness check.

Table 1 provides descriptive statistics for the variables used in the study. For house prices, apartment prices, rents and the disposable income, both the (real) absolute levels and the log of the series are reported, while in the estimations we only use the log of these variables. Since we use a relatively large number of independent variables, there is a risk of multicollinearity in the data. Table A1 in the appendix provides a correlation matrix for the variables used in the estimations. The correlation matrix shows no evidence for any significant degree of multicollinearity in the data.

We use data for the period of 1995 to 2009 which translates to 15 annual observations. We end our sample at 2009 due to the structural break implied by the price increases in large German cities starting in 2010. The cross-sectional dimension of the sample is 127 cities. This allows for a maximum of 1905 observations. In practice, however, this number is reduced to 1316 observations due to missing values in the panel dataset.

3.2 Econometric model and estimation methods

We follow the approach by Annett (2005), Schnure (2005), Hlaváček and Komárek (2011) or Kajuth et al. (2013) by estimating variants of the following econometric model of real estate prices explained by their fundamental determinants:

$$p_{it} = \alpha_i + \alpha_t + \beta_1 \boldsymbol{X}_{it} + \beta_2 \boldsymbol{X}_t + \varepsilon_{it}.$$

In this general formulation, p_{it} refers to either the house or apartment price in year t and city i, α_i are city-specific fixed effects, α_t are year-specific fixed effects, $\boldsymbol{X}_{it}$ is a vector containing determinants that vary both across cities and over time, $\boldsymbol{X}_t$ is a vector of determinants that vary only over time, ε_{it} is the error term and β_1 and β_2 are vectors of the coefficients to be estimated.

The model is a two-way fixed effects panel model which includes both region-specific and year-specific fixed effects. This choice of model can be justified as follows: A general problem of empirically analysing real estate data is that land property, houses and apartments are potentially very

heterogeneous goods. Real estate prices depend to a large extent on characteristics pertaining to the property, the location and the surroundings, the larger region and its infrastructure and much more. A particular feature of real estate is the inability of translocating it. By differentiating data across narrowly defined cities and regions, the BulwienGesa data alleviates this problem to a certain extent. However, it is not possible to include all potentially relevant region-specific factors in the model. Nevertheless, is reasonable to think of the aggregated unobserved heterogeneous characteristics of each region that affects house prices as being time-invariant region-specific fixed parameters which are captured by the α_i terms in the model. The same argument goes for the year-specific fixed effects: The α_t terms are included to capture any global factors affecting all regions in the same way. Furthermore, from an econometric perspective, the fixed effects model applied here is less restrictive than the random effects model regarding the assumptions towards covariance structure since the assumption of independence of the individual group effects and the regressors is not required. Standard assumptions for OLS and FE panel estimation apply.

The model will initially be estimated by pooled OLS (POLS), also referred to as the "between effect estimator" which does not allow including the two-way fixed effects α_i and α_t. We calculated robust standard errors. The POLS estimation is useful as a first step in order to obtain benchmark estimates. In the second step, fixed effects panel regressions are performed applying the "within estimator". The within transformation of this estimator removes the unobservable group effects α_i. This estimator is more appropriate than the least squares dummy variables (LSDV) estimator, since the cross-sectional dimension is relatively large compared to the time dimension. Due to the incidental parameter problem, the coefficients of the dummy variables are not consistent since their number increases with the cross-sectional dimension of the sample (Baltagi 2008). The within estimator applied here does not suffer from this problem since it does not explicitly include dummy variables for the cross-sectional units, but removes the heterogeneous group effects by applying the within transformation. The coefficient estimates, however, are identical to those of the LSDV estimator. The calculated standard errors are robust to cross-sectional heteroskedasticity and within-group serial correlation.

