TALLINN UNIVERISTY OF TEHCNOLOGY
School of Business and Governance
Department of Economics and Finance

Andres Toome

# DETERMINANTS OF HOUSING PRICES IN REAL ESTATE MARKET CYCLES

Master's thesis

Supervisor: Karsten Staehr, PhD

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Andres Toome ……………………………
(signature, date)
Student code: 153729TARM
Student e-mail address: toome.andres@gmail.com

Supervisor: Karsten Staehr, PhD:
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# ABSTRACT

The underlying research subject of the current master thesis is the German housing market between the fourth quarter of 1989 and the fourth quarter of 2017. The purpose of current master thesis is to give an overview of the German housing market, determine the fundamental factors that have influenced housing prices and provide evidence of the cyclicality of German housing market. The perspective of this thesis is relevant for real-estate investors and home-buyers alike. It can serve as a guideline for navigating in the German housing market and provides insight for investment decisions. This master thesis provides a thorough overview of the German real estate market and housing market in particular. The mechanics of the real estate and housing markets are explained in detail. Furthermore, the difference of fundamental and speculative aspects of housing prices is outlined. The resulting cyclical behavior of real estate markets is elaborated and the formation of bubbles within the real estate markets is discussed. For the econometric analysis Engle-Granger two-step approach is used. In the first step cointegration relationship between variables is determined and the residuals from the regression used as an input for the error correction model (ECM). The two-step approach provides insight about the long-term relationship between the variables and quantifies the short-term deviation of prices from the long-term equilibrium level. Factors such as real long-term interest rate, real construction costs, real disposable income and unemployment rate have an inverse long-term association with house prices in Germany. Conversely, population and housing permits have a positive long-term association with house prices in Germany. Real money supply was the only variable that was statistically insignificant. Error correction model results outline that the short-term deviation from the long-term equilibrium level in the previous period will be adjusted by 12% in the current period. The findings suggest that the short-term deviations have been of a higher magnitude and duration after 2003. The highest level of overvaluation was achieved in the second quarter of 2005, whereas the valuation in German housing market reached its bottom in 2010. Current price level reflects a high degree of overvaluation in German house prices as of fourth quarter of 2017.



**Keywords:** house prices, German housing market, real estate market cycle, fundamental factors, bubbles, Engle-Granger two-step approach, conintegration, error correction model

# INTRODUCTION

Real estate is one of the most important sectors in the economy with significant contribution to the GDP. According to Eurostat real estate amounts to approximately 10% of GDP in Europe and according to U.S. Department of Commerce real estate contribution to GDP is approximately 13% in the United States in 2016. The housing markets in particular are of great importance in the overall economy. The affordability of housing and the rental prices have a direct impact on the wealth of property owners and tenants, effectively influencing consumer spending. Hence, the development of housing markets is not only followed closely by private households, commercial banks and institutional investors, but also by central banks and governments for their monetary and fiscal policy decisions.

The collapse of Lehman Brothers and Bear Sterns in 2008 demonstrated how severe consequences the deterioration of housing markets can have on financial institutions. Besides lending substantial sums to real estate businesses banks rely heavily on real estate as collateral and an underlying asset for financial instruments. Real estate investments are highly capital intensive and the use of leverage for direct investments are inevitable in most cases. Real estate serves as collateral for lenders and provides the banking industry assurance if loan repayments become delinquent. Although the international economy and real estate markets are highly interlinked in many ways, housing markets still possess idiosyncratic attributes. The price boom in major housing markets across the world prior the bursting of the bubble in 2007 was not characteristic for the German housing market. In fact, real house prices in Germany declined between 1996 and 2010. The subsequent rally in prices has raised questions about the sustainability of recent price gains and has brought the German housing market under the attention of wider public. Therefore, a study into the housing market in Germany is the research object of this thesis.

Price development in the housing market is of great interest to home owners and real estate investors alike. Their wealth is directly influenced by the changes in house prices. Hence, an investigation of the fundamental factors that have the ability to explain house prices is vital. To understand the price mechanism of house prices it is essential to understand how the supply and demand dynamics work in real estate markets. A set of macroeconomic variables is introduced in this thesis, which could affect the supply and demand for housing and thereby the price determination process. The selection of variables is mainly based on the work of Xu and Tang (2014) and is modified to include variables that could be particularly relevant in the German housing market.

Although fundamental factors are highly important to determine house prices, it is clear that at times this is not sufficient to completely explain the price movements in housing markets. After the recent housing crisis it has become obvious to the general public that pre-crisis housing prices were overvalued, i.e. a bubble existed. The housing bubble was followed by a steep price decline. However, the crisis has dissolved and house prices in many regions have moved beyond the peaks achieved in 2006. This has encouraged the discussion about overvaluation of house prices again. The periods of over- and undervaluation create cycles in real estate markets. Price deviations from the equilibrium level are followed by an adjustment process back to equilibrium. In addition to the fundamental factors inducing price movements in real estate markets, speculation has its role in explaining price changes as well. The future expectations about real estate prices might be formed based on the recent price trends observed in the market. Hence, the price determination in real estate markets might not always be justifiable by the fundamental factors, which calls for a comprehensive analysis of the dynamics of price deviations from the equilibrium level.

The aim of this thesis is to evaluate to what extent fundamental and speculative factors have driven house prices in Germany. The following research questions are investigated:

- What makes the German housing market unique and why has it not demonstrated similar price developments with most other developed countries?
- What are the underlying fundamental factors driving house prices in Germany?
- What causes cyclicality in real estate markets and how do bubbles form in real estate markets?

In order to achieve the objective of this thesis, an econometric analysis is conducted covering a period from the fourth quarter of 1989 to the fourth quarter of 2017 in Germany. The period covers almost thirty years during which the Germany economy and the housing market have transformed significantly. The macroeconomic data series used for the analysis were compiled from public databases and the econometric analysis was conducted with Gretl statistical package. The empirical part of the thesis is based mainly on the methodology developed by Engle and Granger (1987). The Engle-Granger two-step approach is a methodology that in the first step entails Engle-Granger cointegration test and in the second step the estimation of an error correction model (ECM). The Engle-Granger cointegration involves first ensuring that the variables are individually unit root processes. Cointegration can be achieved if the combination of non-stationary time series is stationary, i.e. the residual of the regression of the variables has to be a unit root process as well. Once this is achieved an error correction model can be constructed by using the residual from the cointegration regression as an independent variable. As a result of the two-step approach it is possible to determine the long-term relationship between the independent variables and house prices. Additionally, the error correction model enables to estimate the short-term deviation of house prices from the long-term equilibrium level. Hence, an indication of the cyclicality of house prices in Germany is expected to become evident from the short-term deviations around the long-term equilibrium level.

This thesis has been divided into three chapters. The first chapter includes a comprehensive overview of the theoretical background and real estate concepts. It also describes the processes, which are essential to determine house prices.

The second chapter provides an overview of the housing market in Germany. The discussion outlines the distinctive characteristics of the German housing market.

The third chapter focuses on the empirical analysis. A comprehensive overview of the empirical literature is provided and a sound analysis of the macroeconomic factors is presented. In addition, methodological approach of this thesis is introduced in detail and the results of the econometric analysis are elaborated. Finally, main conclusions are drawn from the analysis and suggestions for future work are given.

The author of this thesis would like to thank his supervisor Mr. Karsten Staehr for providing invaluable advice, support and guidance during the course of writing this thesis.

# 1. BACKGROUND

## 1.1. Importance of real estate as an asset class

The relevance and the connectivity of real estate with other sectors in the economy was evident from the 2007 financial crisis, which saw the deterioration of one national housing market turning into a widespread global crisis with large scale implications on home owners, housing companies and financial institutions. Real estate activities are highly diverse and have strong connections with other economic sectors. Besides property management real estate activities also involve planning, construction, financing, facility management, appraisal, and consultation and brokerage services.

On the backdrop of low interest rates in recent years, real estate has been a preferred investment option for investors looking for an income-producing asset class with fairly low risks. While the world economy has been demonstrating robust growth figures since 2017, investors remain concerned about the repercussions of a long period of expansionary monetary policy and inflated asset prices. The surge in volatility at the start of 2018 was a clear reminder that the long bull-run of the markets is highly vulnerable to adverse economic and political developments. In times of uncertainty investors might prefer higher exposure to real estate as it offers protection against inflation and has low correlation with other financial assets.

Rubens et al. (1989) conducted an empirical study about the effectiveness of real estate as an inflation-hedge. They also involved financial assets in the study and concluded that among all the assets included in the study only residential real estate offered a complete hedge against inflation in the period of 1960-1986. Furthermore the findings outlined that most of the hedging effectiveness was attributable to the income portion of return of residential real estate. The last set of results from the study where mixed-asset mean/variance portfolios were under examination provide extremely useful insight as most investors use real estate as a portfolio hedge. They concluded that mixed-asset portfolios with real estate offer a better hedging effectiveness against inflation than any of the long-term financial assets used in the study. In addition, including real estate in portfolios provide lower risk per unit of return and greater inflation protection.

Investors tend to have a home bias, which might reflect poorly on investment performance as their portfolios become concentrated in one region. In order to reduce portfolio risk it is worth considering international diversification. Hoesli et al. (2004) found by analyzing unhedged returns of mixed-asset portfolios that real estate is an effective portfolio diversifier and proposed that optimal weight for real estate in such a portfolio would be in the 5-15% range. This research emphasized that the inclusion of real estate assets in such portfolios can lead to 5-10% lower risk level in a portfolio. Furthermore, by including international real estate assets in the portfolio the optimal weight for real estate should be approximately 15% and thereby the risk could be reduced by 10-20% compared to a portfolio without real estate assets. Despite the positive effects investors need to remain vary of the currency impact on the portfolio and use either natural or financial portfolio hedge.

The development of capital markets has provided investors with a wide range of financial instruments to attain exposure to real estate. As a result there is a whole universe of opportunities for portfolio diversification. Investors are able to benefit from emerging trends in real estate markets across the globe and use international diversification to sustain portfolio risk. An overview of various real estate investment vehicles is presented in table 1.

Table 1. Real estate investment vehicles

| | **Equity investments** | **Debt investments** |
|---|---|---|
| **Private** | Direct investments | Direct mortgages |
| | Non-listed real estate funds and funds of funds | Real estate debt foundations |
| | Real estate foundations | Private real estate debt funds |
| **Public** | Real estate equities | Real estate company bonds |
| | Listed Real Estate Investment Trusts (REITs) | Mortgage REITs |
| | Listed real estate funds | Mortgage bonds |
| | | Agency mortgage-backed securities |
| | | Mortgage backed securities |

Source: Szelyes et al. (2014)

One possibility to attain real estate exposure while also benefiting from higher liquidity, that institutional and retail investors aspire alike, is through Real Estate Investment Trusts (REITs). In the early years of the REIT conception, the linkage between real estate returns and REIT returns was weak. Later periods however have demonstrated a strengthening relationship. Clayton and MacKinnon (2001) found by using a multi-factor return generating approach during a sample period of 1978-1998 that a significant positive relationship between real estate and REIT returns was observed in the 1990s. The findings of Clayton and MacKinnon suggest that due to the growth and maturation of the REIT market since 1992 there is a higher degree of integration between REITs and property market. Strong linkage between REIT returns and un-securitized real estate returns makes REITs preferable investment vehicle for investors who have neither intention nor interest in maintaining and managing properties. Therefore, in the case of investing in REITs it is also vital to understand the underlying real estate market and the price determinants of the underlying asset.

## 1.2. Demand

The demand for real estate space can be defined as the quantity of space or number of units demanded at various prices as shown on figure 1 and figure 2. Fundamental law of demand in real estate terms states that a lower amount of space or number of units is demanded at higher prices (Kau and Sirmans 1985).

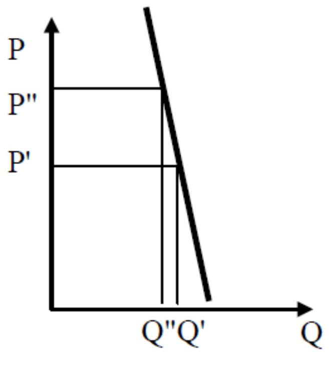


Figure 1. Law of demand (inelastic)
Source: Hyman (1989)

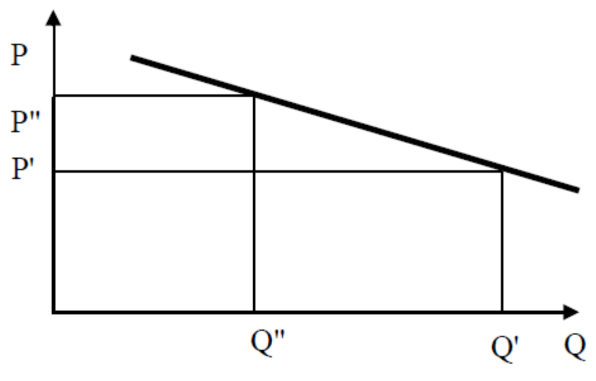


Figure 2. Law of demand (elastic)
Source: Hyman (1989)

As shown on figure 1 and figure 2, the shape of the demand curve can vary due to the sensitivity of demanded quantity to price changes i.e. price elasticity. Price elasticity shows by what percentage the demanded quantity will decrease in response to 1% increase in price. Price elasticity above one is said to be price elastic, while price elasticity below one is said to be price inelastic. Price elasticity of one is called unit elastic. The price elasticity of demand for housing is estimated to be less than one in absolute value on average (Mayo 1981).

$$\varepsilon_D = \frac{\Delta Q/Q}{\Delta P/P} \tag{1}$$

where
$\varepsilon_D$: price elasticity
$\Delta Q/Q$: percentage change in demanded quantity
$\Delta P/P$: percentage change in price

If price elasticity $|\varepsilon_D| > 1$ then demand is price elastic. On the other hand when $|\varepsilon_D| < 1$ demand is price inelastic. In case price elasticity $|\varepsilon_D| = 1$ then the demand is unit elastic. It is important to distinguish between actual prices and expected prices. Analysts may conclude that during periods when prices are increasing and demanded quantity is also increasing the law of demand is being violated. Although this might seem to violate the law of demand it is perfectly consistent with economic theory. In case prices and demanded quantity are both on the rise, increases in demand are not triggered by the actual price increases and instead are induced by expected price increases. In the case of single-family market, actual price increases may discourage some households from buying a house because they can no longer afford it, while expectations of further price increases in the future may actually accelerate the buying decision of some households before prices climb to an even higher level. Therefore, under the assumption of reasonably behaving households, expected price increases may result in an increase in demand for housing, which is opposite to the effect actual price increases would have. The expectations of higher prices represent a shift of demand curve and not a movement along the demand curve (Jowsey 2011).

The demanded quantity does not only depend on prices, but also on other non-price or exogenous determinants, which can be classified to following categories (Kau and Sirmans 1985):

1) Market size (population/employment)
2) Income/Wealth
3) Prices of substitutes
4) Expectations

## 1.3. Supply

Real estate supply describes the association between quantity of space or units supplied at various prices. The long-run aggregate supply describes the relationship between long-run prices and the total space or units supplied over the long-run. The short-run aggregate supply describes market's total stock at a given point in time. Since the stock of real estate is fixed in the short-run, the short-run aggregate supply is plotted as a vertical line on figure 3. That is due to construction lag, which is considered to be 6-12 for residential and industrial, and 18-24 months for office and retail. This results in a completely insensitive short-run supply to price changes. New construction concept provides an overview of the immediate effect on real estate inventory and obeys the fundamental law of supply as seen on figure 4. $P_{min}$ represents the price threshold below which developers can not cover the development costs and make a reasonable profit. Therefore it can be assumed that if property prices are below that price level then no amount of space would be developed (Kau and Sirmans 1985).

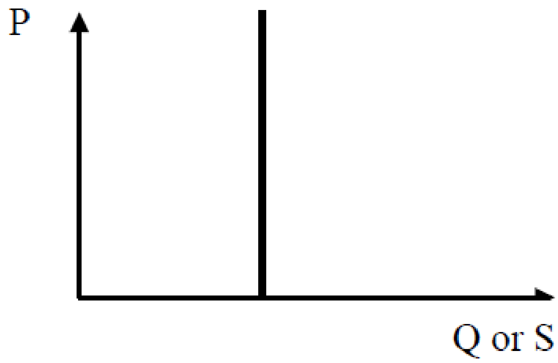


Figure 3. Short-run aggregate supply
Source: Hyman (1989)

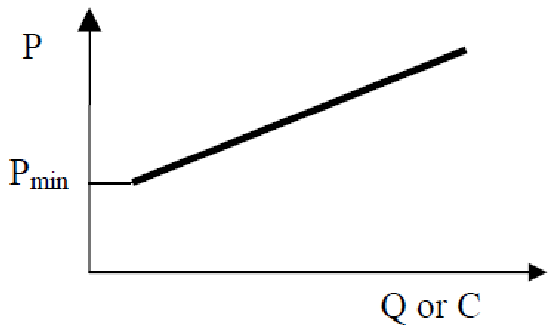


Figure 4. New construction
Source: Hyman (1989)

The factors of production for real estate development include: (1) capital, (2) labor, (3) land, and (4) building materials. The change in production factors induces a shift in the supply curve of new construction as seen on. With higher input prices the profit of a developer is smaller and there is little incentive to provide new space to the market. Therefore the supply curve should shift lower in conjunction with the increase of input prices (Kau and Sirmans 1985).

$$\varepsilon_S = \frac{\Delta Q/Q}{\Delta P/P} \qquad (2)$$

where
$\varepsilon_S$: price elasticity
$\Delta Q/Q$: percentage change in supplied quantity
$\Delta P/P$: percentage change in price

In many cases supply of housing can be constrained. Given the construction lag discussed earlier it takes significant time to develop a project and complete it. In addition, some regions might face geographical constraints. Paciorek (2013) concludes that supply constraints increase volatility through rigorous regulation of land use and geographical limitations. The former sets obstacles for developers to attain permits and conclude zoning. The latter creates difficulties for developers if the area is mountainous or has ample amount of water bodies that complicate the construction process. Therefore, the responsiveness to demand shocks limited, which amplifies house price volatility (Paciorek 2013).

## 1.4. Price determination mechanism

As in the case of any other market, real estate prices are determined through the interaction of supply and demand or sellers and buyers in the marketplace. Figure 5 demonstrates the price determination as the intersection of the demand and supply curves.  At this point the number of willing buyers equals the number of willing sellers (Hyman 1989)

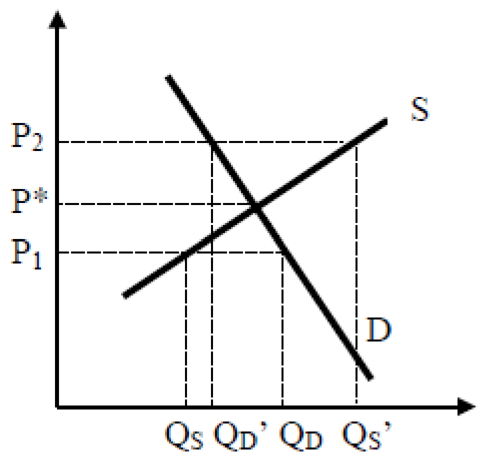


Figure 5. Market price determination
Source: Hyman (1989)

If the market price is at $P_1$, implying a price below equilibrium level, the number of units demanded, $Q_D$, is higher than number of units supplied, $Q_S$. The excess demand will drive prices up to a point where market price equals $P^*$. On the other hand if market price is at $P_2$, the number of units demanded, $Q_D'$, is smaller than the number of units supplied, $Q_S'$. Due to the low interest from the buyers, sellers may opt to decrease prices in order to attract buyers down to a point where market price equals $P^*$ (Hyman 1989).

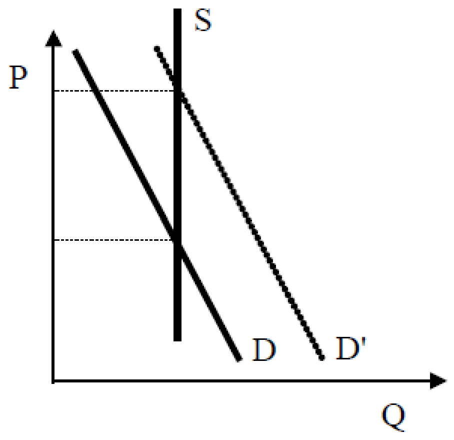


Figure 6. Short-run price changes
Source: Hyman (1989)

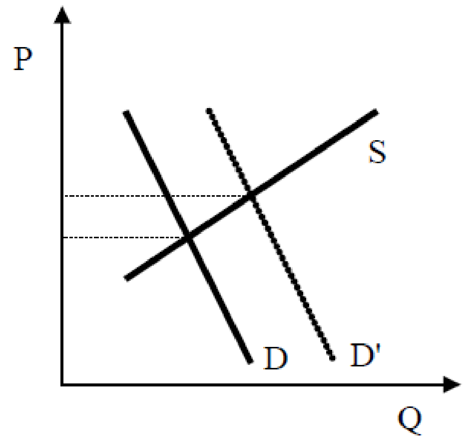


Figure 7. Long-run price changes
Source: Hyman (1989)

Massive immigration would induce upward shift in the demand curve as housing demand for same price level increases. As the supply is fixed in the short-run, the sudden increase in demand will induce a high degree price hike (figure 6), due to the construction lag. In the long-run however developers will eventually respond to this demand shock and new supply will enter the market. Therefore, the residential stock will rise to a level that will lead to new equilibrium price where demanded quantity is equal to supplied quantity as seen on figure 7. It should be noted that the short-run price increase should always be greater than the long-run price increase unless the long-run supply of real estate is perfectly inelastic (vertical line), which is extremely unlikely (Jowsey 2011).

