A TIME DEPENDENT LEAD-LAG STUDY OF HOUSE PRICES AND MONETARY POLICY

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ABSTRACT

Real Estate markets worldwide have experienced high growth rates over the past decades. Simultaneously, most markets have also been subject to boom and bust periods with phases of high volatility. Recent years have shown the severity of such turbulences along with their impact on the world wide economic development. To better understand the tools available with monetary authorities to counteract such developments, researchers have applied a variety of empirical time series correlation analysis techniques. These techniques assist in better understanding the causality and dynamics between the real estate market and monetary policy. However, little research has focused on the fluctuation of correlation over time.

Using the recently introduced Thermal Optimal Path (TOP) Method that was developed by Sornette et al.[119] to quantify the time varying lead-lag dependencies between pairs of economic time series, we analysed the interdependence between the development of monetary policies and changes in the real estate market across various countries.

The results of the study suggest that the lead-lag structure between monetary policy and real estate markets oscillates over time with respect to both positive and negative correlation and the direction of causality. Despite the variations in characteristics of interdependences across countries, we identify qualitatively similar patterns. While the expected lead of the interest rate level over the returns in house prices could be confirmed with a negative correlation during times of stable and prospering economic conditions, it is also found that times of economic distress cause strong perturbations in the lead-lag regimes. For countries that show an overheating real estate market, the results underline a regime change in terms of causality and correlation. This implies that during these times central banks followed the movement of the housing market. However, countries that were not affected by a real estate bust had to cope with low interest rates caused by the global transmission of the financial crisis, which further extended the pressure on housing prices. For the second important instrument of monetary authorities, the money supply, the study cannot confirm a significant relationship with the development in real estate prices. Taken together, this study suggests that the monetary policy of central banks profoundly influences real estate prices depending upon the general economic condition and that this influence is mostly through fixing of interest rates rather than money supply.

Keywords: Dynamic correlation; Lead-Lag; Housing Price; Interest Rate; Thermal Optimal Path; Monetary Policy

CONTENTS

I. INTRODUCTION

The real estate sector is a prominent driver for the wellbeing of the global economy as well as a fundamental indicator for the development of other asset prices[1]. In particular, the residential property sector has shown strong growth across countries for the past two decades. Relatively low interest rates, favourable mortgage and refinancing conditions, together with rising house prices, lead to wealth effects on the consumer side which encouraged consumer spending and boosted macroeconomic conditions.

A theoretical attempt of explaining the development in the real estate market can be found in the so-called "financial accelerator" mechanism presented by Bernanke et al.[2], Kiyotaki et al.[52] as well as Aoki et al.[3] According to this mechanism, rising real estate prices lead to an increasing demand in credit volume so as to finance house purchases on an appreciated price level. Because most of these mortgages are also secured by the property itself (collateral), higher valuation improves the net worth of the household sector by raising its housing capital. Through this mechanism, households increase the capacity for borrowing, which in turn puts pressure on the development of real estate prices. Finally, higher real estate prices reduce the default risks of loans by increasing the value of the pledged collateral, which in turn allows the banks to enlarge their borrowing activities.

Adopting this mechanism, Iacovello[43] and Calza et al.[95] propose that monetary policy is able to amplify this dependence by reducing the target interest rate. According to this theory the value of the property and thus the collateral is determined by the discounted future cash flows, which will increase with a reduction in interest rate levels. Thus, interest rate shocks can propagate through this transmission channel into the housing market, where the effects might be amplified, especially in the case of well-developed mortgage markets[15].

In addition to the financial acceleration mechanism presented above, Rajan[132] and Borio et al.[133] developed the understanding of a "risk-taking channel", which encourages financial institutions to take additional risks in the case of low interest rates. Because these financial institutions are aiming for certain rate of returns, they have to accept higher risks when the yield spread towards the risk free interest rates increases. Consequently, higher prices for riskier assets are expected together with decaying in lending standards such as loan to value ratios, which further increases the leverage of households and increases their net worth.

The above-mentioned findings underline the importance of real estate prices for bank lending and the credit market because it implies that boom-bust cycles can be reinforced and mutually transmitted between the credit market and the property market, thus jeopardizing macroeconomic stability. Considering this risk, Borio et al.[4] argues that monetary policy should be reactive to these kinds of fluctuations within the credit and asset market to ensure financial and long-run price stability.

However, the influence of central banks on such cyclical economic behaviour of real estate prices and credit conditions is controversial. Using different approaches, Adam et al[5], Bordo et al.[6] as well as Goodhart et al.[7] found that the impact of interest rate movements on the development of asset prices, triggered by the central banks, have a highly non-linear effect depending on economic sentiment. This is mainly caused by the perception of market participants depending upon the current phase of the cycle (boom=euphoria, bust=depression). In contrast, empirical evidence such as the vector auto-regression (VAR) studies on OECD countries by Giuliodori[8] or Demary[9] suggest that interest rate shocks have significant effect on house prices. These findings are also supported by other researchers such as Jarocinsky et al.[10], Goodhart et al.[33], Dreger et al.[11] and Assenmacher-Wesche et al.[12] who apply similar methodologies to additional sets of countries. Moreover, Luciani[13], Hume et al.[14] and Taylor[76] even argue that the expansionary monetary policy, with its low levels of interest rates, have significantly contributed to the most recent house price boom.

Despite the influence of such a transmission channel, the national mortgage markets play an important role in the potential success of monetary measures. Traditionally, mortgage markets are either dominated by fixed rate mortgages (FRM) or adjustable rate mortgages (ARM), which determines the sensibility of mortgage rates upon changes in interest rate levels of different maturities. While adjustable rate mortgages are based on the medium term reference rate, such as the 1-year London Interbank Offered Rate (LIBOR), fixed rate mortgages follow the movements of long-term interest rates such as 10 to 30 year Government Bond Yields. Among others, a report by the International Monetary Fund[135] as well as the results of a VAR analysis of ten OECD countries conducted by Jäger et al.[134] suggests that countries that rely strongly on ARMs have higher fluctuations in real estate prices. Contributing to this finding, Sa et al.[15] suggests that the transmission of interest rate levels to housing activities will be stronger in countries where it is less costly to refinance a mortgage.

In addition, innovations in the mortgage market (such as securitized products) have contributed to the responsiveness of the real estate market upon monetary policy decisions[79]. Better liquidity, greater number of market participants, lower transaction costs, and the availability of a common marketplace are suspected to cause a quicker adjustment to changes in interest rate levels[16]. According to Diamond et al.[17], this innovation in the mortgage sector has lead to a misallocation of capital to the real estate market that even amplified the effects of interest rate fluctuations.

Therefore, it is not surprising that central banks take into account the growing importance of the real estate sector by including indicators of its performance into their monetary policy decisions.

The thesis is structured the following way. Part II explains the fundamentals of real estate prices and their interaction with credit cycles as well as the means of measuring the prices of houses. We continue by explaining the goals of monetary authorities and the theoretical measures they have for influencing the real estate market. Finally, we introduce various methods to analyse the dynamic interrelationship between two economic time series. In Part III, the Thermal Optimal Path (TOP) Methodology is introduced and the dataset used for the analysis is described. Part IV focuses on each individual country and shows the results we gained from the TOP method analysis. These results of the different analyses are summarized in part V. Part VI concludes the study.

II. BACKGROUND

II.1. THE SIGNIFICANCE OF REAL ESTATE ASSETS IN THE ECONOMY

II.1.1. REAL ESTATE PROPERTY PRICES

The fundamentals of real estate property prices are similar to those of other asset classes. They are determined by the discounted expected future cash flows over the entire lifetime, as well as demanded rate of return on the investment. On one side, the cash flows include future incomes through rent or sales and expected expenditures caused by consumption, such as utility bills as well as service and maintenance costs. On the other side, expected returns on investment include risk premiums and returns on competing long-term investments. Therefore we see that property prices in the long-run are affected to a large extend by national or regional demand factors, such as the GDP (national income) and average interest rates, as well as by supply factors, including the state of the current building stock, the availability of land, and the general costs for construction.

However, real estate property markets are also influenced by a unique set of parameters, when compared to other types of assets. Because of the immobile nature of real estate, the supply is intrinsically tied to the local market and the creation of new stock is subject to long lags, which are caused by the length of the planning and construction phase. Therefore, short-run supply is completely dependent on historical investment decision, which is strongly influenced by past general economic and real estate market fundamentals. In addition, the responsiveness of the property supply is subject to availability of construction land, the length of governmental approval processes and other legislative and local structural factors, which include taxes and subsidy policies. For example, countries such as the Netherlands, United Kingdom and some of the Nordic countries followed an unresponsive housing policy, which could not prevent the development of real estate bubbles. In the past, this failure in policy was particularly observed in countries like Netherlands or the United Kingdom, where the total volume of housing supply was even reduced during the last house price boom periods, which lead to the further increase in property prices. The causes for such developments are often found in rigorous land development policies that sometimes even introduced caps for the total amount of approved developments.[18] Following a more liberal approach in terms of land and housing development policy, Germany has experienced exceptionally stable real estate prices, which can at least be partly accounted for by its legislation.

The demand in real estate markets is constrained by the demographics of a country and the accessibility of the market. However, the transparency and liquidity of the real estate market is often low because transactions of properties are usually made by bilateral contracts and high transaction costs such as VAT, stamp duties and registration fees. Apart from that, the real estate market is blurred by poor flow of information, a lack of comparability and limited availability or inaccuracy concerning on-going property transactions and sales prices. Particularly, the information necessary to judge the fundamentals of prices within a real estate market are subject to regional market dynamics, which can only be understood by gaining costly in-depth knowledge about the local characteristics of the market.

The financing of those transactions is often provided by bank loans that are widely depended on other real estate as collateral. Selling short of a property is usually not possible and long-term rental contracts cause market prices to be sticky. Therefore, market participants usually have difficulties in forecasting the future development of the property market and its prices. These special characteristics lead to fundamentally different behaviour compared to other assets. This is, in particular, true for short run prices that can significantly deviate from their long-run fundamentals caused by intrinsic factors of the property market. However, long run fluctuations are mostly due to the cyclic movement of economic fundamentals, risk premiums and politically-influenced interest rates.

Another important feature of the real estate market, which is particularly true for the residential market, is that transaction volumes tend to decline with falling house prices. Because houses are durable goods and long-term assets that provide shelter and future incomes, homeowners are reluctant to sell their property at a loss. The intrinsic reservation value for their houses is composed by the historical outlays and discounted predicted future cash flows. In sum, this causes the real estate prices to be less sensitive to economic shocks compared to other equity prices. This leads to slower, less pronounced and often delayed reactions in nominal housing prices.

However, economic cycles have a straightforward implication on the fluctuations of property prices. The improvement of a country's economy will most likely improve the income of an average household and will thus give an upswing in the demand for new homes or in living standards (as of increased square meter per person). This would force house prices to increase. On the commercial side, similar patterns arise. Prospering companies will start expending and increasing their investments, searching for new buildings for storage, manufacturing or office space. This puts an upward pressure on commercial real estate prices and rents. Consequently, a booming real estate market will lead to a change in the risk perception of investments into properties, which in turn drives down the risk premiums that have to be paid. The combination of interest rates, which are partly controlled by policy makers and reduced risk premiums, leads to more favourable conditions when calculating payback times of such real estate investments, which again will have a strong impact on the valuation of property prices.

Apart from the common dynamics in the real estate market, variations in property prices can also be found across different sectors such as residential, commercial, office and retail. While the residential sector, as seen in the most recent real estate crisis, is strongly influenced by national interest rates, the commercial market segment often depends more on the overall economic environment and thus, the wellbeing of firms. This difference in interference by national and local factors can lead to an asynchronous development of both markets.

Overall, market participants are in practice relying heavily on current property prices and extrapolating past market movements into the future. This results in endogenous oscillations[19,20] of property prices and significant deviations from their true fundamental values. Such a deviation can be shown, for example, in the case of booming real estate markets and increasing prices, as described above. In such periods of low perceived risk, developers and constructors initiate new construction projects to leverage on increasing real estate prices. However, their decision is based on current prices and past trends, not taking into account that by the time construction is completed the demand might have collapsed. This will lead to increasing vacancy rates, which together with the oversupply of newly-built properties will force rents and real estate prices to decline, eventually even below their fundamental values.

Excess supply in the real estate market can also be caused by misguided governmental legislation or flawed regulatory implementation, resulting in distorted signals for market participants. The financial liberalization that took place in various industrial and emerging countries after the 1970s can be seen as an example[21,22]. The deregulation led to the formation of new financial institutions that wanted to compete in the market for loans by offering products at much lower prices and less strict terms. With the increase of competition in the market, an oversupply of financial resources for real estate projects was developed. Together with a generally biased belief in an ever-prospering market, more and more potential investors entered the market, fuelling up real estate prices even beyond their fundamental values. In addition, financial institutions followed a lax loan policy to earn money as margins were dropping continuously. The missing or inefficient regulations and the upcoming of guarantees against losses changed the risk perception of the market participants. Lenders started investing in projects, promising high returns and accepting the associated higher risks.

The mechanism described above has garnered much attention in the last few years; especially the most recent real estate bubble in the USA in early 2006 that has elucidated the vulnerability of a whole economy to this kind of real estate cycles. Similar bubbles are also believed to be triggered by the consequences of financial liberalisation, as for example the East Asia Crises[23] in 1997 or the US Savings and Loans Crisis[24] in the late 1980s.

In literature, there are various studies investigating the macro- and microeconomic fundamentals of real estate prices as described above. Most authors use some kind of vector auto-regression (VAR) models to analyse the dependence of various variables (inputs) on housing prices. The studies generally assume a demand-side driven market where prices indicate the need for housing and supply side factors are often absent[25]. Those demand-side factors are, in literature, assessed by various proxies. Tsatsaronis and Zhu[25], for example, use GDP per capita capturing household income, unemployment and wages while McCarthy and Peach[26] as well as others[27] use consumption of non-durables and services and financial wealth as a proxy for the affordability of real estate.

Proxies for the availability of finance options are also different among authors. Tsatsaronis and Zhu[25] use nominal short term interest rates as well as the consumer price growth and the spread between long-term 10-year bonds and 3-year treasury bills, while other researchers[28] use bank credits such as mortgages, housing or private credits as proxies for the financial conditions. However, the most commonly used proxies are short- and long-term interest rates, together with specific market characteristics such as the availability of fixed or variable mortgages, maximum loan to value lending conditions, or other prudential rules[25].

II.1.2. INTERRELATION OF INTERNATIONAL REAL ESTATE MARKETS

International real estate prices, while showing robust growth since the mid 1990s, have developed heterogeneously over the past decades. In countries such as Australia, Ireland, the Netherlands, Spain, United Kingdom, the United States and some Nordic countries, house prices have shown particularly strong growth. While in Germany, Japan and Switzerland real estate prices only showed moderate development.

Compared to the various researches available in the area of international stock market co-movements, the studies aiming at analysing the interdependence of international real estate markets are limited. However, the most recent crisis that emerged in the USA in the summer of 2006, spreading out to European markets in the UK and later on to Spain and Ireland, raised questions on the interrelation of international real estate markets[29,30]. As already explained above, real estate assets are substantially different from other assets, and therefore, are much slower in reacting to exogenous economic pressure. Causes for this phenomenon can be found in the regional fundamentals of the property prices[31] and stronger dependency upon local policies. However, the last decades have shown that today some kind of correlations might exist across markets.

The co-movements of real estate markets can be seen under different timeframes. The long-term movements are dominated by microeconomic fundamentals. Therefore, international and national real estate markets should be balanced in the long run. Otherwise population movements or capital outflows would occur. The timeframe of such interaction would be typically over a few years. In contrast, the short-run dependences are subject to market dynamics, which are often caused by international transmissions of economic shocks. Literature has various explanations for the correlations within national housing markets. However, studies concerning international transmission and co-movement of real estate prices are not yet widely available. Focusing on the European market, Vansteekiste and Hiebert[32] showed (using a global VAR approach) that limited spillovers across the countries exist, with strong overshoots (upon a housing price shock in one country) during the first 1-3 years, which is followed by a long-tailed aggregation period. Goodhart and Hofmann[33] explained the impact of the credit market, expressed by real macroeconomic or monetary variables on the co-movement of house prices. The results of their fixed-effect panel vector auto regression on 17 industrialized countries showed a strong multidirectional link, especially in times of booming house prices. Open economies are also directly impacted by fast changes in international fundamentals, such as world interest rates, global availability of liquidity and general world economic outlooks. Terrones and Otrok[29] could confirm that on one side, fundamental values, such as interest rates and real income growth have a significant influence on house price movements, but on the other side their results also suggest that a major part of the price volatility could be explained by autocorrelations effects. Kiyotaki et al[34] showed in their study that exogenous factors such as world interest rates have a direct impact on domestic house prices as global investors arbitraging across national real estate markets. The globalised economy already leads to close dependency of national stock markets. However, a multiscale dependence of real estate markets in the sense of "contagion effects" is still widely discussed. Contagion in the classical definition is a self-reinforcing cycle, where for example a regional market affects the global market, which in turn puts pressure on the local market. While Fry et al[35] and Mun[36] found evidence of such effects in the Hong Kong Crisis in 1997 and the US Subprime Crisis in 2007, respectively in the Pacific Rim region during four financial crises, other authors like Hatemi and Roca[37] could not confirm such results.

While macroeconomic effects are relatively easy to analyse, non-fundamental effects like consumer expectations are often not that obvious. However, Costello et al[38], among others[39,40] found strong evidence that investors within a market adopt their house price expectations according to movements in other international markets.

II.1.3. RELATIONSHIP OF REAL ESTATE CYCLES AND CREDIT CYCLES

The US subprime crisis and its infestation on the global economy have raised concerns about the role of real estate markets and their impact on the global financial system. The recession that was, and in parts still is, following the most recent crisis, led researchers and economists to further study the real estate sector, especially the housing markets. While the previous two sections have focused on the creation of property prices and the cross-country interrelation of property cycles, we now turn to the interdependence of real estate markets and business cycles. This has been already well documented in a wide number of empirical papers. A study conducted by Leamer[41] analysed the interrelation between the US business cycles, defined by the NBER Dating Committee[a] and the US real estate market cycles between 1947 and 2006. He concluded that the US business cycles are in fact consumer cycles (in terms of contribution to the GDP growth), which are driven by residential investments that in turn could be used as an early warning signal for future recessions. In another paper published by Ahearne et al.[42], in an analysis of 18 major industrial countries the authors find that real house price cycles are positively correlated to the movements of real GDP, consumption, investment, consumer price index, current account balance and output caps. Furthermore, the study identifies that periods of expansionary monetary policies are typically led by phases of house price booms. However, with the beginning of an economic slack and with rising inflation, monetary authorities begin to tighten their policy before housing prices peak. Goodhart and Hofmann[33] provide additional empirical evidence of a "significant multidirectional link between house prices, broad money, private credit and the macroeconomy". This interaction is partly modelled in the paper by Iacoviello[43], who formalizes the interrelation between business cycles and house prices.

In theory, the effect of property prices economies or vice versa is well known. On one hand, property prices are directly influencing private homeowner and commercial or professional real estate owners. On the other hand, property prices have an effect on the credit market and the banks, thus influencing the whole economy of a country.

As for the private sector, the effects are theoretically ambiguous. Increasing property prices may lead to an increase in rents, confronting individuals who rent properties with altered budget constraints that will most likely lead to a reduction in their consumption and borrowing behaviour. In contrast, individuals owning a property will, according to the lifecycle model of consumption, increase their borrowing and consumption[44,45,46]. This so-called wealth effect, shown by Goodhart and Hofmann[47,48], will stimulate economic activities indirectly by increasing homeowners' credit demand. This is also implied by Tobin's q-theory of investment[49], which states that the relationship of the market value of capital to its costs is positively correlated with the amount of on-going investment activities. Translated to the construction sector, this means that increased construction activities are caused by rising property prices, because the ratio of property value to construction costs positively influences construction activity. Ultimately, this will lead to an increased demand in credits to finance such activities.

The ambiguity of the theory is represented in a number of empirical studies. In an analysis conducted by Kennedy and Anderson[50], eight out of 15 industrialized countries had a significantly negative effect of property price fluctuations on the savings behaviour of households, whereas a positive effect was found in the remaining seven countries. In another study, conducted by Case et al.[51], 14 industrialized countries and even individual States of the US were found to have a significant effect on changes in household consumption caused by changes in housing wealth.

a "The NBER's Business Cycle Dating Committee maintains a chronology of the U.S. business cycle. The chronology comprises alternating dates of peaks and troughs in economic activity. A recession is a period between a peak and a trough, and an expansion is a period between a trough and a peak. During a recession, a significant decline in economic activity spreads across the economy and can last from a few months to more than a year. Similarly, during an expansion, economic activity rises substantially, spreads across the economy, and usually lasts for several years." (http://www.nber.org/cycles/recessions.html)

Besides the above-mentioned effects on the private sector, changes in property prices also affect financial institutions. For most individuals and firms the potential amount of borrowed funds is constrained by the ability to provide collateral. As described by Kiyotaki[52] et al. and other researchers[53,54,55], the borrowing capacity is a function of the net worth available as collaterals. Thereby, real estate often functions as a collateral for a credit. Thus, property price increases will lead to an increase in borrowing capacity. In theory, such deviations are also stimulated by the banking sector through the so-called financial acceleration mechanism[52], which shows a twofold effect of house prices on bank stability. On one side, the wellbeing of banks is affected directly by increasing property prices of their own real estate portfolio. On the other side, the value of any collateral pledged by borrowers will increase, which directly reduces the default risks[56] associated, especially in the case of subprime mortgages. Consequently, increasing real estate prices have a direct impact on the risk taking capacity of banks and the likelihood of financial distress in the banking sector[57]. Following the collateral value hypothesis, which states that there is a negative relationship of nominal house price changes and the banks' probability to default, increasing real estate prices will enhance the stability of banks.[58]

On the negative side, moral hazard[59] and adverse selection problems[60] might lead to a clustering of bad risks as collateral values are declining, determined by falling house prices. In contrast, rising house prices can also lead to an increasing risk taking capacity, resulting in dropping rates and excessive supply of new loans to the real estate market. This, in turn, puts additional pressure on the property prices.[61] This is supported by the "balance-sheet" effect that increases the willingness of financial institutions to issue loans because of collaterals increasing in value on their balance sheets[62,52,63]. As investors further bet on even higher real estate prices, the market starts deviating from its fundamental values, increasing the chance of a collapse of prices. The deviation hypothesis therefore suggests that large discrepancies of housing prices from their fundamental values, lead to accumulation of risky assets at financial institutions, which in turn increase their probability of default[58].

II.1.4. FINANCING OF REAL ESTATE

The dynamics within the real estate market are heavily dependent on the availability of a financing system, which supports transactions among market participants. Real estate, particularly residential properties are usually financed by borrowing funds, typically with a mortgage. The property owner, while being liable for the risk of the mortgage, is confronted with potential appreciation or depreciation of the property. This liability is usually a large commitment for a household because it binds a large portion of a household's wealth into a single asset, which is not diversified. This risk can be especially pronounced in times of high income uncertainty[64]. Despite the conditions of loans offered by banks, the housing market is also strongly influenced by various forms of policies, tax breaks and subsidies.