In the panel regressions, two different specifications of the model will be estimated that either exclude or include the year-specific fixed effects α_t. While it is desirable to include these fixed effects to account for any global influences, the number of degrees of freedom decreases due to the inclusion of dummy variables. For this reason, exclusion of the year-specific fixed effects might be seen as the superior specification. Here, both types of specifications will be reported. Similar fixed effects panel estimation approaches comparable to our study have been applied, among others, by Annett (2005), Almeida et al. (2006), Hlaváček and Komárek (2011) or Kajuth et al. (2013).

4. Empirical results

Tables 2 to 4 summarize the results of the different estimations of the empirical model. The tables report the estimated coefficients along with corresponding p-values in parentheses and one, two or three asterisks referring to a coefficient tested to be different from zero at the 10, 5 or 1 percent significance levels.

4.1 POLS regression results

In Table 2, the results of POLS estimations of the model without including either region-fixed or year-fixed effects are presented as a benchmark. Three different specifications are included: specification (1) with the log house prices as the dependent variable, and specifications (2) and (3) using log apartment prices as the dependent variable. Since there is only data for apartment rents, we estimate two variants of the apartment price model with and without rents as an additional explanatory variable for comparability with the house price model.

The following results are note-worthy: of the supply-side determinants, construction enters with a positive sign and the stock with the expected negative sign, the latter of which indicates the role of saturation on real estate markets. The positive relation between construction activity and real estate prices could reflect a supply side reaction of increasing construction in cities with strong demand. Results for the number of transactions is inconclusive.

On the demand side, the demographic and economic variables show the expected signs. Age structure enters with a negative sign indicating that a high share of population outside of working age decreases demand for housing. The number of households or (or size indicator) has a positive sign in line with expectations. Higher unemployment rates are associated with lower real estate prices and a larger labour force with higher prices. The income variable enters with the expected positive sign. The negative sign of the economic structure variables indicates that a higher share of industrial and manufacturing labour in a region is associated with higher real estate prices. All of these results underline the role of the population's size and economic potential for housing demand.

The number of hospitals has the expected positive coefficient indicating that there is more demand in cities with better infrastructure. The interest rate enters positively into the regression equation. This shows that in this setting, interest rates likely rather reflect the general economic environment and cyclical stance than higher financing costs. Including rents as an additional determinant of apartment prices in the third specification slightly increases model fit, while the positive coefficient indicates the expected relation of renting and buying. In summary, the POLS benchmark estimation corroborates the important roles of both the supply-side and demand-side fundamental determinants.

4.2 Panel regression results

Table 3 reports the results of fixed effects panel regressions using house prices as the dependent variable. In specification (1), region-specific fixed effects are included to account for unobserved heterogeneity across regions, but year-specific fixed effects are excluded. Both types of fixed effects are included in specification (2). However, results do not largely differ across these two specifications indicating that overall year-fixed influences not explicitly modelled in our model do not play a major role but that real estate prices are mostly determined by individual or region-specific factors.

The results in the panel regression are slightly less clear-cut than in the benchmark POLS estimations. Still, several variables prove to be robust determinants, namely construction activity which is associated with higher house prices and the stock of real estate which in line with theory is negatively related to prices, and the interest rate. There is some evidence for the role of number of transactions, age structure, number of households and income, but significance varies more compared to POLS regressions.

Table 4 presents the results of four specifications of the panel mode using apartment prices as the dependent variable. Here, several clear conclusions can be drawn. First, the supply-side determinants transactions and construction activity (both having positive signs) and stock of existing apartments (with negative sign) seem to be important determinants of apartment prices. Generally, real estate prices are higher in markets with a more “active” supply side and lower in case of more saturated markets.

On the demand side, age structure, number of households, the unemployment rate, income and number of hospitals have the expected signs, but the unemployment variable is insignificant in these estimations. The interest rate again has a positive sign. These results are mostly robust across specifications. As in the benchmark results, specifications (2) and (4) which include rents as an additional regressor strongly suggest a positive relation of apartment rents and apartment prices. As with the house price regressions, including year-specific fixed effects does not change the results in any significant way.