## 1.5. Speculative forces driving housing markets

As discussed previously in section 1.2 the increase in demand can be induced by the expectations of future price gains. The concept of future price expectations can have a significant impact on asset prices and has been a subject of numerous research papers. Extremely positive future price expectations can lead to inflated asset prices. In many cases the future expectations for prices are in fact extrapolated from the prevailing price trends and therefore may not be a truthful representation of future prices if the fundamental factors are ignored.

Shiller and Case (1988) conducted a study about the behavior of home buyers during the boom phase in the USA during the 1980s. They argued that in a rational market home prices would have been driven by fundamental factors and investors in such a market would use all the available information on changes of fundamentals to forecast the future prices and thereby avoiding prolonged price swings. The actual results were quite different from a rational market behavior. Future market and price expectations were mainly based on the past price movements without taking into consideration the fundamentals of the market. Effectively, this kind of behavior increases the probability of a price boom since home buyers become speculators on the market. Furthermore, they found significant evidence that housing prices were inflexible downward if an economic downturn would not occur.

Speculation is considered to have an adverse effect to stable and healthy market development. However, speculation is somewhat embedded into real estate markets due to construction lag discussed in the earlier section about supply fundamentals. The construction lag can result in a project development period from 6 up to 24 months depending on type of property (Rottke *et al.* 2003). Therefore, it can induce supply shortages in periods where demand picks up rapidly due to some exogenous factor e.g. sudden high immigration. This creates future expectations about further price gains. As the short-run price elasticity is completely price inelastic, the short-run supply is insensitive to price changes and does not result in an immediate increase in new construction (completions). The period until new supply reaches the market is limited by the length of the development period. Hence, during that period market participants might engage in speculative purchases without considering fundamental factors. This is resulted from the fact that their future expectations of price increases are derived from the latest price trend witnessed in the market.

To further clarify on market expectations the following common models of expectations should be considered (Malpezzi and Wachter 2015):

1) Myopic expectations – Assumes that current price levels or increases will continue into the future without taking into account the possibility of negative events. Also referred to as short-sighted pricing behavior.
2) Perfect foresight – Assumes that people have perfect information about the future, which is most probably not true.
3) Rational expectations – Assumes that people use all available information to make an optimal forecast about the future.

4) Adaptive expectations – Assumes that market participants form their future expectation based on the past i.e. relying on past experience and adjusting current prices to derive future expectations.

Herring and Wachter (2002) describe in their paper the concept of disaster myopia. They describe it as the tendency to underestimate the probability of low-frequency shocks. Disaster myopia is a particular form of adaptive expectations and myopia. The ability to estimate a low frequency event, like real estate market collapse, depends on the frequency at which this event has occurred in the past. Due to the fact that these kind events occur at a low frequency makes it hard to estimate and predict such an event in the future with high confidence.

Malpezzi and Wachter (2005) investigated the role of speculation in real estate market cycles. Their conclusions outlined that a simple model of lagged supply response to price changes and speculation is sufficient to generate real estate cycles. That is to induce price deviation from fair value. They find that volatility, the biggest downside of speculation, is strongly related to supply conditions. Even more interestingly the effect of speculation itself depends on supply conditions. Markets with more responsive regulatory environments, or less natural geographical constraints, will demonstrate less volatility and speculative behavior. They conclude that demand conditions in general, and speculation in particular have causal effects on boom and bust cycle in housing and real estate market. Despite that, the effects of speculation appear to be dominated by the effect of price elasticity of supply. In fact, the largest effects of speculation are only observed when the supply is price inelastic.

## 1.6. Housing market bubbles

The essence of a bubble was described by Stiglitz (1990). He stated that if the reason for the prices being high today is only because investors believe that the selling price will be higher tomorrow, and if 'fundamental' factors do not seem to justify such a price level, then a bubble exists. Case and Shiller (2003) elaborate that the notion of a bubble is defined by how people think. Expectations about future price appreciation, the perceived risk of falling prices and their worries of being priced out of the housing market if they do not follow through with home purchase. Case and Shiller (2003) point out that buyers and sellers in the housing market are overwhelmingly amateurs with little experience in trading. The inexperienced market participants are highly involved in the market during a home purchase and might easily overreact to steep price movements and simple stories surrounding price action. This can result in substantial momentum in housing markets.

Shiller (2000) explains that speculative bubbles are caused by ‘percipitating factors’, which influence public opinion about markets and have an outright effect on demand. In addition, ‘amplification mechanisms’ in the form of price-to-price feedback play are also a major percipitating factor. The feedback from initial price gains to further price gains is a self-fulfilling mechanism that amplifies the effects of precipitating factors. Steep price increases is followed by word-to-mouth communication, which spreads optimistic stories and hence creates more upwards price pressure. The amplification can work on the downside as well.

Glaeser and Nathanson (2014) argue that bubbles driven by exuberance over external events can take any kind of form, so long as prices eventually fall. Some announcement may spur temporary price gains and a subsequent collapse, unless it leads to additional price increases. They state that an internally driven-bubble must display positive serial correlation in price growth, that is the momentum that has almost come to define housing bubbles. They conclude that in this view, all bubbles are defined by large variance of price changes, relative to fundamentals and an eventual mean reversion.

The main conclusion from any kind of description of a bubble is that markets are driven by human psychology and at times this can be extremely irrational. People tend to extrapolate recent events and therefore if a price increase occurs people see it as positive sign of future development. In the beginning people may remain hesitant about the price increase and do not buy into it immediately. However, if price gains continue consistently confidence starts building up about the sustainability of the price trend. As a result, the momentum of the trend grows and at some point market participants who did not buy into the rally at an initial stage want increasingly to get involved as well. This process can take years before gaining significant momentum. However once achieved it can take a form of hysteria and in the final stage the pace of price advance tends to be the highest. At this stage the prices probably are above what fundamental factors might suggest and a bubble has formed.

While the formation of a bubble may be slow in the beginning and take significant time to build up, the subsequent ‘burst’ of a bubble and the deterioration is much more volatile. The specific catalyst that ends the rally may be disappointing economic data, uncertainty in the political environment or some unexpected event. Depending on the severeness of the catalyst, the reaction by market participants may range from a light sell-off to a panic. Nevertheless, it will have a sobering effect which breaks the *status quo* of the expectation of eternal growth. People do not like uncertainty and in the midst of a sell-off, a deep analysis of the current situation may not be taken. This may result in a situation where only few buyers remain on the market while the majority is determined to sell. The pressure on the prices is therefore inevitable and as a result the volatility surges. Shiller (2000) refers to this kind of behavior as ‘price-insensitive selling’, which means selling in response of a price drop where the selling activity is insensitive to how low the price goes before the sale is concluded i.e. selling at any price.

Bubbles are easier to determine from hindsight and might not be that obvious at the very moment when a bubble occurs. The infamous tulip mania in the $17^{th}$ century is probably one of the most well-known bubbles. Garber (1989) investigated the nature of the market during the tulip mania. His conclusions indicate that the bulb speculation was not an obvious madness, at least for most of the 1634-1637 ‘mania’. Instead he outlines that only the last month of the speculation for common bulbs remains a potential bubble. Stiglitz (2000) outlines that testing for the presence of bubbles is a difficult task due to the fact that is hard to distinguish whether a bubble exists or the underlying fundamental model is misspecified.

Glaeser (2017) raises the question why real estate booms and busts are so common and whether they can be good for growth. He investigates bubbles of the past in the US and Asia and it becomes obvious that typically bubble-like events have occurred at moments when there was an extraordinary positive change. Periods such as the revolution in transport, or building technology, or periods of widespread industrial growth have induced high future expectation, which at that point seemed reasonable. He also points out that lenders often see real estate as safer collateral compared to industrial investment. Hence banks may not remain reluctant to lend when collateral prices are on the rise. Tsatsaronis and Zhu (2004) offer evidence that the relationship between bank credit and house prices is affected by the prevailing lending practices of mortgage lenders. Even a stronger association occurs between credit and property cycles if lending activity is highly dependable on collateral values.

The housing crisis in 2007 provides good evidence about the influence of lending practices to house prices. The possibility to get a second or third mortgage on a house amplified the exuberance of home owners. In the midst of rising house prices home-owners equity increased and consequently the ability to borrow as well. The over optimism spreads and eventually it creates a self-fulfilling mechanism, which is determined to end with a bust.

The other side of the coin in the lending activity is the financing of housing supply and particularly development financing. While the expectations for future price appreciation remains positive banks might find it easy to sign off real estate projects. Because of the following reasons banks tend to fund real estate investment pro-cyclically (Rottke *et al.* 2003):

- They have too much liquidity during boom phases.
- They do not focus on the quality of the project, but rather on the creditworthiness of the developer.
- According to principal-agent theory, it is hard for real estate loan to pass due diligence during a bust phase and relatively easy during a boom phase.

As a result developers might find it difficult to invest anti-cyclically even though they might realize that this could be a superior strategy.

## 1.7. Housing market cycles

Although at present day the cyclicality of economy and real estate is largely acknowledged by researchers, academic community and the public, there have been plenty of contradictory opinions on the matter in the past. Over the numerous years of research on the subject, authors have recounted numerous reasons and arguments on the irrelevancy of cycles. Even in the late 1980s, it was not uncommon to hear a finance professor dismiss the concept of real estate cycles as a research topic and decision variable, and suggest that research on the subject was misguided (Phyrr *et al.*1999).

However the extensive body of research on the matter has formed a decisive opinion about the existence and relevance of real estate cycles at this date. One of the early pioneers of long real estate cycle research was Roy Wenzlick. He charted long cycles of housing transactions from 1795 through 1973 at the national level, and drew conclusions about the average length of the cycle from his work (Rabinowitz 1980).

After an extensive study of the academic literature, Phyrr *et al.* (1999) concluded that the economic and real estate publications clearly demonstrate the cyclicality of economic factors, cash flow variables (rents, vacancies, capitalization rates) and real estate performance (rates of return) at national and regional levels. Besides academic field the importance of real estate cycles is also of a high importance from the point of view of practitioners. Increasing number of investors and portfolio managers regard real estate cycles with great importance to their investment and portfolio strategies and decisions. As a result real estate brokerage and research houses have increasingly turned to provide investment recommendations to investors by identifying the current state of real estate market and determining in which cycle phase the current market fits.

Mueller and Laposa (1994) described the real estate cycle by constructing a line around the equilibrium vacancy rate and determined the four phases of the real estate cycle: recession, (2) recovery, expansion and contraction (oversupply). The equilibrium vacancy rate serves as an inflection point with recovery and expansion demonstrating declining vacancy rates followed by periods on contraction and recession with rising vacancy rates.

One of the earliest references about equilibrium vacancy rate was made by Clapp (1987). He referred to it as ‘normal’ vacancy and defined as the long term average vacancy rate in the local market, adjusted to reflect recent information on interest rates and expected demand growth. According to Parli and Miller (2014) an equilibrium vacancy rate is defined as a vacancy rate that produces no upward or downward pressure on rents. It should be noted that equilibrium vacancy rate differs between markets, asset classes and time periods (Parli and Miller 2014).

Although there are visualizations about cycles as symmetrical market movement patterns it is rather hard to find such regularity in real life. In reality the phases of market cycles have different characteristics and length. The recovery and expansion phase tend to be longer than contraction and recession phase. Another characteristic that sets market cycle phases apart is volatility. The recovery and expansion phase are typically less volatile whereas the contraction and recession phase is dominated by high degree of uncertainty and therefore is typically characterized by high volatility. A good presentation of a cycle shape (figure 8) is determined by Mueller (1995) where it becomes obvious that the recovery and expansion phase are typically longer and take time to build up. On the contrary, the hypersupply and recession phase tend to be shorter and typically demonstrate high volatility, a direct result of steep price declines.

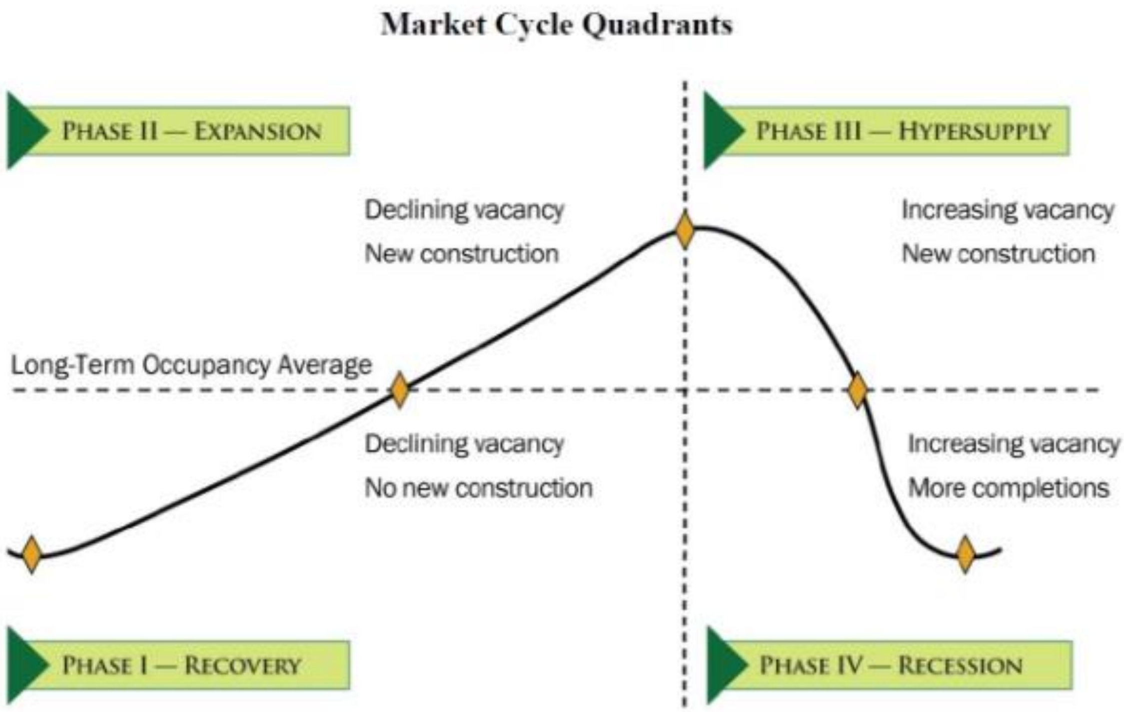


Figure 8. Housing market cycle quadrants
Source: Mueller (1995)

Coming back to the supply and demand relationship in housing markets it is possible to demonstrate that the concept of inelastic supply plays an important role in the cycle development. As already elaborated previously the supply and demand imbalance creates a price level below or above equilibrium level, followed by a subsequent adjustment. This dynamic supply and demand relationship is constantly changing in time and is demonstrated on figure 9.

The cyclicality of real estate possesses a notable problem for appraisers as well. Traditional appraisal models do not factor in cyclical developments. Born and Phyrr (1994) conclude that cycles have a significant impact on appraisal values. That is especially during the peak and at the bottom of the supply/demand cycle. The main problem lies in the fact that appraisal models do not reflect cyclical market realities, in particular property cash flow variables. The standard model uses a linear DCF method that alters the values during the bottom and top of the market. That is, during recovery phase (bottom) the model undervalues property and when the market is at its peak the model overvalues the property.

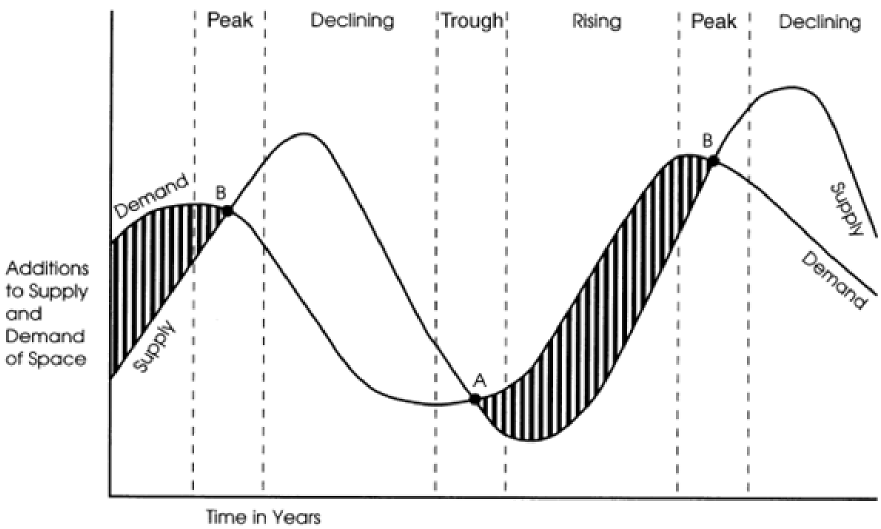


Figure 9. Phases of the real estate supply/demand cycle
Source: Phyrr et al. (1990)

The cycle dynamics clearly exist in real estate and are caused by endogenous and exogenous mechanisms. The endogenous mechanisms are mainly attributed to market imperfections with the most important being time lags. Time lags are caused by the price-mechanism lag, the decision lag and the construction lag. Since the supply volume in real estate is fixed in the short-term an unexpected increase in demand will not have an immediate response from the supply side. Hence, the vacancy rate starts to decline in the short-term which initiates an increase in rents and prices. As soon as vacancy is absorbed below so-called 'natural level' the short-term market reaction can only occur through price movements. The time that passes until prices react is called price-mechanism lag. Since the investment decision is not immediate (e.g. institutions, which invest large sums may have time consuming internal decision making processes), investors may react to changing prices with a lag (decision lag). After the investment decision has been accepted the whole process of planning, zoning and construction, with significant time considerations, needs to be carried out. Consequently, the time from the investment decision until completion of the project is called construction lag (Rottke *et al.* 2003).

Rottke *et al.* (2003) argue that the initial cause for endogenous movement in the real estate market is in fact factors which are exogenous to real estate markets. These exogenous factors occur in a form of a demand shock and are categorized into middle- and long-term influences. Middle-term influences are based on the economic development in a country and its local markets and constitute mainly form the movements in main economic indicators – e.g. inflation, interest rates, GDP or the interest level. On the other hand long-term influences do not result in a sudden shock, but instead come in the form of long-term structural changes – e.g. foundation of European Union, globalization, new technologies etc.

Tsatsaronis and Zhu (2004) point out that residential real estate prices are characterized by long swings. The 17 industrialized countries that were under investigation were reported to experience approximately two full cycles over a period of 33 years. In the broad sense the countries that were examined experienced similar developments. However, the broad overall picture ignores the developments of individual countries. Countries such as Ireland, Netherlands and United Kingdom demonstrated average annual price growth rates in the excess 11% during the period of the study. While the likes of Germany, Switzerland and Japan exhibited rather flat prices. Hence, it is necessary to analyze the development of cycles on a country or even regional basis.

# 2. HOUSING MARKET IN GERMANY

## 2.1. German housing investment market

In recent years German residential direct investment market has been highly active. The real estate market in the European economic powerhouse has become highly regarded among local and increasingly foreign investors. This has been driven by the increasing appetite for yields on the backdrop of low government bond returns. According to CBRE Research (2018) the transaction volume of portfolios with 50 units or more in the German residential real estate market reached €15.2 billion in 2017 (figure 10), outsizing the volume in the previous year by 11%. While this is below record volume achieved in 2015 due to several corporate takeovers, it nevertheless outpaces the 5 year average volume of the years between 2011 and 2016. Data gathered by Savills Research (2018) suggests that the share of foreign buyers of German residential real estate has increased to 23% in 2017 (figure 11), which is 4 percentage points higher than the 5 year average between 2013 and 2017.

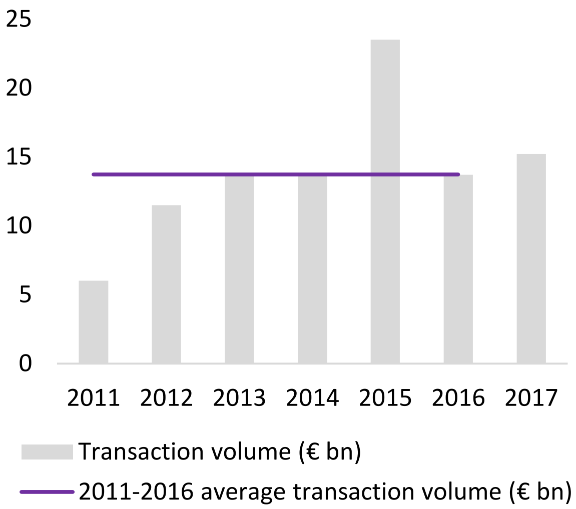


Figure 10. Germany residential real estate transaction volume (portfolios with 50 units or more)
Source: CBRE Research (2018)

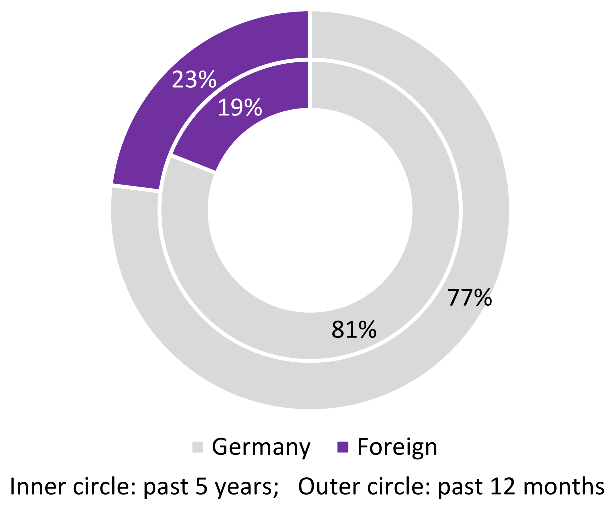


Figure 11. Germany residential real estate transaction volume by origin of buyer (portfolios with 50 units or more)
Source: Savills Research (2018)

## 2.2. German housing market

In recent years the German housing market has reached the headlines of major news publications and has caught the attention of the wider public. The market has turned highly dynamic and has posted real price increases every year since 2010 (figure12). This has been supported, among other things, by households' increased income prospects and favorable funding conditions. While there are many opinions about the recent price surge, the German central bank, has found the housing prices to be inflated. Deutsche Bundesbank (2017) expressed concern towards the residential property market and estimated that housing was overvalued by between 15-30% in 127 German towns in 2016.