Home mortgages can be roughly categorized into two types of products. Fixed-rate mortgages (FRMs) provide a fixed interest rate over the lifetime of the mortgage, whereas adjustable-rate mortgages (ARMs) periodically adjust the interest rates in accordance to public reference rate indices. Fixed rate mortgages, depending on the maturity, are usually well tracked by the rates of long-term government bonds, such as the 10-year or 30-year US treasury bill plus some risk adjustment premium (which in theory should be the same over time). Among the most common indices used for adjustable mortgage rates are the rates on short-term government bonds, such as the 1-year Constant-Maturity Treasury (CMT) securities in the US, and the

Interbank Offered Rates such as the London Interbank Offered Rate (LIBOR) with maturities between one month and one year. A hybrid form of the two mortgages are the "rollover" ARMs, which are initially based on a fixed interest rate and after a certain period adjust those interest rates according to a reference index.

Worldwide, products that are based on the ARMs principle dominate most of mortgage markets. In particular, mortgages in Australia, Canada, Finland, Ireland, Luxembourg, Norway, Portugal, Spain and the United Kingdom tend to feature variable interest rates[65], thus making real estate prices generally prone to changes in the national short-term to medium-term interest rates. This is caused by the fact that since the early 1980s declining interest rates have provided an attractive environment for such products.

Exemptions in the dominance of the ARM products can be found in Belgium, Denmark, France, Germany, Italy, Japan, the Netherlands and the United States where the majority of mortgage financing is based on FRM products[66,67] or in the case of Denmark on other special mortgage products[65].

During times of low or even declining interest rates, ARMs provide a solid and safe finance option. However, they are also bear the risk of increasing interest rates and thus rising monthly mortgage payments, while incomes of households remain at a constant level. This effect had severe consequences for many homeowners in the UK in the early 1990s and was responsible for the subsequent housing crisis[65].

Another aspect of the mortgages financing markets is the ability of early repayment, which is usually subject to penalties. Depending on the height of such a fine, households will be more or less tempted to renegotiate their mortgages in the case of rising house prices or declining interest rates. This behaviour can be seen especially in the United States, because of much lower penalties compared to different countries and innovations in mortgage products like mortgage securitisation that was introduced by Freddie Mac and Fannie Mae[68].

The loan-to-value (LTV) ratio, which varies among countries, is also an important factor in the availability of financing options for the real estate market. It determines "the ratio of the unpaid principal balance of the loan to the lesser of the appraised value or sales price of the property"[69] and indicates the default risk, which is taken by the bank. If the valuation of the collateral is based on market prices or the LTV ratio is a near one, the availability of real estate financing will increase with the rise in housing prices. As a result, market participants have access to higher loans and new potential buyers are able to enter the market, thus fuelling house prices. This could lead to a house price boom or a credit crunch when real estate prices fall[70,71].

Finally, the extent of real estate transaction costs (such as stamp duties, registration fees and taxes) influences the turnover of a market, and therefore, the demand for financing options. This transaction cost can vary between 2% in the United Kingdom and 20% in Belgium (14% in France) and is added to the actual value of the property. Because transactions are part of the cost for real estates, rising demand will most likely have a stronger influence on the real estate prices in markets with low percentage transaction cost.

II.1.5. SECURITIZATION OF REAL ESTATE MORTGAGES

Securitization of mortgages can be described as the pooling of individual loans issued as securities that are backed by the cash flows from those mortgages. In the process of securitization, various financial institutions are involved that connect the capital market, supplying the mortgage credits with the borrowers that require mortgages for investments. While those institutions are acting as economic agents to the customer, they only have temporary interest in the mortgages they facilitate as they are immediately transferring the issued risk and debt to the capital market. Thus, mortgage securitization is very opaque and allows for information asymmetries as lenders and borrowers are not directly connected.

The market for mortgage-backed securities is especially well developed in the United States. In Europe and other countries, even though they have shown rapid growth since the early 1990s, securitization of real estate mortgages is still not common practice. For example, only about 20% of UKs total mortgages for dwellings are secured[42].

In addition, only little literature is available that analyzes the influence of monetary policy on the development of securitized real estate mortgages. However, it is easily understandable that the reduction of interest rate will lead to availability of cheaper mortgages, which in turn will have a direct effect on the market for mortgage-backed securities. Higher liquidity, smaller transaction costs and a greater number of market participants on a common market generally leads to the assumption that the market for securitized real estate compared to the direct real estate market is more informationally efficient. Thus, it is expected that shocks in the economic fundamentals of the real estate market will propagate much faster in the framework of securitization[16,72]. Diamond and Rajan[17] even argue that the development of mortgage-backed securities strengthens the "risk-taking channel", which encourages banks to target riskier assets because the risks are transferred off their balance sheets to the capital market. Maddaloni et al.[73] could confirm these findings for the case of Europe where low interest rates, together with availability of securitization, led to an amplification of the softening of lending standards. In addition, the securitization facilitated foreign investment in mortgage loans[17], which led to increasing capital inflows into the market, putting additional pressure on the stability of the real estate market[15].

II.1.6. HOUSING BUBBLES AND THEIR IMPACT – THE CASE OF THE US

Housing bubbles are a well-known phenomenon in recent global economic history. Over the past decades, several real estate crises have caused distress in the banking sector. In the 1990s, several countries experienced a burst of a housing bubble, with decreasing real estate prices that led borrowers to default on their loans and banks, thus slipping into severe problems as they faced increasing losses[74]. Among the countries involved, Japan, Norway, Switzerland, the United Kingdom and the United States had previously (starting from the mid 1980) experienced an era of substantially-growing bank lending activities.

The most recent global economic crisis, which was caused by a collapse of the US subprime mortgage market, showed once again the enormous potential impact the real estate market has on the banking sector. Even though the cause of the formation of such a real estate bubble may vary between countries, there are still common concepts, which trigger or foster such a development. Using the case of the most recent US real estate crisis some of these aspects will be explained in detail below.

During the period of 1997 to 2006 US housing prices rose by 188%, only to fall again by 33% in mid 2009[b]. The causes of this most recent real estate bubble, which preceded the financial crisis of 2008, are still not completely revealed and there is much theory behind the potential background[75]. Explanations based on macroeconomics follow mostly the argumentation of John Taylor[76], which identifies low interest rates as the cause for the build up of the bubble. His findings propose that extremely low interest rates issued by the Federal Reserve were resulting in cheap mortgage credits, which artificially amplified housing prices. In addition to the macroeconomic understanding of the causes of the bubble, several authors have found federal governments lending and affordable housing policies (e.g. the 1992 Federal Housing Enterprises Financial Safety and Soundness Act) [77] together with loos lending standards[78,79,80,81] and the change of the mortgage market institutional structure[82,83], as the contributors to a rise in housing prices triggered by an increasing amount of less-creditworthy (subprime) borrowers.

An alternative perspective on this topic is given by scientists, which find the responsibilities in the demand of consumers for credits and housing. Part of this is claimed to be a misbelief that house prices will continue to rise forever[84] and a failure to understand the values of real interest rates in times of decline in inflation[85].

On the background of these different theories, A. J. Levitin and S. M Watcher (2010)[75] summarise the potential causes of the bubble as a supply-side phenomenon. They conclude that it was triggered by an excessive supply of housing finance caused by a “fundamental shift in the structure of the mortgage financing market from regulated to unregulated securitization”.

Levitin at al. states that the increase in house prices, during the period of 1997 to 2003, can be rationally explained by fundamental economic values such as the change in demand, rents (compared to purchase) and interest rates. After 2003/2004, however the market shifted toward excessive supply of mortgages, based on an unregulated securities market, especially in the subprime market that showed strong signs of “informational asymmetries between financial intermediaries and investors”. This lead to an underpricing of the risks associated to the mortgages and thus, to an oversupply of financing possibilities. This combination was further enhanced by the financial intermediaries that tried to increase their volume-based profits, allowing homeowners to follow rising house prices, which ultimately led to the creation of a real estate bubble. Levitin et al. further explains that during the period of 2001 to 2003 interest rates where historically low, causing a refinancing boom that fostered earnings of the financial industry. To keep up with the profit expectations in 2003/2004, typically investment banks introduced new unregulated private-labelled securitization products. Before this period, the US regulated government-sponsored entities (GSEs) Fannie Mae and Freddie Mac and the federal agency Ginnie Mae were responsible for issuing most mortgage-backed securities (MBS). As earnings were dependent on the volume of sales of these new products, the institutions became lackadaisical in their underwriting policies (exploiting the inherent information asymmetries), while issuing even more new products, thus expanding the market of borrowers towards lower creditworthy (subprime) customers. Simultaneously, a shift in product types from traditional fixed rate mortgages (FRMs) to non-traditional, non-amortizing adjustable rate mortgages (ARMs) occurred in the market. This new product type was riskier because the structure of these products made it difficult to come up with a sound valuation of

[b] S&P / Case-Shiller Housing Price Index – Composite of 10, nominal prices

the involved risks. As a consequence, during the time of 2003/2004 default risks of mortgages were constantly rising and, nevertheless, risk premiums on housing finance continued to drop[75]. Together with the deterioration in underwriting standards, it led to an oversupply of under-priced housing finance, which in return increased the housing prices without effectively increasing the demand.

On the demand side, growing real estate prices had a substantial effect on the wealth of borrowers, but it also led to higher mortgage burdens. By 2006, the increase in housing prices was slowing down, which resulted in a rise in default rates of subprime borrowers, followed by stricter lending standards. This was caused by the fact that the wealth effect that is associated with the rise in housing prices, could not compensate for the increase in mortgage burdens, forcing borrowers to sell their homes or to become insolvent.

II.1.7. CONSTRUCTION OF REAL ESTATE PRICE INDICES

When talking about real estate prices or even the formation of real estate bubbles, we first have to define a way to measure the development of values of houses over time. Because each house, together with its site, has a unique set of characteristics, the valuation is difficult and cannot be representative for a whole real estate market. To overcome this heterogenic market environment, different indices were developed to provide a form of aggregation of property values on a regional or national level. In theory there are many possible empirical methods and sources of data for constructing real estate price indices. Depending on which function the index should serve, methods and data sources have to be chosen carefully, as each methodology is usually best suited to a certain type of application. In this section, the different empirical methods used in practice are discussed and their benefits and shortcomings are highlighted.

II.1.7.1 AVERAGE AND MEDIAN PRICE INDEX

One of the most commonly used estimators for housing prices is a simple statistical median and mean price[86] where data requirements are minimal. However, the distribution of house prices is usually sharply skewed, so that the fluctuations in the most expensive house prices have a great impact on the average selling price. Therefore, the median is often chosen as the reported average price.

A major drawback of this method, however, is that changes of the qualities of a property are not controlled. Because the quality of the building stock is constantly improving, be it through renovation and demolishing of existing or construction of new buildings, an average or median price index substantially overestimates the price increases of constant-quality-property. In addition, the composition of the sample of transacting properties during each period varies to a certain extent, thus overestimating the price changes during a period of expensive property trades and vice versa.

As a plus, this sort of an index appeals to a wide audience and is easy to construct and interpret.

II.1.7.2 REPRESENTATIVE-PROPERTY PRICE METHOD

This method is similar to the way traditional consumer price indices are constructed. A representative property is defined and price movements of properties conforming to those specifications are recorded in each period. Thus, effort needed for data collection is limited.

One concern regarding this methodology is that due to heterogenic real estate markets data collectors face a high degree of subjectivity when searching for properties which suit the representative definition, thus leading to difficulties in comparing data points in different markets and over time. In addition, quality improvements that are not accounted for in the representative property definition (e.g. installation of an air-conditioning system which might not be specified in the standard definition) will not be correctly mapped in the index. Thus, this could lead to a biased source of improving prices. Finally, by focusing only on one single type of property, the method takes the risk of not including general market information and price movements that might not have an effect on this specific type of property.

II.1.7.3 HEDONIC PRICE MODEL

Trying to overcome the issues with the average-/media-price and the representative-property price method, economists use the hedonic-price model to estimate price indices. The method assumes that the transaction price of a given property is a function of the time period as well as the unique (hedonic) characteristics of the property. These characteristics are the physical features of a property and the lot, such as size and building standard as well as features of the location and its neighbourhood, which affects the transaction price of the property.

After choosing the main influencing factors a hedonic function is postulated and its parameters are estimated using a regression analysis. A common hedonic price function looks as follows:

$$P_{it} = \alpha X_i^{\beta_1} e^{\beta_2 Y_i + \gamma_1 T_{i1} + \gamma_2 T_{i2} + \cdots + \gamma_i T_{in}}$$

or in logs,

$$\ln P_{it} = \alpha + \beta_1 \ln X_i + \beta_2 Y_i + \gamma_1 T_{i1} + \gamma_2 T_{i2} + \cdots + \gamma_i T_{in}$$

with P_{it} being the transaction price of the property i during a time period t. The hedonic attributes of a property are represented by X_i and Y_i, where X is measure continuously and Y being a binary variable (e.g. availability of air-condition). The dummy variable T_{it} marks the time period τ at which the transaction took place. The parameters α, β_j and γ_τ are estimated in the regression, with γ_τ being the price index for the analysed time period.

Compared to the average-/median-price method and the representative-property method, the hedonic-price method has the main advantage that it is able to control for quality changes of the properties. These changes, either due to quality changes of individual properties or due to preferred transactions of one type of property quality, will be reflected in the hedonic attributes X_i and Y_i and not in the estimated parameters of the model. Therefore, this method does not relay on the subjective interpretation of representative property definitions and is able to include the whole property market information for creating a price index.

One of the disadvantages of the method is however, that the collection of suitable data is much more troublesome since in addition to the transaction price at a certain time also, data on all of the hedonic attributes of the property have to be collected. As for the representative-property method, the hedonic-price method is also only capturing quality improvements of recorded hedonic parameters. If certain amenities of a property are not recorded and keep changing over time, this will materialize improperly as a change of price level instead of a change in quality.

The fundamental problem of the hedonic-price method is that "a priory" the "functional form" of the hedonic-price function, including all relevant hedonic characteristics, has to be specified correctly[87]. If the functional form is chosen incorrectly, hedonic variables are being omitted or parameters are changing over time (such as β_j's which are the "marked prices" of each variable) there is a high chance that the estimated price index will be biased.

However, in practice the method seems to be reasonably insensitive toward small deviations of these conditions as long as the major hedonic variables are included within the functional form.

II.1.7.4 REPEAT-SALES METHOD

Because of the great efforts that have to be put into data collection for the hedonic-price model, another method called the repeat-sales method was developed. This method focuses on the transaction of the same property during different time periods. Because most of the hedonic attributes of the property are likely to be the same, they only have to be measured once and consecutively only price changes will be recorded. Thus, the change in property price from one transaction to the other can be expressed as a simple function of the duration of the time period between transactions.

$$\frac{P_{it}}{P'_{it}} = \frac{\alpha X_i^{\beta_1} e^{\beta_2 Y_i + \gamma_1 T_{i1} + \gamma_2 T_{i2} + \cdots + \gamma_i T_{in}}}{\alpha X_i'^{\beta_1} e^{\beta_2 Y_i' + \gamma_1 T_{i1}' + \gamma_2 T_{i2}' + \cdots + \gamma_i T_{in}'}}$$

or, in logs,

$$\ln \frac{P_{it}}{P'_{it}} = \beta_1 \ln \frac{X_i}{X'_i} + \beta_2 (Y_i - Y'_i) + \gamma_1 (T_{i1} - T'_{i1}) + \gamma_2 (T_{i2} - T'_{i2}) + \cdots + \gamma_i (T_{in} - T'_{in})$$

For $X_i = X'_i$ and $Y_i = Y'_i$ the equation can be simplified to

$$\ln \frac{P_{it}}{P'_{it}} = \gamma_1 (T_{i1} - T'_{i1}) + \gamma_2 (T_{i2} - T'_{i2}) + \cdots + \gamma_i (T_{in} - T'_{in})$$

with P'_{it} being the transaction price of the previous sale, while X'_i and Y'_i are the hedonic characteristics of the house at the time of past transaction. The dummy variable $T'_{i\tau}$ indicates the time period τ in which the sales took place and the parameter γ_τ is therefore the price index.

The easy implementation, together with the reduced cost of implementing this methodology, has led to a widespread application, especially within markets of high property transaction frequencies, such as the US.

However, the need for frequent transactions within the property market and the availability of large sales data are one of the main disadvantages of this method. While in the US this is the case, in Western Europe, for example, the application of the repeated-sales method will fail, because of relatively low transaction frequencies.

One of the major advantages, namely the reduced amount of required data, can easily be overestimated, because analysts still have to check whether property characteristics have changed over time. This means that in practice the amount of data required is similar to the hedonic-price method. However, analysts generally assume that characteristics have remained constant, leading to a direct reflection of price increases in the property price index.

The repeated-sales method has another advantage over the hedonic-price model, because it automatically controls the hedonic characteristics that stayed unchanged between multiple transactions, thus making more efficient use of the data of repeated transactions. In contrast, the hedonic-price method only controls the characteristics that are measured. Nevertheless, the repeated-sales index is only able to include property data with at least two transactions that also remained the same quality within the analysed time period; this leads to a large amount of market information, which will not be reflected in the index. This is especially important if some types of properties within a market have lower trading frequencies, thus being less represented in the dataset, which will lead to a bias in the index.

As the hedonic-price method, the repeated-sales method is unable to incorporate changes in the parameters (β_j) of the model. If such changes will occur, the price index will be improperly affected by the implicit market prices. As Shiller[88] pointed out, this can be overcome by estimating separate price indices for each hedonic characteristic on the basis of a generalized repeat-sales formulation.

II.1.7.5 HYBRID MODELS

To resolve the issues of repeated-sales and hedonic-price method, such as failure to use data from properties with only a single transaction during the measurement period, failure of implementing changes in the model parameters ("market price" of attributes) and measurable changes in property quality, hybrid models where introduced[89]. These models are weighted averages of both methods, which impose that estimated price changes in both models have to be equal over time.

II.2. MONETARY POLICY AND ITS INSTRUMENTS

This section introduces the role of monetary policy in a globalized economy that exists today. We especially focus on the impact of decisions of monetary authorities on the development of the real estate market and the effectiveness of the set of instruments that can be applied.

II.2.1. GOALS OF MONETARY POLICY

Monetary policy can be defined as the set of instruments and actions taken by monetary authorities to achieve certain predefined economic objectives. The potential measures include control over money supply, interest rates and exchange rates as well as the influence on the credit conditions offered to the national borrowing market.

While the explicit goals of monetary policy vary across countries, there is a worldwide agreement that ultimately the central banks should focus on price stability and high employment rates, fostering economic growth rates and monitoring imbalances in the country's trading account, which includes stable exchange rates to other currencies to protect international competitiveness and purchasing power.

Traditionally, there are two main themes central banks can follow; contractionary monetary policy for fighting inflation and expansionary monetary policy to combat signs of economic recessions, such as unemployment. When following a contractionary policy, monetary authorities decrease the money supply, for example by increasing the central bank's base rate to increase the cost of loans and reduce the consumption, which eventually stops prices from rising. Expansionary monetary policy on the other hand typically involves at first, a reduction in interest rates by central banks to increase economic activities. This is usually effective because the availability of cheaper liquidity leads to growing aggregated demand. With rising prices and a prospering economy, central banks can again increase the interest rates to stabilize the economic development and counteract inflation.

For the case of the United States since the year 2000, these effects where not showing the anticipated results. While the low interest rates led to an increase in aggregated demand, a rise in prices did not take place. Causes for this can be found in China and other Asian countries entering into the global economy, providing excessive supply of labour-intensive manufacturing goods at prices that are kept artificially low. This reduced the wage pressure within the US, as imports, due to fixed exchange rates, remained at low prices. However, this kind of policy resulted in a current account with an increasing deficit[90] and hugely indebted households. As claimed by the Bank of International Settlement (BIS)[91] the inflation target was set at an extremely high level, thus making it easy for monetary authorities to reach their target and as interest rates stayed at a historical low, cheap mortgages fuelled the development of a real estate bubble. These house prices, on the other hand, generated a wealth effect, which increased the consumption of the household, pushing the current account deficit even further.[92]

II.2.2. INSTRUMENTS OF MONETARY POLICY

As already stated above, the objectives of monetary policy are price stability, full employment and growth in aggregated income. To achieve these targets, central banks have a set of instruments that enable them to control the monetary aggregate, the interest rate and the foreign exchange rates in a way that is favourable for their strategy. The instruments used by each central bank depend to large extent on the level of development of an economy, its financial system and the targets set by monetary authorities.

According to European treaties, the European Central Bank (ECB) has the goal of providing stability of price (control of inflation) for the whole Euro system. To follow the objective of maintaining low inflation rate to the optimum, set to close or below 2% in the medium-term, the ECB has a strategy based on two pillars. On one side it includes a short- to medium-term determination of price developments by analysing a large set of economic and financial indicators, such as demand and labour market conditions, asset prices and financial yields as well as macroeconomic projections. On the other side, the long-term perspective of the money market is used as a crosscheck for the short- and medium-term, by analysing the impact of monetary and credit developments as well as monetary aggregates on the economy. This way, the ECB can carefully select its instruments and apply measures precisely. A set of these potential, commonly-used instruments is provided below.

INTERBANK RATE

The interbank rate is the rate at which other commercial banks (Deposit Money Banks) can borrow funds for the central bank (CB). Changing the interbank rate thus allows them to control the credit supply. As the central bank increases the interbank rate, all commercial banks will follow by adjusting their interest rates charged for loans, which in turn decreases the availability of credit financing in the market. In an opposite way, the central bank can decrease its interbank rates, thus allowing other banks to give out more loans at cheaper conditions.

OPEN MARKET OPERATION

The term open market operation summarises all measures conducted by the central banks that aim to purchase or sale securities (such as Treasury Bills), on behalf of the fiscal authorities to commercial banks or to the non-banking public in the open market. By selling securities, the central bank reduces the supply of reserves and by redeeming the securities it directly affects the money supply with increases in the availability of reserves to the commercial banks.

LENDING BY THE CENTRAL BANK

The central bank can provide credit to a Deposit Money Bank, which affects the monetary base caused by increasing reserves of the bank.

RESERVE REQUIREMENTS

The central bank may define the ratio of reserves (deposit liabilities) that have to be held by a commercial bank in the form of cash and or deposits at the central bank. This reserve limits the availability of loans a bank can give to the economy and thus directly influences the money supply. The assumption made by the central bank, to control money supply through this channel, is that commercial banks maintain a stable relationship between reserve holdings and issued credits.

DIRECT CREDIT CONTROL

The central bank can also directly manipulate the availability of credits from commercial banks by issuing credit ceilings (maximum amount of loans) depending on the industry sector, specifying interest rate caps, demanding certain liquid asset ratios or setting credit guarantees to preferred loans. This helps to precisely allocate funds in accordance with monetary targets.