4.3 Robustness checks

In order to check for the robustness of the above results, the effects of several modifications to the model setup described above have been studied. These additional estimations are not reported here for sake of brevity. First, to further investigate whether differences in cost of living or differences in purchasing power across regions plays a role in our analysis, we re-estimate our models using a purchasing power index variable instead of the disposable income variable. Tables A2 to A4 in the

appendix show all estimation results using the log of the purchasing power index instead of the log of disposable income. Results are largely similar to the one reported above. This gives further support to the notion that differences in purchasing power or cost of living across regions does not play an important role in our analysis.

Second, several other alternative variables have been used in additional regressions to check the robustness of results. Instead of the number of households in each city, the population size or the size of the labour force can be used to capture the size of the regional real estate markets. Instead of disposable income, data on wages can be used to capture the effect of income on housing demand. Instead of the number of hospitals, the number of secondary schools can be used as an indicator capturing the quality of public infrastructure or the available neighbourhood amenities in the cities. Applying each of these alternative variables does not change the results of our estimations. Third, instead of analysing the house price, apartment price, rental price and income variables in real terms by deflating using the consumer price index, we have used the nominal (non-deflated) version of the series. Using the nominal series does not change our results in any significant way.

Fourth, in several additional specifications, the first lag of the real estate price variable has been included as a regressor in the estimation. These lags of the endogenous variable enter with a positive sign indicating that persistence in real estate prices is relevant as would be expected. However, most main results of the estimations presented here remain qualitatively unchanged. Fifth, we have estimated a variation of our model using house price growth rates and apartment price growth rates as the dependent variables. Applying this variation, some of the results reported above are not obtained and results are more inconclusive. This suggests that our results pertain to the real estate price model estimated in log levels in particular, but not necessarily to growth rates of prices.

5. Conclusions

The aim of this paper is to contribute to the literature on fundamental determinants of real estate prices by performing a panel analysis of real estate prices across German regions. Even though in the period 1990-2010, the German real estate market has not experienced volatile price developments or even boom/bust periods as real estate markets in several other countries and real estate prices only started to increase in larger German cities in recent years, the rich panel dataset studied here allows for an analysis of the variation in prices and their determinants across regions and over time.

The empirical analysis sought to establish some results on the role of different fundamental determinants of house prices and apartment prices across German regions. Several general

conclusions can be drawn: A number of variables have proven to be relatively robust determinants of house and apartment prices with the direction of their effects being in line with theoretical predictions. On the supply side, this refers to the construction activity and the stock of existing housing and to a lesser extent to the number of real estate transactions. On the demand side, the size of the regional real estate market as captured by the number of households, the age structure of the population, the regional infrastructure were shown to be the main determinants of real estate prices.

Furthermore, disposable income showed a positive sign in all estimations as expected by theory, but lacked statistical significance in some of the panel regressions. One explanation for this phenomenon might be that income largely varies across regions thus leading to a positive coefficient in the POLS benchmark estimation, but variation is less pronounced over time and within regions thus leading to less significant results in the panel regressions. Nevertheless, these results can be taken as evidence for the role income plays in determining housing demand and thereby driving prices. Interest rates in the analysed sample robustly are associated with higher real estate prices. An interpretation of this is that interest prices do not primarily capture increasing financing costs related to higher interest rates, but they rather reflect the economic environment and cyclical stance of the economy which in turn drives demand for housing. Furthermore, in the case of apartment price regressions, rental prices have been shown to be a robust determinant of real estate price with a positive sign. This in particular reflects that the real estate prices analysed in our study are fundamentally justified: As any asset, a house or apartment can be viewed and valued in terms of the expected future cash flows to be derived from owning this asset.

Overall, the results suggest that there are underlying factors both on the supply side and the demand side which can be used to identify fundamental real estate prices in order to detect misalignments of price developments from fundamentals. Our results stress the fact that real estate price developments cannot only be judged by the price dynamics alone, but that the underlying drivers of price developments need to be taken into account. Even high price increases such as those witnessed in large German cities in recent years likely are to a large degree determined by increasing demand factors and not primarily by market exuberance.