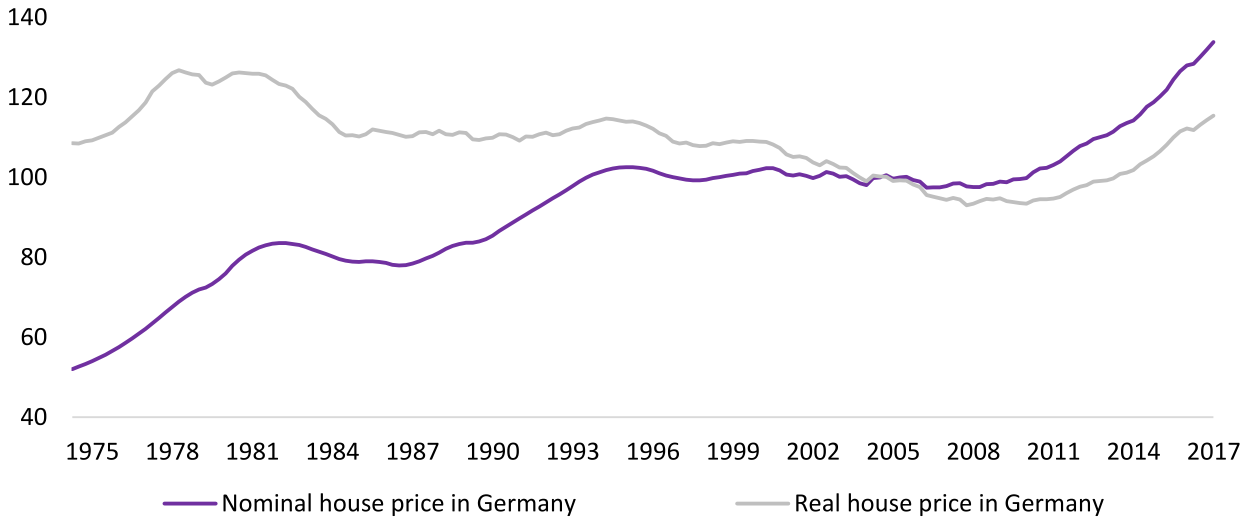


Figure 12. Nominal house price index and real house price index in Germany (2005=100)
Source: Federal Reserve Bank of Dallas

German housing market has demonstrated peculiar developments compared to most of the European countries and USA over the past. As demonstrated in figure 13 the real price development over the more than 30 year period has been much more stable compared to the likes of France, UK, Sweden, Spain and USA. This reflects national idiosyncrasies between housing markets. The real house price was declining in Germany since 1996 up to 2007 while most other developed economies witnessed a considerable appreciation in real house price.

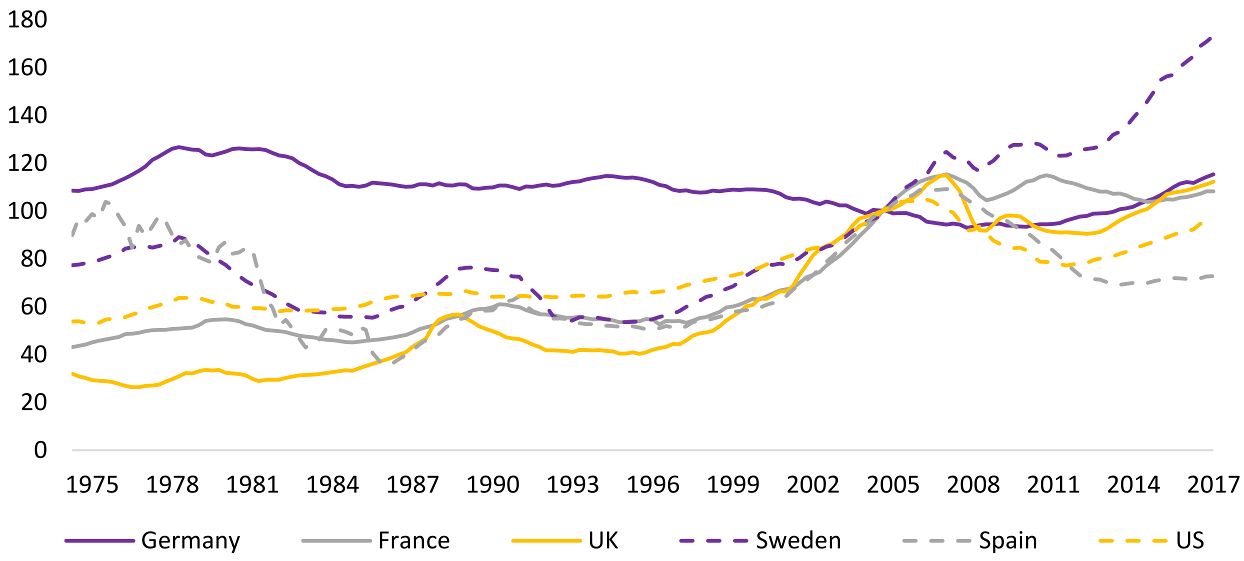


Figure 13. Real house price indexes in selected European countries and U.S. (2005=100)
Source: Federal Reserve Bank of Dallas

The divergence of the real house price development between Germany and other developed countries can be attributed to the well-developed rental market, low home ownership and conservative lending standards in Germany (Schneider and Wagner 2015). Similar housing market developments with Germany are characteristic to other DACH countries, Austria and Switzerland, as well. Germans have a high propensity towards living in a rental space. According to statistics approximately 86% of Berlin's population is living in rented homes while the rates are 79% and 76% in Munich and Hamburg, respectively. In a country-wide comparison, presented in figure 14, Germany has a one of the lowest home ownership ratio (51.7 % according to Eurostat) in Europe. Only Switzerland ranks below Germany while Austria has a slightly higher rate of home ownership. Low home ownership in Germany is a result of policies, which discourage home ownership: an extensive social housing sector with broad eligibility criteria, high transfer taxes when buying real estate, and no tax deductions for mortgage interest payments by owner-occupiers (Kaas *et al*. 2017).

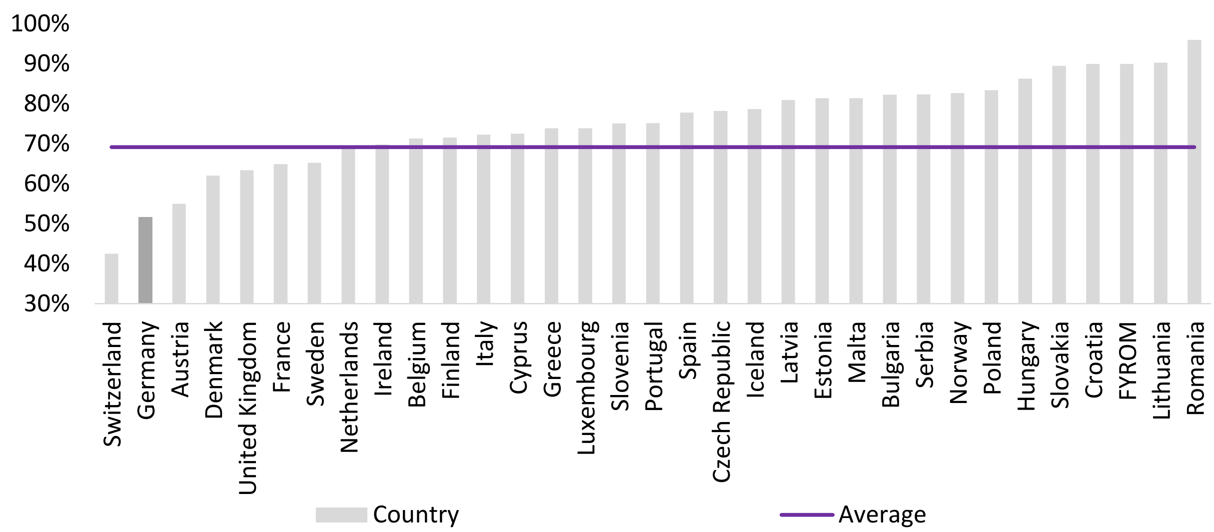


Figure 14. Home ownership rate in European countries in 2016
Source: Eurostat

In addition, the German housing market faces several supply side caveats that slow down the market response to demand shocks. Relatively inelastic supply in Germany is amplified by regulatory hurdles. The regulation for construction land, and environmental and energy efficiency standards complicate the development process (Deutsche Bank Research 2016). New stricter laws on energy efficiency, which were introduced in 2016 do not ease the current situation.

## 2.3. Affordable housing and rent regulation in Germany

Regulations in Germany are designed to promote affordable housing and encourage renting. Favorable tax incentives exist for home owners to rent out their properties and regulation has been historically skewed towards preserving the rights of the tenants. Most tenancies in Germany are with indefinite length and the landlord can terminate the tenancy only if the tenant has been in serious violation with the regulations or the landlord has serious ground for discontinuing the lease e.g. occupying the living space themselves or selling the property. In any case this cannot be executed without a three month notice.

In Germany an important part of regulation is the *Mietspiegel* or the ‘rent mirror’, which aptly describes its functioning, whereby rent must mirror that of the same dwelling in a similar area (Fitzsimonus 2014).  Essentially it is a database of local reference rents, which contains all actual rent prices in the past four years and allows landlords to only increase rents in line with the rents of other dwellings of the same quality in the same locality. This index is published only in every two years and hence lags behind the true market development. According to §558 BGB it is prohibited to increase rents on existing tenancies by more than 20% over a three year period. While §5 WiStG states that the new rents cannot charge a higher rate than 20% above the 'rent mirror', landlords have found a way around that and in some cases the new rents have been increased by 40% above the 'rent mirror' (Fitzsimonus 2014). This has been possible due to a loophole in the law. The maximum rent increase section in the law is conditional upon the landlord exerting undue influence or negligence over the tenant which has resulted in unjust enrichment. However, if the market supply and demand has resulted in a situation where a tenant is willing to pay more than the maximum cap over the 'rent mirror', it is thus the landlord's right to profit from the property and to charge this to the tenant without it being classified as unjustified. That is the reason for debate about the validity and legal effectiveness of the 'rent mirror', which has resulted in several lawsuits.

To address the problem of excess rent increases for new rent contracts the German government introduced a new regulation which took effect in 2015. This included a new instrument to regulate the rental price for new rental contracts called the *Mietpreisbremse* or 'rental break'. According to § 556d BGB new rental contracts must not exceed the local average rent defined by the 'rental mirror' by more than 10%. However, there are exceptions for new builds and buildings, which have gone through considerable refurbishment.

Post World-War II German housing market recovery was dominated to a larger extent by the construction of social housing compared to rest of European countries. This led to implementation of a well-functioning social housing system. Besides social housing other initiatives like promotion of home ownership, direct subsidization of lower-income households and market oriented rents within the freely financed rental housing sector are important pillars of German housing policy (Cornelius and Rzeznik, 2014).

## 2.4. Housing financing in Germany

Another peculiarity of the German housing market is housing financing. German banks are known for prudent lending practices. Even more, German households have a propensity towards saving and are debt averse. According to OECD household debt as a percentage of net disposable income was at 93% in Germany as of 2016 (figure 15). This puts Germany in the bottom half among the OECD countries.

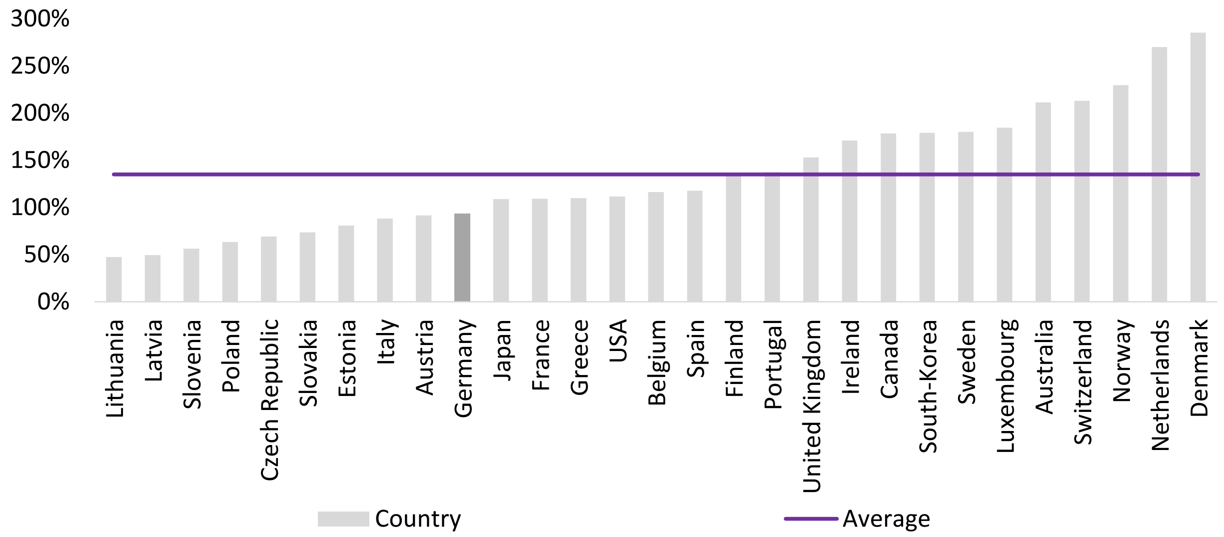


Figure 15. Household debt to disposable income in OECD countries in 2016
Source: OECD

Mortgage lending in Germany can be described as conservative with long maturities and a high share of fixed-rate loans being the common practice. More than 70% of new mortgage loans have a fixed rate over a period of more than five years (Schneider and Wagner 2015). The long duration fixed-interest rate agreements minimize the vulnerability of borrowers to interest rate shocks. This makes Germany somewhat more resilient to rising interest rates as only a relatively small share of housing loans are exposed to fluctuating rates. Approximately 44% of outstanding stock of mortgage loans has a fixed-rate loan for a period of more than 10 years, and approximately 35% have a fixed-rate loan with a period of more than 5 years (Dahl and Góralczyk 2017). While fixed-rate loans provide stability to mortgage borrowers about the costs associated with borrowing, it also entails an opportunity cost. In an environment where rates are declining, these mortgages have a higher cost of debt compared to new loans. While it is possible to refinance old mortgages it would incur high breakage fees, which would probably not lead to a more favorable outcome.

Germany has partly a bank model and partly a mortgage bond model in housing finance. Commercial and savings banks together with credit cooperatives account for about 45% of total mortgages, with savings banks and credit cooperatives being the main financing source for housing. Banks compete mainly with mortgage banks, which find funding for themselves mainly through issuing mortgage and municipal bonds to institutional investors. In addition, Bausparkassen are active in the mortgage market, which rely on savings generated from long-term (6-18 years) housing linked contracts and government savings. The German housing loans have a medium-low LTV ratios (60-80%) and a cap of 80% for first time home buyers (Iacoviello and Minetti 2008).

In German mortgage lending practices the market value of the property is not used to determine the eligibility for a loan, but instead the mortgage lending value is used (Hagen and Siebs 2012). The mortgage lending value is essentially the prudently calculated value of a property. It represents the value of a property, which can probably be achieved throughout the entire life of the property when sold on the free market.

## 2.5. Demographics

Germany faces an ageing population and short-term immigration inflows might not be enough to halt the decline. According to the Federal Statistics Office (Destatis) the current high immigration has only limited effects on the long-term population trends. It is mainly reflected in short-term population growth, but cannot reverse the trend towards increased population ageing. The current age structure of the population is expected to have a stronger impact on the demographic development in the next three decades than the balance of immigration to and emigration from Germany.

In 2015 approximately 890 thousand asylum seekers arrived to Germany which led to a approximately 1% increase in population and created an increased demand for affordable housing in the short- to medium-term. Since 2002 to 2010 the population in Germany was shrinking. This was however reversed after a surge in immigration that and has thereafter resulted in a cumulative positive net immigration of approximately 2.9 million people until 2017. Nevertheless, the inflow of immigrants has dropped significantly after the EU-Turkey agreement and the number of asylum seekers in Germany declined from 890 thousand in 2015 to approximately 260 thousand in 2016 (Dahl and Góralczyk 2017).

According to the latest data the population in Germany stands at 82.7m people. However, current projections by the Federal Statistics Office suggest a significant drop in the population by 2060.

Positive scenario with higher immigration implies a population of 73.1m by 2060, while projections with lower immigration imply a population of 67.6m by 2060. In this context it is interesting to investigate the effect population changes have on house prices.

# 3. EMPIRICAL ANALYSIS

## 3.1. Overview of the empirical literature

There is a vast collection of academic literature and empirical research about the housing market. Many of these research papers investigate the interaction between macroeconomic variables and house prices in particular. These publications provide an extensive overview on the matter and form a basis for this master thesis. Researchers have conducted empirical analyses in several geographies by implementing a variety of econometric analysis methods. Hence, it is appropriate to give an overview and provide a summary about the most relevant publications and their findings.

By examining the impact of major demographic changes in the United States caused by a sharp increase in the population in the 1950s (Baby Boom) and the subsequent decline in the 1970s (Baby Bust), Mankiw and Weil (1989) determined that large demographic changes lead to large changes in the demand for housing and effectively these fluctuations in demand have a substantial impact on housing prices. Furthermore, the findings of the study outlined that an individual creates little housing demand before the age of 20, i.e. children do not necessarily increase a family's need for housing. Demand for housing increases when an individual is between 20 and 30 years old and remains approximately flat after the age of 30.

Abraham and Hendershott (1996) explain that the determinants of housing price changes can be divided into two groups. One that explains changes in the equilibrium price and another that accounts for the adjustment dynamics or changing deviations from the equilibrium price. They provide empirical evidence that the former group includes the growth in real income and real construction costs and changes in real after-tax interest rates. The latter group consists of lagged real appreciation of housing prices and the difference between the actual and equilibrium real house price levels.

The findings by Mankiw and Weil (1989) and by Abraham and Hendershott can be confirmed by a study conducted by Jud and Winkler (2002) in 130 metropolitan areas across the United States. They found that price increases in these metropolitan areas was highly influenced by the real growth in population, income, construction costs and interest rates. Furthermore, they found that the real stock market has a strong current and lagged wealth effect on the increase in real housing prices.

After a thorough research about the determinants of house prices in Central and Eastern Europe, Égert and Mihaljek (2007) established a strong positive relationship between GDP per capita and house prices. In addition, a strong linkage between real interest rates and house prices was found, as well as between private sector housing credit and house prices. Demographic factors and labor market developments also lead to changes of house price dynamics with stronger effect in Central and Eastern Europe as opposed to OECD countries. For improvements in housing quality they used real wages as a wide proxy and found that house prices were affected more strongly to increases in real wages in countries where housing quality was initially poor.

A panel co-integration analysis consisting of 15 countries over a period of thirty years was conducted by Adams and Füss (2010) where they examined the long-term equilibrium relationships between the house prices and macroeconomic variables. The results reveal that macroeconomic variables such as employment, industrial production and money supply increase the demand for houses and effectively elevate house prices. In addition, Adams and Füss studied the effect of short-term interest rates and long-term interest rates on house prices and found that an increase in short-term interest rates increases house prices positively whereas an increase in long-term interest rates decreases house prices.

Borowiecki (2009) studied the Swiss housing price determinants over a 17-year period using a vector-autoregressive model. The research concludes that house prices are the most sensitive to population, with 1 percent increase in population (20 to 64 age cohort) growth leading to 2 percent higher house price growth. In addition, it was found that an increase in construction costs leads to roughly equal increase in prices of housing. Stock market appreciation exhibited also an upwards impact on housing prices. On the flipside the increase in the number of completed dwellings and in the real interest rates puts downward pressure on housing prices. On the qualitative side Borowiecki found that improvements in the quality of new constructed or modified dwellings have a highly positive impact on residential property prices. However, the results did not find highly significant relationship between GDP and house prices.

In a paper examining the determinants of UK housing prices Xu and Tang (2014) apply a co-integration approach and an error correction model for quarterly data in the period between 1971 and 2012. Through cointegration test they conclude that construction costs, credit, GDP and unemployment rate have a positive impact on housing prices, whereas disposable income and money supply have an inverse effect on housing prices. By applying the error correction model they are able to identify that in the short-term the growth in housing prices is affected by the growth of construction costs, credit, interest rates and disposable income.