MORAL SUASION

The central bank is responsible for regulating the operation of the banking system and the licencing of commercial banks within this system. Therefore, they are able to govern commercial banks to follow certain standards, such as credit restraints or expansions, thus pursuing increased savings and supporting export investments.

PRUDENTIAL GUIDELINES

Central banks may issue these guidelines to commercial banks to guarantee that the operations of those banks are in accordance with monetary targets. Such guidelines can involve rules for the management that influence the conducting of their operations.

EXCHANGE RATE

The domestic money supply is directly influenced by the balance of payments account, which summarizes all international transactions. By selling or buying foreign currency, the central bank is able to manipulate foreign exchange rates and the balance of payments account in such a way that it will not negatively affect domestic money supply. However, real exchange rates that are not carefully aligned and they can significantly influence the external competitiveness, and thus exports.

II.2.3. MONETARY POLICY AND REAL ESTATE

Monetary Policy is a strong instrument that affects the entire economy of a country, sometimes with unforeseeable substantial costs. Especially, if developments within an economy unilaterally involve only one sector, the results of monetary actions could have strong side effects in other sectors. However, in case of bubbling economies, contractionary policy can potentially reduce the cost of busts[93,94]. Recent years have shown catastrophic consequences that can follow misdevelopments within the real estate market if there is no precise interference from monetary authorities. Therefore, it is substantial to better understand the dependencies of this market and the consequences of monetary policy actions.

In theory, the real estate market and monetary policy are closely connected, and its transmission channels have been well documented[15]. On one side, the interest rate policy directly influences the real estate market by determining the reference values of real estate financing options such as mortgages. On the other side, the development of the real estate market has an impact on inflation, economic development and the stability of the financial system.

Most central banks indirectly focus on the status of the real estate market because of the above-mentioned reasoning. As national consumer price indices usually include some sort of property rents, overall real estate market developments will have a significant impact on determination of inflation. National construction activities also strongly influence the development of the economy since the sector has a strong weight in the national GDP. In addition, real estate market developments have the potential to indirectly influence the economy through the channel of private consumption.

Lowering interest rates will provide direct relief, especially to customers with variable interest rate mortgages, as they have to pay less interest on their debt. Debtors with fixed interest rate mortgages can also profit when the runtime of the credit expires and refinancing with cheaper mortgages is possible. Tenants will also profit in the medium term as rents will decrease with falling real estate prices due to increased supply. This reduction in household spending can lead to an increase in consumption and investments, which stabilizes the macroeconomic demand.

In contrast, the risk of low interest rates has been shown by history. In periods of low interest rates, there tends to be overinvestment and loose standards both for customers buying houses and banks giving away mortgages. This overinvestment is either characterized by inappropriately high construction activity or investments at wrong places. Loose standards for buyers are usually developed, as costumers overestimate their buying power due to cheap mortgages. In addition, low interest rates lead to increased competition in the mortgage market, with decreasing strictness in lending practices and overall low equity ratios demanded.

However, if central banks want to counteract the development of real estate bubbles, they can effectively increase interest rates again. This leads to more expensive mortgages and thus reduces the affordability of houses for an average household. Together with an indirect reduction of the potential leverage of financial institutions, it could prevent serious damage from an economy. A study conducted by Calza et al.[95] showed that the transmission channels described above are found to be stronger in countries with mortgage markets that are more developed. In addition, countries with higher loan to value ratios are even able to further amplify this effect, as households are able to leverage upon the increasing value of the collateral[52].

While the impact of interest rates on the development of real estate prices is well documented in literature, this is not the case for the other instruments of monetary policy. Money aggregates, which are a measure of the central banks money supply, are also an import policy instrument that allows stimulating output and consumption[96] within an economy and thus could also have a positive impact on the development of real estate prices. However, empirical evidence for this relation is limited[97]. An example of such an analysis can be found in the vector autoregressive study conducted by Berlemann et al.[98] with a focus on the Swiss real estate market.

Therefore, it is well established that central banks today are particularly interested in the development of asset prices in conducting their monetary policy. It is most likely that in the future this perspective will find its way into monetary policy guidelines, as asset prices become increasingly important as a proxy for the world and national economic conditions. Among the asset prices, housing prices are especially relevant because they provide a strong transmission mechanism between monetary policy and the development of the economy. A better understanding of real estate sector and monitoring of its development could therefore substantially improve the forecast of inflation. Following this line of argumentation, some researchers proposed to target asset prices instead of inflation and Leamer[99] in particular even proposed a monetary policy based on real estate market statistics rather than on output gap.

II.3. REVIEW ON THE CAUSALITY OFT TWO TIME SERIES

This master thesis has been conducted using a novel technique, the Thermal Optimal Path (TOP) method for the quantification of time varying lead-lag structures between pairs of economic time series. Therefore, we use this section to elaborate on alternative methods that are used for the analysis of similar datasets. Knowing the limitations of the different methods will give readers a chance to better understand and judge the quality of alternative studies.

While traditionally, correlation analysis techniques are non-dynamic and have to consider issues of stationarity as well as sample size, to provide accurate results, modern methods that evolved with the help of computers are able to deliver time-dependent correlation measures while even overcoming some of the previously named issues.

The list of the introduced method is not claiming to be complete. However, it represents fundamental concepts of the more advanced methods that are today used in practice. Especially within the frequency domain, there is extensive literature available that deals with the multivariate and time-varying coherence of time series. For example, the method of Time-Varying Coherence Function (TVCF), developed by Essaadi et al.[100], which allows one to determine cyclical dependencies of the time series over time without previous treatment for stationarity.

II.3.1. TIME SERIES ANALYSIS

Time series data usually represents a sequence of observations, which are recorded outcomes of an event over a certain interval in time. This could, for example, be housing price indices that are used to describe the fluctuation of the housing valued in a certain area. A time series X is usually represented by

$$X = \{x_1, \dots, x_t\}$$

where x_i is the observed outcome at time $i \in t$ and t is the duration of all observations. The individual observations within a time series can be conducted in variable (irregular time series) or regular intervals (regular time series).

In general, time series analysis seeks to identify patterns and trends in a sequence of data. These patterns can be caused by a systematic underling correlation or could be the results of stochastic processes. These unknown dynamics lead many researchers to develop different methods on time series analysis, to better understand and forecast such time series.

The analysis of one time series might give information about the type of patterns and trends discovered, but might not be sufficient to explain when it will occur. Especially with non-systematic patterns, the causes will often be found in externalities influencing the dynamics of the time series. Therefore, the study of interrelations or “similarities” of two or more different time series (multivariate time series) is an essential part of modern time series analysis.

Most of the data used in research shows non-stationary and complex behaviour. Furthermore, these time series provide only a short period of measurements, which reduces the meaningfulness of classical linear approaches for time series analysis. Therefore, non-linear techniques were developed to analyse data of complex systems.

II.3.2. STATIONARY TIME SERIES

The usual prerequisite of most statistical Time Series analysis is stationarity. If the joint distribution $(x_{t_1}, \dots, x_{t_k})$ of a vector representation of the time series $X_t = \{x_t\}_{t=1}^{T}$ is identical to that of $(x_{t_1+\tau}, \dots, x_{t_k+\tau})$ for all τ (with k being a random positive integer and $(t_1, \dots, t_k)$ being a random selection of points) the time series is considered to be strictly stationary. This strong requirement, however, can hardly be found in empirical data sets. Therefore the weak form of stationarity is often considered. It requires both the mean of a time series X_t and the covariance between X_t and X_{t-l} (l being a random integer) to be independent of time.

Formally, a weak stationary time series fulfils the following conditions:

$E[x_t] = \mu$ with μ being constant,

$var(x_t) = E[(x_t - \mu)^2] = \sigma^2$ with σ^2 being constant and

$cov(x_t, x_{t+l}) = cov(x_t, x_{t-l}) = \gamma_l$ depending only on the distance l between the time series.

In other words, this means that the statistical properties, such as mean, variance and covariance do not change over time.

However, most financial time series show some kind of trend, cyclical behaviour or random walk and thus cannot be assumed to be stationary. The simplest way to overcome this problem is by taking the first logarithmic differences of the original data (e.g. log asset return series). For cases where the original data is required, different mathematical transformations such as de-trending, deflation and seasonal-adjustment can be applied to stationarize the time series.

II.3.3. CROSS-RECURRENCE PLOTS (CRP) AND CROSS-RECURRENCE QUANTIFICATION ANALYSIS (CRQA)

CROSS-RECURRENCE PLOTS (CRP)

A cross-recurrence plot is a graph that illustrates the joint occurrence of a particular state in two separate time series. It therefore helps to reveal all the times, when the phase trajectory of the first time series visits roughly the same area in the phase space as the phase space trajectory of the second time series.

The phase space is reconstructed from a time series x_t following Takens' embedding Theorem[101] that uses an embedding dimension m and a time delay τ, sampled every time t. The reconstructed phase space trajectory is represented by:

$$\overrightarrow{y_t} = (x_t, x_{t+\tau}, \dots, x_{t+(m-1)\tau})$$

The parameters m and τ should be chosen according to usual parameter-detecting methods such as false nearest neighbours for m or mutual information for τ.

The cross-recurrence plot of two time series[102] y_i $(i = 1 \dots N)$ and z_j $(j = 1 \dots M)$ is represented by the visualisation of the $N \times M$ matrix $CR_{i,j}$ which contains either zeros (represented by the white areas in the plot) or ones (represented by the black areas) and is defined as

$$CR_{i,j} = \Theta(\varepsilon - \|y_i - z_j\|)$$

With $\Theta(x)$ being the Heaviside function, ε as the predefined "threshold" for the closeness of the two time-series and $\|\ldots\|$ as the norm (for example the Euclidean norm). To change the "resolution" of the results, ε can be fixed or altered also depending on i and j. The cross-recurrence plot exhibits characteristics of the joint dynamics of both time series. If randomly-distributed recurrence points occur in the plot, this is a sign for two independent processes. If longer diagonal lines occur in the plot, this can be interpreted as periodically stable lead-lag relations between the time series. The distance to the main diagonal (in the case of $N = M$) in the plot represents the actual lead-lag between the movements of the time series.

Cross-recurrence quantification analysis (CRQA)

The Cross-Recurrence Quantification Analysis was developed to quantify the similarity of the phase space trajectories and thus allows determining the dynamic relations between two time series. Marwan and Kurths[103] proposed a measure of similarity, which assesses the distribution of the diagonal length $P_t(l)$ for each diagonal parallel to the main diagonal. The main diagonal is represented by the index $t = 0$, diagonals above the main diagonal (equivalent to a lead of the second time series over the first) are denoted by $t > 0$ and diagonals below the main diagonal (equivalent to a lag) are denoted by $t < 0$.

The probability of both time series having similar states with a time lag of t is shown by the recurrence rate $RR(t)$ which is defined as

$$RR(t) = \frac{1}{N-1}\sum_{l=1}^{N-t} l \cdot P_t(l)$$

The higher the value of RR is, for a given value of t, the higher is the density of recurrence points in the chosen diagonal parallel to the main diagonal.

The determinism measure quantifies the proportion of long diagonal structure formed by recurrence points, to all recurrence points in the matrix. It is calculated by

$$DET(t) = \frac{\sum_{l=l_{min}}^{N-t} l \cdot P_t(l)}{\sum_{l=1}^{N-t} l \cdot P_t(l)}$$

where high $DET(t)$ values represent a deterministic system.

Another measure of similarity of two time series is the average diagonal line length $L(t)$, which shows the average duration of those similarities within the data.

$$L(t) = \frac{\sum_{l=l_{min}}^{N-t} l \cdot P_t(l)}{\sum_{l=l_{min}}^{N-t} P_t(l)}$$

To better understand the results of the cross-recurrence analysis and illustrate the changes in correlation properties, the concept of the line of synchronisation (LOS) was developed by Marwan et al.[104]. The LOS algorithm starts by picking the first point in the cross-recurrence space and then further picks the next recurrent point within a predefined window. If within the window no point is available, the window size is iteratively increased. As a measure of LOS quality, Marwan et al. introduced the following indicator:

$$Q = \frac{N_t}{N_t + N_g}$$

Where N_t and N_g are the number of target and gap points within the line of synchronisation. Higher values of Q demonstrate a better fit of the LOS.

It is important to mention that the soundness of the results, as with all statistical measures, increases with the sample size. While high values of RR suggest that it is likely that both datasets exhibit similar states within a certain time lag t, high values for DET and L give information about the length of the occurrence of those similarities.

II.3.4. CORRELATION ANALYSIS IN THE TIME DOMAIN

Time domain methods are usually based on the standard correlation or cross-correlation analysis. However, for empirical data it is often necessary to de-trend or de-seasonalise the data prior to the correlation analysis. This is important, because strong trends in the data can lead to biased high correlation results, which would suggest a misleading relationship between the time series. Therefore de-trending filters, such as the Hodrick-Prescott (HP) filter, were developed and are frequently used.

Nevertheless, time domain correlation analysis methods are commonly applied in a wide variety of economic studies. They appeal to a many scientists because of their implementation into various statistical software packages and the ease of interpreting their results.

II.3.4.1 LINEAR CORRELATION ANALYSIS

Linear correlation analysis, also known as Pearson's correlation or cross-correlation, is one of the most frequently applied methods for assessing the relationship of two time series. It is a measure of similarity of two different data sets on the basis of a defined time lag. Formally, the sample correlation at lag τ for stationary time series is defined as follows:

$$\rho_{x,y}(\tau) = \frac{cov\big(X(t), Y(t-\tau)\big)}{\sqrt{var\big(X(t)\big) \cdot var\big(Y(t-\tau)\big)}} = \frac{E\big[(X(t)-\mu_x)\big(Y(t-\tau)-\mu_y\big)\big]}{\sqrt{E[(X(t)-\mu_x)^2] \cdot E\Big[\big(Y(t-\tau)-\mu_y\big)^2\Big]}}$$

where μ_x and μ_y represent the mean of X and Y, and τ is the time lag between the two time series. The strength of the linear correlation is shown by $-1 \leq \rho_{x,y}(\tau) \geq 1$, with $\rho_{x,y}(\tau) = 0$ corresponding to both variables being uncorrelated.

If not applied with care, linear correlation analysis can face major statistical issues. The statistical significance of correlation analysis in general is dependent on the sample size and certain correlation values will not guarantee a meaningful economic dependency[105]. Furthermore, in samples with changing dependencies, correlation information is washed out when considering the entire data set. While small intervals could reveal true correlations, results will become increasingly uncertain because the number of considered data points is decreasing. For time series containing stochastic trends, correlation is usually biased upwards and correlation analysis would result in spurious correlation. To overcome these issues, regression techniques such as granger causality test have emerged to better analyse the dependencies of multiple time series.

II.3.4.2 GRANGER CAUSALITY

Granger Causality[106] named by the Nobel Prize winner in Economics Clive Granger is a term for a specific causality relation in time-series analysis. A variable x_t, which is part of the time-series $X = \{x_1, x_2, \dots, x_t\}$ is Granger Causal for y_t which is part of a second time-series

$Y = \{y_1, y_2, \dots, y_t\}$ if the variance of the optimal linear predictor of y_{t+h} based on X and Y has smaller variance than the optimal linear predictor of y_{t+h} based only on Y for all h. In other word if x_t helps predict y_t at some stage in the future.

In the case that x_t Granger causes y_t and y_t Granger causes x_t, X and Y are interacting in a so-called feedback system.

A formal representation of the "direct" Granger causality test is given by the following to equations:

$$x_t = \sum_{i=1}^{L} \alpha_{i1} x_{t-i} + g(z_t) + \varepsilon_{1,t}$$

$$x_t = \sum_{i=1}^{L} \alpha_{i1} x_{t-i} + \sum_{i=1}^{L} \beta_{i1} y_{t-i} + g(z_t) + \eta_{1,t}$$

Thus, testing for Granger Causality can be done by a simple regression which will involve rejecting the null hypothesis $\beta_{ij} = 0 \; \forall \; i$. The test can be simply reversed to check the direction of causality.

As pointed out by Sims (1972), Granger Causality is a powerful tool to test for exogeneity of two time series since X can only be exogenous of Y if X fails to Granger cause Y. If X and Y both fail to Granger cause each other, this is can also be seen as prove of independence of the two time series.

II.3.4.3 CO-INTEGRATION TECHNIQUE (VAR)

Another time domain approach to verify the interdependence between two time series is to check if they are cointegrated[107]. However, economic time series, as described above, are usually non stationary and thus distort correlation analysis of most kinds.

All data that is non stationary only due to unit roots, i.e. that is integrated of the order $I(d)$, can be transformed into a stationary time series by linear transformation. If $x_t \sim I(1)$, then differencing the time series as in $\Delta x_t = x_t - x_{t-1}$ leads to $\Delta x_t \sim I(0)$ by definition. Alternatively, if for the case of two non-stationary time series $\{x_t\}$ and $\{y_t\}$ the linear transformation $y_t - \alpha x_t$ is stationary, x_t and y_t are said to be cointegrated. The cointegration vector is thus given by $[1 - \alpha]$. In summary, cointegration is the case when the linear combination of multiple non-stationary time series results in stationarity.

There are many possible tests for cointegration of time series. Among the most common ones is the Engle-Granger test based on the augmented Dickey-Fuller test and the Johansen test, which is an extended version of the Engle-Granger test dealing with multiple time series. This test uses the vector auto-regression representation (VAR) for testing its hypothesis.

The Engle-Granger test is based on an OLS regression of the linear combination

$$y_t = \alpha_0 + \alpha_1 x_t + u_t$$

For $\{x_t\}$ and $\{y_t\}$ to be cointegrated the residuals u_t have to be stationary. That means that for

$$u_t = \rho u_{t-1} + \varepsilon_t$$

the coefficient ρ has to be $\rho < 1$ and the error term ε_t is a white noise process. The test can be done by an augmented Dickey-Fuller test

$$\Delta\hat{u}_t = (1-\rho)\hat{u}_{t-1} + \psi_1\Delta\hat{u}_{t-1} + \cdots + \psi_m\Delta\hat{u}_{t-m} + \varepsilon_t$$

with the null hypothesis being expressed by $H_0{:}\, 1-\rho = 0$. However, this test has been criticised[108] and further developed to increase the power of the hypothesis testing[109,110]. In general, if the null hypothesis is rejected, one accepts that the residuals are stationary and therefore the time series are cointegrated. This however, does not necessarily imply a direct causal relationship between the time series. The relation can be seen as a "long-run equilibrium" because it acts as an attractor that leads to convergence in the case of departures from the relation[111].

The Johansen test procedure for multivariate cointegration is based on the maximum likelihood estimator of the vector error correction model (VECM).

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t$$

The VECM can be seen as a first differenced VAR where Πy_{t-1} is responsible for correcting short-run fluctuations of the variables describing the long run (cointegrated) relationship. The coefficient matrix Π has a reduced rank $\mathrm{r} < n$ with n being the size of the vector y_t and r being the number of cointegrating relationships such that $\Pi = \alpha\beta'$ and $\beta'\ y_t$ is stationary. Thus, each column of β is a cointegration vector and the number of available cointegration vectors (the rank r) expresses the number of time series that can be constructed by a linear combination of the remaining series. The null hypothesis is therefore rejected, if the rank of the matrix is $r \geq 1$. Johansen proposed two different likelihood ratio tests to identify the cointegration rank r of the coefficient matrix Π.

The trace test is given by:

$$H_0{:}\quad J_{trace} = 0 = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i)$$

and the maximum eigenvalue test is given by

$$H_0{:}\quad J_{max} = 0 = -T \ln(1-\hat{\lambda}_{r+1})$$

where "T is the size of the sample and $\hat{\lambda}_i$ is the i^{th} largest canonical correlation of Δy_t with y_{t-1} after correcting for lagged differences and deterministic variables when present".[112] Within the Johansen test it is important to consider how many lagged variables p should be considered for the test. As high numbers increase the distortion from the long-run cointegrated relationship and small numbers will lead to an increasingly biased estimator of the residuals ε_t.

II.3.5. CORRELATION ANALYSIS IN THE FREQUENCY DOMAIN

In contrast to the time domain methods presented above, the frequency domain methods analyse mathematical functions or signals with respect to their underling frequencies. With the help of mathematical models such as Fourier transform, a time series can be completely decomposed into its cyclical components. Such components can be described by their periods and frequencies (Fourier representation), where periods are the time length of a cycle and frequencies are the number of occurrences of one state within a defined time period. The Fourier transform method is able to detect those cycles and compute their corresponding frequencies. The results are usually presented in a so-called spectrum, which is a plot of the amplitude (rate of occurrence) against the frequencies.

II.3.5.1 SPECTRAL ANALYSIS

One of the most commonly used data analysis methods within the frequency domain is Spectral analysis. It is widely used by economists, because it can also be extended to the multivariate case, which allows the simultaneous analysis of multiple time series. While the univariate analysis identifies the intrinsic cycles within one single time series, the multivariate also known as cross-spectrum analysis is aimed to uncover common cycles in terms of magnitude and lead-lag patterns of multiple time series.

The Fourier representation of a time series, as a function of sines and cosines, is the basis of every Spectral analysis. Today, many consecutive methods based on the frequency analysis of a dataset have been derived using different types of Fourier transformations. Depending on the properties of a data set, the Fourier transformation has to be chosen.

DISCRETE FOURIER TRANSFORMS

The Discrete Fourier Transform (DFT) is used to convert a finite sample of a continuous function into its frequency domain representation. This method treats the data as it was sampled from a periodic time series and thus shares the same patterns as the whole series.

The DFT of any discrete time series $\{x_n\}$ with N observations, which transforms the series given as a function of time t to a complex valued function of k with $\Delta\omega = \frac{2\pi}{N}$, is given by

$$X(k) = \sum_{n=0}^{N-1} x_n e^{-in(\frac{2\pi k}{N})}$$

where $X(k)$ represents the distribution of energy (variance) over the frequencies. In the case of stochastic time series the spectral density function is usually considered as the Fourier transform. It describes the distribution of power over the frequencies and is given by

$$f_{xx}(k) = \sum_{\tau=-(N-1)}^{(N-1)} R_x(\tau) e^{-i\tau(\frac{2\pi k}{N})}$$

with $R_x(\tau) = cov(x_n, x_{n-\tau})$ defined as the auto-covariance function of $\{x_n\}$. It can also be expressed in a non-imaginary representation

$$f_{xx}(k) = \sigma_x^2 + 2\sum_{\tau=1}^{N-1} R_x(\tau) \cos\left(\frac{2\pi\tau k}{N}\right)$$

For non-deterministic discrete stationary time series, the spectrum is a continuous function of k. The total variance of the data is represented by the area underneath the curve, where large peaks indicate a strong cyclical component at the specified frequency range.

