Long run apartment price dynamics in Swedish and German cities

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Abstract

Purpose – This study examines the long term effects of macroeconomic fundamentals on apartment price dynamics in major metropolitan areas in Sweden and Germany.

Design/methodology/approach – The main approach is panel cointegration analysis that allows to overcome certain data restrictions such as spatial heterogeneity, cross-sectional dependence, and non-stationary, but cointegrated data. The Swedish dataset includes three cities over a period of 23 years, while the German dataset includes seven cities for 29 years. Analysis of apartment price dynamics include population, disposable income, mortgage interest rate, and apartment stock as underlying macroeconomic variables in the model.

Findings – The empirical results indicate that apartment prices react more strongly on changes in fundamental factors in major Swedish cities than in German ones despite quite similar development of these macroeconomic variables in the long run in both countries. On one hand, overreactions in apartment price dynamics might be considered as the evidence of the price bubble building in Sweden. On the other hand, these two countries differ in institutional arrangements of the housing markets, and these differences might contribute to the size of apartment price elasticities from changes in fundamentals. These arrangements include various banking sector policies, such as mortgage financing and valuation approaches, as well as different government regulations of the housing market as, for example, rent control.

Originality/value – In distinction to the previous studies carried out on Swedish and German data for single-family houses, this study focuses on the apartment segment of the market and examines apartment price elasticities from a long term perspective. In addition, the results from this study highlight the differences between the two countries at the city level in an integrated long run equilibrium framework.

Keywords Panel cointegration, Dynamic OLS, Housing market, Price determinants, Macroeconomy

Paper type Research paper

1. Introduction

House prices have been rising in many countries since the 1990s (Figure A1 in Appendix 1). In some European countries such as, for example, Sweden and Norway, the price growth was so extreme, that it raised debates about emerging speculative bubbles (Asal, 2019). At the same time, this dynamics were not evident for all European countries. For example, in Germany and Portugal, real house prices have been stagnating over the last few decades (Figure A1 in Appendix 1). The real house price growth in Sweden during 1995–2018 was plus 216 percent or 9.4 percent per year, while in Germany, it was only 18.6 percent for the same period or one percent per year (Source: Eurostat, Author's calculations).

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On the one hand, such high and persistent growth in house prices makes it an attractive investment that outperforms the traditional investments in stocks and bonds even if taking into account the lower liquidity of this type of asset. On the other hand, high house price growth in comparison with slow income growth occurring in the low-interest-rate environment makes housing less affordable with time. One more consequence of this process is that high house price growth might be an indicator of a potential bubble formation (Lind, 2009), and thus, it might cause risks for the stability of the financial system. For example, one might suspect a potential price bubble formation in cooperative apartments segment in Sweden, because it looks more volatile in the long run in comparison with single family house price dynamics (Figure A2 in Appendix 1).

Although the main factors that contribute to housing price growth in different countries at macroeconomic level are well examined [1], one question remains: What are the factors that prevent housing prices from persistently rising in the long run? If one of the goals of central bank policy is to maintain stability in the financial system, which in turn is closely connected to the housing market, then the focus should be on the relatively stable housing markets and factors that contribute to this.

Intention of this study is to analyze housing price dynamics from this new perspective and to correct this probably conceptual misunderstanding. It might be achieved by making a comparative analysis of two rather similar but contrasting countries – one with stable price dynamics such as, for example, Germany and the other one with the persistent price growth that has been observed in Sweden over recent decades. To the author's best knowledge this kind of analysis has not been conducted before and the results from it might help to understand long run property market dynamics in a better way. In line with this intention, the main *research question* of this study is:

RQ1. Can changes in fundamental factors explain the difference in long run apartment price dynamics in Germany and Sweden?

As the major housing stock is generally concentrated in larger urban agglomerations, it is worth making such a comparative analysis on the regional level, like metropolitan areas. The rest of the paper is organized as follows: Section 2 contains a brief literature review of studies focused on housing price determinants in different countries. Section 3 describes the data. Section 4 presents the methodological approach and panel cointegration technique for non-stationary panel data used to estimate the long run equilibrium relationship between apartment prices and macroeconomic fundamentals. Section 5 provides the empirical results of the model implementation. Finally, Section 6 contains conclusions and policy implications.

2. Brief literature review on macroeconomic determinants of housing prices

Empirical literature provides extensive evidence regarding various factors that affect housing price dynamics. The primary body of research is quite large and consists of more than three hundred thousand different studies that analyze factors affecting housing prices [2]. Most of the studies on housing price dynamics focused on the USA, UK, and a few other countries, primarily OECD members [3].

Only a selected number of studies are presented below to highlight the essence of the extensive research in this area. The selection of studies was made to match the following criteria: (1) Studies within housing economics area of reseach, (2) Studies are published in scientific journals, and (2) Studies cover developed countries in Europe and the USA. Some of these studies were done on an aggregated country level, others on a regional level, and in some cases, they cover both levels. These studies provide a base for the development of a methodological approach and a model in this paper.

Ozanne and Thibodeau (1983) were one of the first who attempt to discover the determinants of house prices in the USA, but their regression results were not significant.

Other studies on more extensive data have found interconnections between different fundamental economic factors and house price dynamics. Particularly, Reichert (1990) has found that population, employment, mortgage rate, permanent income and construction costs affect the house prices at a national and regional level, and the impact of these variables differ between different regions. Poterba (1991) concluded that changes in real income and real construction costs are important explanatory factors of the cross-city pattern of house price appreciation. Abraham and Hendershott (1996) have found that the growth in real income and real construction costs and changes in the real after-tax interest rate, employment growth, income growth and real interest rate have an impact on house price changes. Baffoe-Bonnie (1998) demonstrated that housing prices are influenced by economic fundamentals such as mortgage rates, consumer price index, changes in employment and money supply. Jones and Hyclak (1999) also confirmed that unemployment and size of the labour force affect house prices. Jud and Winkler (2002) have found that real housing price appreciation is strongly influenced by the growth of population and real changes in income, construction costs and interest rates, as well as growth in housing wealth. A recent study carried out by Oikarinen *et al.* (2018) explores spatial heterogeneity in house price dynamics and discuss the role of price elasticity of housing supply as well as income elasticity of prices.