Sutton (2002) used a VAR model to determine the factors influencing housing prices in six advanced economies – the United States, the United Kingdom, Canada, Ireland, the Netherlands and Australia. The conclusions from this publication outlined that the changes in housing prices can be attributed to fluctuations in national income, interest rates and stock prices. The main empirical findings suggested that favorable economic developments captured by these variables played a major role in the house price gains over the studied period, although in some instances the prices appeared to increase more than these fundamental variables were able to explain.

A concise overview of the most important independent variables used in the academic literature is presented in table 2. It includes variables that were meaningful in the reviewed publications and can explain house prices.

Table 2. Summary matrix of independent variables used in reviewed academic literature

| | Mankiw and Weil (1989) | Abraham and Hendershott (1996) | Jud and Winkler (2002) | Égert and Mihaljek (2007) | Adams and Füss (2010) | Borowiecki (2009) | Xu and Tang (2014) | Sutton (2002) | Total count |
|---|---|---|---|---|---|---|---|---|---|
| Interest rate | | X | X | X | X | X | X | X | 7 |
| Construction costs | | X | X | | X | X | X | | 5 |
| Population | X | | X | X | | X | | | 4 |
| Income | | X | X | X | | | X | | 4 |
| GDP | | | | X | | | X | X | 3 |
| Unemployment/employment | | | | X | X | | X | | 3 |
| Stock market | | | X | | | X | | X | 3 |
| Credit | | | | X | | | X | | 2 |
| Money supply | | | | | X | | X | | 2 |
| Dwelling completions | | | | | | X | | | 1 |
| Real industrial production | | | | | X | | | | 1 |
| Lagged real appreciation in housing prices | | X | | | | | | | 1 |
| Difference between actual and equilibrium real house price levels | | X | | | | | | | 1 |
| Quality improvements of newly constructed dwellings (quality index) | | | | | | X | | | 1 |
| Development of housing markets and housing finance institutions | | | | X | | | | | 1 |
| Labor force size | | | | X | | | | | 1 |

Source: Author

## 3.2. Data selection

The first and foremost is to determine the dependent variable to be used in the analysis. In order to do that it is essential to choose a variable with the right characteristics for the research problem. As there are several variations of housing indexes available it is not instantly explicit, which would be the best fit for current analysis. As the analysis is aimed at determining the factors influencing housing prices in Germany the underlying index should have wide enough coverage to provide information about price developments across Germany. The following questions are under consideration for the dependent variable:

1) House prices or apartment prices
2) Nominal or real values
3) Unadjusted or seasonally adjusted values
4) Index values or growth rates

The main problem that arises in the selection of the housing index is to determine whether it should contain house prices, apartment prices or a mix of both. The dynamics of house prices and apartment prices tend to be similar and should in a broad sense move in the same direction, whereas the rate of price movement can be different. As demonstrated in figure 16, which shows the latest rally in the German real estate market, the price increases for apartments have outpaced house prices tremendously since 2010.

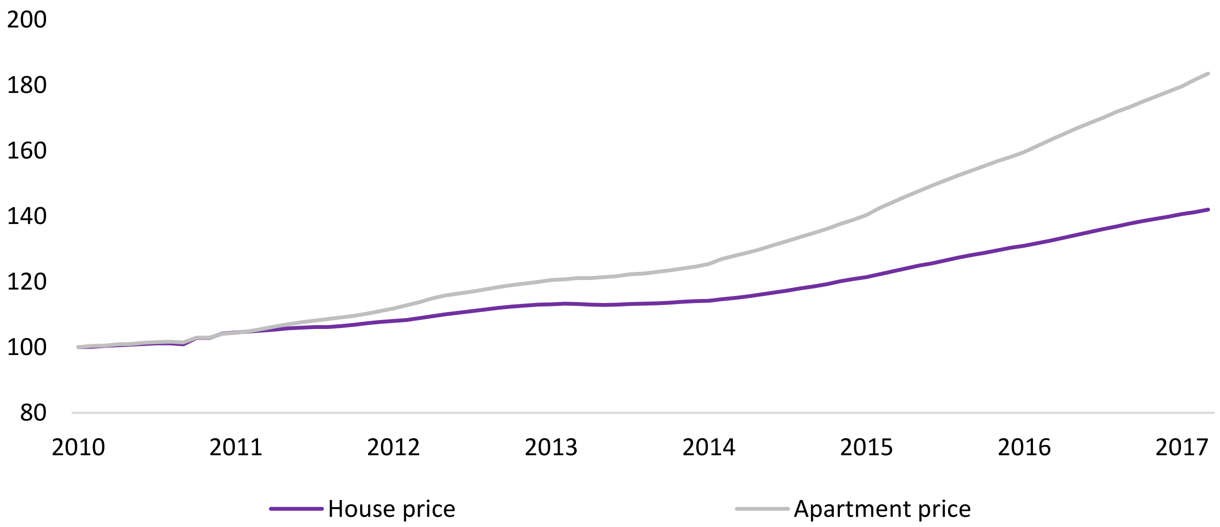


Figure 16. IMX Immobilienindex real estate index for houses and apartments (2010=100)
Source: Immobilienscout24

In some developed countries like the United States and the United Kingdom the share of population living in houses can stand as high as approximately 80% while in Germany it stands at only 42% as of 2016 according to Eurostat (figure 17).

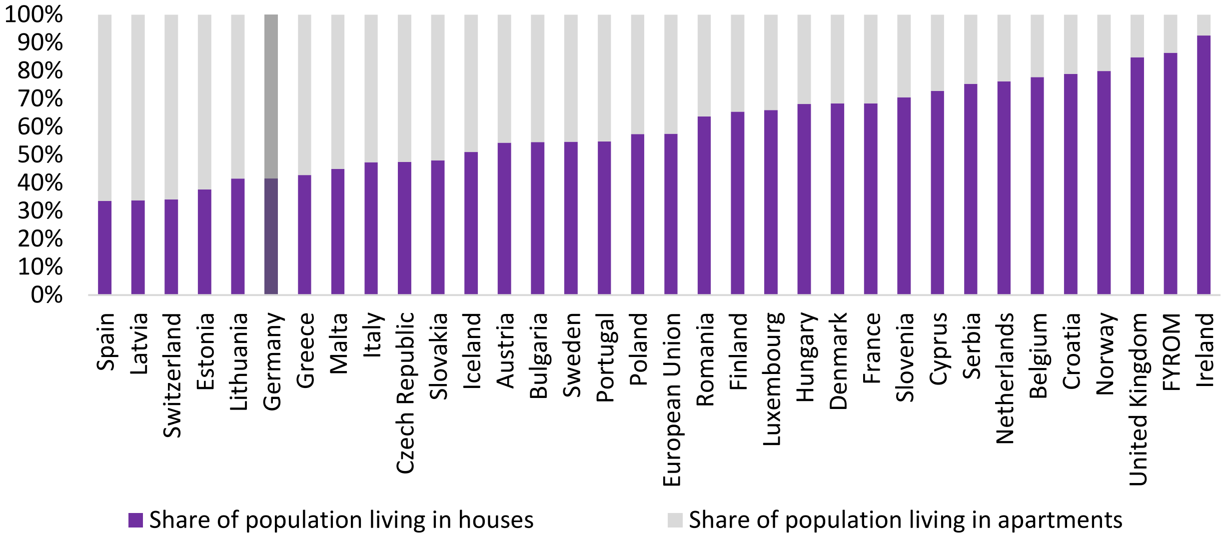


Figure 17. Population distribution by dwelling type in European countries in 2016
Source: Eurostat

The following available housing indexes were under consideration for dependent variable:

1) Federal Reserve Bank of Dallas real house price index – The Globalization and Monetary Policy Institute of the Federal Reserve Bank of Dallas produces an international house price database, which includes quarterly house prices. For every country a house index that is most consistent with the quarterly U.S. house price index for existing single-family houses is chosen. The index is compiled by data from Bundesbank, BulwienGesa AG and Federal Statistical Office (Destatis) and has a starting date in 1975.
2) Bundesbank nominal residential property price index – Transaction based price index calculated by Bundesbank based on the data provided by BulwienGesa AG for terraced housing, owner-occupied apartments and single-family detached homes. Available annual data starting from 2004 to 2016.
3) Federal Statistics Office (Destatis) real house price index – The house price index compiled by the Federal Statistics Office complies the average price development of typical transactions in the real estate market (owner-occupied flats and one-/two family houses). The index includes both newly built and existing properties in quarterly time series starting from 2000.

4) OECD real house price index – The house price index covers the sale of newly-built and existing dwellings, following the recommendations from Residential Property Prices Indices (RPPI) manual. Data series starts from 1975.

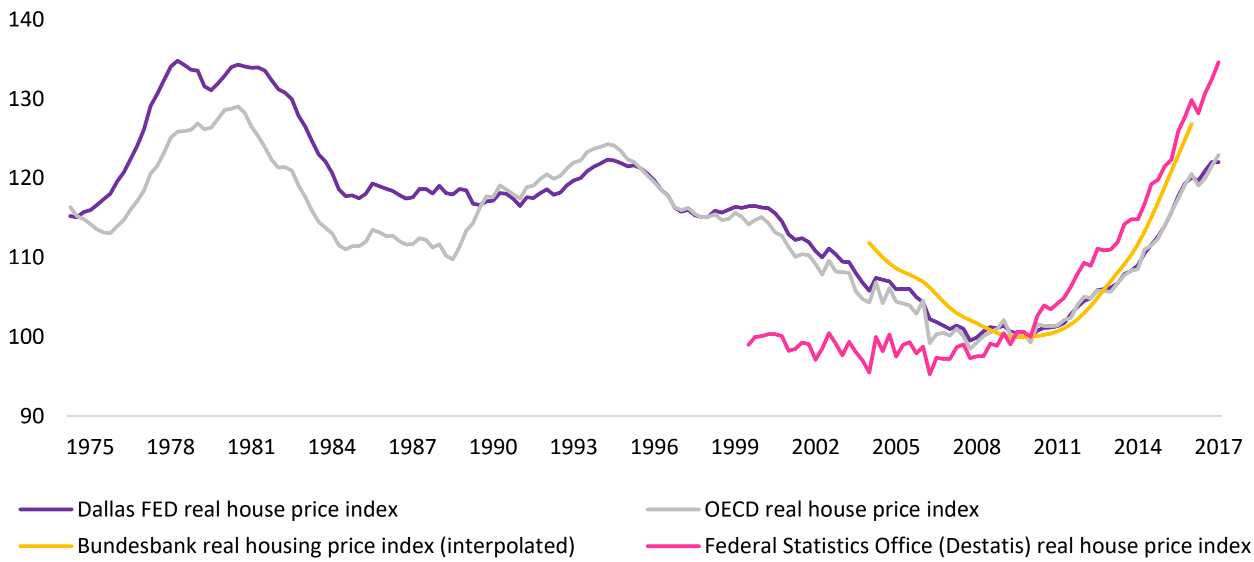


Figure 18. Comparison of available housing indexes in Germany (rebased 2010=100)
Source: Dallas FED, Bundesbank, Federal Statistics Office (Destatis), OECD

As seen on figure 18, all indexes follow broadly the same trend. Although indexes, which include house and apartment prices have outperformed indexes consisting only of house prices, the general direction remains the same. It was evident from figure 17 that higher proportion of Germans (58%) lives in apartments. Hence, the housing index should be one which also includes apartment prices. However, these indexes do not have a very long track record. The data series from Federal Statistics Office contains historical data starting from 2000, which provides a rather short timeframe for the analysis of real estate prices. The timeframe chosen for the analysis is from fourth quarter of 1989 to fourth quarter of 2017. The selection of the timeframe was based on the following considerations:

1) Data availability before 1990s is limited for East Germany
2) Including only West Germany prior to 1990s would distort the results
3) The economic development between East and West Germany was not coherent

The selection of independent variables used in the master thesis is largely based on the model specification of Xu and Tang (2014). This specification is adjusted by eliminating GDP as the income effect is better described at a household level by disposable income. Some empirical studies have found that GDP is important house price driver. This however is not confirmed by Borowiecki (2009) who reported that extensive trials to incorporate GDP into the model did not deliver significant or plausible results.

As discussed in section 2.5. the demographic changes in Germany are a vital part of the discussion when it comes to the German housing market. Moreover, the findings of Mankiw and Weil (1989), Jud and Winkler (2002), Égert and Mihaljek (2007), and Borowiecki (2009) confirm that population might play a significant role in the determination of house prices. Hence, for the purpose of this study population variable is included to study the effect that the population changes have on the German housing market. In addition, the supply effect discussed in section 1.3 is of great importance in the theoretical aspect. This has been confirmed by Borowiecki (2009) as his findings outlined that a 10% increase in the number of completed dwellings in one year results in a house price deflation of approximately 1.2% the following year and 0.6% two years afterwards. However, obtaining quarterly data for house completions in Germany proved infeasible as the available time series from Bundesbank and Federal Statistics Office are for annual time data. Instead housing permits are used as a proxy for completions. Table 3 presents the model specification that is used in further analysis.

Table 3. Model specification and sources

| **Variable** | **Description** | **Source** |
|---|---|---|
| RHP | Real house price | Federal Reserve Bank of Dallas |
| RLTR | Real long-term interest rate | OECD |
| RCCI | Real construction costs | Federal Reserve Bank of St. Louis |
| POP | Population | Federal Statistics Office (Destatis) |
| RDI | Real disposable income | Federal Reserve Bank of Dallas |
| UNEMP | Unemployment rate | OECD |
| RM3 | Real money supply M3 | Bundesbank |
| PERM | Housing permits | Federal Reserve Bank of St. Louis |

Source: Author

It can be expected that there is a strong association between interest rates and housing prices. Housing purchases are usually highly levered with LTV levels of 60-80% describing the typical financing structure of this kind of transaction (Iacoviello and Minetti 2008). A decline in interest rates should incentivize housing buyers to go ahead with their purchase decision since financing a loan at lower rate would mean, *ceteris paribus*, that the cost of buying a property would be lower. Using long-term interest rates in the context of Germany is appropriate as was evident from the discussion in section 2.4., since majority of mortgage loans in Germany fixed for 5 or more years (Schneider and Wagner 2015). The findings of Abraham and Hendershott (1996), Jud and Winkler (2002), Égert and Mihaljek (2007), Adams and Füss (2010), Borowiecki (2009), Xu and Tang (2014), and Sutton (2002) also confirm that interest rates can explain movements in house prices.

The input prices related to completing a building are an essential part of a new build dwelling. As construction prices fluctuate it should induce a price change in new built houses as well. Higher input prices are expected to be passed on by developers and hence should be reflected in house prices. Empirical studies by Abraham and Hendershott (1996), Jud and Winkler (2002), Adams and Füss (2010), Borowiecki (2009), and Xu and Tang (2014) confirm that higher construction costs lead to higher house prices.

In its essence housing is a means to accommodate people. Hence, a change in the number of underlying occupiers should result in a change in demanded quantity for houses. As discussed in section 1.4., an increase in population should increase house prices, e.g. an influx of immigrants, would shift the demand curve to the right and therefore would result in higher house prices. Mankiw and Weil (1989), Jud and Winkler (2002), Égert and Mihaljek (2007), and Borowiecki (2009) study the effect of population on house prices and confirm that an increase in population leads to higher house prices.

Real disposable income describes the actual income that is available for households to spend. It is expected that higher real disposable income would lead to higher house prices as the surplus income can find its way to house purchases. Disposable income reflects the ‘cash in hand’ that households might spend on a house purchase. The analysis conducted by Abraham and Hendershott (1996), Jud and Winkler (2002), Égert and Mihaljek (2007), and Xu and Tang (2014) suggest an association between disposable income and house prices. While most find that higher disposable income leads to higher house prices, Xu and Tang (2014) conclude that disposable income has an inverse relationship with house prices in the long-run.

Unemployment rate represents the ratio of working age population that are not employed and thus do not generate income (excluding government support). Since they do not produce income that could be deployed towards house purchase it can be expected that higher unemployment rate leads to lower house prices. There is valid evidence in the academic literature about the association between unemployment rate and house prices. While Égert and Mihaljek (2007), and Adams and Füss (2010) find an inverse relationship between these variables, Xu and Tang (2014) reach a positive relationship. Hence, further investigation is needed to determine how the German house prices respond to changes in unemployment rate.

Goodhart and Hofmann (2008) outline that from a theoretical point the association between monetary variables, house prices and the macroeconomy is multi-facetted. They explain that due to the optimal portfolio adjustment mechanism an increase in money triggers an increase in asset prices. Therefore, from a theoretical point of view increased supply of money leads to higher house prices (Goodhart and Hofmann 2008). This is confirmed by Adams and Füss (2010), but not confirmed by Xu and Tang (2014) as they find an inverse relationship between money supply and house prices. Hence, a further study in the context of Germany is appropriate.

As discussed in chapter 1.3., supply for housing is fixed in the short-run due to construction lags. However, once housing supply increases, it is expected that the surge in supply will put downward pressure on house prices. The findings of Borowiecki (2009) confirm an inverse relationship between housing supply and house prices. Due to the lack of quarterly data for housing completions, housing permits will be used as an indicator for housing supply. Table 4 presents the summary of expected outcomes from the regression.

Table 4. Expected relationship between independent variables and real house price

| **Independent variable** | **Description** | **Expected sign** |
|---|---|---|
| RLTR | Real long-term interest rate | - |
| RCCI | Real construction costs | + |
| POP | Population | + |
| RDI | Real disposable income | + |
| UNEMP | Unemployment rate | - |
| RM3 | Real money supply M3 | + |
| PERM | Housing permits | - |

Source: Author

## 3.3. Data

Data in this master thesis ranges from 1989 Q4 to 2017 Q4 and covers a period of more than 25 years. The graphical illustration of the data, presented in figure 19, reveals that series such as real disposable income and real money supply have a deterministic trend during the respective period. Other series exhibit random walk or random walk with drift.

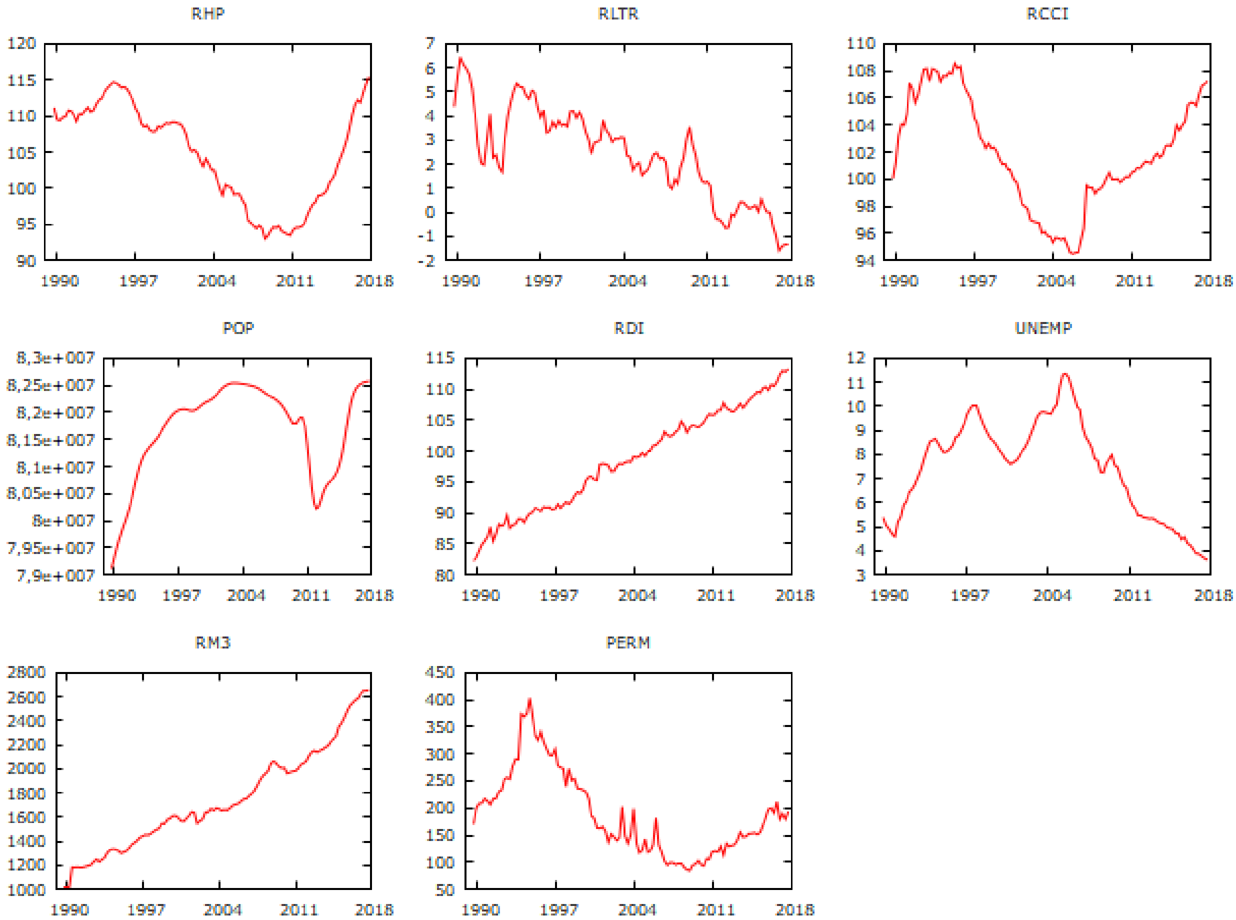


Figure 19. Initial time series (1989 Q4 to 2017 Q4)
Source: Author (Gretl output)

The macro economic data is rather interesting for Germany. As seen in figure 19 (RHP), real house prices have been almost stagnant over a more than 25 year period. At the same time disposable income and money supply have surged substantially. Real long-term interest rate has declined from approximately 6% in the beginning of the 1990s to negative territory by the end of 2017. During the same period unemployment rate has increased from approximately 5% level in the beginning of 1990s to approximately 11% at the peak in 2005, and fell thereafter to the range of 3-4% as of 2017.