For the case of the comparison of two stationary time series $\{x_n\}$ and $\{y_n\}$ in the frequency domain, the cross-spectrum analysis is given by

$$f_{xy}(k) = \sum_{\tau=-(N-1)}^{(N-1)} R_{xy}(\tau)e^{-i\tau(\frac{2\pi k}{N})}$$

with $R_{xy}(\tau) = cov(x_n, y_{n-\tau})$ defined as the cross-covariance function of $\{x_n\}$ and $\{y_n\}$. The function $f_{xy}(k)$ is generally an uneven function and is thus represented by complex numbers. The real part $\Lambda_{xy}(k)$(co-spectrum) and the imaginary part $\Psi_{xy}(k)$(quadrature spectrum) can be decomposed in the following way

$$f_{xy}(k) = \Lambda_{xy}(k) + i\Psi_{xy}(k)$$

The cross-amplitude spectrum $A_{xy}(k)$, which describes the relationship between the magnitudes of the components in the time series at different frequencies, is thus given by

$$A_{xy}(k) = \sqrt{\Lambda_{xy}(k)^2 + \Psi_{xy}(k)^2}$$

The phase spectrum $\Phi_{xy}(k)$is represents the relative phasing of the components at different frequencies. It measures the amount by which one series is leading the other at a certain frequency and thus indicates the time delay between the two time series. The spectrum is therefore able to provide information about the lead-lag relation between the data over time. It is given by

$$\Phi_{xy}(k) = \arctan\left(\frac{\Lambda_{xy}(k)}{\Psi_{xy}(k)}\right)$$

with the exceptions

$$\Phi_{xy}(k) = \begin{cases} 0 & \text{if } \Psi_{xy}(k) = 0 \text{ and } \Lambda_{xy}(k) > 0 \\ \pm\pi & \text{if } \Psi_{xy}(k) = 0 \text{ and } \Lambda_{xy}(k) < 0 \\ \pi/2 & \text{if } \Psi_{xy}(k) > 0 \text{ and } \Lambda_{xy}(k) = 0 \\ -\pi/2 & \text{if } \Psi_{xy}(k) < 0 \text{ and } \Lambda_{xy}(k) = 0 \end{cases}$$

A measure of linear predictability, at different frequencies, between two time series is given by the squared coherence spectrum $\kappa_{xy}(k)$. It is a function of the cross spectrum and the auto-spectra of the two time series[113,114]

$$\kappa_{xy}(k) = \frac{A_{xy}(k)^2}{f_{xx}(k)f_{yy}(k)}$$

The measure of coherence is similar to R^2 in the time domain and is an indicator for the strength of common cycles and synchronisation. Squared coherence can be plotted against frequency to identify the pattern of correlations between pairs of components. The value of squared coherence is between 0 and 1 with higher values representing stronger relationships of the cyclical components of the two time series.

SHORT-TERM (STFT) OR WINDOWED FOURIER TRANSFORMS

The short-term or Windowed Fourier Transform (WFT) was developed to better represent data which is non-stationary (i.e. non periodic). This method allows providing a time-frequency representation of the data, giving simultaneous information about cyclical components and their occurrence in time.

The STFT uses a window function to divide the time series into segments, where stationarity can be assumed and each section is analysed for its frequency components separately. This can be expressed as:

$$X(m,k) = \sum_{n=0}^{N-1} x_n w(n-m) e^{-in(\frac{2\pi k}{N})}$$

where $w(m)$ is the analysis window, which is assumed to be non zero only in the interval $[0, m_w - 1]$.

The window functions width and position over the actual time series localizes the signal in time. If for the outer boundaries of the windowed time series sharp transitions exist, this section is weighted differently in such a way that it converges to zero at its endpoints.

The problem of this method is that to get a good resolution in time, the window function has to be narrow, while for a good frequency resolution a wide window has guaranteed sufficient data points for the analysis. This problem is also known as the Heisenberg uncertainty principle.

II.3.5.2 WAVELET ANALYSIS

Similar to the Fourier analysis, the wavelet analysis is a frequency domain method that uses wavelet functions as a basis instead of sines and cosines. The wavelet analysis was developed to overcome the problem of time resolution loss in the classical Fourier analysis and improve the time-frequency resolution compared to the short-term Fourier analysis. This is essentially helpful for time series that show fluctuations in their cyclical components over time. The inherent problem of a time-frequency representation of a time series is the uncertainty principle expressed by Heisenberg, saying that it is impossible to know which spectral component occurs at any given time. The best that can be done is to investigate what spectral components exist within a defined interval of time. The wavelet analysis uses the fact that high frequency components can be better resolved in time (i.e. less data points need to be analysed to define the cyclical component) and lower frequency components are better resolved in frequency.

The wavelets are obtained from a so called “mother wavelet” $\psi(t)$, by simply scaling and translating it as follows

$$\psi_{s,\tau}(t) = \frac{1}{\sqrt{s}} \psi\left(\frac{t-\tau}{s}\right)$$

The parameter s is a dilation factor controlling the length of the wavelet and τ represents the location factor indicating the centre of the wavelet. The term $\frac{1}{\sqrt{s}}$ is responsible for normalizing the energy across the different scales. A commonly used wavelet is for example the Morlet wavelet,

$$\psi(\tau) = \frac{e^{i\omega_0\tau}}{\pi^{1/4}e^{-u^2/2}}$$

where ω_0 is the central frequency of ψ. For the wavelet transformation, the scale parameter s has to be transformed to a frequency parameter $\omega \approx \frac{\omega_0}{s}$ with ω_0 representing the central frequency of the energy ψ in the Fourier domain. The Discrete Wavelet Transform (DWT) for a discrete time series $\{x_n\}$ with N observationsis given by

$$W_x(\omega, \tau) = \sqrt{\frac{\omega}{\omega_0}} \sum_{n=0}^{N-1} x_n \psi^* \left((n-\tau)\frac{\omega}{\omega_0}\right)$$

For two stochastic time series $\{x_n\}$ and $\{y_n\}$ Hudgins et al[115,116] proposed the Cross Wavelet Transform (XWT) defined as

$$W_{xy} = W_x W_{y*}$$

where W^x and W^y are the wavelet transforms of $\{x_n\}$ and $\{y_n\}$ respectively. The wavelet coherence between time series $\{x_n\}$ and $\{y_n\}$ at frequency ω and time τ is defined by

$$R_{xy}^2(\omega, \tau) = \frac{\left|S_{xy}(\omega, \tau)\right|^2}{S_x(\omega, \tau) S_y(\omega, \tau)}$$

In this equation $S_{xy}(\omega, \tau)$ is the wavelet cross spectrum (WCS) between $\{x_n\}$ and $\{y_n\}$ and $S_y(\omega, \tau)$ respectively $S_x(\omega, \tau)$ are the wavelet auto-spectra (WAS). The estimates of the WCS and the WAS are defined as follows

$$\widehat{S_{xy}}(\omega, \tau) = \frac{1}{N} \sum_{n=1}^{N} W_{x_n}(\omega, \tau) \overline{W_{y_n}(\omega, \tau)}$$

$$\widehat{S_x}(\omega, \tau) = \frac{1}{N} \sum_{n=1}^{N} \left|W_{x_n}(\omega, \tau)\right|^2$$

$$\widehat{S_y}(\omega, \tau) = \frac{1}{N} \sum_{n=1}^{N} \left|W_{y_n}(\omega, \tau)\right|^2$$

The wavelet coherence $\widehat{R_{xy}^2}(\omega, \tau)$ indicates the time-frequency dependence between two time series and is expressed by a normalized measure between 0 and 1. Values close to 1 are seen as an evidence for a significant coherence between $\{x_n\}$ and $\{y_n\}$.

As for the spectral analysis the wavelet coherence phase[117] is also defined as

$$\phi_{xy}(\omega, \tau) = \arctan\left(\frac{\Im(\widehat{S_{xy}}(\omega, \tau))}{\Re(\widehat{S_{xy}}(\omega, \tau))}\right)$$

Gish and Cochran[118] developed a null hypothesis H_0 based on the wavelet coherence for testing whether two time series $\{x_n\}$ and $\{y_n\}$ are independent white noise.

$$H_0: \quad \widehat{R^2_{xy}}(\omega, \tau) \leq r_a$$

$$r_a = 1 - \alpha^{1/(N-1)} \quad \text{for} \quad 0 \leq \alpha \leq 1$$

where α is the significant level for rejecting the null hypothesis.

Today, cross wavelet analysis is one of the most advanced techniques for analysing the time varying interdependence between two economic time series. However, because it is a complex application and depends on the quality of the input data, it is not widely applied in economics.

III. METHODOLOGY

In this section we introduce the Thermal Optimal Path method as well as the data chosen for the analysis. The TOP method, introduced by Sornette and Zhou[119], has already been applied to a couple of time series and is still subject to further research. However, the quality of the results are promising, especially when comparing the method with other dynamic time-decencies analysis techniques. The method is situated in the time domain, but unlike other popular methods, it uses a non-parametric approach. In some senses, it has similarities to the cross recurrence analysis, which is also based on the construction of a "distance matrix" ("phase space") but extents this tool by the concept of a weighted average minimal path within the "phase space" or the "distance matrix". This allows one to better analyse non-monotonic correlations of time series with less pronounced lead-lag relationships.

Despite the major advantages of the TOP method, our analysis also faces some difficulties that are sourced in the scarce availability of suitable data. While the TOP method is good in finding stable patterns within datasets of many observations, the outcomes become harder to interpret as the amount of measurements decrease and the dynamics of the lead-lag pattern increase. Even though the temperature allows for some adjustments in this regard, we face the additional problem of losing essential information when temperature increases. The datasets available on monetary policy measures and especially on the real estate market are not optimal. While most countries have some kind of yearly or quarterly data on residential housing market, only a few countries have a history of tracking the development of the market on a more frequent basis or even providing statistics on the entire real estate market. The United States and the United Kingdom are well-documented examples that offer a wide variety of monthly and quarterly indices that allow reconstructing the development of the housing market until the early 1950s. In large parts of Europe and Asia, this is however not the case. The importance of such statistical data were only recently realised and measurements are therefore limited, providing sometimes only less than one decade of suitable information.

In addition to the limitation in data availability, we also have to account for the differences in the construction of statistical representations of the real estate market. As described earlier, there are various possibilities of measuring and aggregating data within a market, which can potentially lead to biased comparisons.

Furthermore, it is important to realise that the TOP method, while producing astonishing straightforward results, is not a direct indicator for a causal relationship between two time series. It also does not allow to precisely determine whether a lead-lag relationship is positive, in the sense that an increase in one time series follows an increase in the other, or negative. However, this issue can be overcome by visualizing the results together with lead-lag patterns corresponding to an "a priory" assumption on the direction of correlation.

III.1. THE THERMAL OPTIMAL PATH (TOP) METHOD

The thermal optimal path (TOP) method is a novel non-parametric method to identify the dynamic time variation of the lead-lag structure between two time series. It was introduced by Sornette and Zhou[119] in 2005 and successfully applied to a number of economic researches. In 2006, Zhou and Sornette analysed the causality relationship between the movements of the US stock market and the Treasury bond yields, which allowed confirming previous results that the stock market leads all decisions of the Federal Reserve Funds as well as the yield rates with short maturities, during the period of 2000 to 2003[120]. In another paper both authors showed, on the basis of an analysis of the historical volatility of US inflation and the economic growth rate, that the TOP method is able to significantly outperform traditional cross-correlation methods[121].

The method is based on the following framework. A distance matrix $E_{X,Y}$ is composed of the elements:

$$\epsilon_{-}(t_1, t_2) = \sqrt{[X(t_1) - Y(t_2)]^2}$$

$$\epsilon_{+}(t_1, t_2) = \sqrt{[X(t_1) + Y(t_2)]^2}$$

$$\epsilon_{\pm}(t_1, t_2) = min[\epsilon_{-}(t_1, t_2), \epsilon_{+}(t_1, t_2)]$$

Where X and Y are two standardized time series with $\{X(t_1): t_1 = 0, \dots, N\}$ and $\{Y(t_2): t_2 = 0, \dots, N\}$. The elements $\epsilon_{\pm}(t_1, t_2)$ are a measure of the distance between the realization of the first time series at time t_1 and the second timer series at time t_2. The matrix $E_{X,Y}$ with its $(N+1)\times(N+1)$ elements therefore embodies all possible pairwise distances between the two time-series. Note that the distance matrix is constructed to allow for non-monotonic behaviour of time-series correlations, which allows identifying trends of both positive and negative correlation.

The matrix $E_{X,Y}$ is then used to determine an optimal path that describes and quantifies the lead-lag relationship between the two studied time series. The scheme on how the optimal lead-lag path is found is illustrated in Figure 1. The first and second time series are indexed with t_1 and t_2. Each node within the matrix contains the distance information for each pair $\epsilon_{\pm}(t_1, t_2)$. The path along the main diagonal corresponds to the instant comparison of the time series one and two ($t_1 = t_2$). A path above the diagonal corresponds to the second time series leading the first and a path below correspond to the opposite case. Also shown in the figure are the allowed causal steps, represented by the red arrows, in order to construct the lead-lag path. A path constructed by this method is composed of a continuous set of nodes (with the constraint that time flows from the past to the future) beginning at the lower left corner and ending at the upper right corner. Whether the path is a true representation of the actual lead-lag structure between two time-series can be determined by the sum of the distances along its length, also called the "cost" of the path. It is important to note that the single layer approach followed here was found to perform better then the multi-layer approach[120], which allowed the nodes to connect over multiple time steps.

To ease the later analysis it is convenient to use a rotated coordinate system, with axis x and t such that:

$$t_1 = 1 + \frac{(t-x)}{2}$$
$$t_2 = 1 + \frac{(t+x)}{2}$$

thus

$$x = t_2 - t_1$$

Where t is the main diagonal direction of the (t_1, t_2) system and x represents the distance perpendicular to the diagonal. The origin $(t = 0, x = 0)$ is thus identical to $(t_1 = 1, t_2 = 1)$ and the standard reference path is along the diagonal with $x = 0$. Each other path (Lead-Lag structure) can be represented by a relationship $t_2(t_1)$ respectively $x(t)$. Per definition this means that a positive value of x corresponds to $t_2 > t_1$, which means that on the optimal thermal path the second time-series $Y(t_2)$ is lagging behind the first time-series $X(t_1)$.

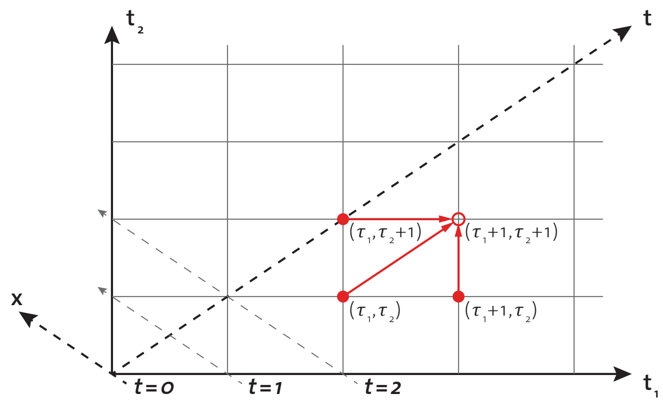

Figure 1: Representation of the two-layer approach in the lattice (t_1, t_2) and the rotated axis (x, t) according to the text. Illustrated by the three red arrows are the moves allowed to reach any node in one single step.

While the goal of the TOP method analysis is to discover the lead-lag relationship of two time-series by finding the optimal path with the minimum of average distances (sum of distances divided by the length), the reliability of the results can be strongly influenced by noise patterns. In order to avoid such bias and to discover a robust lead-lag relation, Sornette and Zhou proposed to define an average over many possible path (with similar costs), each weighted according to a Boltzmann-Gibbs factor[119,120,121] to derive the "thermal" optimal path.

This is done by calculating the "probability" $G(x,t)/G(t)$ for a path to be at distance x from the diagonal for a value of t along the diagonal, with $G(x,t)$ being the partition function for all values of x at a fixed time t and their sum $G(t) = \sum_x G(x,t)$. The probability $G(x,t)/G(t)$ helps to identify the best compromise between the combinatorial weight of a set of paths with similar mismatches or "entropies" and the path with the absolute minimum mismatch or "energy" as defined above.[122]Figure 1 indicates that there are essentially three ways one may use to arrive at node $(t_1 + 1, t_2 + 1)$, a vertical path from $(t_1 + 1, t_2)$, a horizontal path from $(t_1, t_2 + 1)$ and a diagonal path from (t_1, t_2).

According to Wang et al.[123] the recursive equation of the partition function can be written as follows:

$$G(x,t+1) = [G(x-1,t) + G(x+1,t) + G(x,t-1)]\, e^{-\epsilon(x,t)/T}$$

The exponent $\epsilon(x,t)/T$ is defined by each element of the distance matrix $\epsilon(x,t)$ (see above), where the "Temperature" T represents the input factor controlling the above-mentioned compromise between combinatory entropy and minimal mismatch[122]. With an increasing value of T the number of paths with similar mismatch are considered in the partition function. In the opposite, for $T \to 0$ only one single path, with the minimum cost is considered. Guo et al.[122] describes the further procedure within the algorithm in the following way. "To get $G(x,t)$ at the t[th] layer, we need to know and bookkeep the previous two layers from $G(\cdot,t-2)$ to $G(\cdot,t-1)$. After $G(\cdot,t)$ is determined, these values are normalized by $G(t)$ so that $G(x,t)$ does not diverge at large t. The boundary condition of $G(x,t)$ plays an crucial role. For $t = 0$ and $t = 1$, $G(x,t) = 1$. For $t > 1$, the boundary condition is taken to be $G(x = \pm t, t) = 0$, to prevent paths to remain on the boundaries".

With the help of the partition function $G(x,t)$, the statistical average position of the path weighted by the $G(x,t)$'s can be calculated. Thus, the local thermal average time lag $\langle x(t)\rangle$ at time t over all possible lead-lag correlations weighted by the distance $\epsilon(x,t)$ (as a measure of co-movements of two time-series), is given by

$$\langle x(t)\rangle = \sum_x \frac{x\, G(x,t)}{G(t)}$$

Therefore the optimal thermal path can be determined for a given temperature T and an initial lead-lag x_0. In addition, the "energy" or cost of the path $e_T(x_0)$ can be defined as the thermal average of the measure $\epsilon(x,t)$ of similarities of two time-series.

$$e_T = \frac{1}{2(N-|x_0|)-1} \sum_{t=|x_0|}^{2N-1-|x_0|} \sum_x \frac{\epsilon(x,t)G(x,t)}{G(t)}$$

III.1.1. TESTING OF THE METHOD WITH ARTIFICIAL DATA

To verify the soundness of the TOP Method, we conduct a numerical example with the use of two artificial time series $X(t_1)$ and $Y(t_2)$. At first, the time series $X(t_1)$ is generated from an autoregressive (AR) process, following the procedure proposed by Sornette et al.[119]:

$$X(t_1) = bX(t_1 - 1) + \xi$$

where $b < 1$ and the serial uncorrelated noise is $\xi \sim N(0, \sigma_\xi)$. The second time series $Y(t_2)$ is derived as a linear function of $X(t_1)$ with a time lag τ

$$Y(t_2) = aX(t_2 - \tau) + \eta$$

with a being a constant and the noise $\eta \sim N(0, \sigma_\eta)$ that is serially uncorrelated. The interdependence of the two time series $X(t_1)$ and $Y(t_2)$ is disturbed by the amount of noise and can be described by the factor $f = {}^{\sigma_\eta}/_{\sigma_\xi}$. An increase of σ_η and therefore f, will result in a degrading of the dependence between the time series.

For the following example, the parameters for two time series with a duration of $N = 300$ are set to $a = 0.7$, $b = 0.8$, $\sigma_\xi = 1$ and $f = 1/5$. To allow multiple changes in the lead-lag regime of the two time series, we define the model in the following way:

$$Y(t) = \begin{cases} 0.8X(t+5) + \eta & 1 \leq t \leq 100 \\ 0.8X(t) + \eta & 101 \leq t \leq 200 \\ 0.8X(t-10) + \eta & 201 \leq t \leq 300 \end{cases}$$

where the time lead-lags are $\tau_1 = -5$, $\tau_2 = 0$ and $\tau_3 = 10$ and each change in the lead-lag structure is designed to occur after periods of 100 time steps. As defined above, a positive τ corresponds to the time series X leading the time series Y (where a negative value is indicating the opposite).

Figure 2 shows the results of applying the optimal thermal causal path method to the artificial time series generated upon following the system above. The average thermal path $x(t)$ is determined as a function of t time steps at three different temperatures $T = 2$, $T = 1$ and $T = 0.5$. To allow for an initial and final lead-lag structure, we analyse a total of 10x10 thermal optimal paths with 10 different starting points $(t_{1,start}, t_{2,start})$ and 10 ending points $(t_{1,end}, t_{2,end})$. Out of these samples, the overall optimal path $x(t)$is selected as the one with the least average energy among the 100 sampled thermal paths.

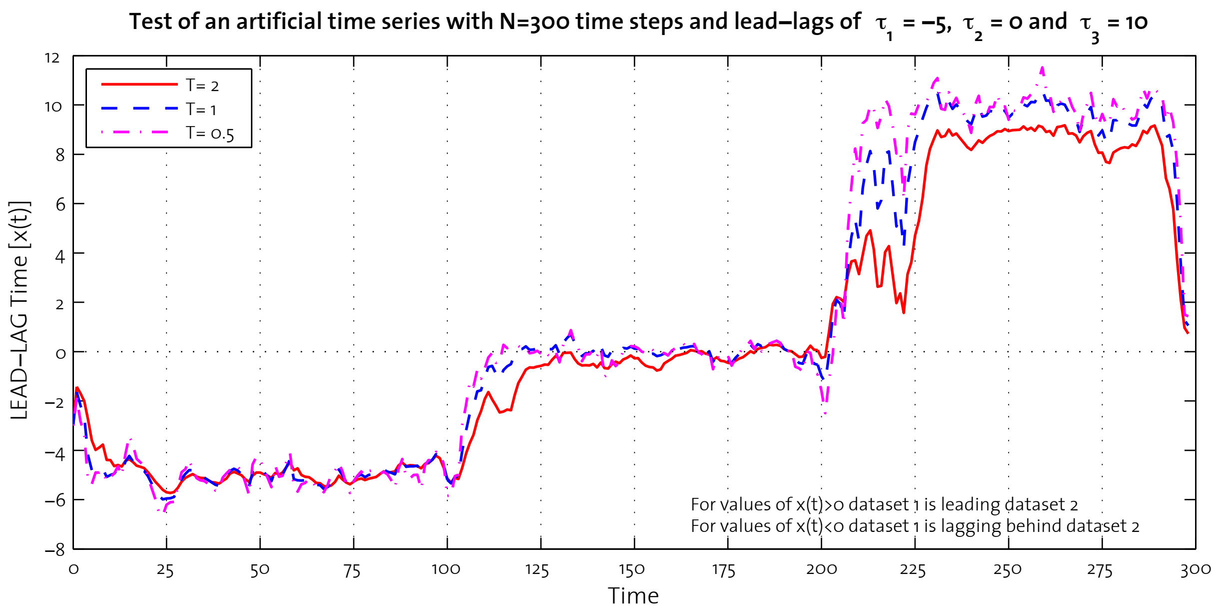

Figure 2: Average thermal path of the two artificial time series with N=300 time steps at different temperatures

The time lags within the three different time periods are clearly resolved and only short transient perturbations occur at the points of changing time lags. The same test can also be demonstrated with linear change of τ over time, where we also found the method to produce sound results.