Giussani and Hadjimatheou (1992) were one of the first to develop an econometric model for house prices in the UK. They suggested that the number of households, personal disposable income per capita, house building costs and the total housing stock are the driving forces behind increases in house prices in the long run. Their results also suggest that fiscal and monetary policy have a direct impact on house prices, both in the short and the long run, through changes in personal disposable income, interest rates, and tax allowance on mortgage interest payments. Muellbauer and Murphy (1994) have found that the main determinants of the regional deviation in house prices from the UK average are income, rate of return, index of financial liberalization, mortgage interest rate, mortgage stock/income ratio, rate of acceleration of unemployment and regional population. Xu and Tang (2014) concluded that construction cost, credit, GDP, interest rate, and unemployment rate have a positive impact on house prices, while disposable income and money supply are negatively correlated with house prices. White (2015) confirmed the existence of a cointegrating relationship between Greater London real house price movements and income, gross mortgage lending and interest rates. A recent study carried out by Sivitanides (2018) provide evidence of a strong long run relationship between London house prices and key macroeconomic variables, such as UK GDP, London population and housing completions.

Studies done on an international level demonstrate a similar effect from fundamentals in comparison with studies done in the USA and UK. For example, Englund and Ioannides (1997) confirmed that GDP growth and real interest rate are strongly significant, but demographics do not appear to matter at all. Terrones and Otrok (2004) postulate that the growth rate of real house prices is explained by the past growth rates of real house prices, housing affordability ratio, real income growth, interest rates, the growth rate of real credit, population growth and a bank crisis dummy. The empirical results of Adams and Füss's (2010) study indicate that house prices are affected by construction costs and long term interest rates. Caldera Sánchez and Johansson (2011) concluded that the housing stock tends to have a positive and significant effect on prices in the long run, while the effect of declining interest rates is modest or small.

It is interesting to note that while some of the authors argue that fundamental factors affect housing prices (McCarthy and Peach (2004), Himmelberg *et al.* (2005), Hwang and Quigley (2006), Cameron *et al.* (2006)), others point out that the impact of these factors can be different depending on the data period, the underlying econometric model specifications, affordability indicators and asset pricing approaches (Case and Shiller (1990, 2003), Girouard *et al.* (2006), Mikhed and Zemčik (2009), Kundan Kishor and Marfatia (2017)). In addition, some of the factors

might have stronger effects, while other low or no effect at all (Quigley (1999), Capozza *et al.* (2004), Gallin (2006), Miles and Pillonca (2008), Taltavull de La Paz and White (2012)).

Studies done after the Global financial crisis add other factors to the analysis. For example, Wheaton and Nechayev (2008) point out that second home and speculative buying, as well as the emergence of the risk-priced sub-prime mortgage market, are new and unique factors in the housing market in comparison with previous research in this area. Duca *et al.* (2011) found that credit standards for first-time homebuyers are important determinants of house prices, along with income, real user costs and the housing stock.

In summary, a majority of the literature in housing economics considers factors that might affect house prices both from the demand and the supply side. On the demand side, the typical factors are household income, interest rates on mortgage loans, different demographics, and labour market factors such as population and employment growth. Construction costs and housing stock developments often represent the supply side. The variety of factors that affect house prices are often called "fundamentals." Another group of factors that are different from fundamentals includes expectations and behavior of the market participants, financing conditions, mortgage valuation policies, etc.

3. Data

3.1 Selection of the study objects

The three Swedish and seven German cities were selected for comparative analysis in this study. For various historical, geographical, social, economical and other reasons, the housing market in Germany and Sweden is heterogeneous and diverse in terms of price and types of housing. The largest metropolitan areas in Sweden are Stockholm, Gothenburg, and Malmö.

The biggest German metropolitan areas are often called the "Big 7". They are Berlin, Hamburg, Munich, Cologne, Frankfurt, Stuttgart, Düsseldorf. Because houses in the eastern states of Germany do not meet modern standards of construction, they were not considered comparable for this study, and therefore they excluded from the analysis below (i.e. Berlin). Bremen is added to analysis to make German dataset more comparable with Swedish dataset on city level.

The size of the housing cooperative apartment segment in the total housing stock varies between 24–41 percent in Swedish cities and between 26–45 percent in Germany (Figures A3 and A4 in Appendix 2). The apartment segment represents quite significant and, in some cases, even a major part of the total housing stock in large metropolitan areas, therefore the analysis in this study has a main focus on it.

3.2 Data description

The dataset consists of 2 cross-section panels: 3 major cities in Sweden of 23 periods each (year 1996–2018) and 7 major cities in Germany of 29 periods each (years 1990–2018). The dataset is unbalanced with some missing values for certain variables either at the beginning or at the end of the dataset. All economic variables expressed in real terms. In contrast to all other variables like population and income that are different on the city level, the mortgage interest rate is common for all cities in each country. Data sources and detailed descriptions are presented in Table A1 (Appendix 3). Tables 1 and 2 provide descriptive statistics for Swedish and German cities data [4]. Later, all variables used in econometric estimations transformed into natural logarithm form mainly for the purpose of comparative analysis.

4. The methodology and the model

4.1 The methodological approach

This study applies DiPasquale and Wheaton (1992) theoretical framework for the long run equilibrium model of supply and demand in the housing market. It also applies Adams and

Füss's (2010) approach and Pedroni's (2004) econometric methodology with some smaller modifications explained below. One principal difference is that analysis is done at a cross-city panel level in distinction to Adams and Füss's (2010) study, where the analysis was done on cross-country panel level. City level is more homogeneous compared to country level because countries might differ in socio-economic and legal environments, while cities of the same country do not [5]. Therefore, the comparative analysis of two countries based on two cross-city panels seems to be more appropriate in this setting.

For Sweden, the majority of studies were done on house price data for single-family houses which is available for an extended period (Asal (2018, 2019), Berg (2002), Claussen (2013), Hort (1998), Turner (1997), Wilhelmsson (2008), Yang *et al.* (2010)).

Turner's (1997) analysis focus on transaction prices for cooperative dwellings in Sweden during 1980–1993. He concluded that prices were affected by change in macroeconomic factors, credit deregulation and credit constraints. Hort (1998) applied the restricted error-correction model for real house price changes in 20 urban areas in Sweden in 1967–1994. Her findings confirmed that movements in income, user costs and construction costs had significant impact on real house prices. Berg (2002) argued that after tax real interest rates, stock prices and industrial production were important factors for real house price change in Stockolm region.