Table 5. Summary statistics for 113 observations (1989 Q4 to 2017 Q4)

| | RHP | RLTR | RCCI | POP | RDI | UNEMP | RM3 | PERM |
|---|---|---|---|---|---|---|---|---|
| Mean | 104.70 | 2.40 | 101.86 | 8.17E+11 | 98.50 | 7.43 | 1,739.20 | 188.14 |
| Median | 106.54 | 2.41 | 101.50 | 8.20E+11 | 98.32 | 7.80 | 1,656.70 | 167.85 |
| Minimum | 93.00 | -1.59 | 94.48 | 7.91E+11 | 82.29 | 3.63 | 1,015.30 | 84.69 |
| Maximum | 115.42 | 6.43 | 108.54 | 8.26E+11 | 113.24 | 11.35 | 2,654.80 | 402.90 |
| Std. Dev. | 6.89 | 1.89 | 4.06 | 8.62E+09 | 8.21 | 2.02 | 416.75 | 76.86 |
| C. V. | 0.07 | 0.79 | 0.04 | 0.01 | 0.08 | 0.27 | 0.24 | 0.41 |
| Skewness | -0.27 | -0.13 | -0.05 | -1.10 | -0.06 | -0.16 | 0.44 | 0.80 |
| Ex. Kurtosis | -1.33 | -0.71 | -1.01 | 0.29 | -1.14 | -1.03 | -0.58 | -0.11 |
| Confidence level (95%) | 114.26 | 5.40 | 108.11 | 8.25E+11 | 110.86 | 10.49 | 2,577.20 | 348.81 |

Source: Author (Gretl output)

Summary statistics of the data, presented in table 5, reveals that real house price index has a maximum value of 115.42. Real house price in Germany peaked in the fourth quarter of 2017. Therefore it has outgrown its previous top achieved in 1995 (114.7) in the period under examination. The bottom level (93.0) was reached in the third quarter of 2008 and the growth up to 2017 fourth quarter has been approximately 24% since then. This translates into a real CAGR of approximately 2.4% since 2008. All variables besides the real money supply and housing permits are negatively skewed. Frequency distribution charts for positively skewed variables have longer tails on the right whereas money supply and housing permits have a longer tail on the left.

The correlation matrix presented in table 6 quantifies the correlation association between the log variables used in the model. Correlation coefficient ranges between the extremes of -1 and 1. The sign of the correlation coefficient indicates the direction of the association while the magnitude of the correlation coefficient indicates the strength of the association.

Table 6. Correlation matrix for log variables with 113 observations (1989 Q4 to 2017 Q4)

| | PERM | RM3 | UNEMP | RDI | POP | RCCI | RLTR | RHP |
|---|---|---|---|---|---|---|---|---|
| **RHP** | 0.84 | -0.42 | -0.07 | -0.57 | -0.05 | 0.66 | 0.43 | 1.00 |
| **RLTR** | 0.51 | -0.86 | 0.46 | -0.86 | -0.13 | 0.10 | 1.00 | |
| **RCCI** | 0.71 | -0.13 | -0.47 | -0.29 | -0.38 | 1.00 | | |
| **POP** | -0.11 | 0.30 | 0.52 | 0.33 | 1.00 | | | |
| **RDI** | -0.65 | 0.97 | -0.38 | 1.00 | | | | |
| **UNEMP** | 0.13 | -0.48 | 1.00 | | | | | |
| **RM3** | -0.53 | 1.00 | | | | | | |
| **PERM** | 1.00 | | | | | | | |

Source: Author (Gretl output)

In the sample range from 1989 Q4 to 2017 Q4 with 113 observations the highest positive correlation among all the variables exists between real disposable income and real money supply (0.97). In addition, a strong positive association exists between real house prices and housing permits (0.84), and between real construction costs and housing permits (0.71). Fairly strong positive relationship is evident between real construction costs and real house price (0.66). Moderate positive association can be observed between unemployment rate and population (0.52). Real long-term interest rate has a moderate positive relationship with housing permits (0.51), unemployment rate (0.46), and house prices (0.43).

On the other side of the specter, a strong negative correlation is observable for real long-term interest rates with real disposable income (-0.86), and real money supply (-0.86). Housing permits also have a relatively strong correlation with real disposable income (-0.65), and real money supply (-0.53). Additionally, real house price has a negative association with real disposable income (-0.57), and real money supply (-0.42). Furthermore, real construction costs and unemployment rate have an inverse relationship, with the correlation coefficient implying a moderate negative correlation (-0.47).

## 3.4. Methodology

This master thesis follows the methodology proposed by Xu and Tang (2014). They implement the Engle-Granger two-step approach, which will be introduced in this master thesis. It consists of Engle-Granger cointegration test and a subsequent construction of an error correction model. Besides Xu and Tang (2014), it has also been used for instance in Barot and Yang (2012). Error correction model has been widely used in previous studies of housing prices, e.g. Feng et al. (2010), Jacobsen and Naug (2005). As already outlined in section 1.7., the deviation from the long-term equilibrium in housing markets is evident. Hence, it is reasonable to expect that house prices are cyclical in the short-term, but will establish the equilibrium level determined by the fundamentals in the long-term (Englund 2011). Hence, an error correction model that can capture this dynamic adjustment is highly useful.

The Engle-Granger two-step method is a single equation technique. It tests for cointegration by using a cointegration ordinary least squares (OLS) regression method and uses the residuals from this regression as an independent variable in the error correction model (ECM).
This methodology has been described in Greene (2002). In the first step it is essential to determine if all variables are I(1), i.e. are the variables stationary after taking the first difference. If the variables are I(1) then a cointegration regression follows, which uses ordinary least squares (OLS) method. The residuals from the regression must be tested to determine whether they are I(0) or not. In case residuals are I(0) it is possible to continue to the next step, in case the residuals are I(1) it is necessary to estimate a model containing only first differences. The second step is to build an error correction model that contains the estimated residuals from the initial regression. The cointegration regression only considers the long-term property of the model, and does not deal with the short-term dynamics explicitly. The long-run relationship measures firsthand the association between variables, while the short-tern dynamics measure any kind of dynamic adjustment between the first differences of variables.

## 3.5. Stationarity test

A stationary time series has statistical properties, which are constant over time. A strictly stationary process is where any $t_1, t_2, \dots, t_T \in Z$, any $k \in Z$ and $T = 1, 2, \dots$ (Tong 1990)

$$F y_{t_1}, y_{t_2}, \dots, y_{t_T}(y_1, \dots, y_T) = F y_{t_1+k}, y_{t_2+k}, \dots, y_{t_T+k}(y_1, \dots, y_T) \qquad (3)$$

where
$F$: joint distribution function for a set of random variables

In other terms, a strictly stationary series has the same values at any time, $t$. This implies that the probability of $y$ falling into a particular interval is always the same (Brooks 2008). However, in practice strictly stationary series is sometimes overlooked and researchers also use weakly stationary series. A weak form of stationarity is present when the following conditions hold (Baumöhl and Lyócsa 2009):

$$E[y_t] = \mu \wedge |\mu| < \infty \tag{4}$$

$$var(y_t) = E[(y_t - \mu)^2] = \sigma^2 \wedge |\sigma^2| < \infty \tag{5}$$

$$covar(y_t, y_{t+k}) = covar(y_t, y_{t-k}) = \gamma_k \wedge |\gamma_k| < \infty \tag{6}$$

Therefore, a stationary process should have a constant mean, constant variance and constant autocovariance structure. If stationarity is ignored by researcher then the results are inaccurate, i.e. spurious regression problem. In case the time series is not stationary it is possible in most cases to derive at a stationary time series by taking the first difference of the series. Although sometimes it might be necessary to take higher order differences to achieve stationarity. It is useful to take natural logarithm of the data before differencing in order to deal with linear trends (Baumöhl and Lyócsa 2009). The most common method to test for stationarity of series is the Augmented Dickey-Fuller (ADF) test. The pioneering work on the unit root testing was done by Dickey and Fuller (1979). The ADF test considers higher order of data generating process, which can be presented as:

$$\Delta y_t = \psi y_{t-1} + \sum_{i=1}^{p} \alpha_i \, \Delta y_{t-i} + u_t \tag{7}$$

Dickey-Fuller tests examines the null hypothesis that $\varphi = 1$ in:

$$y_t = \varphi y_{t-1} + u_t \tag{8}$$

against the one-sided alternative that $\varphi < 1$. Therefore the null hypothesis states that the series contains a unit root, i.e. is non-stationary. The alternative hypothesis states that series does not contain a unit root, i.e. is stationary.

Firstly, to evaluate if series are stationary a graphical interpretation is undertaken. The series under examination are the natural logarithms of the initial time series (figure 20) in accordance with the model specification of Xu and Tang (2014), and Jacobsen and Naug (2005). At initial inspection it appears that real disposable income and real money supply have a deterministic trend and are clearly non-stationary. Real long-term interest rate has a downward stochastic trend and appears to be non-stationary as well. All other series also exhibit features of a trend, however during the period under examination some series demonstrate a change in the trend. For example real house price has a clear downward trend between the period of 1996 to 2010, but thereafter the trend reverses and a clear upward movement is observable from 2010 to 2017. Initial investigation indicates that series are non-stationary at level.

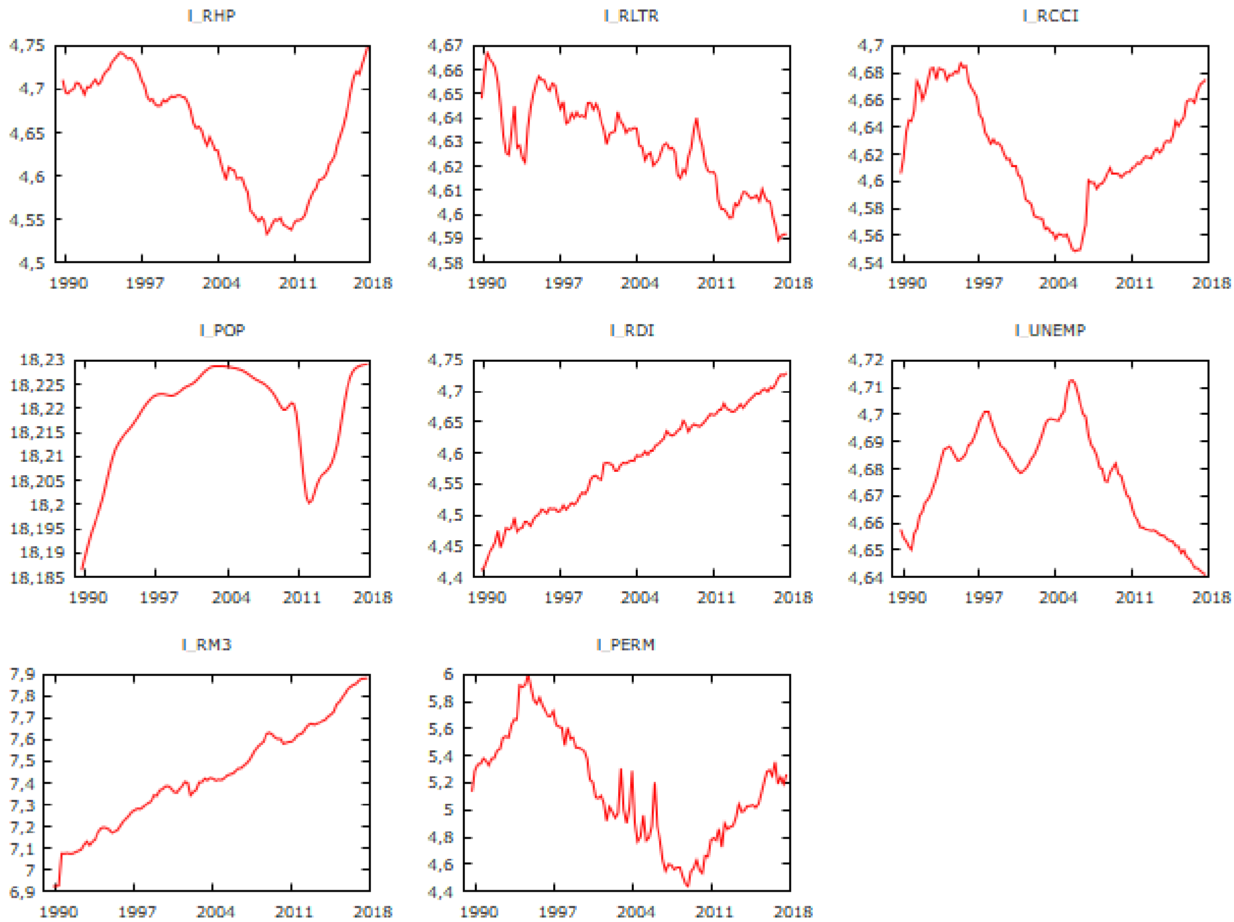


Figure 20. Time series of natural logarithms
Source: Author (Gretl output)

In order to understand if series are I(1) it is necessary to take the first difference. The graphical presentation (figure 21) shows that obvious trends have been removed by taking the first difference. Most of the differenced time series look like white noise. Therefore, it can be assumed the series are stationary after taking the first difference, i.e. the series are integrated at I(1).

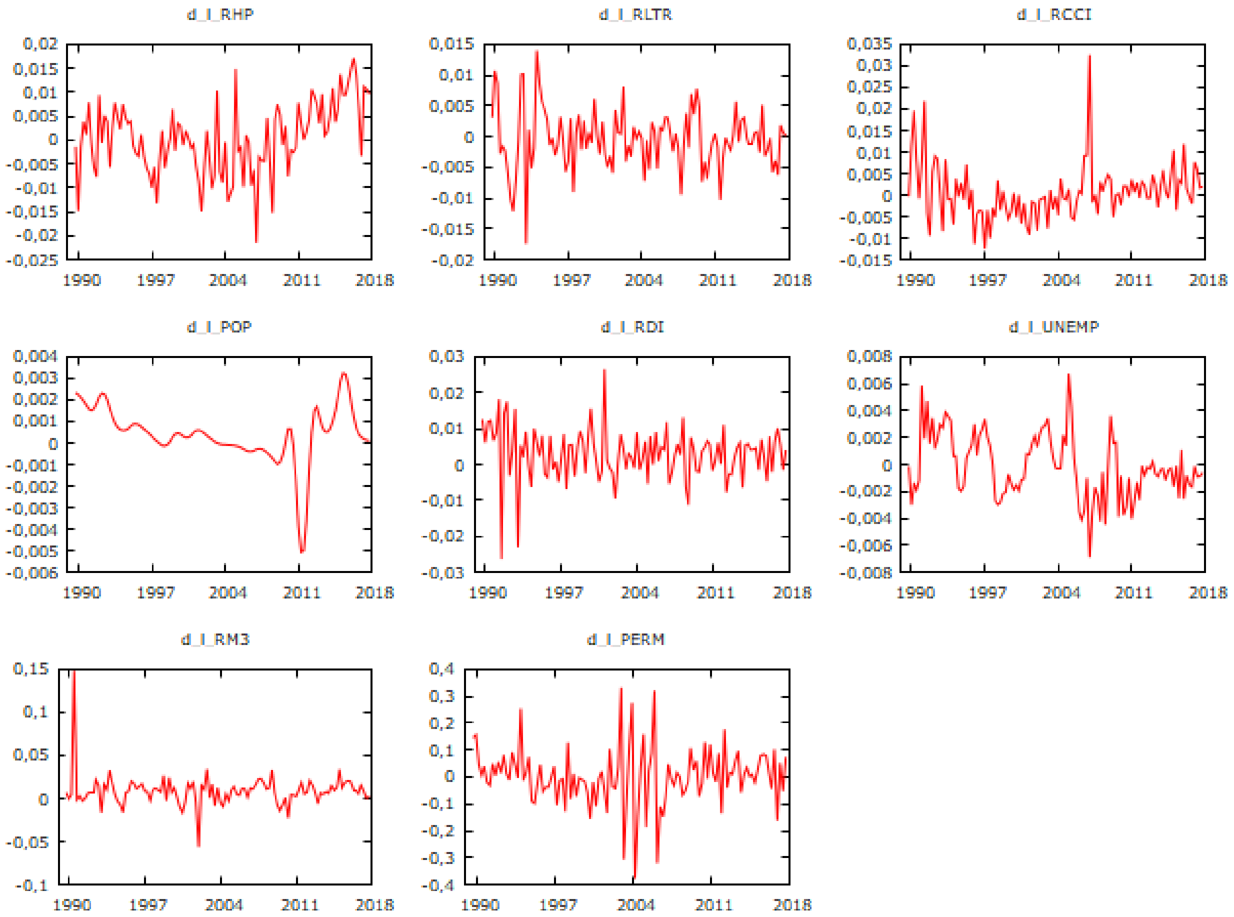


Figure 21. Time series of differenced natural logarithms
Source: Author (Gretl output)

Although the graphical presentation provides some evidence about time series properties it is not a reliable method to determine stationarity. In order to be certain whether the initial graphical analysis is accurate, a unit root test has to be conducted. That makes it possible to identify if the time series are actually I(1) and whether Engle-Granger two-step approach is appropriate analysis method to continue with. To test for unit root an ADF test is conducted (table 7). The lag order of the test is set to four since the underlying data is with quarterly frequency.

Table 7. Results of Augmented Dickey-Fuller test

| Variable | At level | Analysis | First difference | Analysis |
|---|---|---|---|---|
| l_RHP | 1.000 | Constant and trend | 0.013 | Without trend |
| l_RLTR | 0.093 | Constant and trend | 0.000 | Without trend |
| l_RCCI | 0.714 | Without trend | 0.001 | Without trend |
| l_POP | 0.063 | Constant | 0.010 | Without trend |
| l_RDI | 0.058 | Constant and trend | 0.000 | Constant |
| l_UNEMP | 0.814 | Constant and trend | 0.000 | Constant and trend |
| l_RM3 | 0.051 | Constant and trend | 0.000 | Constant |
| l_PERM | 0.571 | Without trend | 0.000 | Without trend |

Source: Author

In the first stage ADF test for unit root is conducted at level. The results reveal that real house price, real construction cost index, unemployment rate and housing permits are non-stationary even at 10% significance level. All other variables are non-stationary at 5% significance level. Hence, the null hypothesis cannot be rejected and it can be concluded that time series are non-stationary at I(0). The next step is to test stationarity of first differences. By taking the first difference most time series in finance achieve stationarity (Baumöhl and Lyócsa 2009). The results of the unit root test clearly indicate that all the time series are significant at 5% significance level as their p-value is below 0.05. Therefore, null hypothesis is rejected and the conclusion is that time series are I(1). As an outcome of the ADF unit root test it is confirmed that after taking the first difference of non-stationary time series the resulting time series are in fact stationary. In the light of these results it is plausible to continue the analysis with Engle-Granger two-step approach as the requirement for I(1) time series is fulfilled.

## 3.6. Cointegration test

Let $w_t$ be a $kx1$ vector of variables. Components of $w_t$ are integrated of order $(d, b)$ if:

1) All components of $w_t$ are $I(d)$
2) There is at least one vector of coefficients $\alpha$ such that $\alpha' w_t \sim I(d, b)$

In practice, a lot of financial variables contain a unit root, and therefore are I(1). In this context, a set of variables can be defined as cointegrated if a linear combination of them is stationary, i.e. I(0) and hence integrated at order of zero. Cointegration relationship can also be viewed as a long-term or equilibrium phenomenon. That is because cointegrating variables might deviate from the association in the short-term, but the relationship will be consistent in the long-term, i.e. the short-term deviation from the equilibrium will be restored (Brooks 2008).

The results of unit root test conducted in the previous section confirm that the time series are I(1), therefore a test for cointegration is appropriate. The most common tests for cointegration are Engle-Granger test and Johansen test. Engle and Granger (1987) suggest a cointegration test, which consists of estimating the cointegration regression by OLS, obtaining the residuals and applying ADF unit root test for these residuals. If the null hypothesis of a unit root in the ADF test regression residuals is not rejected, the conclusion would be that a stationary combination of the non-stationary variables has not been found and therefore there is no cointegration. If the null hypothesis is rejected however, the conclusion is that the combination of non-stationary variables is stationary. Therefore these variables are cointegrated (Greene 2002). Engle-Granger cointegration test has some shortcomings. In case of small sample size the test does not provide reliable results. In addition, if the dependent variable is not known initially then Engle-Granger test is not appropriate (Xu and Tang 2014). In this master thesis the dependent variables is known and the sample size provides enough observations for reliable estimates.