In addition to the determinants analysed in this paper, other variables might be important as well. Regarding the role of the mortgage interest rates, incorporating a measure of inflation expectations might prove helpful in order to capture expectations regarding real interest rates. In order to better analyse housing demand effects, it seems promising to incorporate both a wealth variable such as a stock market indicator and a credit variable as both household wealth and the availability of mortgage loans to private households can be regarded as additional important determinants. Furthermore, integrating a measure of monetary liquidity might prove worthy since liquidity may be a significant

non-fundamental driver of real estate prices (Belke 2010). Stronger real estate price developments in recent years in some German cities and regions coincide with a looser monetary policy of the European Central Bank. Finally, since the dataset used here provides not only real estate price data but also data on apartment rents, another direction to take the analysis of this paper would be to use the prices and rents series to calculate price-to-rent ratios and analyse overvaluation from this perspective similar to the analyses by Gros (2007) and Hlaváček and Komárek (2011), among others.

The analysis conducted in this paper offers important insights into the fundamental determinants of real estate prices. Speculative price increases and bubble developments can pose a severe problem for macroeconomic policy. Therefore, such an analysis is highly relevant from a policy perspective. One such option might be to use regional data for developing a system of regional indicators (Dreger and Kholodilin 2011). Using regional data for developing a system of regional indicators of real estate market developments and aggregating these in order to come up with an overall indicator could be used for guiding and evaluating policy decisions.

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Tables

Table 1
Descriptive statistics

Variable	obs.	minimum	mean	maximum	std. dev.
House price	1316	107.88	309.45	730.42	108.69
Log house price	1316	4.68	5.67	6.59	0.36
Apartment price	1316	1028.04	2056.47	3933.02	451.38
Log apartment price	1316	6.94	7.61	8.28	0.22
Rent	1316	4.22	6.98	12.98	1.32
Log rent	1316	1.44	1.93	2.56	0.18
Transactions	1316	1.76	9.58	36.79	2.97
Construction	1316	0.006	2.92	21.29	2.00
Stock	1316	413.85	521.09	681.18	43.26
Age structure	1316	43.05	56.29	70.84	5.29
Households	1316	20.21	150.01	1905.28	232.06
Unemployment	1316	4.5	13.31	27.2	4.20
Economic structure	1316	0.47	3.75	12.59	1.70
Income	1316	12915.41	17229.02	30374.02	2292.99
Log income	1316	9.47	9.75	10.32	0.13
PPI	1316	74.4	98.99	141.3	11.81
Log PPI	1316	4.31	4.589	4.95	0.12
Hospitals	1316	0.008	0.03	0.086	0.015
Interest rate	1316	1.38	3.04	5.05	0.99

Source: Data is taken from the RIWIS database (BulwienGesa 1995-2010) with the exception of the interest rates taken from Eurostat (1995-2010).

Table 2
Pooled OLS estimations (1995-2010)

	(1)	(2)	(3)
Dependent variable:	Log house prices	Log apartment prices	
Log rent			0.6665 ***
			(0.000)
Transactions	-0.0075 ***	0.0011	0.0035 ***
	(0.000)	(0.293)	(0.000)
Construction	0.0036	0.0122 ***	0.0051 ***
	(0.207)	(0.000)	(0.001)
Stock	-0.0012 ***	-0.0004 ***	-0.0000
	(0.000)	(0.000)	(0.826)
Age structure	-0.0122 ***	-0.0099 ***	-0.0025 ***
	(0.000)	(0.000)	(0.000)
Households	0.0003 ***	0.0003 ***	0.0002 ***
	(0.000)	(0.000)	(0.000)
Unemployment	-0.0293 ***	-0.0154 ***	-0.0103 ***
	(0.000)	(0.000)	(0.000)
Economic structure	-0.0098 **	0.0010	-0.0062 ***
	(0.008)	(0.703)	(0.002)
Log income	1.0024 ***	0.5392 ***	0.2148 ***
	(0.000)	(0.000)	(0.000)
Hospitals	0.4924	1.2476 ***	1.7758 ***
	(0.147)	(0.000)	(0.000)
Interest rate	0.0510 ***	0.0466 ***	0.0228 ***
	(0.000)	(0.000)	(0.000)
Observations	1316	1316	1316
R^2	0.701	0.748	0.840
F-test (overall)	305.9	387.5	621.0