Wilhelmsson (2008) investigated the relationship between house prices and income in various regions in Sweden by using a panel data set of over 281 municipalities in 1991–2005. He found that income and employment have positive effect on price to income ratio, while vacancy rates, income tax and mortgage rates affected it in opposite way. Yang *et al.* (2010) measured the impact of interest rate shocks on regional house prices in Sweden in 1991–2002. They have found significant differences in monetary policy effects at regional level in Sweden. Claussen (2013) came to the conclusion that growth of house prices in Sweden in

Variable name	Number of observations	Mean	Standard deviation
Price for apartments per sq.m, SEK	69	24751.2	17221.7
Population, number of inhabitants	87	1142741.0	585846.9
Apartment stock in multifamily buildings, dwellings	87	141254.7	108063.9
Total apartment stock per capita	87	0.5	0.0
Disposable income per capita, thousands SEK	69	155.0	41.6
Mortgage interest rate, percent	78	3.4	2.1
Unemployment rate, percent	42	8.6	2.2

Table 1. Descriptive statistics for Swedish cities

Variable name	Number of observations	Mean	Standard deviation
Price for apartments per sq.m, Euro	203	2252.8	889.9
Population, number of inhabitants	203	919487.4	423730.5
Apartment stock in multifamily buildings, dwellings	161	154793.3	73324.5
Total apartment stock per capita	196	0.5	0.0
Disposable income per capita, Euro	154	20415.4	2963.5
Mortgage interest rate, percent	175	3.0	1.9
Unemployment rate, percent	147	8.6	2.4

Table 2. Descriptive statistics for German cities

1986–2011 might be explained by the development of household real disposable income, after tax real mortgage rate and household real financial wealth.

One of the recent studies done by Asal (2018) demonstates that growth of real house prices in Sweden in 1986–2016 was affected by growth in mortgage credit, real after-tax mortgage interest rates, disposable income and the real effective exchange rate. Asal (2019) study suggest that Swedish real house prices have been overvalued since the mid-2000s and that undervaluation of the real exchange rate partially explains the recent buildup of the housing bubble.

Apartment prices data in Sweden covers slightly more than about two decades, which is a rather short period, if observations are taken annually. To overcome this restriction, it is worth following the methodology applied in Adams and Füss (2010) and applying the panel cointegration approach proposed by Pedroni (1999, 2004). This approach allows us to use the T observations of time series of a single city as well as to pool the observable data over all cities N so that the effect of $N \cdot T$ real observations is available for analysis. The advantage of this method is that: (1) it provides robust estimations due to larger sample asymptotics; (2) it estimates the country result at aggregated level by weighting the individual cities estimations; and (3) it presents differences among cities' elasticities, which allows us to analyze the level of cross-city integration. In addition, Adams and Füss (2010) point out that the panel data variables on house prices and their fundamentals are often cointegrated even when there is no cointegration between them in individual time series (Adams and Füss, 2010, p. 38).

Previous research done on German data includes, for example, studies done by Dust and Maening (2007), Koetter and Poghosyan (2010) that analyze single-family house prices at a regional level and include shorter time series such as one year or a decade. The study carried out by Kajuth *et al.* (2013) differentiates between single-family houses and apartments and point to significant effects of the housing stock per capita, income per capita, unemployment, population density, and growth expectations on house prices. They conclude that apartments in German cities show significant overvaluation of between 5 and 7 percent in the years 2011 and 2012, while single-family houses do not. Belke and Keil (2018) demonstrated that supply-side factors such as construction activity and housing stock as well as the demand side factors in the form of apartment rents, market size, age structure, local infrastructure and rental prices are robustly linked to fundamental real estate prices and thus can be used to detect misalignments of market prices.

In distinction to the previous Swedish and German studies presented above and which are mainly based on data for single-family houses, this study focuses on the apartment segment of the market and examines apartment price elasticities from a long term perspective. In addition, the results from this study highlight the differences between the two countries at the city level in an integrated long run equilibrium framework.

4.2 Macroeconomic fundamentals of apartment prices in the long run

In line with DiPasquale and Wheaton (1992) model and the literature review presented in Section 2, the following variables were chosen for analysis as macroeconomic fundamentals of apartment prices in the long run:

(1) *Disposable income:* According to DiPasquale and Wheaton (1992), an increase in economic activity leads to an increase in demand for space, D. This shifts the demand curve to the right and leads to an increase in rents, R, which increases house prices, P. According to Adams and Füss (2010), the widely used indicator of economic activity is disposable income, I. Therefore, the long run price elasticity of income is determined as follows:

$$\underbrace{\frac{\partial P}{\partial I}}_{+} = \underbrace{\frac{\partial P}{\partial D}}_{+} \cdot \underbrace{\frac{\partial D}{\partial I}}_{+} \tag{1}$$

(2) *Mortgage interest rate:* An increase in the mortgage interest rate affects the demand for houses negatively. A higher mortgage interest rate, r, lead to lower demand, which in turn decrease construction, C, and thus translates to lower housing stock, S. Lower housing stock increases rents, R, and house prices, P. Therefore, the long run price elasticity to mortgage interest rate is determined as follows:

$$\underbrace{\frac{\partial P}{\partial r}}_{-} = \underbrace{\frac{\partial P}{\partial S}}_{+} \cdot \underbrace{\frac{\partial S}{\partial C}}_{-} \cdot \underbrace{\frac{\partial C}{\partial D}}_{-} \cdot \underbrace{\frac{\partial D}{\partial r}}_{-} \tag{2}$$

(3) *Housing stock and construction:* An increase in construction leads to the higher housing stock in the long run and vice versa. Higher housing stock lead to lower house prices keeping all other variables unchanged. Thus, the long run elasticity of prices to construction is determined as:

$$\underbrace{\frac{\partial P}{\partial C}}_{+/-} = \underbrace{\frac{\partial P}{\partial S}}_{-} \cdot \underbrace{\frac{\partial S}{\partial C}}_{+} \tag{3}$$

The minus sign of the effect of the construction and housing supply on house prices depends on the size of the construction in relation to the shift in demand. If overbuilding occurs, the effect of construction and thus increase in the supply of housing will be negative, while if the opposite situation takes place. i.e. when the size of the construction corresponds to the shift in demand or is less than that, the effect on prices will be either zero or positive [6].