The initial OLS regression is based on natural logarithms of the selected variables outlined in the beginning of this chapter. The following regression equation will be tested for cointegration:

$$l\_RHP_t = \alpha + \beta_0(l\_RLTR_t) + \beta_1(l\_RCCI_t) + \beta_2(l\_POP_t) + \beta_3(l\_RDI_t) + \beta_4(l\_UNEMP_t) + \beta_5(l\_RM3_t) + \beta_6(l\_PERM_t) + \varepsilon t \tag{9}$$

Different time periods were tested to achieve the most appropriate setting. The end date for all tests was set to fourth quarter 2017 to capture the latest price surge in the German house prices into the model. Tests were run for periods starting from fourth quarter of 1989, second quarter of 1991 and first quarter of 1993. The results from Engle-Granger cointegration test (table 8) indicated that the period starting from the fourth quarter of 1989 entailed the best model specification as the R-squared was the highest.

Table 8. Results of Engle-Granger cointegration test

| Step 2 of Engle-Granger cointegration test: testing for unit root in uhat (ADF test) | |
|---|---|
| Sample size | 112 |
| Lags, criterion AIC | 4 |
| Test statistic: tau_c(8) | -5.94278 |
| p-value | 0.0149 |
| 1-st order autocorrelation coeff. for e | 0.061 |

Source: Author (Gretl output)

The Engle-Granger cointegration test reveals that the p-value from the unit root test on the residuals stands at approximately 0.014. Therefore the null hypothesis can be rejected at a 5% significance level. As an outcome of the test it can be concluded that cointegration exists as the combination of non-stationary time series is stationary.

Since the first step of the two-step Engle-Granger approach confirms that cointegration exists between the variables then the next step is to proceed with an error correction model. However, if the results would have indicated that cointegration does not exist then error correction model would not be an appropriate analysis method to continue with. The findings of cointegration between house prices and the macroeconomic factors that can explain house prices are also coherent with the results of Xu and Tang (2014), Feng *et al.* (2010) and Jacobsen and Naug (2005).

In the case that conintegration would had not existed between the variables then other econometric analysis methods had to be implemented. One of the possibilities would have been vector autoregressive (VAR) model. To use the VAR model, the combination of the time series should not be cointegrated. In case cointegration does not exists, VAR model should be implemented (Asari *et al*. 2011).

## 3.7. Error correction model

In the previous step, Engle-Granger cointegration test confirmed that residuals of the initial regression model are I(0) and therefore cointegration exists. This gives the basis to construct an error correction model in the second step of the Engle-Granger two-step approach. The first step of the Engle-Granger two-step approach entailed the following regression:

$$y_t = \alpha + \gamma x_t + u_t \tag{10}$$

The results of this regression produce an error correction term $u_t$:

$$u_t = y_t - \alpha - \gamma x_t \tag{11}$$

The second step of Engle-Granger two-step procedure is to use $u_t$ and to estimate error correction model that is a combination of first differences and lagged levels (Engle and Granger 1987):

$$\Delta y_t = \beta_1 \Delta x_t + \beta_2 (u_{t-1}) + v_t \tag{12}$$

$$\Delta y_t = \beta_1 \Delta x_t + \beta_2 (y_t - \alpha - \gamma x_t) + v_t \tag{13}$$

Provided that cointegration exists between $y_t$ and $x_t$ then $u_t$ will be I(0) even though the components are I(1). Therefore it is valid to use OLS and standard procedures on statistical inference on the error correction model. The error correction model states that $\Delta y_t$ can be explained by $\Delta x_t$ and the lagged $u_t$. Here $u_{t-1}$ can be thought of as an equilibrium error that occurred in the previous period. $\gamma$ denotes the long-term relationship between $x$ and $y$, while $\beta_1$ describes the short-term relationship between changes in $x$ and $y$. As to $\beta_2$, it can be explained as the speed of adjustment back to equilibrium or it measures the proportion of last period's deviation that is corrected for in current period (Brooks 2008). All the variables in the ECM equation are stationary, and therefore, ECM has no spurious regression problem.

Error correction model was constructed with the same variables as the initial regression model. In addition, the lagged (1 period) residual from the initial regression was added as an independent variable. Other variables were tested with different lag orders. The final specification was achieved with a lag order of 1 for population and unemployment rate. Real money supply and housing permits were given a lag of 2. All other variables were included into the model with a lag order of 3. Lagged independent variables identify a relationship between variables where a change in the dependent variable is explainable by the change in the independent variable at a particular period in the past. Therefore a change in the independent variable today induces a change in the dependent variable after a predefined period in the future.

## 3.8. Analysis of Engle-Granger two-step approach results

In the first step of the Engle-Granger two-step approach a cointegration test was conducted that indicated the presence of cointegration between the variables. Therefore it was plausible to continue with constructing the error correction model. Engle-Granger cointegration test gives insight on the long-term relationship between the variables. The cointegration regression results (table 9) reveal several interesting facts about the long-term relationship between macroeconomic variables and house prices in Germany.

Table 9. Cointegration regression results using 113 observations (1989 Q4 – 2017 Q4)

Cointegration OLS:OLS, using observations 1989:4-2017:4 (T = 113)
Dependent variable: l_RHP

| | Coefficient | Std. Error | t-ratio | p-value | |
|---|---|---|---|---|---|
| const | −48.0788 | 4.83430 | −9.945 | <0.0001 | *** |
| l_RLTR | −0.414588 | 0.195835 | −2.117 | 0.0366 | ** |
| l_RCCI | −0.269571 | 0.0856093 | −3.149 | 0.0021 | *** |
| l_POP | 3.79341 | 0.305485 | 12.42 | <0.0001 | *** |
| l_RDI | −0.322844 | 0.156790 | −2.059 | 0.0420 | ** |
| l_UNEMP | −2.51646 | 0.192482 | −13.07 | <0.0001 | *** |
| l_RM3 | −0.0835073 | 0.0510038 | −1.637 | 0.1046 | |
| l_PERM | 0.126772 | 0.00890769 | 14.23 | <0.0001 | *** |

| | | | |
|---|---|---|---|
| Mean dependent var | 4.648903 | S.D. dependent var | 0.066606 |
| Sum squared resid | 0.033035 | S.E. of regression | 0.017738 |
| R-squared | 0.933514 | Adjusted R-squared | 0.929082 |
| F(7, 105) | 210.6115 | P-value(F) | 8.60e-59 |
| Log-likelihood | 299.4323 | Akaike criterion | −582.8646 |
| Schwarz criterion | −561.0455 | Hannan-Quinn | −574.0107 |
| rho | 0.523046 | Durbin-Watson | 0.904195 |

Source: Author (Gretl output)

The long-term relationship between real long-term interest rate and house prices is inverse and suggests that a decline in interest rates will have positive effect on house prices in the long-term. This finding is consistent with the work of Abraham and Hendershott (1996), Jud and Winkler (2002), Égert and Mihaljek (2007), Adams and Füss (2010), Borowiecki (2009), Xu and Tang (2014), and Sutton (2002). Similar inverse long-term association is identifiable between unemployment rate and house prices. This confirms the findings by Égert and Mihaljek (2007), and Adams and Füss (2010), however is not consistent with the findings of Xu and Tang (2014). Population has a positive long-term relationship with house prices according to the conintegration regression. Therefore, an increase in the population would induce higher house prices in the long-term, which is consistent with the findings of Mankiw and Weil (1989), Jud and Winkler (2002), Égert and Mihaljek (2007), and Borowiecki (2009). Although, it was expected that an increase in real disposable income would lead to higher house prices, the results indicate that the long-term relationship is negative between these variables. This finding is counter-intuitive and contradicts the conclusions of Abraham and Hendershott (1996), Jud and Winkler (2002), Égert and Mihaljek (2007). However from figure 22 it is observable that during the whole period under consideration real disposable income increased at a fairly constant pace. This cannot be concluded for real house prices however. The decline in real house prices between 1996 and 2010 is clearly moving in the opposite direction with real disposable income. An inverse relationship between disposable income and house prices was also witnessed by Xu and Tang (2014) in the UK during an approximately 40 year period.

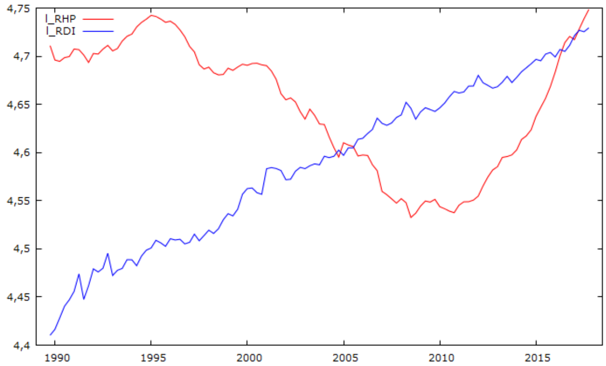


Figure 22. Natural logarithms of real house price and real disposable income
Source: Author (Gretl output)

The real money supply, similarly to real disposable income, had an inverse long-term relationship with house prices in Germany during the observed period. This is not in accordance with the theoretical considerations and the findings of Goodhart and Hofmann (2008), and Adams and Füss (2010). However, Xu and Tang (2014) have also found that a negative association was present in the UK during the period between the first quarter of 1971 and the fourth quarter of 2012. The long-term relationship between the real construction costs and real house price is negative according to the model. This indicates that if input prices for construction rise, house prices will decline. This is not consistent with the findings of Abraham and Hendershott (1996), Jud and Winkler (2002), Adams and Füss (2010), Borowiecki (2009), and Xu and Tang (2014). Discussion in chapter 1 outlined that increasing supply should lead to lower house prices. The long-term relationship between housing permits and house prices however is positive according to the results. This contradicts the findings of an inverse relationship between housing supply and house prices by Borowiecki (2009).

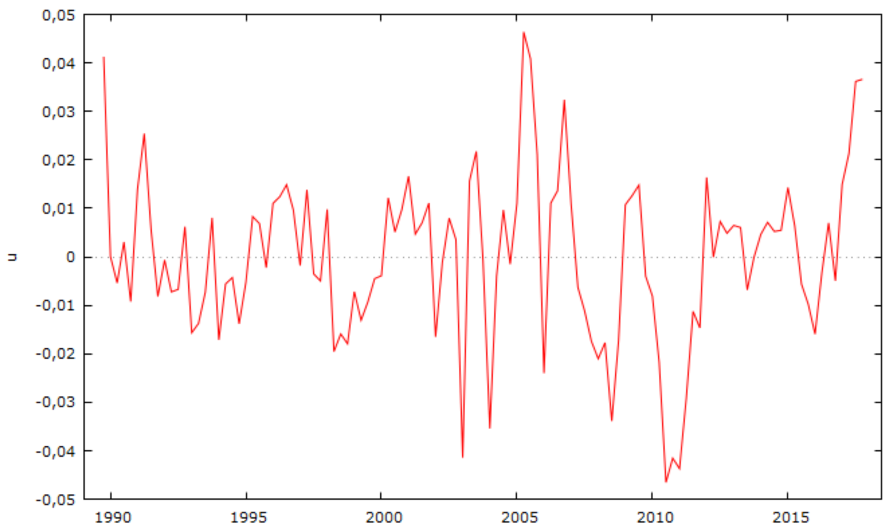


Figure 23. Residuals from the cointegration regression
Source: Author (Gretl output)

The graphical illustration of the initial regression residuals (figure 23) suggests that actual house prices deviate from the equilibrium level. This indicates that during some period's actual house prices do not correspond to the price level that is suggested by fundamental factors investigated in the model specification. The return to zero implies that prices eventually come back to the equilibrium level. Fluctuation between the negative values and positive values outlines that real house prices in Germany are in fact cyclical and do not follow the equilibrium level on a constant basis. The swings in the residuals are with greater amplitude and duration after 2003. Prior to that, deviations from the equilibrium level were smaller and occurred in a shorter time frame.

Before error correction model estimation results can be explained it is necessary to evaluate the model. For that purpose a series of tests needs to be conducted to confirm that the error correction model specification is appropriate. Firstly Ramsey's RESET test, which is a general model specification test. It tests whether a non-linear combination of the fitted values help to explain the dependent variable. The null hypothesis is that the model specification is adequate and the alternative hypothesis is that the model is misspecified (Brooks 2008). The results, presented in appendix 2, indicate a p-value of 0.87 and therefore the null hypothesis is not rejected, which in turn means that the model specification is adequate.

To test for heteroscedasticity, White's test is carried out. White's test estimates whether the variance of errors in a regression model is constant. The null hypothesis is that the errors are constant, i.e. heteroscedasticity is not present. The alternative hypothesis is that errors are not constant, i.e. heteroscedasticity is present Brooks (2008). Test results, presented in appendix 2, provide a p-value of 0.03 and therefore the null hypothesis is not rejected at a 1% significance level.

As a next step autocorrelation is tested in the model. Autocorrelation refers to the correlation of a time series with its own past and future values (Greene 2002). Breusch-Godfrey test is conducted to test for autocorrelation in the regression model. A lag order of four is used since quarterly data is analyzed. The null hypothesis is that there is no autocorrelation up to order of four, whereas the alternative hypothesis states that autocorrelation exists. As shown in appendix 4, the p-value 0.84 indicates that null hypothesis is not rejected and therefore the model does not contain autocorrelation up to the fourth lag order.

As a next procedure, the model is tested for multicollinearity. Multicollinearity refers to a setting where independent variables are highly correlated with each other (Brooks 2008). In order to test for multicollinearity a variance inflation factor (VIF) test is carried out. It quantifies the degree of multicollinearity in a multiple regression. The test indicates multicollinearity if the VIF value is higher than 10. As shown in appendix 5, all variables come in below two and therefore the model does not suffer a problem of multicollinearity.

In order to test for normality of residuals Jarque-Bera test is conducted. It is a test for goodness of fit and tests whether the sample data have the skewness and kurtosis that are similar to normal distribution (Greene 2002). The null hypothesis is that the data are normally distributed. The alternative hypothesis is that the data does not come close to normal distribution. As shown in the appendix 6, p-value of the test is 0.12 and the null hypothesis is not rejected at a 10% significance level. Hence, the residuals are normally distributed. The tests indicate that the model specification is appropriate and error correction model estimates are reliable.

Error correction model helps to explain the deviations between the growth in house prices and the growth in other variables. It identifies the short-term relationship between house prices with macroeconomic variables and the error correction term (deviation from the long-term relationship). The error correction term applied in the error correction model has an elasticity of -0.12 and is significant at a 1% level (table 10). The coefficient indicates that the model corrects its previous level of disequilibrium by 12% in the current period. Error correction term also shows the speed of adjustment of the price level from the equilibrium level. This is in line with the results of Oikarinen (2005) who found, using an error correction model with various model specifications, that the quarterly speed of adjustment for housing prices in Helsinki metropolitan area was approximately 10-15%. In addition, the empirical analysis conducted by Annett (2005) suggests that the speed of adjustment is in line with the findings of current thesis. Annett (2005) tested an error correction model with two different model specifications and estimated error correction terms of -0.12 and -0.13. Therefore the speed of adjustment is approximately 12-13% according to these estimates. The findings of Xu and Tang (2014) however indicate that the quarterly speed of adjustment was merely 3.7% in UK. DiPasquale and Wheaton (1994) found that once house prices deviated from the long-term equilibrium level, the adjustment back to equilibrium occurred at an approximate speed of 29% per year in the United States during the period between 1963 and 1990. Hence, the conclusion of DiPasquale and Wheaton (1994) outlines a slightly slower adjustment process.

Table 10. Results of error correction model

ERROR CORRECTION MODEL: OLS, using observations 1990:4-2017:4 (T = 109)
Dependent variable: d_l_RHP

| | Coefficient | Std. Error | t-ratio | p-value | |
|---|---|---|---|---|---|
| const | −0,000408783 | 0,000668792 | −0,6112 | 0,5425 | |
| d_l_RLTR_1 | −0,185947 | 0,126569 | −1,469 | 0,1450 | |
| d_l_RCCI_1 | 0,172145 | 0,102240 | 1,684 | 0,0954 | * |
| d_l_POP_1 | 0,872282 | 0,480489 | 1,815 | 0,0725 | * |
| d_l_RDI_2 | −0,161045 | 0,0825739 | −1,950 | 0,0540 | * |
| d_l_UNEMP_1 | −0,0561517 | 0,278047 | −0,2020 | 0,8404 | |
| d_l_RM3_2 | 0,0593207 | 0,0326732 | 1,816 | 0,0725 | * |
| d_l_PERM_4 | 0,0110023 | 0,00534985 | 2,057 | 0,0424 | ** |
| u_1 | −0,123978 | 0,0376853 | −3,290 | 0,0014 | *** |
| d_l_RHP_1 | 0,457867 | 0,0831208 | 5,508 | <0,0001 | *** |

| | | | |
|---|---|---|---|
| Mean dependent var | 0,000460 | S.D. dependent var | 0,007385 |
| Sum squared resid | 0,003487 | S.E. of regression | 0,005935 |
| R-squared | 0,407863 | Adjusted R-squared | 0,354032 |
| F(9, 99) | 7,576784 | P-value(F) | 2,23e-08 |
| Log-likelihood | 409,4063 | Akaike criterion | −798,8126 |
| Schwarz criterion | −771,8992 | Hannan-Quinn | −787,8982 |
| rho | −0,013681 | Durbin's h | −0,287445 |

Source: Author (Gretl output)

On the contrary to the findings of Xu and Tang (2014) interest rate did not turn out to be significant at a 10% significance level. Although the negative short-term association of interest rate with house prices is similar to Xu and Tang (2014) results, the model does not provide statistical evidence that the association is meaningful. They find that interest rate with a lag order of two has a short-term relationship with house prices. Applying the same lag order in current model does not lead to similar results. Annett (2005) also contradicts current findings by outlining that real long-term interest rate with a lag order of one has a significant negative short-term association with house prices. The results indicate that real construction cost, with a lag order of one, is significant at a 10% significance level. The coefficient outlines a positive short-term relationship with house prices. This confirms the analysis of Xu and Tang (2014) who also found that lagged construction costs have a short-term positive association with house prices. They also concluded that in the context of UK a lag order of one for construction costs was appropriate. Feng *et al.* (2010) also determined a positive short-term relationship between residential construction costs and house prices in major cities and on a national level in China. The model outlines that the population variable with a lag order of one is significant at a 10% significance level. There is a strong positive relationship between population and house prices in the short-term. Real disposable income variable, with a lag order of two, is significant on a 10% significance level. This does not correspond well to the theoretical considerations as the model indicates a negative short-term association with house prices. Therefore, the result is not coherent with the findings of Xu and Tang (2014) and Jacobsen and Naug (2005) who found a positive short-term association between disposable income and house prices. The results of Annett (2005) and Feng *et al.* (2010) indicate that there could be a positive association between real income and house prices, although the coefficient is not statistically significant. Real money supply at a lag order of two is statistically significant at a 10% significance level and demonstrates a positive short-term relationship with house prices. Unemployment rate did not prove to be statistically significant. Therefore the data does not provide enough evidence about the association with house prices.

## 3.9. Main conclusions and suggestions

The results of the econometric analysis demonstrate that the housing market in Germany is cyclical. The long-term relationship between macroeconomic variables and house prices becomes evident from the cointegration analysis. The regression results outline that variables such as real long-term interest rate, real construction costs, real disposable income, unemployment rate and real money supply have an inverse long-term association with house prices in Germany. In contrast, population and housing permits have a positive long-term association with house prices in Germany. Except for real money supply, all variables are statistically significant at a 5% significance level.

The negative long-term association between real long-term interest rate and house prices is consistent with the findings of several research papers. It confirms that the decline in interest rates lowers the borrowing costs and improves the affordability of housing, which in turn is reflected in higher demand and house prices. The positive long-term association between population and house prices confirms that an increase in the underlying occupiers increases house prices. Considering that the population growth in Germany has largely been the result of influx of immigrants there is a reason for concern once immigration loses its momentum. The regression results demonstrated that unemployment rate has negative long-term relationship with house prices. Considering the current unemployment rate of approximately 3.6% in Germany, it is not reasonable to expect it to decline much further. This is the lowest level during the period since the beginning of 1990s and therefore investors should remain cautious about further developments. If in fact, the long-term relationship between unemployment rate and house prices holds then a trend reversal in unemployment rate might lead to lower house prices.
Not all of the findings about long-term associations between macroeconomic variables and house prices are consistent with economic theory and the results described in reviewed literature. It was expected that real construction costs would have a positive impact on house prices. Conversely, regression results suggest that real construction costs lead to higher house prices. In addition, the association between real disposable income as well as real money supply with real house prices was expected to be positive, however, the regression results indicate a negative association. Graphical analysis reveals that real disposable income and real money supply have been surging during the same period that real house prices have been declining. Real money supply was the only variable that was statistically insignificant. Therefore it can be concluded that there was not enough evidence to confirm that the negative sign of the regression coefficient would imply an inverse association with house prices.

It can be concluded that due to the peculiarities of German housing market, similar long-term associations with other countries are not evident for all variables. The rental friendly regulation and social housing incentives have resulted in one of the lowest low home ownership rates in

Europe. In addition, the risk-averse profile of German people and financial institutions has led to conservative lending practices. Therefore, house prices in Germany have not been following the same pattern as in other countries and not all fundamentals describe house price changes similarly to other regions.