Source: Own calculations. Data is taken from the RIWIS database (BulwienGesa 1995-2010) with the exception of the interest rates taken from Eurostat (1995-2010). The table reports estimation results for pooled OLS estimations of the empirical model. For each estimated coefficient, the p-value is reported in parentheses with significance levels marked by *** <0.01, ** <0.05 and * <0.1. Calculated standard errors are robust.

Table 3

Fixed effects panel estimations with log house prices as dependent variable (1995-2010)

	(1)	(2)
Transactions	0.0023 *	0.0008
	(0.075)	(0.521)
Construction	0.0060 ***	0.0067 ***
	(0.001)	(0.000)
Stock	-0.0015 ***	-0.0016 ***
	(0.001)	(0.000)
Age structure	-0.0047	-0.0054 *
	(0.187)	(0.070)
Households	0.0004	0.0009 **
	(0.300)	(0.012)
Unemployment	0.0035 **	0.0006
	(0.036)	(0.849)
Economic structure	-0.0113	0.0133
	(0.110)	(0.121)
Log income	0.2650 **	0.1205
	(0.039)	(0.157)
Hospitals	1.3276	0.8961
	(0.133)	(0.283)
Interest rate	0.0395 ***	0.0404 ***
	(0.000)	(0.000)
Region-specific FE	yes	yes
Year-specific FE	no	yes
Observations	1316	1316
Groups	96	96
R^2 (within)	0.597	0.725
F-test (overall)	33.9	41.1

Source: Own calculations. Data is taken from the RIWIS database (BulwienGesa 1995-2010) with the exception of the interest rates taken from Eurostat (1995-2010). The table reports estimation results for fixed effects panel estimations of the empirical model. For each estimated coefficient, the p-value is reported in parentheses with significance levels marked by *** <0.01, ** <0.05 and * <0.1. Calculated standard errors are robust to cross-sectional heteroskedasticity and within-group serial correlation.

Table 4

Fixed effects panel estimations with log apartment prices as dependent variable (1995-2010)

	(1)	(2)	(3)	(4)
Log rent		0.2482 ***		0.2817 ***
		(0.000)		(0.000)
Transactions	0.0042 ***	0.0038 ***	0.0037 ***	0.0028 ***
	(0.002)	(0.001)	(0.004)	(0.005)
Construction	0.0080 ***	0.0064 ***	0.0079 ***	0.0060 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Stock	-0.0011 ***	-0.0008 **	-0.0010 ***	-0.0007 **
	(0.001)	(0.016)	(0.003)	(0.036)
Age structure	-0.0133 ***	-0.0112 ***	-0.0138 ***	-0.0114 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Households	0.0013 ***	0.0014 ***	0.0016 ***	0.0016 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Unemployment	-0.0008	-0.0004	-0.0041	-0.0038
	(0.541)	(0.731)	(0.170)	(0.187)
Economic structure	-0.0169	-0.0131	-0.0043	0.0012
	(0.134)	(0.239)	(0.720)	(0.919)
Log income	0.2085 **	0.1062	0.1413 *	0.0498
	(0.032)	(0.249)	(0.081)	(0.528)
Hospitals	1.8434 **	1.7564 ***	1.5833 *	1.4848 **
	(0.019)	(0.010)	(0.051)	(0.027)
Interest rate	0.0251 ***	0.0205 ***	0.0309 ***	0.0231 ***
	(0.000)	(0.000)	(0.000)	(0.004)
Region-specific FE	yes	yes	yes	yes
Year-specific FE	no	no	yes	yes
Observations	1316	1316	1316	1316
Groups	96	96	96	96
R^2 (within)	0.712	0.733	0.748	0.767
F-test (overall)	78.0	77.5	44.1	53.4

Source: Own calculations. Data is taken from the RIWIS database (BulwienGesa 1995-2010) with the exception of the interest rates taken from Eurostat (1995-2010). The table reports estimation results for fixed effects panel estimations of the empirical model. For each estimated coefficient, the p-value is reported in parentheses with significance levels marked by *** <0.01, ** <0.05 and * <0.1. Calculated standard errors are robust to cross-sectional heteroskedasticity and within-group serial correlation.