(4) *Population:* Many studies found insignificant or even adverse effects of population growth, H, on house prices (Mankiw and Weil (1989), Hort (1998), Poterba (1991)). Nevertheless, this study considers it because population growth is one of the driving factors behind rapid urbanization and increasing housing demand in the cities. An increase in population might happen through natural demographic growth like baby boom periods, as well as high immigration from outside of the country and natural urbanization processes when people move to the cities from rural areas. Adding this variable to the equation of house prices might also help to avoid omitted variable bias. An increase in population lead to higher demand for space, D, thus leading to an increase in house prices, P. The price elasticity of population growth is determined as follows:

$$\underbrace{\frac{\partial P}{\partial H}}_{+} = \underbrace{\frac{\partial P}{\partial D}}_{+} \cdot \underbrace{\frac{\partial D}{\partial H}}_{+} \tag{4}$$

(5) *Unemployment rate:* Higher unemployment, U, is usually observed over periods with low economic activity and, therefore, considered as a factor that leads to a decrease in

demand for housing. Moreover, considering the unemployment rate as a part of the equation for house prices might help to capture the effect of the changes in the employment rate of the labour force that is part of the population. Thus, the price elasticity of the change in unemployment rate is determined as follows:

$$\underbrace{\frac{\partial P}{\partial U}}_{-} = \underbrace{\frac{\partial P}{\partial D}}_{-} \cdot \underbrace{\frac{\partial D}{\partial U}}_{-} \tag{5}$$

4.3 The long run model of supply and demand

In line with DiPasquale and Wheaton (1992) model the demand function is given as

$$D_t = \alpha + \beta' x_t^D + \delta' z_t^D + e_t, \tag{6}$$

where x_t^D is a vector of macroeconomic variables affecting demand. Vector z_t^D captures city-specific factors affecting the housing demand at the micro-level, such as location, social environment, mortgage market characteristics, and taxation regulations. For estimation of the macroeconomic impact on the house prices the vector z_t^D should be incorporated into the error term, e_t, and Eq. (6) will be written as

$$D_t = \alpha - \beta_1 P_t + \beta_2 H_t + \beta_3 I_t - \beta_4 r_t - \beta_5 U_t + \tilde{e}_t. \tag{7}$$

In Eq. (7) higher house prices P_t have a negative impact on demand (unless it is not a speculative demand), while higher income or population growth has a positive effect on demand. Higher mortgage rate and unemployment rate are expected to have negative effect on demand for housing.

In a similar way housing supply is given by

$$S_t = \eta + \gamma' x_t^S + \lambda' z_t^S + \nu_t. \tag{8}$$

According to Colwell (2002), the long run supply of houses is directly connected to the construction of new houses and the depreciation levels of housing stock. Housing construction depends on house price level and construction costs. Construction costs include a wide range of cost items, including building materials and transportation, as well as labour costs. It is reasonable to assume that the construction costs level is not very diverse among different housing developers due to competition in the construction industry. Thus, change in construction costs affect long run housing supply through construction level in the short run.

One more component that affects the long run supply of houses is the depreciation rate. Since the maintenance level and overall housing standard is quite high in Sweden and Germany, we can assume that the depreciation rate is close to zero and to ignore the effect depreciation has on housing supply. Therefore, in line with DiPasquale and Wheaton (1992) and Colwell (2002), the long run housing supply equals to initial housing stock plus aggregated housing construction over the long term minus depreciation of housing stock. With an assumption of zero depreciation rate, the long run housing supply equals to total aggregated housing construction or total housing stock constructed over the long term.

Thus, the supply equation is expressed as

$$S_t = \eta + \gamma_1 P_t + \gamma_2 S_t + \tilde{\nu}_t, \tag{9}$$

which incorporates micro factors such as the availability of land, governmental building provisions, construction costs level and depreciation of housing into the error term, $\tilde{\nu}_t$.

In Eq. (9) higher house prices act as an incentive for housing developers to increase the supply of houses. Given that supply equals demand in equilibrium relationship, and then solving for house prices and considering panel structure, the final equation for house price will be

$$P_{it} = \alpha_i^* - \gamma_{2i}^* S_{it} + \beta_{2i}^* H_{it} + \beta_{3i}^* I_{it} - \beta_{4i}^* r_{it} - \beta_{5i}^* U_{it} + e_{it}^*, \quad (10)$$

with

$$\alpha_i^* = \frac{\alpha_i - \eta_i}{\gamma_{1i} + \beta_{1i}}, \gamma_{2i}^* = \frac{\gamma_{2i}}{\gamma_{1i} + \beta_{1i}} = \frac{\partial P_i}{\partial S_i}, \beta_{2i}^* = \frac{\beta_{2i}}{\gamma_{1i} + \beta_{1i}} = \frac{\partial P_i}{\partial H_i}, \beta_{3i}^* = \frac{\beta_{3i}}{\gamma_{1i} + \beta_{1i}} = \frac{\partial P_i}{\partial I_i},$$

$$\beta_{4i}^* = \frac{\beta_{4i}}{\gamma_{1i} + \beta_{1i}} = \frac{\partial P_i}{\partial r_i}, \beta_{5i}^* = \frac{\beta_{5i}}{\gamma_{1i} + \beta_{1i}} = \frac{\partial P_i}{\partial U_i}, \text{and } e_{it}^* = \tilde{e}_{it} \ - \tilde{\nu}_{it}.$$

According to the theoretical model outlined above the expected sign for $\gamma_{2i}^*, \beta_{4i}^*, \beta_{5i}^*$ is negative, and for β_{2i}^* and β_{3i}^* is positive.

The econometric approach in this study is to apply the cointegration analysis for non-stationary panel data. The panel data combines information on the variation of the city data with information over time. The analysis is done on two levels: (1) The variables are tested for stationarity using panel unit root tests; (2) The long run equilibrium relationships are estimated though panel cointegration tests.

4.4 Panel unit root tests

Im *et al.* (2003) proposed the unit root test that allows for heterogeneous autoregressive roots known as the IPS test. Results of IPS stationarity tests for the Swedish and German datasets are presented in Tables 3 and 4. As it comes from the *p*-values from the IPS test the null hypothesis could not be rejected for all variables. Taking first differences revials stationarity in the panel setting so that all variables are considered as $I(1)$ and thus suitable for cointegration test procedure.