However, reducing the available amount of data for processing decreases the sensibility of the thermal optimal path methods. To illustrate this and to get a better understanding of the capabilities of the method, we rerun the example with a reduced set of time points of $N = 90$.

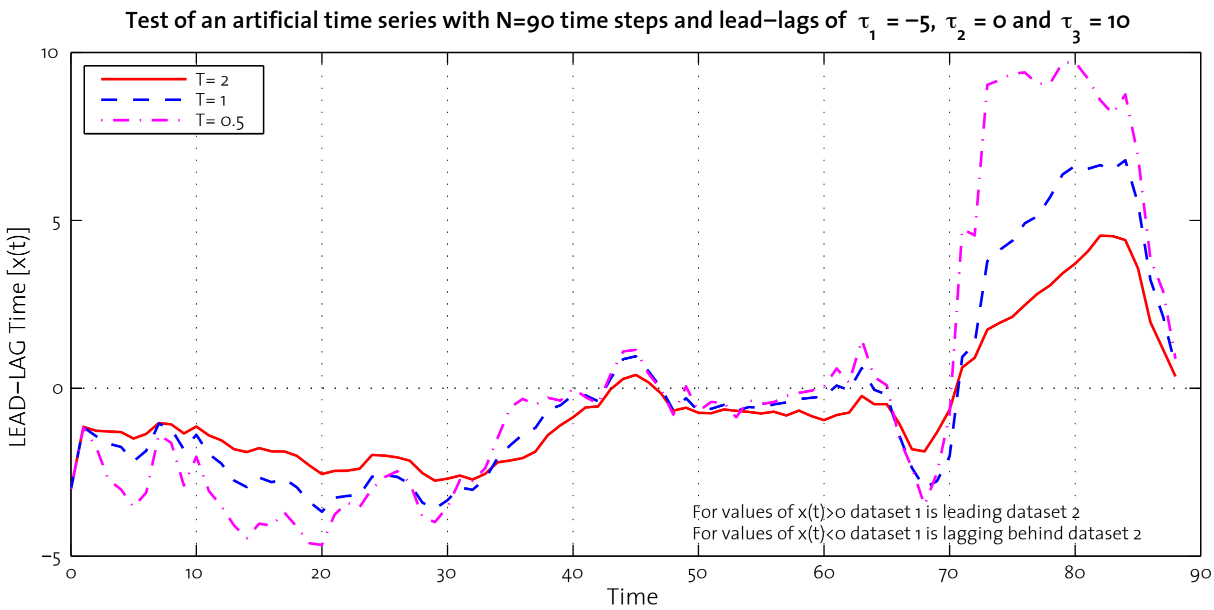

Figure 3: Average thermal path of the two artificial time series with N=90 time steps at different temperatures

As can be seen from Figure 3, the resolution of the lead-lag structure has clearly decreased. Yet, it is still possible to qualitatively identify the dynamics, even though especially the periods of changing lead-lag structures are fairly blurred. In the results we can also identify the compromise we have to make in terms of the temperature used for the analysis. While low temperatures are faster in detecting a change in lead-lag patterns, higher temperatures significantly reduce the disturbances, which occur in these situations. This makes it by far more reliable in identifying time varying interdependencies in the case of fast changing lead-lag structures.

For further tests of the method and application to real life data, please refer to Sornette et al.[119] , Zhou et al.[120,121] and Guo et al.[122].

III.2. DATA

During the conduct of this master thesis, a large dataset was collected that described the development of the real estate markets and the market operations of monetary policy in various countries. This dataset includes over 30 different counties, covering residential and commercial real estate price indices as well as stock market real estate indices, statistics on the transactions within the real estate market, statistics on the development of the mortgage market and proxies of the effect of monetary policy, such as central banks base rates, Interbank rates, yields of government bonds and money aggregates.

While the amount of available data is at first overwhelming, only a few time series within the dataset are suitable for a comparative analysis. Especially countries that have no tradition in the statistical aggregation of economic data or only just began with this kind of measurements, provide insufficient amounts of data for a trustworthy analysis. In addition, various countries only provide yearly or quarterly data, which often lack in resolution for the use of the TOP method.

Another issue are changes in the way time series are constructed, which could lead to biased results. This can be seen in the unique case of Europe with its Economic and Monetary Union (EMU). Since 1998 the European Central Bank took over the role of its member states' individual central banks, which lead to decupling of the direct impacts of monetary decisions (especially base interest rates) on the regional real estate markets.

In the following section, we provide an overview of the housing and interest rate data that we chose for analysis. Emphasis was laid on the compilation of large economies that have similar dataset available and give a good representation of the development of the real estate market worldwide. In addition, we focused on countries that have recently experienced a real estate boom and have a representative and well-documented time series.

For the subsequent TOP Method analysis, logarithmic returns are used for the analysis of monthly and quarterly data sets. The returns are defined as continuously compounded returns as follows:

$$R_{\ln}(t) = \ln\big(X(t)\big) - \ln(X(t-1))$$

with $X(t)$ being the initial non-stationary time series at time t. After generating the return time series, the data is being normalized so that their mean is zero and their standard deviation is equal to one. This procedure ensures the comparability of the time series and allows to produce meaningful results during the TOP method analysis.

III.2.1. REAL ESTATE DATA

As already discussed above, finding a meaningful approximation of the true changes in housing prices can be difficult. However, house price indices are today widely available across countries and are regularly chosen for empirical analysis. In addition, more and more stock market indices are constructed that either summarize the development of the real estate companies or real estate investment trusts (REITs). Nevertheless, there is still a strong discussion on whether house prices or commercial real estate prices could be assessed with the help of such stock market indices as a proxy[124,125].

In general, house prices are known to vary seasonally between -2% and +1% in a way that reflects seasonal changes in demand. During Christmas and the New Year, house price tends to decrease sharply while during June-July, prices show a broad peak. Strong seasonal influence can, however, make it difficult to interpret monthly changes in house prices in terms of either trends or irregular volatility. Therefore, it is common practice to report seasonally adjusted (SA) house prices. In the following analysis we use seasonal adjusted house price data whenever available.

Below, we describe the different datasets we used for the analysis, providing a methodological explanation of the way the time series is constructed.

III.2.1.1 Australia

Australian Bureau of Statistics (ABS) House Price Index - Eight Capital Cities[c]

The ABS house price index is constructed using the housing data of eight capital cities, Sydney, Melbourne, Brisbane, Adelaide, Perth, Hobart, Darwin and Canberra. It "uses a stratification approach to control for compositional change in the sample of houses used to compile the House Price Indexes each quarter. This approach stratifies (clusters) houses according to two characteristics: the long-term level of prices for the suburb in which the house is located, and the neighbourhood characteristics of the suburb, as represented by the ABS Socio-Economic Indexes for Areas (SEIFA)."[126]

The cluster weight is defined as the proportion of housing value within a cluster compared to the total value of housing stock in the capital city. Each quarter, the median prices of houses within a cluster are determined on the basis of comparing current and past median prices of the cluster. Summing up the weighted values of each cluster results in the total housing value of the entire city. Therefore, the dynamics of the capital price index is subject to both, movements of median prices within a cluster and the weight of each cluster in the index.

Finally, the countrywide house price index based on the observation of eight capital cities is constructed by summing up the weighted city house price indices. However, low numbers of transactions within a period can substantially affect the median value within one cluster and thus the calculation of the whole index.

The ABS House Price Index - Eight Capital Cities data is available beginning third quarter 1986.

S&P ASX 200 A-REIT Index[d]

The Standard and Poor's ASX 200 index is the primary investable benchmark in Australia. It covers approximately 78% of the equity market capitalization. As a sector index the ASX200 A-REIT contains all Real Estate Investment Trusts (REIT) represented in the index and therefore provide a good overview of the professionally-managed Australian property market starting from 2000.

[c] Source: http://www.abs.gov.au/

[d] Source: Bloomberg

III.2.1.2 CHINA

NATIONAL BUREAU OF STATISTICS OF CHINA – REAL ESTATE MARKET DATA[e]

The real estate market data provided by China's National Bureau of Statistics consists of quarterly data on Land Price Index for residential and commercial real estate, the total floor space under construction for residential buildings and the selling price index of residential real estate.

SHANGHAI STOCK EXCHANGE PROPERTY INDEX

Shanghai Stock Exchange Property Index is a capitalization-weighted index that measures the performance of the property sector of the SHCOMP Index. The index was developed on April 30, 1993 and consists of 34 members.

III.2.1.3 UNITED KINGDOM

HALIFAX - HOUSE PRICE INDEX[f]

The Halifax House Price Index is produced by Halifax (part of the HBOS plc group), the largest mortgage provider in the UK. It is the longest-running monthly house price series covering the whole country and covers all types of houses beginning from January 1983. The Halifax bank covers roughly 25% of all UK's mortgages, allowing it to use a monthly sample of typically 15000 house purchase transactions of residential properties to construct the index. Because only already approved loans are covered, the Halifax HPI is faster in publishing the development of the house prices compared to e.g. the Land Registry, which uses complete mortgages.

The Halifax index is estimated by using a hedonic regression model to estimate the price of a typical house and its characteristics (such as type of property, region, age of property, number of habitable rooms, garages, bathrooms, etc.). The typical housing characteristics are based on the year 1983 and are recorded for every transaction. However, the weights of these characteristics are able to change every period to compensate for a shift in demand. In addition, the final index is adjusted for seasonal fluctuations to allow for inter-year comparability.

NATIONWIDE BUILDING SOCIETY - HOUSE PRICE INDEX[g]

The Nationwide Building Society House Price Index is very similar to the Helifax HPI. It is based on its own mortgage transactions on an approval stage, accounting for 10% of UK's total mortgage market. The monthly data is available since 1993, covering "true market price" transactions all over England.

The Index is volume weighted and constructed using a hedonic regression model to estimate the price for a typical house and its characteristics. Unlike the Halifax Index, the characteristics of the typical house are revised every year, which allows for the change in quality of the real estate stock. The data is aggregated using regional weightings based on the HM Land Registry and finally adjusted for seasonal fluctuations.

[e] Source: Bloomberg

[f] Source: http://www.lloydsbankinggroup.com/media1/research/halifax_hpi.asp

[g] Source: http://www.houseprices.uk.net/links/

LSL PROPERTY SERVICE/ACADAMETRICS HOUSE PRICE[h]

The LSL Property Service/Acadametrics House Price Index is published since 1971 on monthly basis, using every residential property transaction in England and Wales recorded by UK's Land Registry. Because recording and publishing every single real estate transaction takes time, the LSL Acad forecast the development of the future property price index with the help of alternative Index series and adjusts these forecasts upon the publication of the actual property transactions.

Therefore, the LSL Property Service/Acadametrics House Price Index combines the advantage of short publication periods, as can be found with approved mortgage-based indices together with the accurate property price representation that can be found in the case of the Land Registry dataset.

BRITISH BANKERS ASSOCIATION (BBA) – LOANS APPROVED FOR HOUSE PURCHASING[i]

The data is based on UK's main high street banking groups (MBBG) which account for two-third of all mortgages lending outstanding. On a monthly basis, it records every approved loan for a house purchase starting in 1993.

III.2.1.4 UNITED STATES

S&P/CASE-SHILLER C20 HOME PRICE INDEX[j]

Karl Case, Robert Shiller and Allan Weiss developed the index as a method of analysing home price trends by comparing repeated sales of the same homes. Today, the index is owned and maintained by Fiserv and was further developed together with Standard & Poor's. The S&P/Case-Shiller Home Price Index is updated monthly and is composed of the observed changes in single-family home price in 20 different major metropolitan areas starting in 2000. The calculation of the index is based on a three-month moving average algorithm, which includes that past two and the current month. The data used for constructing the index is based on arms-length sales of the same single-family home, ensuring that the quality of the home stayed the same. After identifying outliers in the sample (e.g. due to changes in quality) the weight of each sales pair is constructed in accordance to the statistical distribution of price changes within one geographic area, the time interval between the sales and the initial home value. Finally, all house prices are aggregated and divided by the initial value to generate the House price Index.

FEDERAL HOUSING FINANCE AGENCY (FHFA FORMALLY OFHEO) HOUSE PRICE INDEX[k]

The FHFA HPI index is published monthly by the US Federal Housing Finance Agency (FHFA) as an index of the single-family housing prices. The HPI is constructed by measuring the weighted average price change in repeated sales of houses in 363 metropolitan areas. The Data is gained by repeat mortgage transactions on single-family properties, which have been purchased or securitized, by Fannie Mae or Freddie Mac since January 1975. However, the index has a natural cap because individual mortgage data entering the index are subject to conforming amount limits. Compared to the S&P/Case-Shiller C20 HPI, the FHFA HPI uses equal weights for each housing transaction and is based on mortgage transactions rather than official information from the local authorities.

[h] Source: http://www.acadametrics.co.uk/acadHousePrices.php

[i] Source: Bloomberg

[j] Source: Bloomberg

[k] Source: http://www.fhfa.gov/

BLOOMBERG REAL ESTATE OPERATING COMPANY INDEX

The Bloomberg Real Estate Operating Company is a capitalization-weighted index of Real Estate Operating Companies that have a market capitalisation of $15 million or greater. The BBREOC Index was developed with a base value as of December 31,1996.

U.S. CENSUS BUREAU – NEW SINGLE FAMILY HOUSES SOLD & FOR SALE[l]

The U.S. Census Bureau records every real estate offer and completed real estate transactions within the United States. The data is seasonally adjusted and published on a monthly basis starting from 1963.

III.2.1.5 SWITZERLAND

SWISS NATIONAL BANK - RESIDENTIAL PROPERTY PRICE INDICES[m]

The Swiss National Bank (SNB) Property Price Indices (PPI) are quarterly published and compiled by Wüest & Partner since 1970. Prior to 1995, the index was reconstructed using samples of roughly 100000 real estate transactions per year, which were grouped into homogeneous clusters and weighted according to a moving average. Today, the index is continuously updated using transaction data from Internet property portals such as Homegate, Immoscout24, Immoclick and Immostreet.

III.2.2. MONETARY POLICY DATA

As proxies for the effects of monetary policy we use the interest rates offered within a country as well as data on the money aggregates published by central banks.

For the analysis of interest rates, a set of short-, medium- and long-term rates were chosen in accordance with the theoretical background presented in the previous chapter. As for short-term interest rates, we study the effective central bank base rate that is directly influenced by the country's monetary policy. The medium-term interest rate is represented by the one-year Interbank Offered rates (e.g. LIBOR), which is commonly used as a lead index for adjustable mortgage rates. Finally the influence of long-term interest rates is studied by analysing the 10-year maturity government bonds, which are theoretically correlated with fixed rate mortgages up to 30 years of maturity.

For the analysis of monetary aggregates we use, depending on the countries, the monetary base (M0/M1) and the so-called broad money (M3/M4).

However, since not every type of data is available in a sufficient time period for the various countries, we provide an overview of the actually used datasets below.

All interest rate data, except the once indicated were obtained from Bloomberg.

III.2.2.1 AUSTRALIA[n]

As proxies for the Australian interest rate levels, we use the Reserve Bank of Australia's Interbank Cash Rate, the 12-month Australian Dollar LIBOR and the 10-year Australian Government Bond Yields.

[l] Source: http://www.census.gov

[m] Source: http://www.snb.ch

[n] Source: http://www.rba.gov.au/

For the money aggregates we use M1 (currency plus bank current deposits of the private non-bank sector) and M3 (M1 + all other deposits of the private non-banking sector plus certificates of deposit issued by banks).

III.2.2.2 CHINA

As proxies for China's interest rate levels, we use the Chinese Central Bank Base Rate, collected by the IMF, the 1-year Interbank Rate and the 10 year Government Bond Generic Bid Yield provided by Bloomberg.

III.2.2.3 UNITED KINGDOM

As proxies for the interest rate levels in the United Kingdom we use the Bank of England's Official Bank Rate, the 12-month average British Pound LIBOR and the 10-year UK Government Bond Note Generic Bid Yields constructed by Bloomberg.

For the money aggregates we use the money stock M0 (Cash outside Bank of England and Banks' operational deposits with Bank of England) and the money supply M4 (Cash in circulation, private-sector retail bank and building society deposits, private-sector wholesale bank, building society deposits and Certificate of Deposit).

III.2.2.4 UNITED STATES

As proxies for the interest rate levels in the United States, we use the effective Federal Funds Rate (FFR), which is the open market rate that follows the Target Rate issued by the Federal Reserve, the 12-month US Dollar LIBOR and the 10-year Treasury Bond.

For the money aggregates we use M1 (Cash in circulation, Bank reserves and banks demand accounts) and M2 (M1 + Banks savings and money market accounts and small deposits).

III.2.2.5 SWITZERLAND

As proxies for the Swiss interest rate levels, we use the Swiss National Bank (SNB) Cash Rate published by the IMF, the 12-month Swiss Francs LIBOR and the 10-year Swiss Government Bond Note Generic Bid Yields constructed by Bloomberg.

For the money aggregates we use M1 (Cash in circulation), M2 (M1 + Bank deposits and saving deposits at banks) and M3 (M2 + Swiss Franc time deposits at banks).

IV. RESULTS

In the following section we apply the TOP method to the dataset introduced above. Among the countries analysed are Australia, China, the United Kingdom, the United States and Switzerland. The countries where chosen in accordance with the availability of data and to provide a representative overview of the real estate market worldwide. Due to the limited amount of time for this study, further results of other countries are not discussed but the results are available upon request.

In addition to each TOP method analysis we introduce a graph that illustrates the variations of the lead-lag patterns when accounting for monotonic or non-monotonic behaviour. As explained previously, we find it reasonable to assume that the interrelation of the time series fluctuate between a positive and negative correlation. This implies that an increase in the first time series can either lead to a gain or a loss in the second time series, for every instant in the analysis. However, by following the assumption of non-monotonic behaviour, expressed by $\epsilon_{\pm}(t_1, t_2) = min[\epsilon_{-}(t_1, t_2), \epsilon_{+}(t_1, t_2)]$, we lose information on the direction of causality. Thus, it is necessary to regain this information of the causal link between the two economic time series by a comparative analysis of the three major assumptions, being positive correlation ($\epsilon_{-}(t_1, t_2) = \sqrt{[X(t_1) - Y(t_2)]^2}$), negative correlation ($\epsilon_{+}(t_1, t_2) = \sqrt{[X(t_1) + Y(t_2)]^2}$) and mixed correlation ($\epsilon_{\pm}(t_1, t_2) = \min\left(\epsilon_{-}(t_1, t_2), \epsilon_{+}(t_1, t_2)\right)$). A conclusion of the direction of causality can thus be drawn by a visual interpretation of the three lead-lag dynamics.

Because of the unique way the TOP method averaging algorithm works, we find periods within the analysis where the lead-lag signal fluctuates between the directions of causality. This can be caused by weak signals or strong noises within the dataset, which prevents a clear interpretation of the sign of correlation.

The temperature used in our analysis was carefully chosen to guarantee data accuracy while dampening some of the noise trajectories. With a chosen temperature of T=3 we find robust and qualitatively similar results to previous analysis within a temperature range between T=2 and T=4. Furthermore, the results of the TOP Method lead-lag analysis are gained by allowing a brought initial lead-lag window of up to three years to capture the true interdependence in the beginning of the datasets. However, as seen in the Figures below the calculated initial lead-lag sometimes strongly overshoots, but levels off to reasonable values of $x(t)$ after usually only half a year.

It is important to mention that even though the TOP method is a powerful tool when comparing the time dependent relation of time series, results do not prove causality.

IV.1. AUSTRALIA

For the analysis of the interdependence between the Australian real estate market and its monetary policy we use the House Price Index of Australia's 8 Capital Cities, which is quarterly published by the National Statistical Office (NSO) and a representation of the Australian real estate sector by the ASX 200 A-REIT Index published by Standard and Poor's (S&P). For the interest rate data we use the Reserve Bank of Australia's Official Interbank Cash Rate, the 12-month Australian Dollar LIBOR and the 10-year maturity Government Bond Yields. All data is available starting form the first quarter of 1989, with the exception of the S&P industry sector index, which is available starting Q1 2001 until the last quarter in 2011.

IV.1.1. INTEREST RATES AND HOUSE PRICES

Figure 4 shows the quarterly development of the three different interest rate proxies. During the two decades covered in the graph, we see that Australian interest rate levels have declined from around 15% to today's 5%. This reduction has particularly occurred in the early 1990s and the beginning of 2009. The overly high interest rates in the beginning of the 90's where caused by the monetary policy of the Central Bank, which tried to control the economy to cope with the stock market boom between 1983-1987, its crash in 1987 and the property boom that continued until 1989. In the aftermath of the real estate price crash, interest rates plunged again to a low level, staying almost constant until the end of 2007 when the global financial crisis hit Australia, which forced the Central Bank to further reduce its Cash rate.

During this period, the real estate market has seen a continuous increase in price levels. Especially between 1997 and 2010 the market showed high growth rates which were only disturbed by a small stagnation in 2004 and minor decline in 2008.

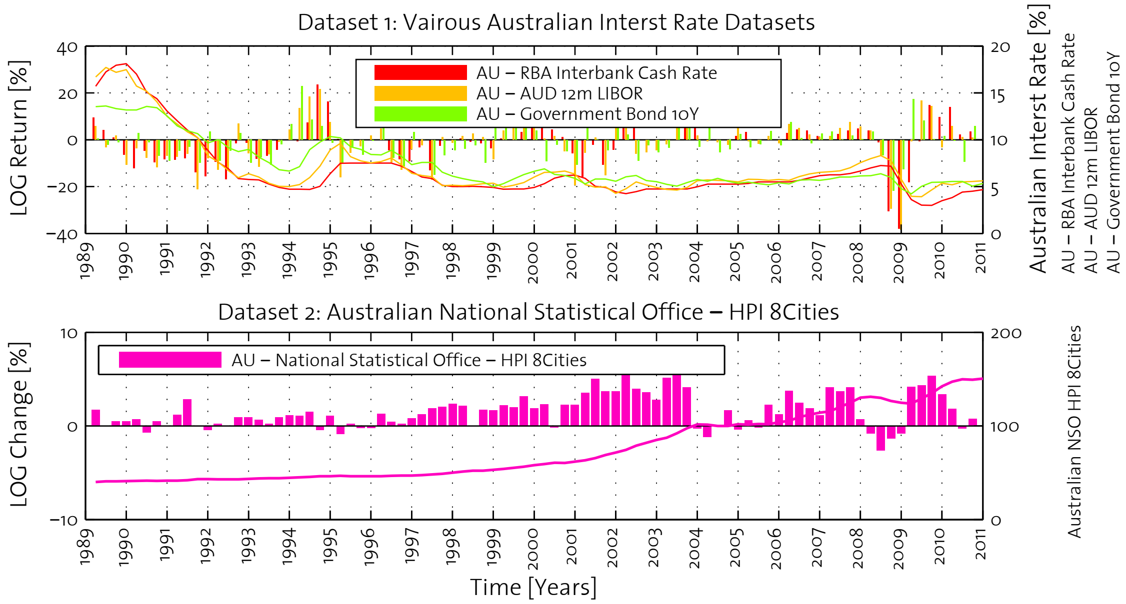

Figure 4: Quarterly Australian interest rate data of the Reserve Bank of Australia's Interbank Rate, the 12-month Australian Dollar LIBOR and the 10-Year Government Bond as well as the Australian house price development according to the National Statistical Office's House Price Index measure in the 8 capital cities between the first quarter of 1989 and the last quarter of 2010.