Appendix

Table A1
Correlation matrix

	Log rent	*Trans-actions*	*Construc-tion*	*Stock*	*Age structure*	*House-holds*	*Unem-ployment*	*Econ. structure*	*Log income*	*Log PPI*	*Hospitals*	*Interest rate*
Log rent	1.0000											
Transactions	0.0226	1.0000										
Construction	0.2956	0.2739	1.0000									
Stock	-0.3958	-0.0357	-0.1731	1.0000								
Age structure	-0.4773	-0.0749	-0.3708	0.0215	1.0000							
Households	0.4125	-0.1598	-0.0362	0.0712	-0.2132	1.0000						
Unemployment	-0.4919	-0.1255	-0.0362	0.5034	0.0328	0.0010	1.0000					
Econ. structure	0.1191	-0.0981	-0.0908	0.2953	-0.4274	0.1649	0.0725	1.0000				
Log income	0.4924	0.1061	-0.0833	-0.3763	0.1051	0.1495	-0.7008	-0.1387	1.0000			
Log PPI	0.6378	0.1224	0.0512	-0.3964	-0.0349	0.2163	-0.7592	-0.1106	0.8253	1.000		
Hospitals	0.0692	0.1619	0.0541	-0.0789	-0.1444	-0.1358	-0.2600	0.0098	0.1606	0.1229	1.0000	
Interest rate	0.3416	0.1193	0.4640	-0.3193	-0.2214	0.0154	-0.0647	-0.3059	-0.0085	0.1408	0.0619	1.0000

Source: Data is taken from the RIWIS database (BulwienGesa 1995-2010) with the exception of the interest rates taken from Eurostat (1995-2010).

Table A2

Pooled OLS estimations using PPI variable (1995-2010)

	(1)	(2)	(3)
Dependent variable:	Log house prices	Log apartment prices	
Log rent			0.6529 ***
			(0.000)
Transactions	-0.0082 ***	0.0011	0.0036 ***
	(0.000)	(0.345)	(0.000)
Construction	-0.0001	0.0101 ***	0.0044 ***
	(0.984)	(0.000)	(0.002)
Stock	-0.0014 ***	-0.0005 ***	-0.0001
	(0.000)	(0.000)	(0.313)
Age structure	-0.0104 ***	-0.0089 ***	-0.0022 ***
	(0.000)	(0.000)	(0.001)
Households	0.0002 ***	0.0003 ***	0.0002 ***
	(0.000)	(0.000)	(0.000)
Unemployment	-0.0150 ***	-0.0107 ***	-0.0092 ***
	(0.000)	(0.000)	(0.000)
Economic structure	-0.0092 ***	0.0008	-0.0063 ***
	(0.010)	(0.772)	(0.002)
Log PPI	1.6156 ***	0.7299 ***	0.2645 ***
	(0.000)	(0.000)	(0.000)
Hospitals	1.3653 ***	1.6595 ***	1.9195 ***
	(0.000)	(0.000)	(0.000)
Interest rate	0.0291 ***	0.0362 ***	0.0193 ***
	(0.000)	(0.000)	(0.000)
Observations	1316	1316	1316
R^2	0.744	0.758	0.839
F-test (overall)	437.1	376.4	590.1

Source: Own calculations. Data is taken from the RIWIS database (BulwienGesa 1995-2010) with the exception of the interest rates taken from Eurostat (1995-2010). The table reports estimation results for pooled OLS estimations of the empirical model. For each estimated coefficient, the p-value is reported in parentheses with significance levels marked by *** <0.01, ** <0.05 and * <0.1. Calculated standard errors are robust.