4.5 Panel cointegration test

The Pedroni (2000) test for cointegration is applicable to heterogeneous panel with multiple regressors. This test also allows for unbalanced panels to be tested. Pedroni (2000, 2004) demonstrates that under general requirements the test statistics follow a normal distribution as T and N grow large and that the group and panel ADF statistics have the best power

Variables	Level		First difference	
	t-bar	*p*-value	*t*-bar	*p*-value
Apartment price per sq.m, SEK	−1.6713	0.3654	−3.7103***	0.0006
Population, number of inhabitants	0.1775	0.9998	−2.2293*	0.0838
Apartment stock in multifamily buildings, dwellings	−0.6026	0.9683	−2.5075**	0.0333
Disposable income per capita, thousands SEK	−2.1121	0.1284	−5.1196***	0.0000
Mortgage interest rate, percent	−1.0175	0.6997	−3.3777**	0.0386
Unemployment rate, percent	−2.5059*	0.0600	−4.8580***	0.0004

Note(s): The IPS test is based on the individual ADF regressions with an intercept, trend, and the first lag of the dependent variable. The test statistic has an asymptotic standardized normal distribution
* denotes rejection of the null hypothesis of unit root based on their *p*-value at the 0.10 significance level
** denotes rejection of the null hypothesis of unit root based on their *p*-value at the 0.05 significance level
*** denotes rejection of the null hypothesis of unit root based on their *p*-value at the 0.01 significance level

Table 3.
Stationarity test for Swedish variables

Variables	Level		First difference	
	t-bar	*p*-value	*t*-bar	*p*-value
Apartment price per sq.m, Euro	−0.8855	0.9739	−4.3016***	0.0000
Population, number of inhabitants	−0.4320	0.9996	−4.3768***	0.0000
Apartment stock in multifamily buildings, dwellings	−1.6250	0.4004	−2.7139***	0.0009
Disposable income per capita, Euro	−2.0931**	0.0420	−4.6199***	0.0000
Mortgage interest rate, percent	−0.9750	0.7166	−4.4288**	0.0118
Unemployment rate, percent	−1.9508	0.1023	−3.9213***	0.0000

Note(s): The IPS test is based on the individual ADF regressions with an intercept, trend, and the first lag of the dependent variable. The test statistic has an asymptotic standardized normal distribution
** denotes rejection of the null hypothesis of unit root based on their *p*-value at the 0.05 significance level
*** denotes rejection of the null hypothesis of unit root based on their *p*-value at the 0.01 significance level

Table 4.
Stationarity test for German variables

properties when $T < 100$, with the panel v and group p-statistics performing comparatively worse.

Table 5 presents Pedroni (1999) test statistics for the Swedish dataset. A group ADF test statistic of −1.672 for the Pedroni (1999) test rejects the null hypothesis of no cointegration at a 5 percent significance level. Thus, apartment prices in Sweden are cointegrated with apartment stock, population, disposable income, mortgage interest rate, and unemployment.

Table 6 presents Pedroni (1999) test statistics for the German dataset. A test statistic of −2.086 for the Pedroni (1999) test rejects the null hypothesis of no cointegration at a 5 percent significance level. Thus, apartment prices in Germany are cointegrated with apartment stock, population, disposable income, mortgage interest rate, and unemployment.

4.6 Cointegration-vector estimates

The single equation cointegration vector estimator proposed by Engle and Grander (1987) provides consistent estimations when the sample size T is large, but the statistical properties might be different for a smaller sample size. Inder (1993) and Stock and Watson (1993) demonstrate with macroeconomic time series data that results might produce quite poor estimations when the number of observations is not large.

The Panel Dynamic Ordinary Least Squares (DOLS) estimator introduced by Saikkonen (1991), Phillips and Moon (1999), and Pedroni (2000) augments the conventional OLS estimator by taking serial correlation and endogeneity of the regressors into account. In a

Test statistics	Panel	Group
v	−1.599	
rho	1.643	2.388
t	−5.480***	−6.638***
ADF	0.187	−1.672**
Number of panel units	3	
Number of regressors	5	
Number of observations	39	

Note(s): Null Hypothesis: No cointegration. Time trend is included. Data have not been time-demeaned. Automatic lag length selection based on AIC [7]
All statistics are from Pedroni's procedure (1999), where the adjusted values can be compared to the $N(0, 1)$ distribution. The Pedroni (2004) statistics are one-sided tests with a critical value of −1.64 ($k < -1.64$ implies rejection of the null), except the v-statistic that has a critical value of 1.64 ($k > 1.64$ suggests rejection of the null)
***, ** indicates rejection of the null hypothesis of "No cointegration" at 1% and 5%, levels of significance

Table 5.
Pedroni (1999) test statistics for the Swedish dataset

Test statistics	Panel	Group
v	−0.688	
rho	1.793	2.878
t	−0.257	0.006
ADF	1.212	−2.086**
Number of panel units	7	
Number of regressors	5	
Number of observations	133	

Note(s): Null Hypothesis: No cointegration. Time trend is not included. Data have been time-demeaned. Automatic lag length selection based on AIC
All statistics are from Pedroni's procedure (1999), where the adjusted values can be compared to the $N(0, 1)$ distribution. The Pedroni (2004) statistics are one-sided tests with a critical value of −1.64 ($k < -1.64$ implies rejection of the null), except the *v*-statistic that has a critical value of 1.64 ($k > 1.64$ suggests rejection of the null)
** indicates rejection of the null hypothesis of "No cointegration" at 5% level of significance

Table 6. Pedroni (1999) Test statistics for the German dataset

series of Monte-Carlo simulations Kao and Chiang (2000) and Mark and Sul (2003) test the small sample performance of the panel DOLS estimator and provide evidence that it, in general, outperforms single-equation estimation techniques.

Keeping in mind restrictions that are valid for the dataset used in this study the main goal is to obtain the coefficient vector estimate γ' of

$$y_{it} = a_i + \gamma' x_{it} + u^*_{it}, \tag{11}$$

with the regressors x_{it} being integrated of order 1: $x_{it} = x_{it-1} + v_{it}$. In Eq. (11) y_{it} is the apartment price of a city i and time t and x_{it} is a $5x1$ vector of apartment stock, population, disposable income, mortgage interest rate, and unemployment rate of city i and time t respectively. Correlation of the additional error component v_{it} with u^*_{it} is a potential source of bias and an effective protection from this bias is to explicitly control for this relationship by regressing u^*_{it} on p leads and lags of v_{it},

$$u^*_{it} = \sum\nolimits_{s=-p}^{+p} \delta'_{is} v_{it-s} + u_{it} = \sum\nolimits_{s=-p}^{+p} \delta'_{is} \Delta x_{it-s} + u_{it} = \delta'_{is} z_{it} + u_{it}, \tag{12}$$

where the second equality follows from $x_{it} = x_{it-1} + v_{it}$ and the third equality is simply a vectorized notation to conserve space [8]. Inserting this expression into (11) yields the endogeneity and serial-correlation adjusted regression:

$$y_{it} = a_i + \gamma' x_{it} + \delta'_i z_{it} + u_{it} \tag{13}$$

from which the coefficient vector $\beta_{DOLS} = (\gamma', \ \delta'_i, \ \ldots, \ \delta'_N)'$ can be obtained.