Below in Figure 5 we present the results of the lead-lag analysis between the returns of Australian interest rates and the change in the house price index for the 8 Australian capital cities. In the first decade, until the year 2000 we see a stable interrelation for all three interest rates with different maturity. While both short- and medium-term interest rates are leading the house price development, the outcome of the analysis suggests that returns of long-term Government Bond Yields are lagging behind the house data by about 2 quarters. For the short maturity rates, the lead of the Reserve Bank of Australia's (RBA) Interbank Cash Rate is with an average of 4 quarters stronger than the 2-quarter lead of the Australian Dollar 12 month LIBOR.

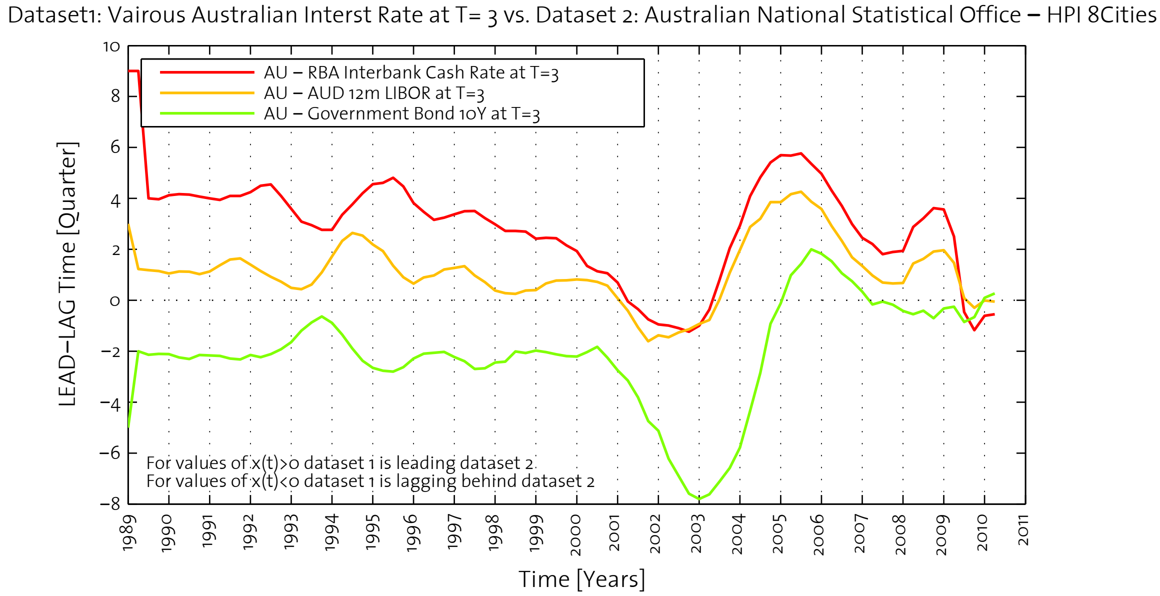

Figure 5: Lead-Lag dependence $x(t)$ between the returns of various Australian interest rates and the returns of the 8 Capital Cities House Price Index measured by the Australian National Statistical Office on a quarterly level at temperature T=3

During the period of 2000 and 2005 the lead-lag patterns of the analysis are strongly distorted. We can observe a regime shift towards a general lead pattern of the house prices over the interest rates. This is astonishing because Australia was only marginally affected by the burst of the dotcom bubble, which was especially pronounced in Europe and the United States after early 2000. During this period, with the exception of one quarter, positive growth rates were seen for house prices along with decreasing interest rates as a reaction to the financial crisis. Therefore, one conclusion can be that the prospering real estate market took over the position of economic health indicator for the entire Australian economy, which then encouraged the RBA against the slowly increase in their Official Cash Rate band. In the following time, the lead-lag regime changed once more towards the initial setup. The impact of the global finical crisis in 2008, which brought a steep drop in target interest rates and a smaller drop in house prices, is also visible as a dent in the graph shown in Figure 5.

Figure 6 gives additionally information about the direction of the lead-lag relationship. The graph shows that the determined interrelation under the assumption of non-monotonic ($\epsilon_{\pm}$) behaviour clearly follows the path of the negative correlation, which implies that a reduction in interest rates leads to an increase in the level of house prices. This finding is also confirmed when analysing the short- and long-term interest rate proxies. However, during the period of 2001 to 2004 a clear statement about the direction of correlation cannot be made.

Despite some external trends, which are not modelled in this analysis, we find the results of the analysis being in accordance with the theoretical background. As elaborated in the previous chapters, we know that the majority of mortgages in Australia are based on adjustable rates. Thus, it is not surprising that the short term interest rates, represented by the RBA Interbank Cash Rate and the 12 month LIBOR, lead the development (negative correlation) of house prices as they are the key determinants for setting mortgage rates and providing cash for potential home owners.

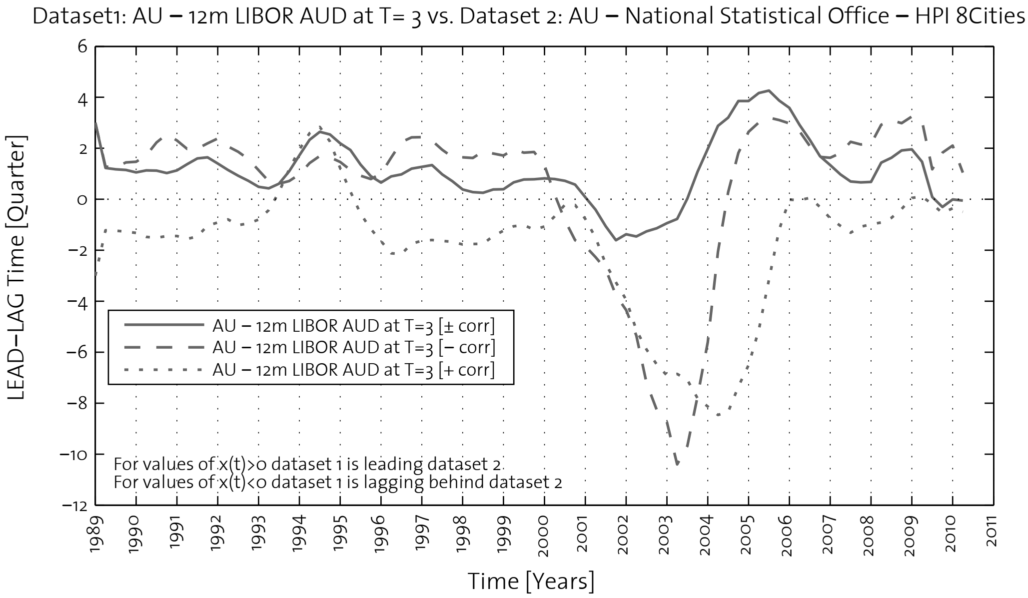

Figure 6: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

IV.1.2. INTEREST RATES AND THE REAL ESTATE INDUSTRY

Apart from the direct effect of interest rates on house prices, we also investigate the impact on Australian Real Estate Investment Trusts (A-REIT).

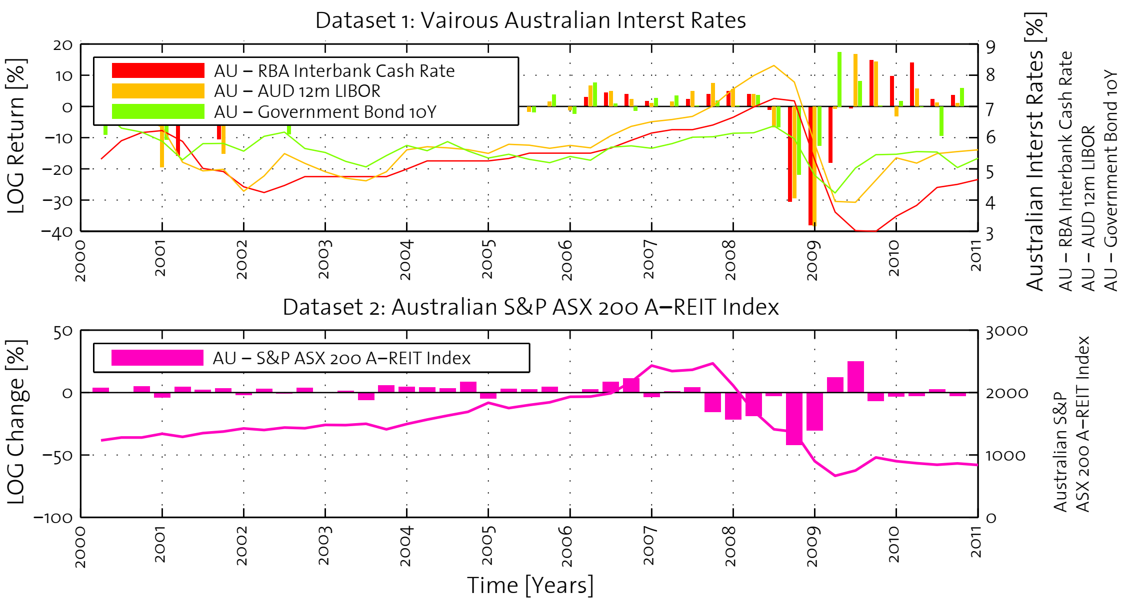

Figure 7: Quarterly Australian interest rate data of the Reserve Bank of Australia's Interbank Rate, the 12-month Australian Dollar LIBOR and the 10-Year Government Bond as well as the development of the Real Estate industry in accordance to the S&P ASX 200 A-REIT Index between the first quarter of 2000 and the last quarter of 2010.

The interest rate data presented in Figure 7 is the same as already described above, ranging from the first quarter of 2000 to the last quarter of 2010. The second part shows the development of the A-REIT sector, summarized by the S&P ASX 200 A-REIT Index. Similar to the development of Australian house prices, the time series shows a continuous growth until 2007, followed by a considerable drop below the starting point in 2000. Within a little more than one year the S&P index had lost roughly two third of the initial value in 2007. Until today, the index shows no signs of recovery.

Figure 8 displays the dynamic lead-lag relation between the various Australian interest rates and the Australian S&P ASX 200 A-REIT Index during the last decade. For the whole period, the returns of the S&P index are leading the changes in the interest rate data for all three maturities. In early 2000 the lead is roughly one quarter of a year, which linearly increases to almost a one-year lead by the end of 2009. Thereafter, the lead is reduced again in the direction of the initial values.

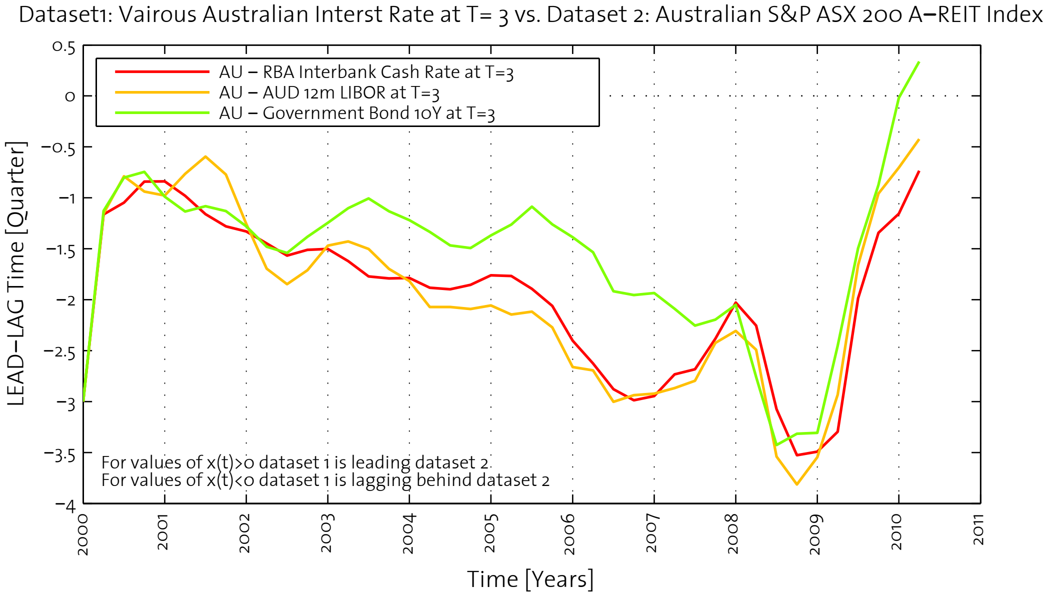

Figure 8: Lead-Lag dependence $x(t)$ between the returns of various Australian interest rates and the returns of the Australian S&P ASX 200 A-REIT Index on a quarterly level at temperature T=3

For the 1-year Australian Dollar LIBOR, Figure 9 confirms the dominance of the lead-lag path, assuming a negative correlation (ϵ_+) between 2000 and 2006. Thereafter, the lead-lag path could also be described by a positive correlation. For the RBA Interbank Rate the path fluctuates between negative and positive correlation until 2005 and later continues following the positive correlation path. The results for the 10-year Government Bond Yields are found to be similar to the one of the 1-year LIBOR.

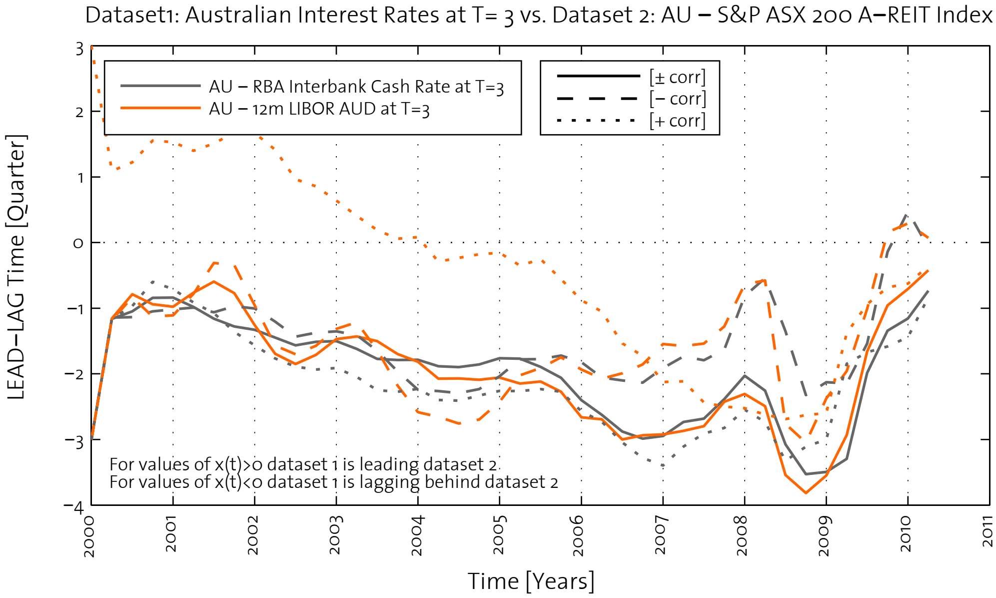

Figure 9: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

The S&P ASX 200 A-REIT index can be seen as a representation of bundled, professionally managed real estate assets that are traded on the stock market. Therefore, the results are coherent, especially starting from 2005, with previous findings of Guo et al.[122] who discovered a similar lead-lag pattern for the interdependence between the S&P 500 index and US interest rate data. The interpretation of the RBA Interbank Rate and the S&P ASX200 A-REIT suggests a strong interest of monetary authorities in the development of the stock market as a proxy of the health of the whole economy.

IV.1.3. Money Aggregate and House Prices

Supply of money is the second important instrument of a central bank and it is responsible for potentially influencing both output as well as consumption. Figure 10 shows the development of the money supply measured by the RBA money aggregates M1 and M3. Over the last 20 years, the money supply has experienced continuous growth with only minor disturbances during the beginning of 2002 and 2008.

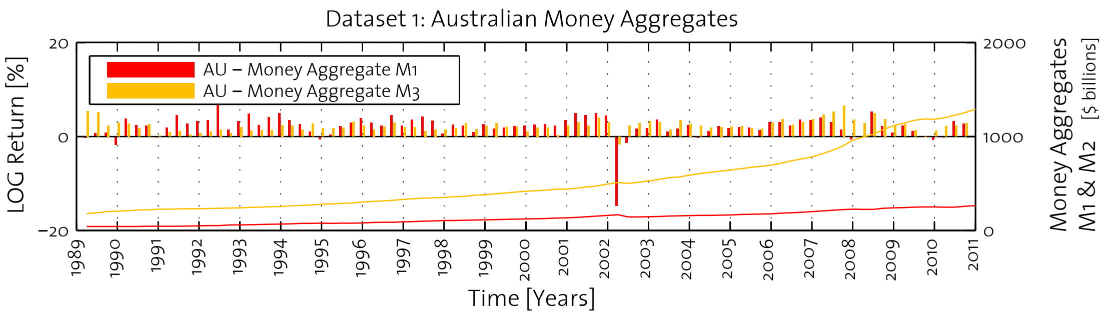

Figure 10: Quarterly development of the money aggregates M1 and M3 published by the Reserve Bank of Australia

In the dependency analysis of the Australian Money Aggregates and the Australian National Statistical Office HPI we combine both data sets that are presented above. The results shown in Figure 11 indicate that during 1989 and 2002 there has been a stable relationship between the change in monetary aggregates and the returns of house prices in Australia. During this period the money aggregate M3, which includes all currency in circulation as well as all bank deposits, is lagging behind the changes in house prices by about four quarters of a year. The lag of the money aggregate M1, which is solely the currency in circulation plus current deposits of the private non-banking sector, is with 2 quarters only half of the one of M3. After the year 2000 both lead-lag relations experience some distortions with a first overshoot to a stronger pronounced lag and than a correction towards a leading relationship, especially for the money aggregate M3. However, during the period between 2006 and 2011, the interrelations are less clear because we can see a leading and lagging dependency for M3 respectively M1.

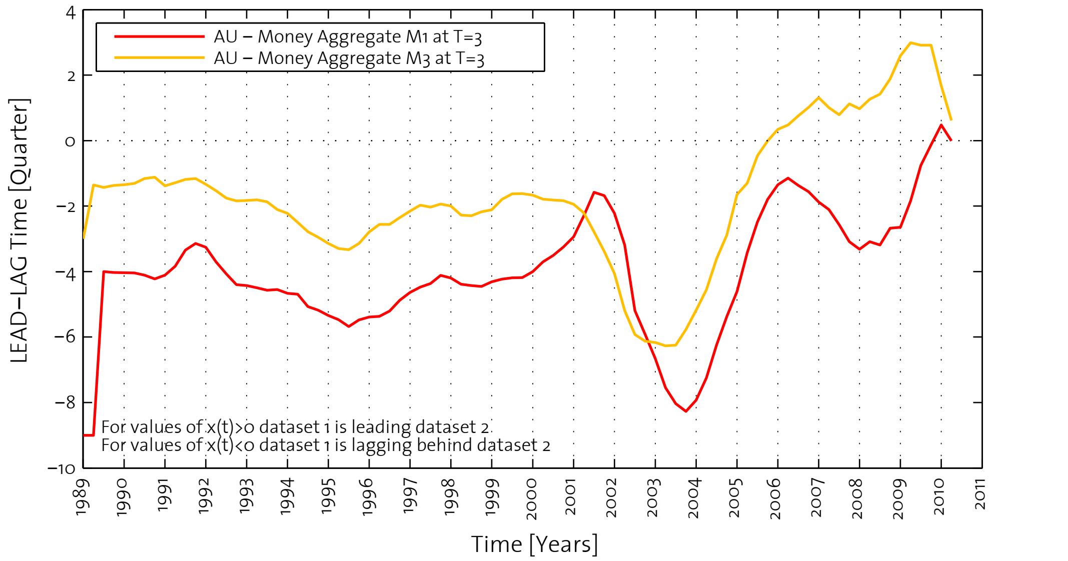

Figure 11: Lead-Lag dependence $x(t)$ between the returns of the two Australian money aggregates and the returns of the 8 Capital Cities House Price Index measured by the Australian National Statistical Office on a quarterly level at temperature T=3

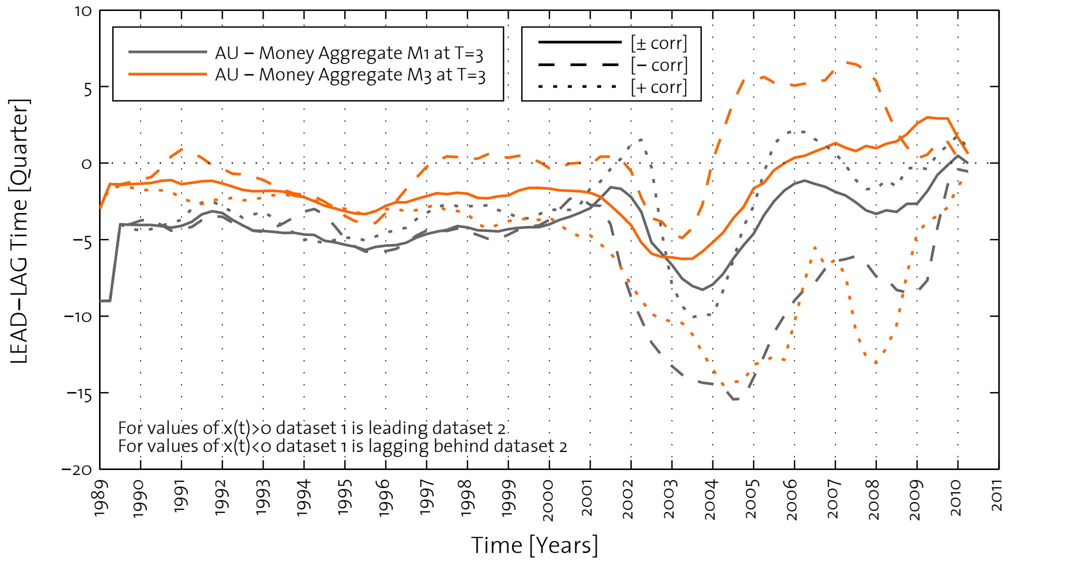

Figure 12: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

Figure 12 indicates that for an analysis of the money aggregate no clear statement can be made regarding the direction of causality. During the whole period, the analysis based on non-monotonic behaviour fluctuates between positive and negative correlation. In theory, however, we expect that money aggregates lead the development of house prices based on a positive correlation because an increase in output and consumption is usually ascribed to a growth in money aggregates. Our results represented in Figure 11 however, indicate that this is not true for the case of Australia, where the house prices, with the exception of the period after 2006, are leading the development of the money supply. Even though the direction of correlation remains unclear from this analysis, it seems reasonable to assume that the prospering real estate sector could have taken over the function of an indicator for the "wellbeing" of Australia's economy during the last two decades. Thus, the Australian Reserve Bank fostered a continuous increase in money supply to guarantee price stability and liquidity for the growing market.