Table A3

Fixed effects panel estimations with log house prices as dependent variable and using PPI variable (1995-2010)

	(1)	(2)
Transactions	0.0023 *	0.0006
	(0.073)	(0.620)
Construction	0.0057 ***	0.0069 ***
	(0.002)	(0.000)
Stock	-0.0014 ***	-0.0016 ***
	(0.001)	(0.000)
Age structure	-0.0045	-0.0055 *
	(0.211)	(0.068)
Households	0.0005	0.0009 **
	(0.197)	(0.013)
Unemployment	0.0033 **	0.0008
	(0.049)	(0.802)
Economic structure	-0.0111	0.0131
	(0.111)	(0.129)
Log PPI	0.1511	0.1502
	(0.274)	(0.216)
Hospitals	1.2345	0.8560
	(0.182)	(0.307)
Interest rate	0.0372 ***	0.0377 ***
	(0.000)	(0.000)
Region-specific FE	yes	yes
Year-specific FE	no	yes
Observations	1316	1316
Groups	96	96
R^2 (within)	0.592	0.725
F-test (overall)	33.2	40.4

Source: Own calculations. Data is taken from the RIWIS database (BulwienGesa 1995-2010) with the exception of the interest rates taken from Eurostat (1995-2010). The table reports estimation results for fixed effects panel estimations of the empirical model. For each estimated coefficient, the p-value is reported in parentheses with significance levels marked by *** <0.01, ** <0.05 and * <0.1. Calculated standard errors are robust to cross-sectional heteroskedasticity and within-group serial correlation.

Table A4

Fixed effects panel estimations with log apartment prices as dependent variable and using PPI variable (1995-2010)

	(1)	(2)	(3)	(4)
Log rent		0.2536 ***		0.2783 ***
		(0.000)		(0.000)
Transactions	0.0040 ***	0.0037 ***	0.0034 ***	0.0027 ***
	(0.002)	(0.001)	(0.006)	(0.007)
Construction	0.0080 ***	0.0063 ***	0.0082 ***	0.0062 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Stock	-0.0010 ***	-0.0007 **	-0.0010 ***	-0.0007 **
	(0.002)	(0.019)	(0.003)	(0.031)
Age structure	-0.0132 ***	-0.0111 ***	-0.0139 ***	-0.0115 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Households	0.0014 ***	0.0014 ***	0.0016 ***	0.0016 ***
	(0.000)	(0.000)	(0.000)	(0.000)
Unemployment	-0.0008	-0.0004	-0.0038	-0.0035
	(0.502)	(0.718)	(0.204)	(0.219)
Economic structure	-0.0164	-0.0127	-0.0045	0.0011
	(0.144)	(0.251)	(0.699)	(0.923)
Log PPI	0.2202	0.1215	0.2046 *	0.1158
	(0.105)	(0.357)	(0.079)	(0.291)
Hospitals	1.7403 **	1.6997 **	1.5311 *	1.4594 **
	(0.029)	(0.012)	(0.056)	(0.026)
Interest rate	0.0226 ***	0.0191 ***	0.0273 ***	0.0213 ***
	(0.000)	(0.000)	(0.000)	(0.005)
Region-specific FE	yes	yes	yes	yes
Year-specific FE	no	no	yes	yes
Observations	1316	1316	1316	1316
Groups	96	96	96	96
R^2 (within)	0.716	0.733	0.749	0.767
F-test (overall)	78.91	77.59	42.70	52.92

Source: Own calculations. Data is taken from the RIWIS database (BulwienGesa 1995-2010) with the exception of the interest rates taken from Eurostat (1995-2010). The table reports estimation results for fixed effects panel estimations of the empirical model. For each estimated coefficient, the p-value is reported in parentheses with significance levels marked by *** <0.01, ** <0.05 and * <0.1. Calculated standard errors are robust to cross-sectional heteroskedasticity and within-group serial correlation.