The interpretation of the DOLS estimator is similar to a conventional panel OLS estimator except in one important respect: A fixed-effect estimator would show the response of apartment prices at a time t or generally at a time $t - p$. The DOLS estimator shows the *long run* effects, which capture the accumulation of effects over time, as well as the stickiness of apartment prices. Thus, if all variables are in natural logarithms, the elements of the coefficient vector $\gamma' = (\gamma'_{1i}, \gamma'_{2i}, \gamma'_{3i})$ demonstrates the average long term percentage in the regressor.

5. Empirical results

Table 7 demonstrates the estimation results for each city in Sweden as well as for the whole panel at the country level. In the latter case, the coefficients were obtained by averaging the

Table 7.
DOLS estimates for Swedish cities

City	Apartment stock		Population		Disposable income		Mortgage interest rate		Unemployment rate	
	Coef	*t*-stat	Coef	*t*-stat	Coef	*t*-stat	Coef	*t*-stat	Coef	*t*-stat
Stockholm	2.158***	49.94	7.332***	11.88	1.921***	17.55	−0.358***	−11.66	−0.207*	−1.43
Gothenburg	3.681***	19.94	13.61***	5.09	2.65***	8.01	−0.526***	−21.11	−0.916***	−7.27
Malmö	5.249***	34.12	5.534***	5.56	3.219***	8.24	−0.484***	−17.19	0.689***	6.44
Number of obs	21		21		18		21		9	
t-stat critical value at	df = 19	2.539	df = 19	2.539	df = 16	2.583	df = 19	2.539	df = 7	2.998
1%, 5%, 10% significance level		1.729		1.729		1.746		1.729		1.895
		1.328		1.328		1.337		1.328		1.415
Panel group DOLS (group mean average)										
Coefficient	3.696***	60.04	8.826***	13.01	2.597***	19.51	−0.456***	−28.84	−0.145	−1.31
Number of obs	63		63		54		63		27	
t-stat critical value at	df = 61	2.390	df = 61	2.390	df = 52	2.423	df = 61	2.390	df = 25	2.485
1%, 5%, 10% significance level		1.671		1.671		1.684		1.671		1.708
		1.296		1.296		1.303		1.296		1.316

Note(s): * and *** represent significance at error levels of 10% and 1%, respectively

individual city coefficients. Therefore, we can interpret the panel group coefficients as a group country's results.

Population and disposable income have a positive impact. Thus, a one percent increase in population leads to an 8.8 percent increase in apartment prices, and a one percent increase in disposable income leads to a 2.6 percent increase in apartment prices. This estimation of income elasticity of prices for apartments is higher than approximately one present elasticity found by Hort (1998), Claussen (2013) and Asal (2018) for single-family house prices in Sweden, and when compared to results of this study for the German dataset, which indicate that a one percent increase in disposable income leads to an almost one percent increase in apartment prices in German cities. As Terrones and Otrok (2004) note, real income growth per capita increases households' purchasing power and borrowing capacity, which, together with lower interest rates, increases households' capacity to borrow and drives house prices up.

Despite the expected negative impact on apartment prices from the supply side, apartment stock estimate has a positive sign–a one percent increase in apartment stock leads to a, on average, 3.7 percent increase in apartment prices in Swedish cities. Meen (2002) argues that if the housing supply is perfectly inelastic, the increase in demand will be choked off by higher prices. At the other extreme, if supply is fully elastic, the output will increase to the point at which prices are unchanged and therefore, higher supply elasticities induce lower long run income elasticities of house prices. Moreover, the ratio of house prices to income in the long run not only is determined by the *direct* estimate of the coefficient on income in the house price equation but is a *systems* property depending also on the effect of the housing stock on prices and the price elasticity of new housing supply (Meen (2002), p. 12). Housing supply in Sweden is not considered as perfectly elastic due to regulations that exist in the rental sector, and this leads to the process that demand for apartments in housing cooperatives is continually growing despite persistent growth in prices, which in turn perfectly corresponds to the supply side response over the long term.

The mortgage interest rate has an inverse impact on apartment prices. A one percent decrease in mortgage interest rate leads to a 0.456 percent increase in apartment prices in Swedish cities but only a 0.095 percent increase in German cities. Estimation of mortgage interest rate impact in Sweden is similar to estimation result of −0.45 percent obtained for single-family house prices in study done by Adams and Fuss (2010). It is worth noting that the effect of the increase in mortgage interest rates might be different from the effect when decrease occurs. Claussen (2013) reported that an increase in the after tax real mortgage rate of one percentage point is associated with a reduction in the long run equilibrium level of the single-family house prices by 6 percent, while in Asal (2018) study this estimation was 8 percent and in Asal (2019) study 2 percent.

The results strongly confirm the theoretical implications of the DiPasquale and Wheaton (1992) model. However, individual effects vary widely among cities. For example, the effect of population growth on apartment prices in Gothenburg is about twice as large as in Stockholm and Malmö. Unemployment has a negative effect in Gothenburg, while positive in Malmö and is insignificant in Stockholm. The impact of unemployment is insignificant at the country level.

The results for the German dataset in Table 8 indicate that apartment stock, mortgage interest rate, and unemployment reduce apartment prices. Thus, a one percent increase in apartment stock leads to 2.4 percent decrease in apartment prices, while a one percent decrease in the mortgage interest rate leads to a 0.095 percent increase in apartment prices in German cities. The unemployment rate has a negative effect, though it is not that strong – only 0.43 percent.