Error correction model estimation suggests that the residual from the initial regression, i.e. the error correction term, has a coefficient of -0.12 at a 1% significance level. This indicates that the short-term deviation from the long-term equilibrium level has a speed of adjustment of approximately 12%. Hence, when the price deviates from the equilibrium level it will adjust back to the equilibrium by 12% in every quarter following the deviation. Since the error correction term has a lag order of one it does not adjust in that period where the deviation occurred. Instead the adjustment process starts in the following quarter. Therefore, after one year approximately 31% of the deviation has restored back towards the equilibrium level. After seven periods more than half of the deviation has been adjusted. These findings are broadly in line with the conclusions of other research papers. The cyclical nature of the housing market in Germany is evident from the initial regression residuals. The movement around the equilibrium level indicates that in the short-term prices deviate from the long-term equilibrium price. The price deviation from the equilibrium has been of lesser extent from the beginning of 1990s up to 2003. From 2003 to 2010 the deviations from the equilibrium lasted for a shorter period and deviated substantially more compared to the former period. Although, the housing crisis was not that explicit in Germany there is still evidence of increased volatility in the residuals. The deviation from the equilibrium level reached the maximum level in the second quarter of 2005. That marks the period where the overvaluation in house prices was the highest during the reviewed period. In 2010 the deviation from the long-term equilibrium was the most negative during the whole period under consideration. Hence, in 2010 the housing market in Germany was considerably undervalued. This is consistent with the fact that house prices were in decline from 1996 to 2010, although macroeconomic indicators were improving, e.g. increasing real disposable income during the same period. After 2010 prices have started to adjust towards equilibrium and reached the equilibrium level in 2012. Since then prices fluctuate above the equilibrium level, indicating some degree of overvaluation. Since the start of 2017 the deviation from the equilibrium level has risen significantly to the positive territory. Consequently, the model suggests a high degree of overvaluation in fourth quarter of 2017. Since the upward price momentum has already lasted several years, speculative forces might dominate in housing market. If the rally continues and fundamentals do not keep up with the house price increase there is significant reason for concern that a bubble is forming.

In any case there is reason for investors to remain wary about the German housing market. Some macroeconomic factors indicate that the economy is in the late cycle. In case a negative scenario would prevail in the future, house prices might react adversely with great volatility. The econometric model developed in this master thesis suggests that house prices in Germany are currently overvalued and therefore investments to German housing market should be considered prudently. If macroeconomic indicators do not keep up with the price trend then there is reason for concern.

In addition to the determinants analyzed in this master thesis, other variables might be important as well. In order to investigate longer term dynamics, i.e. before German re-unification, it would be useful to include longer time series into the analysis. This however needs additional resources to gather relevant data for East Germany as well. Furthermore, future studies might want to consider using multiple equation methodologies such as vector error correction (VECM) or vector autoregressive (VAR) models, depending on the suitability of data.

# CONCLUSION

The aim of this thesis was to evaluate to what extent fundamental and speculative factors have driven house prices in Germany. The housing market in Germany has demonstrated price changes not consistent with other developed countries over a 25 year period. After a decline in prices from 1996 to 2010, the recovery has been rapid and has reached a level that has alarmed the German central bank (Bundesbank) and financial regulators. Hence, a study to determine the macroeconomic factors that can explain house prices in Germany and whether these factors can fully explain latest price developments was appropriate.

An extensive overview of previous academic publications was given, which formed a sound basis for this master thesis. An understanding of the cyclical nature of house prices is essential for investors and homeowners. The fundamental supply and demand concept plays an important part in determining house prices. Additionally, market expectations are also critical and during particular periods, expectations might be over exaggerated and could lead to the formation of a bubble. Stiglitz (1990) outlined that bubbles are a result of investor expectations of higher prices tomorrow due to the fact that prices are high today. The subsequent burst of the bubble and the repetition of the process forms real estate cycles. Essentially the short-term fluctuations in house prices from the long-term equilibrium level indicate an over- or undervaluation in the prices. The supply of real estate plays an important role in the formation of cycles in housing market. Supply for housing is fixed in the short-term and in case a demand shock occurs, the responsiveness to provide the demanded space will be weak.

In order to achieve the objective of this thesis, an econometric analysis was conducted during a period from the fourth quarter of 1989 to the fourth quarter of 2017 in Germany. Engle-Granger two-step approach was used to conduct the empirical analysis. The first step consisted of Engle-Granger cointegration test to identify whether a combination of non-stationary series is stationary. It was desirable that the time series would be integrated in the first order, I(1), to conduct the cointegration test. The following procedure involved setting up an error correction model. The model incorporated the residual from the cointegration regression as an independent variable. Thereby it was possible to quantify the short-term deviation of prices from the long-term equilibrium level.

The cointegration regression outlined several interesting findings about the long-term relationship between macroeconomic indicators and house prices. Factors such as real long-term interest rate, real construction costs, real disposable income and unemployment rate have an inverse long-term association with house prices in Germany. Conversely, population and housing permits have a positive long-term association with house prices in Germany. Real money supply was the only variable that was statistically insignificant. However, not all of these findings are coherent with the economic theory and the conclusions outlined in other academic publications. The association of real construction costs, disposable income and housing permits is not in line with the work of other authors. The structural differences in the German housing market with other housing markets such as low home ownership, rental friendly regulation, supply constraints, conservative lending practices and social housing incentives have resulted in an idiosyncratic housing market.

Deeper analysis of the long-term regression residuals reveals that German housing market exhibits cyclical characteristics. The short-term deviations from the equilibrium level indicate that in certain periods, prices are not entirely explained by the fundamentals. During the period under consideration, prices have deviated to a lesser extent before 2003. From there on, the short-term deviations have increased in magnitude and duration. The highest level of overvaluation was achieved in the second quarter of 2005. The period of approximately four years surrounding that time demonstrated the most volatile deviations from the equilibrium. In 2010 the valuation in German housing market reached its bottom, during the period under review. This is consistent with the fact that house prices were in decline from 1996 to 2010, although macroeconomic indicators were improving, e.g. increasing real disposable income during the same period. The period after 2010 has exhibited a steep return towards the equilibrium level and also marks the period where house prices started to increase. Since the start of 2017 the deviation from the equilibrium level has reached deep into the positive territory. Consequently, it reflects a high degree of overvaluation in German house prices as of fourth quarter of 2017.Since the upward price momentum has already lasted several years, speculative forces might dominate in the housing market. If the rally continues and fundamentals do not keep up with the house price increase then there is reason for concern that a bubble is forming.

Error correction model estimation indicates that the short-term deviation from the long-term equilibrium level has a speed of adjustment of approximately 12%. Hence, when the price deviates from the equilibrium level it will adjust back to the equilibrium by 12% per every quarter following the deviation. Since the error correction term has a lag order of one it does not adjust in the period where the deviation occurred. Instead the adjustment process starts in the following quarter. Therefore, after one year approximately 31% of the deviation has restored back towards the equilibrium level. After seven periods more than 50% of the deviation has been adjusted.

In any case there is reason for investors to remain wary about the German housing market. Some macroeconomic factors indicate that the economy is in the late cycle. In case a negative scenario would prevail in the future, house prices might react adversely with great volatility. Investments to German housing market should be considered prudently. If macroeconomic indicators do not keep up with the price trend then there is reason for concern.

In addition to the determinants analyzed in this master thesis, other variables might be important as well. In order to investigate longer term dynamics, i.e. before German re-unification, it would be useful to include longer time series into the analysis. This however needs additional resources to gather relevant data for East Germany as well. Furthermore, future studies might want to consider using multiple equation methodologies such as vector error correction (VECM) or vector autoregressive (VAR) models, depending on the suitability of data.

# KOKKUVÕTE

## ELAMUKINNISVARA HINDA MÕJUTAVAD TEGURID LÄBI KINNISVARA TSÜKLITE

Andres Toome

Käesoleva magistritöö eesmärgiks oli hinnata, kui suur mõju on fundamentaalsetel faktoritel ning kui suurt rolli mängib spekulatsioon Saksamaa elamukinnisvara hindade kujunemisel. Saksamaa elamukinnisvara turg on viimastel aastatel olnud äärmiselt dünaamiline, kuid ei ole järginud sarnaseid trende elamukinnisvara turgudega teistes arenenud riikides. Pärast hinna langust perioodil 1996 kuni 2010 on elamu hinnad läinud tugevale tõusutrendile ning see on tekitanud kartust nii Saksamaa keskpanga (Bundesbank) kui ka regulatiivsetes asutuste seas. Kardetakse, et elamukinnisvara hinnad on tõusnud tasemini mis ei ole enam fundamentaalnäitajatega õigustatav. Sellest tulenevalt on Saksamaa elamukinnisvara uurimine äärmiselt päevakajaline ning seetõttu oli asjakohane võtta ette uurimus, et aru saada mis on sellise hinna dünaamika tinginud.

Antud magistritöö käigus teostati põhjalik ülevaade varasematest akadeemilistest väljaannetest, ning seeläbi moodusdati tugev baas edasise analüüsi teostamiseks. Investorite ning koduomanike jaoks on äärmiselt oluline aru saada kuidas kinnisvara hinnad ning tsüklid kujunevad. Nõudluse ja pakkumise kontseptsioon on tähtsaks aluseks sellele, et aru saada kuidas elamukinnisvara hinnad moodustuvad. Lisaks sellele on tarvis mõista, et turuosaliste ootused kinnisvara hindade suhtes on samuti olulised. Teatud perioodidel võivad ootused olla üle hinnatud ning see võib viia kinnisvara 'mulli' tekkimiseni. Stiglitz (1990) on välja toonud, et kinnisvara 'mullid' on tingitud sellest kui investorite kõrge hinna ootus on tingitud puhtalt faktist, et hinnad on kõrged täna. Kinnisvara hinna mulli lõhkemine ning protsessi taaskordumine tekitab tsüklilisust hindades. Lühiajalised hinna kõikumised mis kaugenevad pika ajalisest tasakaalu tasemest võivad viidata ülehinnatud või alahinnatud kinnisvarale. Lisaks sellele mängib kinnisvara pakkumine olulist rolli hindade kujunemisel. Kuna pakkumine on lühiajaliselt fikseeritud siis ei suuda see vastata kiirelt tõusvale nõudlusele ning viib hinnad tasakaalu tasemest eemale.

Selleks, et saavutada magistritöö eesmärk oli tarvis teostada ökonomeetriline analüüs. Vaadeldav periood hõlmas enam kui 25. aastat ning kattis vahemiku alates 1989. aasta neljandast kvartalist kuni 2017. aasta neljanda kvartalini. Ökonomeetrilise analüüsi läbiviimiseks identifitseeriti, kõige sobilikumaks meetodiks Engle-Granger'i kahe osaline meetod. Esimese sammuna viidi läbi Engle-Granger'i kointegratsiooni test, mille eesmärgiks oli välja selgitada kas mitte-statsionaarsete aegridade kombinatsioon on statsionaarne. Selleks, et kointegratsiooni testida oli vajalik, et aegread oleksid vähemalt esimest järku integreeritud, I(1). Järgnevalt seati üles ühe võrrandiga veaparadus mudel (ECM), mis ühe seletava muutujana sisaldas kointegratsiooni regressiooni jääkliikmeid. Antud metoodika võimaldas arvuliselt väljendada lühiajalisi hinna liikumisi eemale tasakaalu seisundit.

Kointegratsiooni testi käigus teostatud regressioon tõi välja, et reaal intressimäär, reaal ehituskulu, reaal sissetulek ning töötuse määr omavad negatiivset pikaajalist seost maja hindadega Saksamaal. Teisalt tõi aga analüüs välja, et populatsioon ja ehitusload omavad positiivset pika ajalist mõju maja hindadele. Raha pakkumine aga ei andnud statistiliselt olulist tulemust. Kõik tulemused ei ole aga kooskõlas teoreetiliste aspektidega ning teiste autorite järeldustega. Peamiselt, ei ole leitud seosed reaal ehituskulude, reaal sissetuleku ning ehituslubade kontekstis kooskõlas teiste autoritega. See on aga põhjendatav Saksamaa elamukinnisvaraturu eripäradega. Nimelt on antud tulemused mõjutatud sellest, et Saksamaa elamukinnisvara turule on omane madal kodu omamise määr, üürimist soodustav regulatsioon, regulatiivselt piiratud pakkumine, konservatiivsed laenamise tavad ning sotsiaalse majutuse suur osakaal.

Analüüsides regressiooni jääkliikmeid on võimalik tuvastada hinna tsüklilised omadused. Lühiajalised kõikumised tasakaalu seisundist viitavad sellele, et teatud perioodidel ei ole hind täielikult selgitatavad läbi fundamentaalsete tegurite. Vaadeldud perioodil ilmnes, et hind kaugenes tasakaalu seisundist vähemal määral enne 2003. aastat. Sealt edasi on hinna kõikumised tasakaalu seisundist olnud suurema amplituudi ning kestvusega. Kõige suurem positiivne kõikumine toimus 2005. aasta teises kvartalis, mis viitab sellele, et antud perioodil esines ülehinnatus. Vastupidiselt olid maja hinnad Saksamaal suurel määral alahinnatud 2010-dal aastal. Sellele eelnevalt oli hind pikalt languses, kuid samal ajal näitas majandus paranemise märke. 2010. aasta algusest on maja hinnad Saksamaal tõusnud ning lühiajaliselt on hind eemaldunud tasakaalu asendist. Sellest tulenevalt on hetkel Saksamaa maja hinnad kõrgamal kui fundamentaal näitajad selgitada suudavad. Kui hinnatõus jätkub, tasub olla äärmiselt ettevaatlik ning veenduda, kas tõus on ka selgitatav fundamentaalnäitajatega. Vastasel juhul on suur tõenäosus, et tekib kinnisvara hinna mull. Veaparandusmudel tulemused näitavad, et hindade taastumis tempo on 12% ühes perioodis. Antud näitajat võib tõlgendada kui taastumiskiirust tasakaalu seisundisse. Selleks, et 50% kõrvalekaldest taastuks kulub seitse perioodi, ehk peaaegu kaks aastat.

Tulevased uurimused võiksid keskenduda uute näitajate sissetoomisele mudelisse. Lisaks oleks kasulik uurida ka pikemat perioodi, kuid selleks on vajalik eelnevalt koguda andmed mis ei pruugi lihtsalt kättesaadavad olla. Tulenevatelt andmete sobivusest võib kaaluda ka vector veaparandusmudeli (VECM) või vector autoregressiivse mudeli kasutamist (VAR).

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# APPENDICES

## Appendix 1. Data

| | RHP | RLTR | RCCI | POP | RDI | UNEMP | RM3 | PERM |
|---|---|---|---|---|---|---|---|---|
| 1989-Q4 | 111.2 | 4.4 | 100.0 | 79,113,035 | 82.3 | 5.4 | 1015.9 | 170 |
| 1990-Q1 | 109.5 | 5.5 | 101.2 | 79,290,039 | 82.8 | 5.1 | 1015.3 | 199 |
| 1990-Q2 | 109.4 | 6.4 | 103.2 | 79,457,325 | 83.8 | 4.9 | 1019.9 | 208 |
| 1990-Q3 | 109.8 | 6.1 | 104.1 | 79,612,514 | 84.8 | 4.7 | 1182.7 | 209 |
| 1990-Q4 | 109.9 | 6.0 | 104.0 | 79,753,227 | 85.4 | 4.6 | 1181.0 | 217 |
| 1991-Q1 | 110.8 | 5.7 | 104.8 | 79,879,443 | 86.1 | 5.2 | 1184.4 | 213 |
| 1991-Q2 | 110.7 | 5.1 | 107.1 | 80,000,565 | 87.7 | 5.4 | 1181.1 | 206 |
| 1991-Q3 | 110.1 | 4.1 | 106.7 | 80,128,352 | 85.4 | 5.9 | 1181.4 | 217 |
| 1991-Q4 | 109.2 | 2.8 | 105.7 | 80,274,564 | 86.6 | 6.1 | 1188.9 | 218 |
| 1992-Q1 | 110.3 | 2.1 | 106.2 | 80,446,206 | 88.2 | 6.4 | 1195.9 | 230 |
| 1992-Q2 | 110.2 | 2.0 | 107.2 | 80,631,271 | 87.9 | 6.6 | 1203.0 | 233 |
| 1992-Q3 | 110.8 | 3.0 | 108.1 | 80,813,000 | 88.2 | 6.8 | 1229.4 | 253 |
| 1992-Q4 | 111.2 | 4.1 | 108.2 | 80,974,632 | 89.6 | 7.1 | 1248.2 | 256 |
| 1993-Q1 | 110.6 | 2.3 | 107.3 | 81,103,362 | 87.6 | 7.4 | 1227.5 | 253 |
| 1993-Q2 | 110.8 | 2.4 | 108.1 | 81,202,203 | 88.0 | 7.8 | 1248.0 | 278 |
| 1993-Q3 | 111.7 | 1.9 | 108.0 | 81,278,124 | 88.2 | 8.2 | 1260.6 | 291 |
| 1993-Q4 | 112.2 | 1.7 | 108.0 | 81,338,093 | 89.0 | 8.5 | 1302.2 | 290 |
| 1994-Q1 | 112.5 | 3.1 | 107.2 | 81,388,779 | 89.0 | 8.6 | 1326.9 | 373 |
| 1994-Q2 | 113.3 | 4.0 | 107.6 | 81,435,647 | 88.5 | 8.7 | 1334.2 | 368 |
| 1994-Q3 | 113.9 | 4.6 | 107.6 | 81,483,867 | 89.3 | 8.5 | 1330.3 | 374 |
| 1994-Q4 | 114.3 | 5.0 | 107.9 | 81,538,603 | 89.9 | 8.3 | 1321.1 | 403 |
| 1995-Q1 | 114.7 | 5.4 | 107.8 | 81,603,327 | 90.1 | 8.1 | 1299.7 | 368 |
| 1995-Q2 | 114.6 | 5.2 | 108.5 | 81,674,725 | 90.8 | 8.1 | 1308.3 | 334 |
| 1995-Q3 | 114.3 | 5.2 | 108.2 | 81,747,785 | 90.6 | 8.2 | 1319.2 | 325 |
| 1995-Q4 | 113.9 | 4.9 | 108.3 | 81,817,499 | 90.3 | 8.4 | 1346.2 | 340 |
| 1996-Q1 | 114.0 | 4.7 | 107.1 | 81,879,628 | 91.0 | 8.7 | 1370.8 | 322 |
| 1996-Q2 | 113.6 | 5.0 | 106.6 | 81,933,029 | 90.8 | 8.8 | 1386.3 | 310 |
| 1996-Q3 | 113.0 | 5.0 | 106.2 | 81,977,331 | 90.9 | 9.0 | 1405.0 | 298 |
| 1996-Q4 | 112.2 | 4.4 | 105.8 | 82,012,162 | 90.5 | 9.3 | 1429.2 | 297 |
| 1997-Q1 | 111.1 | 3.9 | 104.5 | 82,037,277 | 90.6 | 9.7 | 1441.2 | 308 |
| 1997-Q2 | 110.4 | 4.2 | 104.1 | 82,052,932 | 91.4 | 9.9 | 1452.3 | 278 |
| 1997-Q3 | 109.0 | 3.3 | 103.1 | 82,059,505 | 90.8 | 10.0 | 1448.8 | 274 |
| 1997-Q4 | 108.5 | 3.4 | 102.8 | 82,057,379 | 91.3 | 10.0 | 1462.6 | 273 |