IV.2. CHINA

Compared to other countries, an analysis of the Chinese market is difficult because of the limited amount of data available. For the following analysis, we compare three quarterly and one monthly real estate market proxies with the development of the Chinese short- to long-term interest rates. The real estate market data consists of the Land Price Index for residential and commercial real estate, the total floor space under construction for residential buildings, the selling price index of residential real estate and the Shanghai Stock Exchange Property Price Index. The limiting factor in this analysis is the lack of historical interest rate data. Only the Chinese Central Bank Base Rate, which is collected by the IMF, is available since the first quarter of 1998. The 1-year Interbank Rate is available starting only in 2007 while the 10-year Government Bond Generic Bid Yield provided by Bloomberg is available since 2005. Because of this, we present the results of our analysis in a reversed fashion for various timeframes.

IV.2.1. INTEREST RATES AND HOUSE PRICES

In the upper three graphs of Figure 13 we display the development of the real estate market representations. The land price index for commercial and residential buildings, compiled by the National Bureau of Statistics of China, shows strong fluctuations during the period of analysis. Overall, there is a trend of increasing land prices, which was sharply disturbed by a steep drop between 2008 and 2009. On the second graph we see the total amount of residential floor space under construction with a similar upwards trend and strong seasonal fluctuations over the past 13 years. The actual Real Estate Selling Price data, provided as a dataset of quarterly price changes is shown in the third graph. During the beginning of the observation in the year 1998 and during the global financial crisis in 2008, we observe a minor downwards correction of the price level. However, in general there is a continuously strong increase in quarterly real estate prices, showing in some parts even exponential growth as can be seen for the period between 2001 to 2005. The fourth graph visualizes the movement of the Shanghai Stock Exchange Property Price Index. In contrast to the Residential Selling Price Index, it shows a small price peak in early 2001, which is followed by declining prices until 2005 when the trend is reversed. In mid 2005 the appreciation of price levels starts to pick up in speed, leading to an enormous increase in real prices with a climax in early 2007. Thereafter, in an environment of economic uncertainty, prices decrease again, reaching a low in 2008 followed by a small recovery and additional losses until today.

Finally, in the last graph we present the movement of the Base Interest Rate issued by the People's Bank of China. In the early 1990s, China's interest rates were constantly falling and its economy was booming, which resulted in ever-increasing inflation rates that peaked at around 17%. As a consequence, China's Central Bank increased the money supply and interest rate levels. This development was interrupted in 1998-1999 when the Chinese economy slowed down as a result of the Asian Financial Crisis. As illustrated in the Figure 13, the interest rate levels stayed on a stable plateau until 2001, showing only minor fluctuations. With the bust of the dotcom bubble, the People's Bank of China drastically reduced the interest rate levels over 4 years, waiting for a recovery of the economy to return to higher interest rate levels. This was the case in 2005 where interest rates jumped up again, only to be lowered once again as consequence of the global financial crisis in 2008. Until today, China has kept the rates on a low level.

When directly comparing the development of the Real Estate Selling Price with the levels of the People's Bank of China's base rate, we see during the period of 2001 to 2005 a strong, almost exponential growth of real estate prices, which directly corresponds with a period of dropping interest rates. After the interest rate reaches its plateau, the changes in house prices equalise.

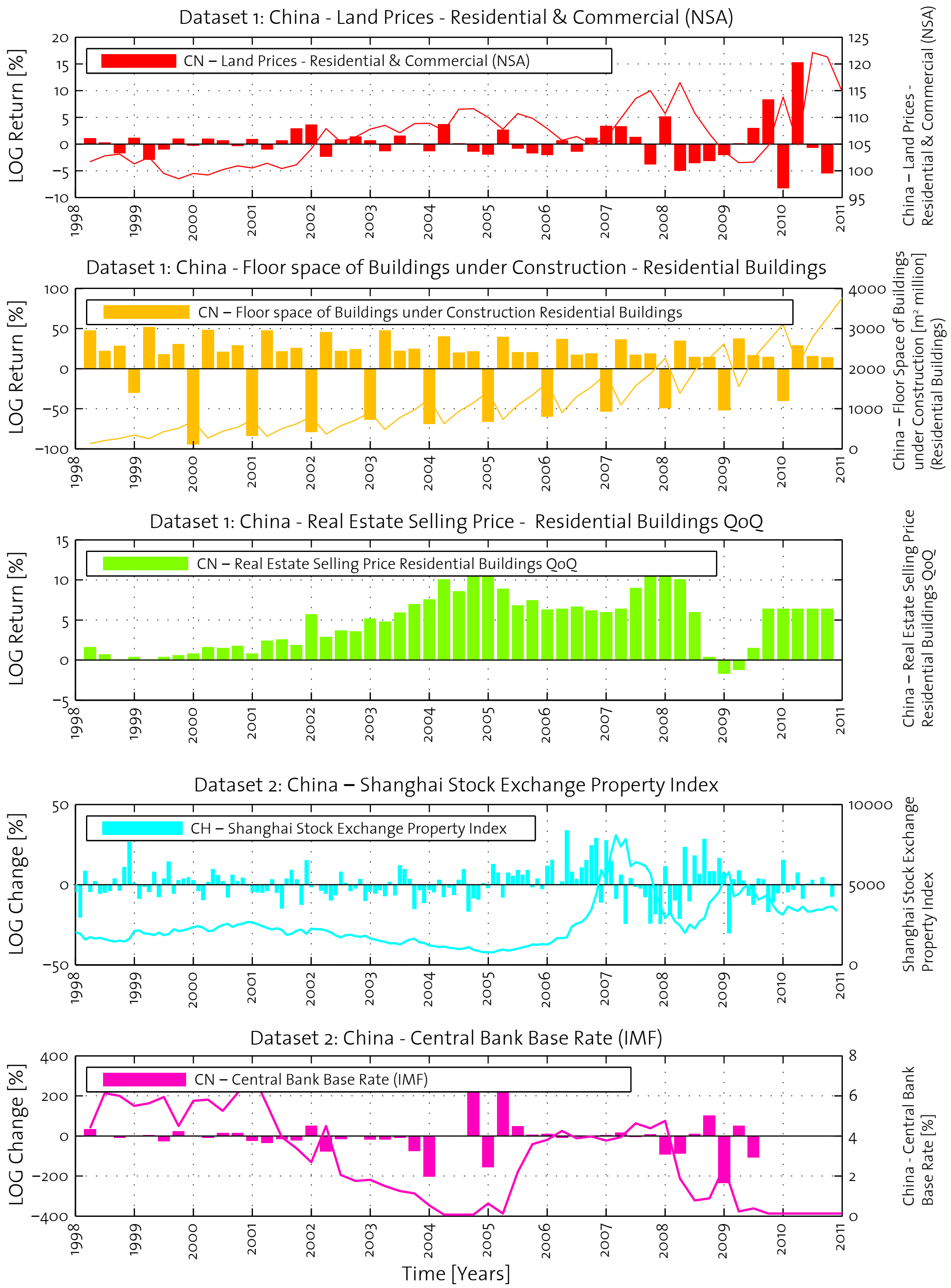

Figure 13: Quarterly Chinese real estate market data on the land price development for the residential and commercial sector, the total amount of residential floor space under construction and the quarterly change of residential real estate selling prices as well as the development of the Chinese Central Bank Base Rate published by the IMF between the first quarter of 1998 and the last quarter of 2010.

The results of the lead-lag analysis shown in Figure 14 endorse our previous findings gathered by the visualisation of the input data. Until 2006, we observe that the Central Bank Base Rate leads all three real estate market proxies with initially one to two quarters lead, which after

2003 is further increased to 4 to 6 quarters of a year. Thereafter, corresponding with the emergence of the global financial crisis, the interdependence changes towards a less stable lead-lag regime with all three price indices leading the interest rate and the residential floor space under construction lagging behind the interest rate level. The spike in the lead-lag regimes in early 2005 could be interpreted by a change in market perception that was triggered by a steady decrease in interest rate levels starting form 2001. It seems that investors not only considered the most recent changes in interest rates but also the ones of the more distant past.

Dataset1: Vairous Real Estate Market Data at T= 3 vs. Dataset 2: China - Central Bank Base Rate (IMF)

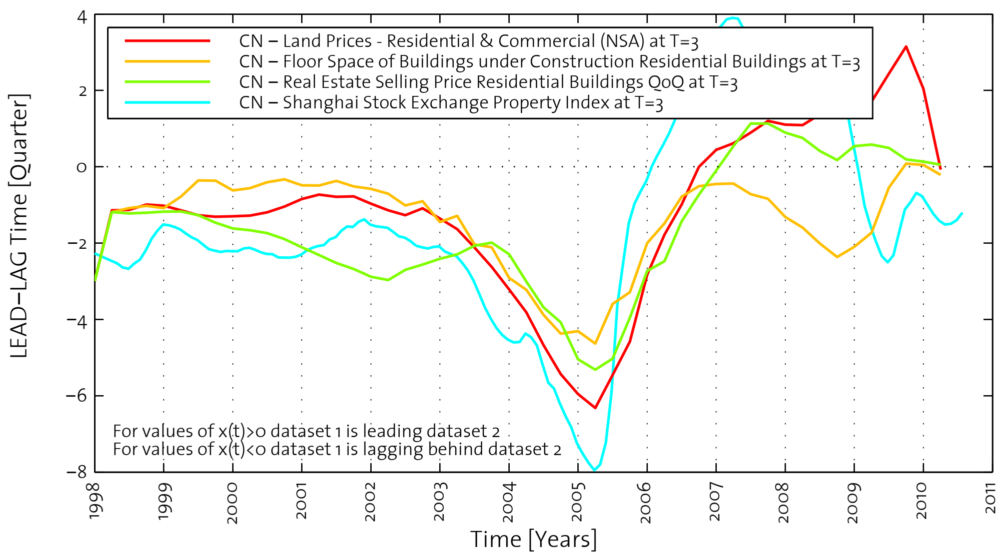

Figure 14: Lead-Lag dependence $x(t)$ between the returns of the three chines real estate market proxies and the returns of the Chinese Central Bank Base Rate on a quarterly level at temperature T=3

Dataset1: Vairous Real Estate Market Data at T= 3 vs. Dataset 2: China - Central Bank Base Rate (IMF)

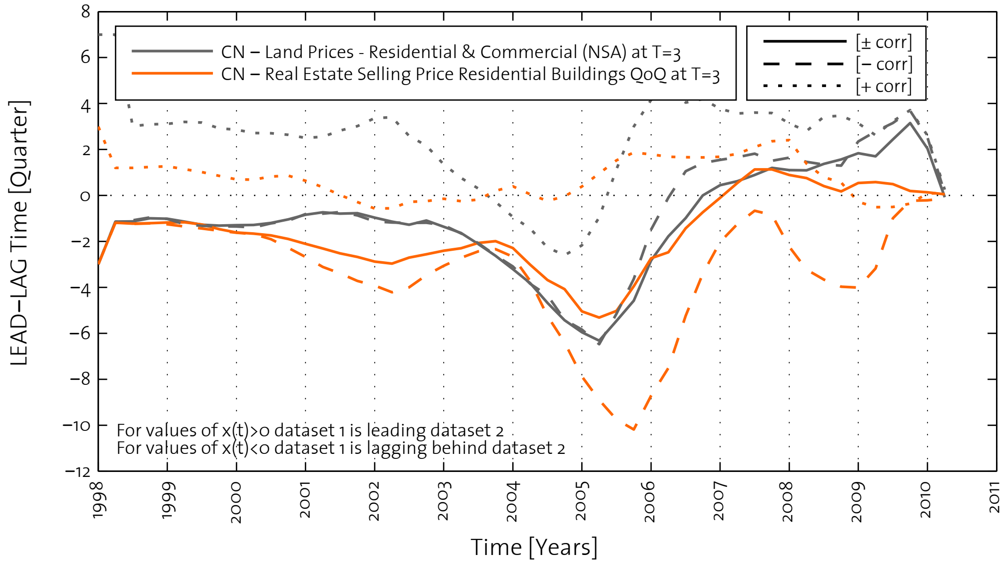

Figure 15: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

Figure 15 shows as an example the variations of the lead-lag patterns considering the three types of assumptions concerning monotonicity. The result is in line with the other two real estate market datasets, clearly illustrating that the lead-lag structure, which allows non-monotonic behaviour follows the assumption of negative correlation until late 2006. This implies that a reduction in interest rates leads to an increase in house prices, and therefore in construction activity. Thereafter, we can identify signs of a positive correlation between the datasets of real estate market prices leading the interest rate level development. One explanation for this finding might be that the Chinese Central Bank, concerned about the negative development of house prices, reduced its Base Rate to counteract this development in the real estate market.

To confirm the results we gathered by using the People's Bank of Chinas base rate we apply the same analysis for the Chinese 1-year Interbank Rate and the 10-year Government Bond Generic Bid Yields. Both input data is presented in Figure 16 and Figure 17, showing similar patterns as we have already identified in Figure 13. In 2008 both interest rate levels decreased by about 2%, followed by a slow recovery until today.

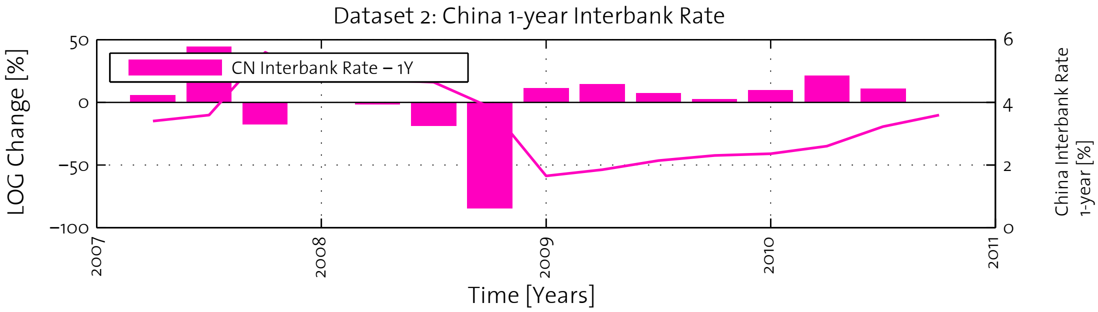

Figure 16: Quarterly data of the development of the Chinese 1-year Interbank Rate between the first quarter of 2007 and the last quarter of 2010.

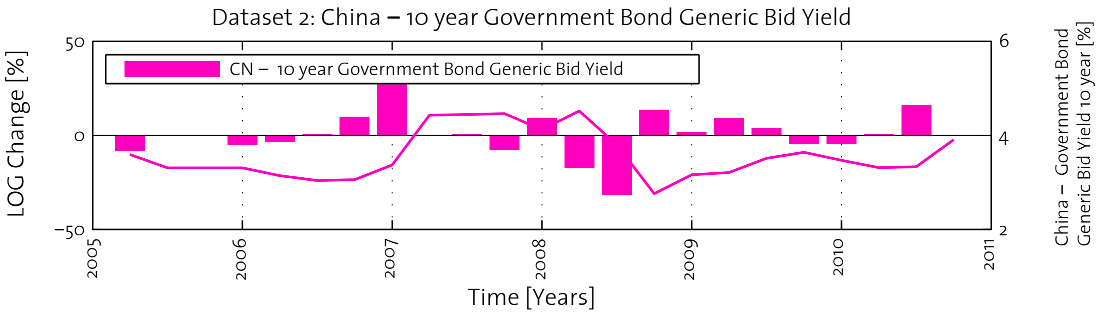

Figure 17: Quarterly data of the development of the 10-year Government Bond Generic Bid Yields between the first quarter of 2005 and the last quarter of 2010.

Figure 18 and Figure 19 show the lead-lag analysis of the real estate market data with the medium- and long-term interest rate respectively on a reduced time frame. Even though the meaningfulness of the results are reduced by the limited amount of data points available, the outcome of the analysis is able to verify the findings of Figure 14 by showing a similar lead-lag pattern. In addition, we find the variations of the lead-lag patterns for the Chinese 1-year Interbank Rate and the 10-year Government Bond Generic Bid Yield to be the same as for the last analysis.

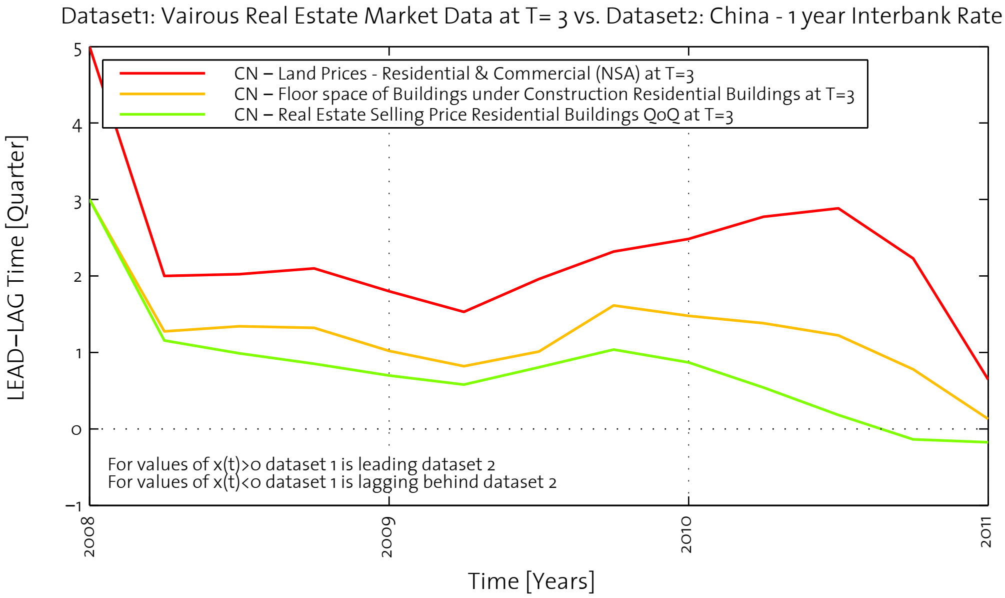

Figure 18: Lead-Lag dependence $x(t)$ between the returns of the three chines real estate market proxies and the returns of the Chinese 1-year Interbank Rate on a quarterly level at temperature T=3

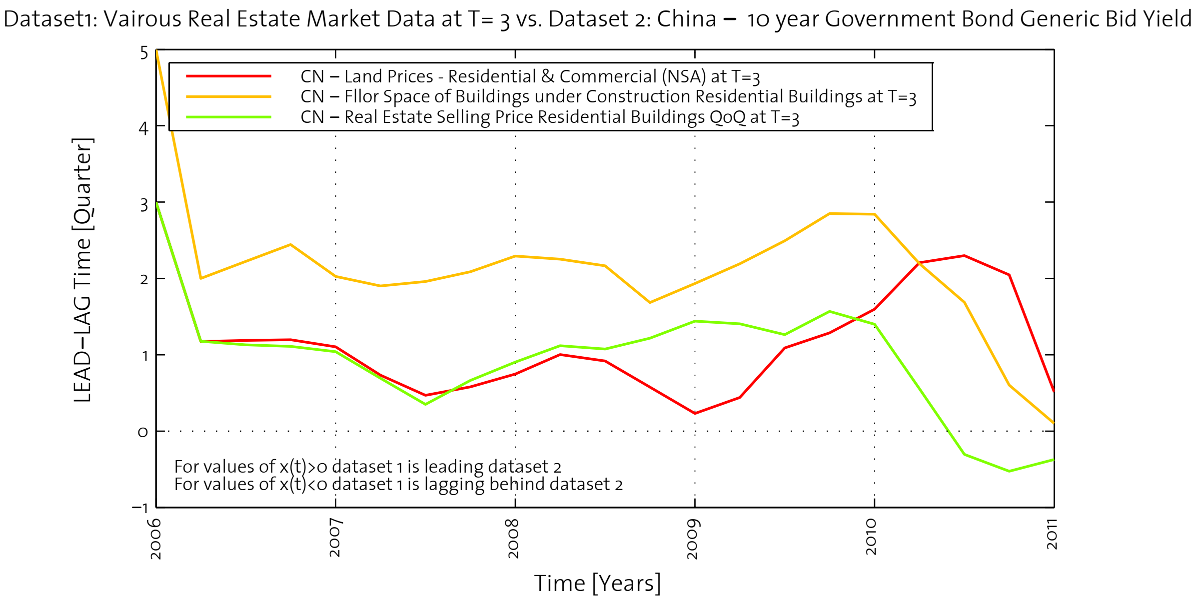

Figure 19: Lead-Lag dependence $x(t)$ between the returns of the three chines real estate market proxies and the returns of the Chinese 10-year Government Bond Generic Bid Yields on a quarterly level at temperature T=3

IV.3. UNITED KINGDOM

In the United Kingdom our study compares three major house price indices (HPI) with interest rates covering short- to long-term maturities including the Bank of England's Official Bank Rate, the 1-year British Pound LIBOR and the 10-year Government Bond Generic Bid Yields constructed by Bloomberg. Two of the house price datasets used are gained from the largest mortgage providers in the UK, namely the seasonal adjusted Nationwide Building Society (NBS) HPI and the seasonal adjusted Halifax HPI (incl. all house types). As a third dataset, we chose the House Price Index published by LSL Property Services/Acadametrics, which is based on transaction data from UK's Land Registry.

In a next step we investigate the impact of a change in house prices, or interest rates on the amount of approved mortgages. For this analysis we use data provided by the British Bankers Association (BBA) starting with January 1993.

In a final analysis for the UK we focus on the impact of money supply on real estate prices. Therefore, we compare the three house price indices with the money aggregates M0 and M4 published by the Bank of England.

IV.3.1. INTEREST RATES AND HOUSE PRICES

The fist dataset in Figure 20 illustrates the development of the UK interest rates over two decades starting from 1991. Within this period one sees an almost continuous decline of interest rates with two particularly steep drops during 1991-1992 and by the end of 2008. In late 1980s, the Bank of England had to cope with the aftereffects of the stock market crash in October 1987 leading to comparably low interest rates, which supported the creation of a house price bubble. With the intention to stop this development, the Bank of England increased its base rate. However, in 1991 the bubble collapsed with a significant impact on the UK's economy, resulting once again in a decline of interest rate levels. This development was further pronounced by the so-called "Black Wednesday" which was triggered by the UK joining the European Exchange Rate Mechanism (ERM). In the period between 1992 and 2008 the interest rates remained on a relatively stable level with a less pronounced downward trend and only minor fluctuations around an average interest rate of roughly 5%. Stronger variations only occurred around the period of the bust of the dotcom bubble in late 2000. The most recent drop in interest rate levels was directly associated with the peak in United States' house prices around 2006 and the following credit crunch in 2007.

The second graph in Figure 20 shows the development of housing prices measured by the Nationwide Building Society. After the collapse of the 1991 housing bubble, the prices stayed almost constant for over half a decade, followed by a period of massive growth that climaxed by the end of 2008. Starting from early 2009, the house prices exhibited a small moderation that was again followed by light decrease of the valuation of real estate. It is interesting to see that the peak of the real estate prices is delayed by over one year compared to the peak in the United States.