The effect of the population variable was found insignificant for Germany. However, individual cities' effect varies a lot from a highly positive impact of 9.7 percent in Düsseldorf

Table 8.
DOLS estimates for German cities

City	Apartment stock		Population		Disposable income		Mortgage interest rate		Unemployment rate	
	Coef	*t*-stat	Coef	*t*-stat	Coef	*t*-stat	Coef	*t*-stat	Coef	*t*-stat
Bremen	2.337***	11.48	2.152***	4.01	−3.879**	−2.35	−0.045*	−1.59	0.05	0.30
Cologne	−0.937***	−7.41	−5.92***	−8.69	2.564***	3.67	−0.073***	−3.14	0.87	1.03
Düsseldorf	−2.377***	−7.17	9.697***	8.64	1.494	1.08	−0.061**	−2.54	−1.602***	−5.14
Frankfurt (main)	−1.929**	−1.82	−5.83***	−6.12	2.739***	3.29	−0.084***	−5.79	1.119***	3.4
Hamburg	−3.817	−1.15	−3.657***	−6.12	1.521	1.23	−0.122***	−3.66	−1.464**	−2.22
Munich	−7.32	−0.40	3.339***	6.87	0.04	0.04	−0.178***	−5.43	−3.463***	−4.73
Stuttgart	−2.565**	−2.48	0.187	0.14	2.269	1.33	−0.104***	−4.18	1.502***	3.27
Number of obs	18		24		17		20		16	
t-stat critical value at	df = 16	2.583	df = 22	2.508	df = 15	2.602	df = 18	2.552	df = 14	2.624
1%, 5%, 10% significance level		1.746		1.717		1.753		1.734		1.761
		1.337		1.321		1.341		1.330		1.345
Panel group DOLS (group mean average)										
Coefficient	−2.373***	−3.39	−0.004	−0.48	0.964***	3.13	−0.095***	−9.95	−0.427*	−1.55
Number of obs	126		168		119		140		112	
t-stat critical value at	df = 124	2.358	df = 166	2.358	df = 117	2.364	df = 138	2.358	df = 110	2.368
1%, 5%, 10% significance level		1.658		1.658		1.660		1.658		1.662
		1.289		1.289		1.290		1.289		1.291

Note(s): *, **, and *** represent significance at error levels of 10%, 5%, and 1%, respectively

to minus 5.9 percent in Cologne and minus 5.8 percent in Frankfurt, which lies in line with previous research (Mankiw and Weil (1989)).

Comparison of results in Tables 7 and 8 provide evidence that the impact of Swedish fundamentals, in general, is much stronger than the impact of German fundamentals. However, if one is to compare the descriptive statistics of Swedish and German data (Tables 1 and 2), the size of fundamentals in both countries are quite similar. Moreover, the development of fundamentals over the long run are not able to explain the large difference of 759 percent in apartment price dynamics between two countries (Table 9). The population and disposable income that are drivers of apartment prices from the demand side were growing much faster in Swedish cities than in Germany, but the apartment stock that affects prices from the supply side also demonstrated much stronger growth. This would balance the pressure on housing prices from the demand and supply side. The mortgage interest rate was falling faster in German cities, and that drives apartment prices up, but the effect is quite moderate in comparison to Swedish cities.

6. Conclusions and policy implications

This study examines the impact of macroeconomic fundamentals on apartment prices in Germany and Sweden in the long run. The estimations presented in this paper lead to one important conclusion that is different from the studies done before: apartment price dynamics in Swedish cities differs, to a great extent, from those in German cities despite quite similar underlying development of fundamentals. The results have demonstrated that fundamental factors like population, disposable income, mortgage interest rate, and apartment stock determine the development of apartment prices in Sweden over the long term, but the reactions of the same factors are smaller in Germany.

Why do similar changes in fundamentals results in different long term dynamics of apartment prices in Germany and Sweden? One of the hypotheses might be that it might be the evidence of the price bubble building in Sweden. Another hypotheses might be that these two countries differ in institutional arrangements of the housing markets, and these arrangements might contribute to the size of apartment price elasticities from changes in fundamentals. These arrangements include various banking sector policies, such as

Variables	Time period	Swedish cities Total growth, %	Swedish cities Per annum, %	German cities Total growth, %	German cities Per annum, %	Difference Total growth, %	Difference Per annum, %
Price for apartments per sq.m, SEK	1996–2016	831.84	11.57	72.82	2.68	759.02	8.89
Population, number of inhabitants	1996–2016	25.75	1.15	9.78	0.46	15.97	0.69
Apartment stock in multifamily buildings, dwellings	1996–2016	73.88	2.72	26.50	1.18	47.38	1.54
Disposable income per capita, (thousands SEK/Euro)	1996–2016	120.06	4.02	39.20	1.67	80.86	2.35
Mortgage interest rate, percent	1996–2016	−85.67	−4.30	−100.03	−5.03	14.36	0.73
Unemployment rate, percent	2005–2016	−10.42	−0.95	−39.66	−3.61	29.24	2.66

Table 9. Long run development of fundamentals in Swedish and German cities

mortgage financing and valuation approaches, as well as different government regulations of the housing market as, for example, rent control. A study of these institutional arrangements and their implications for housing price dynamics might be an interesting topic for further research.

Notes

1. See section 2 for research overview on macroeconomic determinats of housing prices.
2. The search for housing price determinants studies was done using the Royal Institute of Technology (Sweden) library catalogue, which includes over 100 databases and subscriptions to over 11,000 e-journals as well as a large number of open access resources.
3. For extended research overview in housing and macroeconomics see, for example, studies done by Leung (2004), Panagiotidis and Printzis (2016), Piazzesi and Schneider (2016).
4. Taking into account that the exchange rate between Swedish krona and Euro fluctuated between 8.5 and 10 SEK to 1 Euro over the last two decades (Source: ECB), the simple calculation of economic variables in both countries into the same currency allows the conclusion to be drawn that underlying fundamentals presented in Tables 1 and 2 are very similar in both countries.
5. At the same time cities of the same countries might be heterogeneous due to local socio-economic differences.
6. For the effects of supply elasticity on house prices see, for example, studies done by Glaeser *et al.* (2008) and Oikarinen *et al.* (2018). They provide evidence that lower supply elasticity caused larger and longer price bubbles in the 2000s. However, the study done by Davidoff (2013) concludes that there is no evidence that differences in supply elasticity caused different reactions in house prices in the USA during the 2000s housing cycle. Hort (1998) explains that "The long-run supply of housing is likely to be an increasing function of the level of house prices for two reasons. First, since the supply of urban land is fixed, land prices tend to increase with the size of the urban housing stock, i.e. as land for development becomes more scarce. Second, unless the production possibility frontier between structures and other goods is flat, the long-run equilibrium price of new structures will be an increasing function of demand." (Hort, 1998, p. 95)
7. Akaike's information criterion (AIC) is used to estimate the autoregressive lag length. It is superior to the other criteria under study in the case of a small sample in the way that it minimizes the chance of under estimation while maximizing the chance of recovering the true lag length (Khim-Sen (2004)).
8. p is usually chosen to be around 2 for annual observations.