## Appendix 1. Continuation

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1998-Q1 | 108.7 | 3.8 | 102.3 | 82,047,988 | 91.8 | 9.7 | 1479.9 | 239 |
| 1998-Q2 | 108.1 | 3.5 | 102.6 | 82,036,988 | 91.5 | 9.4 | 1494.4 | 272 |
| 1998-Q3 | 107.8 | 3.8 | 102.3 | 82,031,092 | 91.9 | 9.1 | 1505.6 | 251 |
| 1998-Q4 | 107.9 | 3.6 | 102.3 | 82,037,011 | 92.8 | 8.9 | 1545.9 | 254 |
| 1999-Q1 | 108.6 | 3.7 | 102.1 | 82,059,119 | 93.4 | 8.7 | 1542.3 | 236 |
| 1999-Q2 | 108.3 | 3.6 | 101.5 | 82,092,440 | 93.1 | 8.6 | 1579.9 | 235 |
| 1999-Q3 | 108.7 | 4.2 | 101.1 | 82,129,663 | 93.8 | 8.4 | 1590.5 | 233 |
| 1999-Q4 | 109.0 | 4.2 | 101.1 | 82,163,475 | 95.3 | 8.2 | 1609.6 | 229 |
| 2000-Q1 | 108.9 | 3.9 | 100.6 | 82,188,769 | 95.8 | 8.0 | 1612.2 | 217 |
| 2000-Q2 | 109.1 | 4.2 | 100.6 | 82,209,262 | 95.9 | 7.8 | 1596.2 | 185 |
| 2000-Q3 | 109.2 | 3.9 | 100.0 | 82,230,878 | 95.4 | 7.7 | 1570.1 | 182 |
| 2000-Q4 | 109.0 | 3.4 | 99.8 | 82,259,540 | 95.3 | 7.6 | 1564.6 | 163 |
| 2001-Q1 | 108.9 | 3.0 | 99.0 | 82,299,252 | 97.8 | 7.7 | 1592.5 | 162 |
| 2001-Q2 | 108.3 | 2.4 | 98.1 | 82,346,343 | 97.9 | 7.8 | 1610.4 | 165 |
| 2001-Q3 | 107.3 | 2.9 | 98.0 | 82,395,226 | 97.8 | 7.9 | 1642.8 | 157 |
| 2001-Q4 | 105.7 | 2.9 | 97.8 | 82,440,309 | 97.6 | 8.2 | 1635.9 | 137 |
| 2002-Q1 | 105.1 | 3.0 | 97.0 | 82,477,033 | 96.7 | 8.3 | 1546.1 | 152 |
| 2002-Q2 | 105.3 | 3.8 | 96.9 | 82,504,949 | 96.8 | 8.5 | 1569.5 | 146 |
| 2002-Q3 | 104.8 | 3.4 | 96.8 | 82,524,638 | 97.6 | 8.8 | 1585.6 | 140 |
| 2002-Q4 | 103.8 | 3.2 | 96.8 | 82,536,680 | 98.0 | 9.2 | 1640.2 | 145 |
| 2003-Q1 | 103.0 | 2.9 | 96.0 | 82,541,838 | 97.8 | 9.5 | 1641.3 | 202 |
| 2003-Q2 | 104.1 | 3.1 | 96.1 | 82,541,605 | 98.1 | 9.7 | 1669.1 | 149 |
| 2003-Q3 | 103.4 | 3.0 | 95.8 | 82,537,657 | 98.3 | 9.8 | 1654.9 | 135 |
| 2003-Q4 | 102.5 | 3.1 | 95.8 | 82,531,671 | 98.2 | 9.7 | 1675.1 | 151 |
| 2004-Q1 | 102.4 | 3.1 | 95.3 | 82,525,010 | 99.1 | 9.7 | 1668.4 | 198 |
| 2004-Q2 | 101.1 | 2.4 | 95.7 | 82,517,785 | 99.0 | 9.7 | 1652.8 | 136 |
| 2004-Q3 | 100.0 | 2.3 | 95.6 | 82,509,799 | 99.1 | 9.9 | 1661.2 | 117 |
| 2004-Q4 | 99.0 | 1.7 | 95.5 | 82,500,849 | 99.7 | 10.1 | 1656.7 | 122 |
| 2005-Q1 | 100.5 | 2.0 | 95.6 | 82,490,527 | 99.2 | 10.8 | 1672.3 | 143 |
| 2005-Q2 | 100.3 | 2.1 | 95.2 | 82,477,583 | 100.0 | 11.3 | 1695.4 | 118 |
| 2005-Q3 | 100.1 | 1.5 | 94.6 | 82,460,558 | 100.0 | 11.3 | 1704.5 | 121 |
| 2005-Q4 | 99.1 | 1.7 | 94.5 | 82,437,995 | 100.9 | 11.2 | 1711.0 | 132 |
| 2006-Q1 | 99.2 | 1.8 | 94.6 | 82,409,242 | 101.0 | 10.8 | 1730.6 | 182 |
| 2006-Q2 | 99.2 | 2.1 | 94.6 | 82,376,883 | 101.5 | 10.4 | 1749.5 | 132 |
| 2006-Q3 | 98.2 | 2.4 | 95.5 | 82,344,307 | 101.9 | 10.0 | 1752.0 | 118 |
| 2006-Q4 | 97.6 | 2.5 | 96.4 | 82,314,906 | 103.1 | 9.9 | 1772.7 | 102 |
| 2007-Q1 | 95.6 | 2.2 | 99.5 | 82,290,836 | 102.5 | 9.1 | 1791.9 | 95 |
| 2007-Q2 | 95.2 | 2.3 | 99.4 | 82,269,313 | 102.3 | 8.7 | 1819.5 | 99 |
| 2007-Q3 | 94.8 | 2.1 | 99.4 | 82,246,319 | 102.6 | 8.5 | 1860.3 | 99 |
| 2007-Q4 | 94.4 | 1.1 | 98.9 | 82,217,837 | 103.2 | 8.3 | 1903.8 | 96 |

## Appendix 1. Continuation

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2008-Q1 | 94.8 | 1.0 | 99.3 | 82,180,374 | 103.4 | 7.8 | 1939.1 | 97 |
| 2008-Q2 | 94.4 | 1.4 | 99.3 | 82,132,545 | 104.8 | 7.8 | 1959.8 | 97 |
| 2008-Q3 | 93.0 | 1.2 | 99.6 | 82,073,492 | 104.2 | 7.3 | 1983.2 | 91 |
| 2008-Q4 | 93.4 | 1.9 | 100.1 | 82,002,356 | 103.0 | 7.2 | 2049.3 | 86 |
| 2009-Q1 | 94.1 | 2.3 | 100.5 | 81,921,754 | 103.8 | 7.6 | 2063.6 | 85 |
| 2009-Q2 | 94.6 | 3.1 | 100.0 | 81,848,206 | 104.2 | 7.8 | 2049.5 | 94 |
| 2009-Q3 | 94.5 | 3.5 | 100.0 | 81,801,708 | 104.0 | 8.0 | 2020.1 | 97 |
| 2009-Q4 | 94.8 | 2.8 | 100.0 | 81,802,257 | 103.8 | 7.6 | 2005.2 | 103 |
| 2010-Q1 | 94.1 | 2.4 | 99.8 | 81,855,423 | 104.2 | 7.5 | 2007.0 | 95 |
| 2010-Q2 | 93.9 | 1.7 | 100.0 | 81,909,074 | 104.7 | 7.1 | 1961.9 | 93 |
| 2010-Q3 | 93.6 | 1.3 | 100.2 | 81,896,653 | 105.4 | 6.7 | 1970.4 | 106 |
| 2010-Q4 | 93.5 | 1.2 | 100.1 | 81,751,602 | 106.0 | 6.6 | 1977.7 | 105 |
| 2011-Q1 | 94.2 | 1.3 | 100.5 | 81,435,707 | 105.8 | 6.2 | 1982.2 | 119 |
| 2011-Q2 | 94.5 | 1.1 | 100.6 | 81,024,124 | 105.9 | 5.9 | 2000.6 | 121 |
| 2011-Q3 | 94.5 | 0.1 | 100.8 | 80,620,355 | 106.6 | 5.8 | 2037.9 | 119 |
| 2011-Q4 | 94.7 | -0.3 | 100.8 | 80,327,900 | 106.6 | 5.5 | 2048.6 | 129 |
| 2012-Q1 | 95.1 | -0.3 | 101.1 | 80,221,861 | 107.8 | 5.5 | 2063.0 | 113 |
| 2012-Q2 | 96.1 | -0.4 | 101.3 | 80,263,747 | 107.0 | 5.4 | 2106.5 | 135 |
| 2012-Q3 | 97.0 | -0.7 | 101.2 | 80,386,671 | 106.7 | 5.4 | 2138.3 | 129 |
| 2012-Q4 | 97.7 | -0.6 | 101.2 | 80,523,746 | 106.4 | 5.3 | 2151.4 | 131 |
| 2013-Q1 | 98.0 | -0.1 | 101.6 | 80,622,015 | 106.5 | 5.3 | 2138.4 | 133 |
| 2013-Q2 | 99.0 | -0.2 | 101.9 | 80,684,253 | 107.0 | 5.3 | 2151.5 | 141 |
| 2013-Q3 | 99.1 | 0.1 | 101.6 | 80,727,167 | 107.7 | 5.2 | 2162.0 | 155 |
| 2013-Q4 | 99.2 | 0.4 | 101.8 | 80,767,463 | 107.0 | 5.1 | 2178.5 | 146 |
| 2014-Q1 | 99.8 | 0.4 | 102.4 | 80,821,238 | 107.6 | 5.1 | 2191.7 | 147 |
| 2014-Q2 | 100.8 | 0.3 | 102.5 | 80,902,146 | 108.2 | 5.0 | 2224.0 | 152 |
| 2014-Q3 | 101.2 | 0.1 | 102.4 | 81,023,231 | 108.6 | 4.9 | 2244.5 | 153 |
| 2014-Q4 | 101.9 | 0.2 | 102.9 | 81,197,537 | 109.1 | 4.9 | 2273.4 | 154 |
| 2015-Q1 | 103.3 | 0.3 | 104.0 | 81,430,105 | 109.6 | 4.7 | 2350.9 | 151 |
| 2015-Q2 | 104.3 | 0.0 | 103.6 | 81,693,966 | 109.4 | 4.7 | 2380.3 | 155 |
| 2015-Q3 | 105.3 | 0.5 | 104.0 | 81,954,150 | 110.2 | 4.5 | 2425.0 | 168 |
| 2015-Q4 | 106.5 | 0.2 | 104.3 | 82,175,684 | 110.4 | 4.6 | 2475.6 | 182 |
| 2016-Q1 | 108.1 | 0.0 | 105.5 | 82,332,125 | 109.9 | 4.3 | 2525.9 | 197 |
| 2016-Q2 | 110.0 | 0.0 | 105.7 | 82,431,139 | 110.7 | 4.2 | 2549.3 | 200 |
| 2016-Q3 | 111.5 | -0.6 | 105.6 | 82,488,917 | 110.5 | 4.1 | 2573.1 | 191 |
| 2016-Q4 | 112.2 | -1.0 | 105.4 | 82,521,653 | 111.2 | 3.9 | 2586.8 | 212 |
| 2017-Q1 | 111.9 | -1.6 | 106.2 | 82,543,209 | 112.3 | 3.9 | 2626.4 | 180 |
| 2017-Q2 | 113.1 | -1.4 | 106.9 | 82,558,127 | 112.9 | 3.8 | 2647.5 | 189 |
| 2017-Q3 | 114.3 | -1.3 | 107.0 | 82,568,620 | 112.8 | 3.7 | 2648.2 | 180 |
| 2017-Q4 | 115.4 | -1.3 | 107.2 | 82,576,900 | 113.2 | 3.6 | 2654.8 | 194 |

Source: Dallas FED; OECD; St. Louis FED; Destatis; Bundesbank

# Appendix 2. Ramsey's RESET test

Auxiliary regression for RESET specification test
OLS, using observations 1990:4-2017:4 (T = 109)
Dependent variable: d_l_RHP

| | coefficient | std. error | t-ratio | p-value | |
|---|---|---|---|---|---|
| const | -0,000654160 | 0,000830273 | -0,7879 | 0,4327 | |
| d_l_RLTR_1 | -0,186565 | 0,132404 | -1,409 | 0,1620 | |
| d_l_RCCI_1 | 0,158565 | 0,107470 | 1,475 | 0,1433 | |
| d_l_POP_1 | 0,854937 | 0,514564 | 1,661 | 0,0998 | * |
| d_l_RDI_2 | -0,161041 | 0,0876817 | -1,837 | 0,0693 | * |
| d_l_UNEMP_1 | -0,0487477 | 0,281495 | -0,1732 | 0,8629 | |
| d_l_RM3_2 | 0,0551260 | 0,0373780 | 1,475 | 0,1435 | |
| d_l_PERM_4 | 0,0116702 | 0,00590708 | 1,976 | 0,0510 | * |
| u_1 | -0,131492 | 0,0442513 | -2,971 | 0,0037 | *** |
| d_l_RHP_1 | 0,477070 | 0,115705 | 4,123 | 7,89e-05 | *** |
| yhat^2 | 14,7936 | 28,4958 | 0,5192 | 0,6048 | |
| yhat^3 | -872,699 | 3056,51 | -0,2855 | 0,7759 | |

Test statistic: F = 0,136211,
with p-value = P(F(2,97) > 0,136211) = 0,873

Source: Author (Gretl output)

# Appendix 3. White's test

```
White's test for heteroskedasticity
OLS, using observations 1990:4-2017:4 (T = 109)
Dependent variable: uhat^2

                    coefficient    std. error    t-ratio    p-value
  -----------------------------------------------------------------
  const              3,96309e-05   1,13938e-05    3,478     0,0010   ***
  d_l_RLTR_1        -0,00293567    0,00164566    -1,784     0,0801   *
  d_l_RCCI_1         0,00359053    0,00209309     1,715     0,0920   *
  d_l_POP_1         -0,0208278     0,0116908     -1,782     0,0804   *
  d_l_RDI_2         -0,000638527   0,00130355    -0,4898    0,6262
  d_l_UNEMP_1        0,00575066    0,00449449     1,279     0,2062
  d_l_RM3_2          0,000604095   0,000528392    1,143     0,2580
  d_l_PERM_4         0,000177589   8,79131e-05    2,020     0,0484   **
  u_1                0,000440114   0,000461060    0,9546    0,3440
  d_l_RHP_1          0,00184273    0,00159999     1,152     0,2545
  sq_d_l_RLTR_1     -0,132193      0,186153      -0,7101    0,4807
  X2_X3             -0,177872      0,274452      -0,6481    0,5197
  X2_X4             -0,901646      1,28414       -0,7021    0,4856
  X2_X5              0,0123688     0,232231       0,05326   0,9577
  X2_X6              1,48197       0,750587       1,974     0,0535   *
  X2_X7              0,262527      0,118243       2,220     0,0306   **
  X2_X8             -0,0747763     0,0197517     -3,786     0,0004   ***
  X2_X9             -0,0910246     0,116959      -0,7783    0,4398
  X2_X10             0,702379      0,299101       2,348     0,0226   **
  sq_d_l_RCCI_1     -0,0964432     0,167937      -0,5743    0,5682
  X3_X4             -4,58918       1,76535       -2,600     0,0120   **
  X3_X5              0,281456      0,227930       1,235     0,2222
  X3_X6             -0,112771      0,614595      -0,1835    0,8551
  X3_X7              0,171172      0,115670       1,480     0,1447
  X3_X8              0,0139494     0,0138181      1,009     0,3172
  X3_X9              0,150775      0,104579       1,442     0,1552
  X3_X10             0,152477      0,231203       0,6595    0,5124
  sq_d_l_POP_1      -4,93663       3,16930       -1,558     0,1252
  X4_X5              0,434849      1,10967        0,3919    0,6967
  X4_X6              5,14555       4,35358        1,182     0,2424
  X4_X7              0,499303      0,721021       0,6925    0,4916
  X4_X8             -0,0770629     0,0702629     -1,097     0,2776
  X4_X9             -0,635459      0,438331      -1,450     0,1529
  X4_X10             4,42702       1,53831        2,878     0,0057   ***
  sq_d_l_RDI_2       0,00802751    0,0735433      0,1092    0,9135
  X5_X6              0,166242      0,524171       0,3172    0,7524
  X5_X7              0,146267      0,102522       1,427     0,1594
  X5_X8             -0,0149146     0,0131042     -1,138     0,2601
  X5_X9             -0,120037      0,0988844     -1,214     0,2301
  X5_X10            -0,0737391     0,187148      -0,3940    0,6951
  sq_d_l_UNEMP_1    -0,798492      1,08336       -0,7371    0,4643
  X6_X7             -0,219920      0,296855      -0,7408    0,4620
  X6_X8             -0,0259658     0,0320091     -0,8112    0,4208
  X6_X9             -0,0190338     0,242848      -0,07838   0,9378
  X6_X10            -0,767089      0,548038      -1,400     0,1673
  sq_d_l_RM3_2      -0,00960742    0,0109610     -0,8765    0,3846
  X7_X8             -0,00872236    0,00818154    -1,066     0,2911
  X7_X9             -0,00600097    0,0334047     -0,1796    0,8581
  X7_X10            -0,262389      0,101204      -2,593     0,0122   **
  sq_d_l_PERM_4      0,000722991   0,000322224    2,244     0,0290   **
  X8_X9              0,00535520    0,00420265     1,274     0,2080
  X8_X10             0,0186020     0,0100934      1,843     0,0708   *
  sq_u_1             0,0194126     0,0148363      1,308     0,1963
  X9_X10            -0,0390931     0,0681663     -0,5735    0,5687
  sq_d_l_RHP_1      -0,325383      0,114438      -2,843     0,0063   ***

  Unadjusted R-squared = 0,694325

Test statistic: TR^2 = 75,681433,
with p-value = P(Chi-square(54) > 75,681433) = 0,027383
```

Source: Author (Gretl output)

## Appendix 4. Breusch-Godfrey test

```
Breusch-Godfrey test for autocorrelation up to order 4
OLS, using observations 1990:4-2017:4 (T = 109)
Dependent variable: uhat

                 coefficient    std. error     t-ratio    p-value
  ----------------------------------------------------------------
  const           0,000110864   0,000689082     0,1609     0,8725
  d_l_RLTR_1      0,00443013    0,131466        0,03370    0,9732
  d_l_RCCI_1      0,0505458     0,121625        0,4156     0,6786
  d_l_POP_1      -0,0744017     0,528779       -0,1407     0,8884
  d_l_RDI_2      -0,00847938    0,0848692      -0,09991    0,9206
  d_l_UNEMP_1     0,131025      0,329275        0,3979     0,6916
  d_l_RM3_2       0,000366990   0,0335634       0,01093    0,9913
  d_l_PERM_4      8,19869e-06   0,00577089      0,001421   0,9989
  u_1            -0,0225196     0,0483052      -0,4662     0,6421
  d_l_RHP_1      -0,0640991     0,177096       -0,3619     0,7182
  uhat_1          0,0622892     0,222907        0,2794     0,7805
  uhat_2          0,107731      0,148537        0,7253     0,4701
  uhat_3          0,123122      0,122561        1,005      0,3177
  uhat_4         -0,0205252     0,123521       -0,1662     0,8684

  Unadjusted R-squared = 0,014365

Test statistic: LMF = 0,346149,
with p-value = P(F(4,95) > 0,346149) = 0,846

Alternative statistic: TR^2 = 1,565820,
with p-value = P(Chi-square(4) > 1,56582) = 0,815

Ljung-Box Q' = 1,0684,
with p-value = P(Chi-square(4) > 1,0684) = 0,899
```

Source: Author (Gretl output)

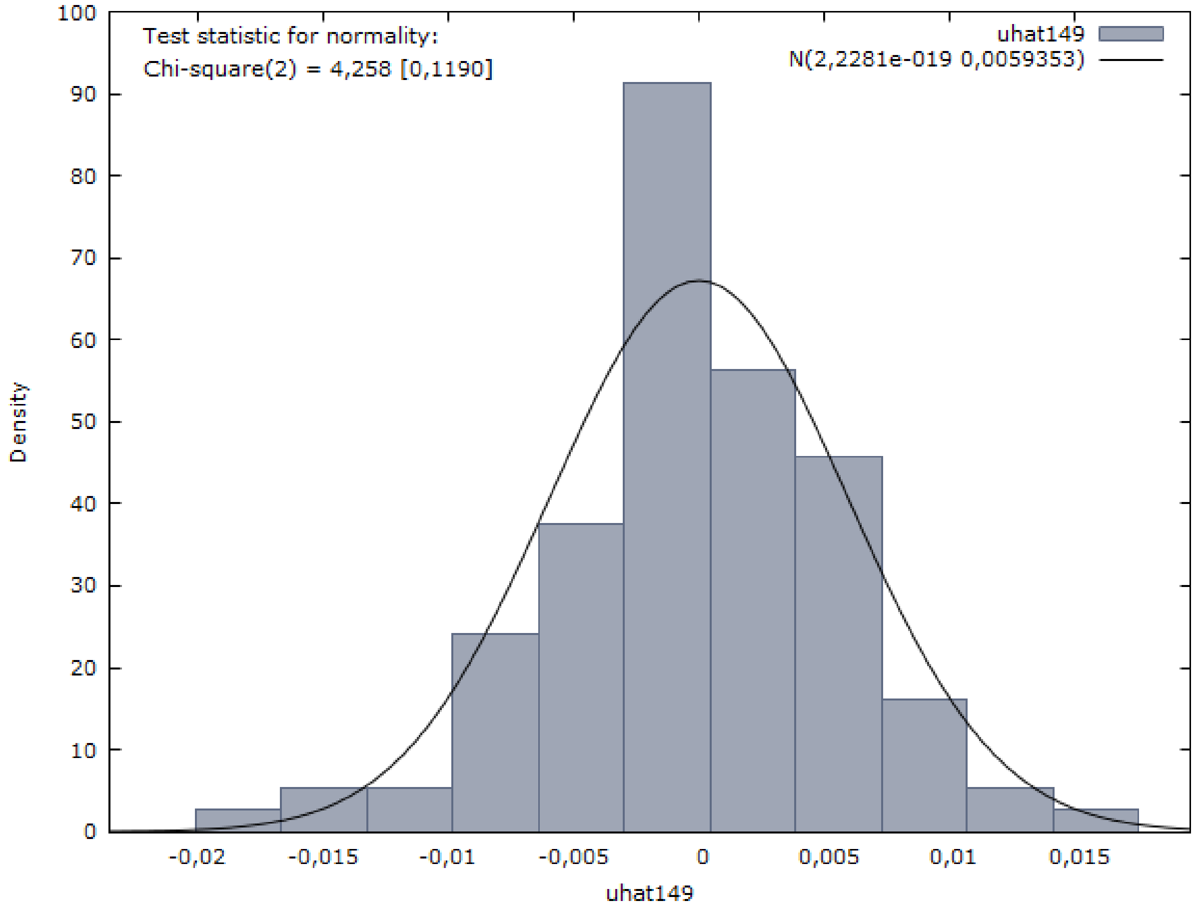
## Appendix 5. Variance inflation factor (VIF) test

```
Variance Inflation Factors
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

  d_l_RLTR_1    1,119
  d_l_RCCI_1    1,199
   d_l_POP_1    1,212
   d_l_RDI_2    1,121
 d_l_UNEMP_1    1,374
   d_l_RM3_2    1,098
  d_l_PERM_4    1,020
         u_1    1,206
   d_l_RHP_1    1,141
```

Source: Author (Gretl output)

## Appendix 6. Jarque-Bera test for normality




Source: Author (Gretl output)