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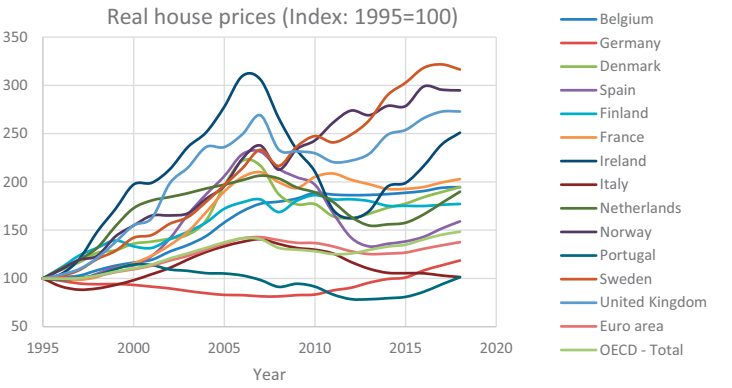
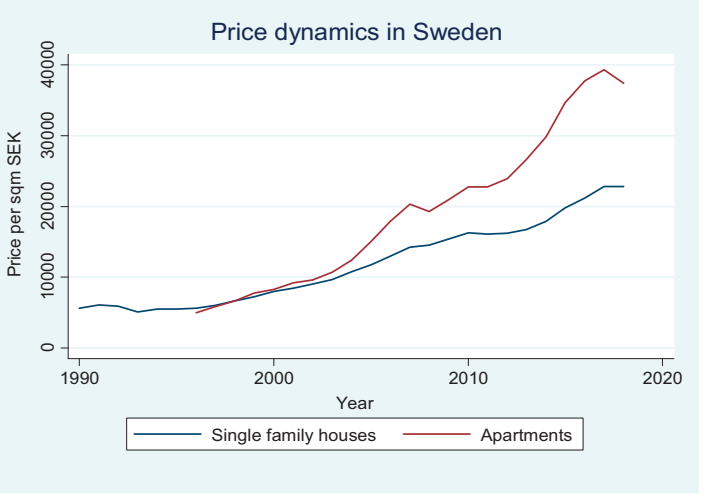
Appendix 1



Source(s): Eurostat

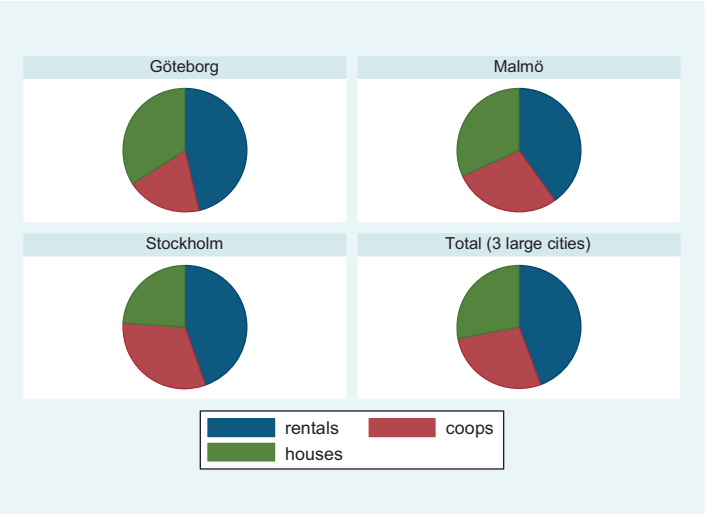
Figure A1.
Real house prices (Index: 1st quarter 1995 = 100)



Source(s): Mäklarstatistik

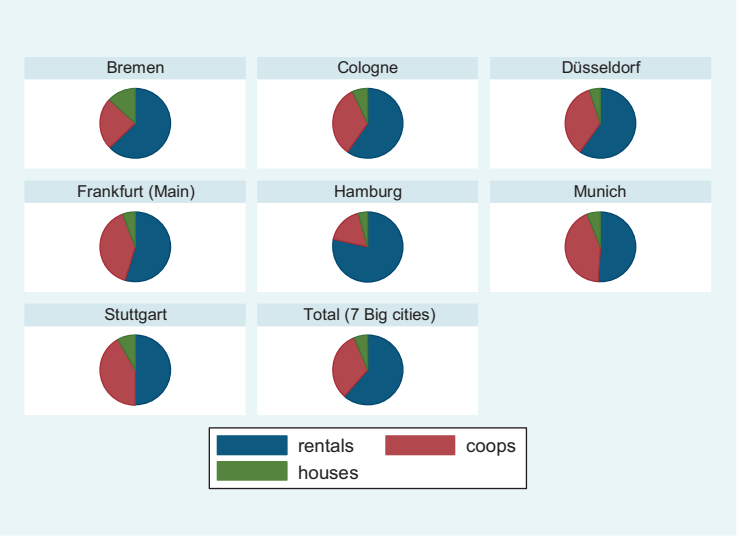
Figure A2.
Housing price dynamics in Sweden

Appendix 2



Source(s): SCB

Figure A3. Housing market structure by tenure type in Sweden



Source(s): BulweinGesa AG

Figure A4. Housing market structure by tenure type in Germany

Appendix 3

Table A1. Variables definitions and data sources

Variable	Definition	Unit	Data source
Apartment price	Real apartment price per square meter (average)	EUR (Germany) SEK (Sweden)	National Statistical Bureau and Mäklarstatistik (Sweden) BulweinGesa AG (Germany)
Population	Total number of inhabitants	Person	National Statistical Bureau (Sweden) BulweinGesa AG (Germany)
Apartment stock in multifamily buildings	Total apartments stock (existing and new construction)	Number of dwelling units	National Statistical Bureau (Sweden) BulweinGesa AG (Germany)
Disposable income per capita	Real disposable income of private persons	Thousands SEK (Sweden) EUR (Germany)	National Statistical Bureau (Sweden) BulweinGesa AG (Germany)
Mortgage interest rate	Interest rate for mortgage borrowing	Percent	Riksbanken and Swedbank (Sweden) Deutsche Bundesbank (Germany)
Unemployment rate	Unemployed persons as proportion in a total labour force	Percent	National Statistical Bureau (Sweden) BulweinGesa AG (Germany)

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