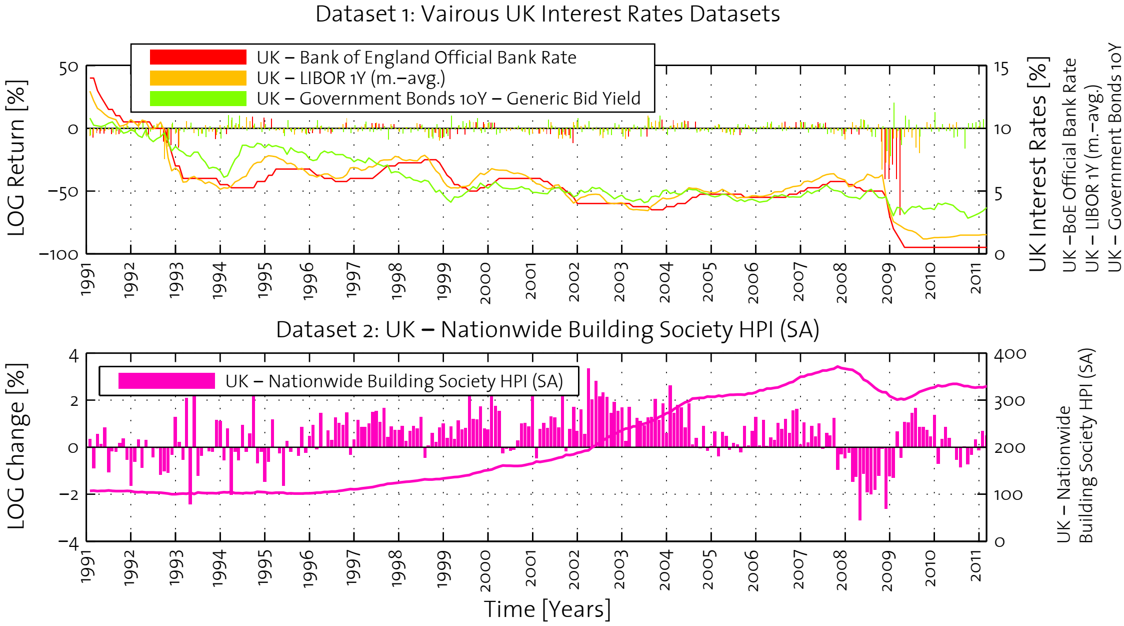

Figure 20: Monthly UK interest rate data of the Bank of England's Official Bank Rate, the UK Pound 1-year LIBOR and the 10-Year Government Bond as well as the seasonal adjusted House Price Index published by Nationwide Building Society between January 1991 and March 2011.

The lead-lag analysis of the UK interest rates and the NBS HPI are presented in Figure 21. On a first glimpse, we might see that the results do not match the ones we have seen in our previous comparisons. Over the first decade, our analysis reveals an average 10-month lag of the 10-year maturity Government Bond yield compared to the NBS House Price Index. For the two short- and medium-term interest rate measures, the Bank of England's Official Rate and the UK LIBOR, the signals are weaker, yet showing a stable 2-4 month lead of the interest rates over the HPI, at least during the period between 1995 and 2000.

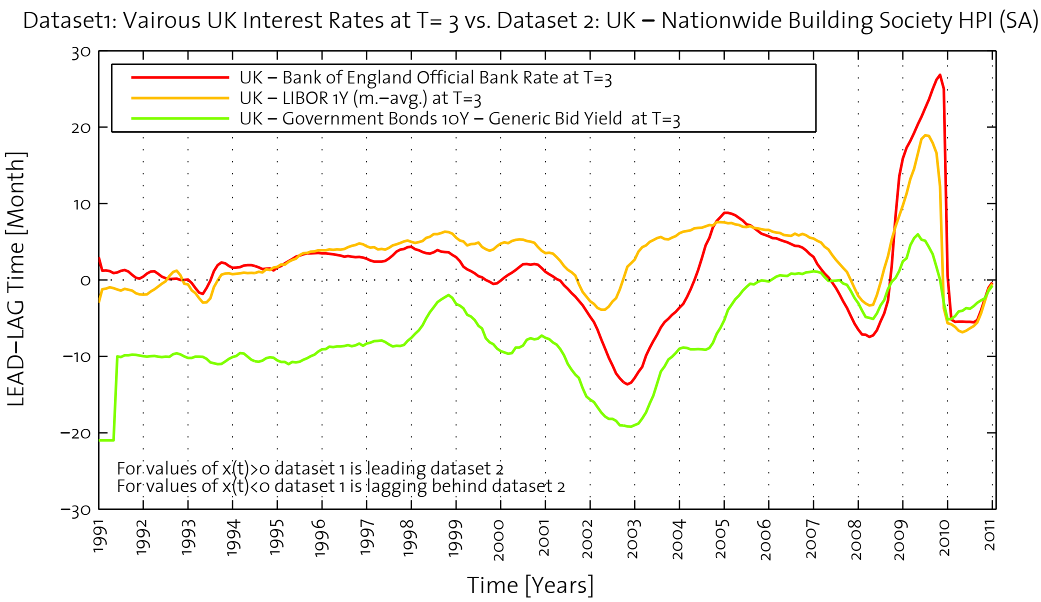

Figure 21: Lead-Lag dependence $x(t)$ between between the returns of various UK interest rates and the returns of the seasonal adjusted UK's Nationwide Building Society HPI on a monthly level at temperature T=3

This period coincides with the slow recovery of the UK's housing market as well as low and stable interest rates, leading to the availability of fairly cheap housing finance options. At the time of the dotcom bubble, all three lead-lag relations are disturbed but return to their previous configuration until 2007. In the last period until 2011 strong deflections, potentially triggered by the global financial crisis, hinder a clear interpretation.

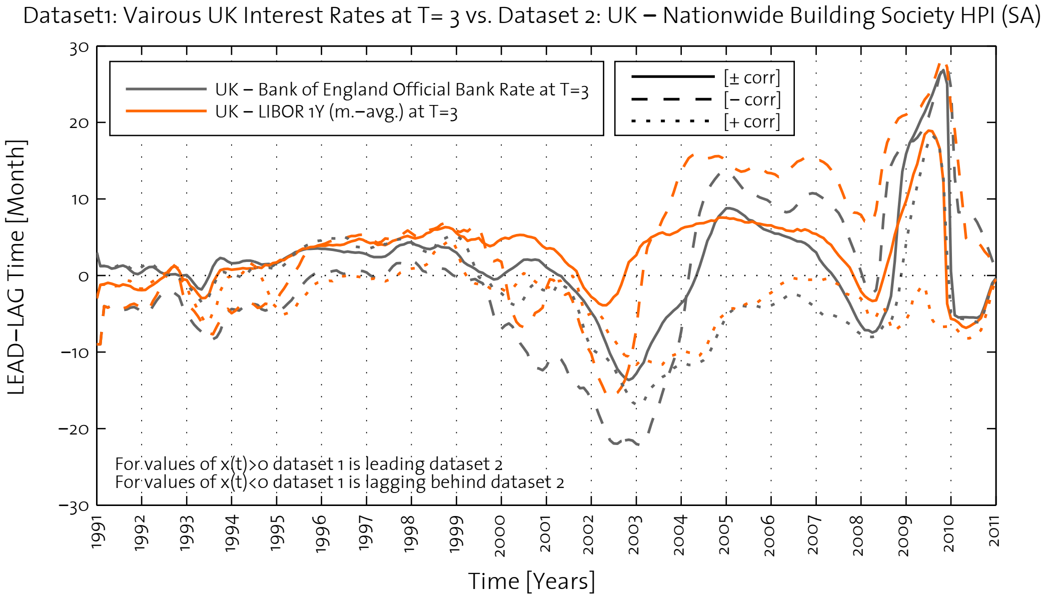

Figure 22: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

Figure 22 demonstrates the variations of the lead-lag pattern for the short- and medium-term interest rate levels. During most of the time period analysed we see that for both interest rates the non-monotonic lead-lag path follows the path of negative correlation. This implies that a reduction in interest rate level will lead to an increase in real estate prices. However, during the time of the dotcom bubble, as well as at the time of the global financial crisis in 2007, this relationship seems to fluctuate more, resulting in both lead-lag regimes moving towards a positive correlation.

When considering that traditionally houses are financed by mortgages, which in the United Kingdom are mostly based on adjustable rates, the picture we see between 1995 and 2007 is quite coherent. As described in the previous chapter, the adjustable rate mortgages (ARM) use medium term interest rate proxies, such as the 1-year UK Pound LIBOR, to adjust the mortgage rates upon changes in the interest rate level. The results gained in the TOP Method analysis are able to confirm that through the described mechanism, the change in 1-year LIBOR leads the changes in UK's house prices with a time difference of one quarter to half a year. The only exceptions are the two periods following the dotcom crisis and the US Credit Crunch, which show a tendency for a positive correlation. This result suggests that the Bank of England reduced its base rate because of declining house prices. Therefore, it identifies the Central Bank's efforts of coping with the consequences of the economic turbulences. For the UK, the influence of the 10-year Government Bond Yield can be neglected since it only has a theoretical impact on loans that are based on fixed rates (FRM). However, both the 1-year LIBOR and the 10-year Government Bonds Yields, are closely interrelated to the Bank of England's official bank rate as they represented in theory the discounted averaged expected future interest rates for one respectively 10-years.

To better understand and verify the results we gathered in the last analysis, we compare UK's Interest Rates with the House Price Index developed by the Halifax Bank (Figure 24) and by the

LSL Property Services/Acadametrics (Figure 27). In Figure 23 the interest data is presented again to ease the comparison between the two types of time series. The lower part of the graph shows the development of the seasonal adjusted Halifax HPI that reveals the same patterns we previously saw with the NBS HPI. Until 1999, there was a relatively consistent development in house prices which, by the beginning of the 20th century, entered a state of constant growth with a small plateau in the end of 2004 and a peak in the end of 2007.

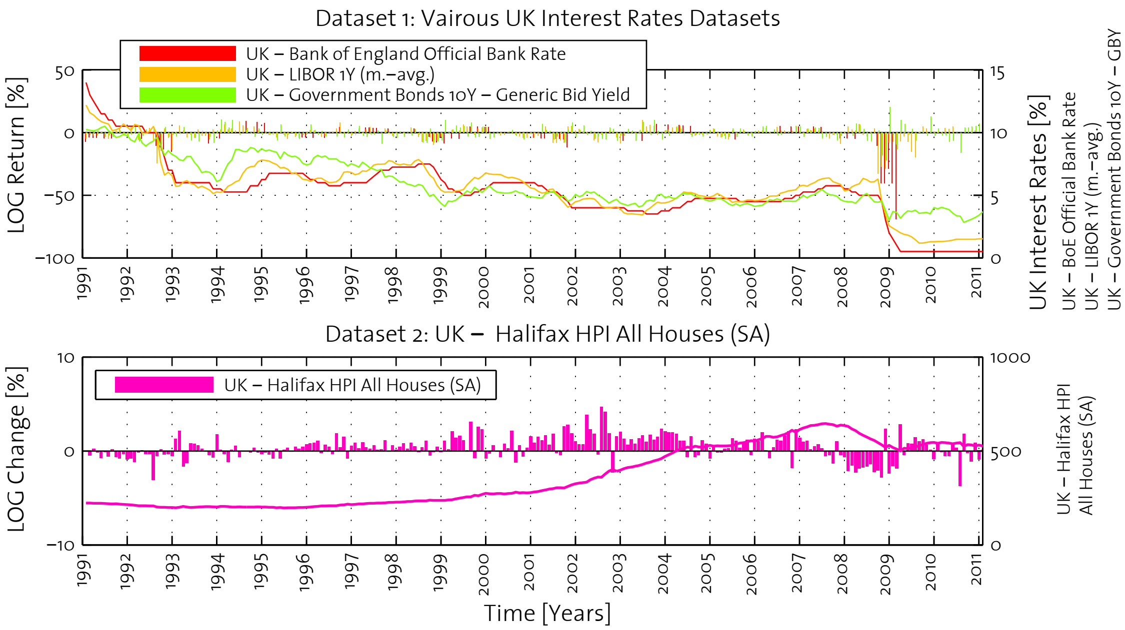

Figure 23: Monthly UK interest rate data of the Bank of England's Official Bank Rate, the UK Pound 1-year LIBOR and the 10-year Government Bond as well as the seasonal adjusted House Price Index for all house types published by Halifax between January 1989 and March 2011.

The lead-lag analysis of the UK interest rates and the Halifax HPI presented in Figure 24 corresponds to our previous findings in Figure 21. Especially, during the period between 1991 to 2001, a leading relationship of the 1-year LIBOR over the house prices can be identified that is roughly within the same magnitude as it has already been found for the case of the NBS HPI. The disturbances between 2001 and 2004 as well as after 2008, which are presumably caused by the two major crises, are also present with even stronger signs of overshoots.

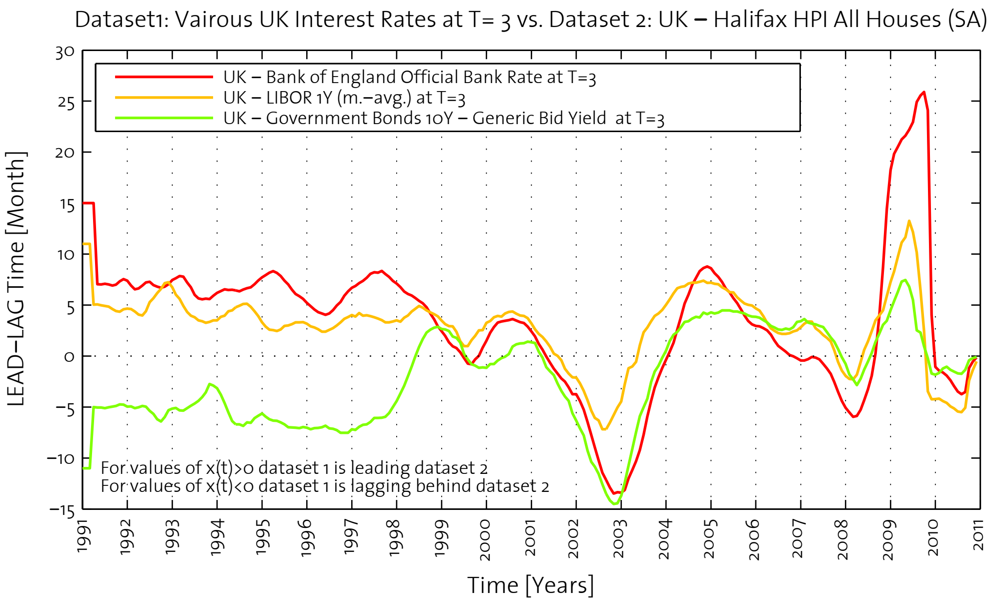

Figure 24: Lead-Lag dependence $x(t)$ between between the returns of various UK interest rates and the returns of the seasonal adjusted UK's Halifax HPI for all house types on a monthly level at temperature T=3

Figure 25 allows determining the direction of causal relationship. From the mid 90's onwards we see once more that the lead-lag relationship assuming non-monotonicity closely relates to the pattern of negative correlation. Before that period, the UK 1-year LIBOR seems to be positively correlated. However, this finding could also result from initial fluctuations of the lead-lag pattern, caused by the setup of the TOP method. During the times of economic contractions we identify similarly to Figure 22 a tendency towards a positive correlation.

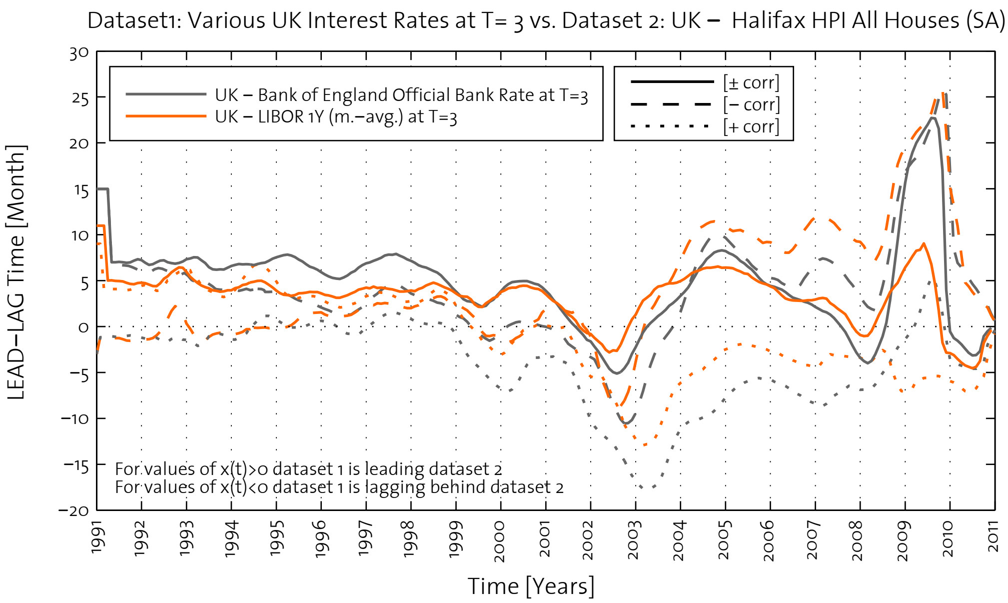

Figure 25: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

As a final comparison, we introduce a third House Price Index, which is of a different nature compared to the previous two. Rather than using private data gathered by Mortgage providers, it relies on official data from the government body responsible for recording land and property ownership, the Land Registry.

Figure 26 visualises the same interest data together with the house prices calculated by LSL Property Service/Acadametrics. This measure of the house price development is similar to the indices based on private mortgage data with a sideward moving stable period until 1998, followed by a steep incline, which peaked in the end of 2007.

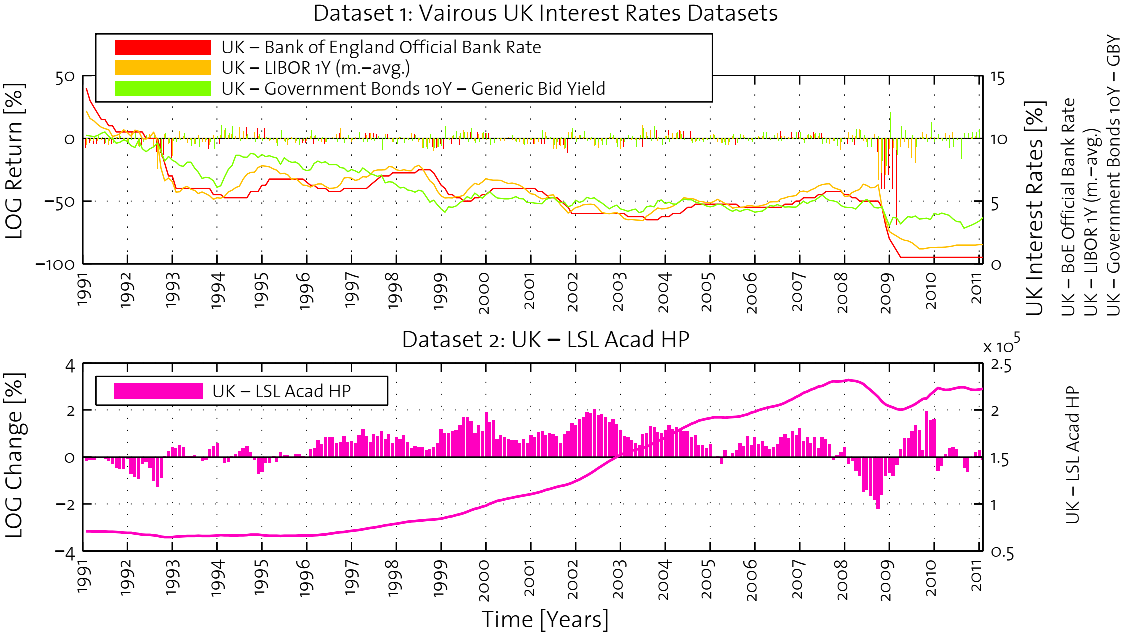

Figure 26: Monthly UK interest rate data of the Bank of England's Official Bank Rate, the UK Pound 1-year LIBOR and the 10-year Government Bond as well as the LSL Property Services/Acadametrics House Price Index between January 1989 and March 2011.

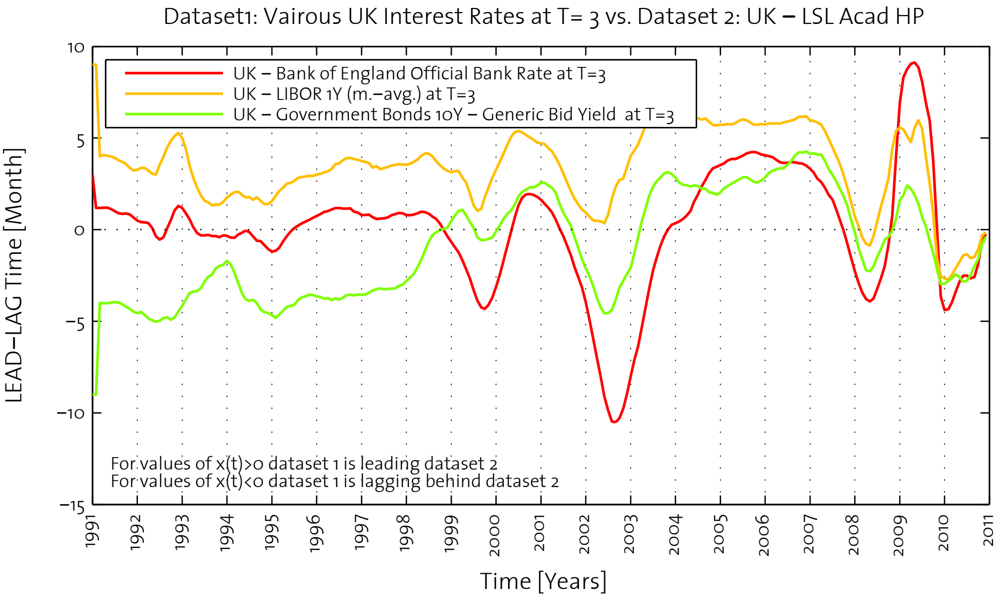

Figure 27: Lead-Lag dependence $x(t)$ between between the returns of various UK interest rates and the returns of the seasonal adjusted UK's LSL Property Services/Acadametrics HPI on a monthly level at temperature T=3

The TOP Method analysis for these datasets, shown in Figure 27 and Figure 28, verifies our past findings once again. This time the lead of the 1-year LIBOR over the house price index has a similar time delay between a quarter of a year and half a year and shows less fluctuations over the period analysed. However, the variation of the lead-lag patterns suggests a tendency towards a positively-correlated relationship, which is especially noticeable during the periods of crisis that corresponds with a drop in interest rate levels. During the time of stable economic conditions, the non-monotonic path fluctuates strongly between the two directions of causality, thus allowing no clear interpretation.

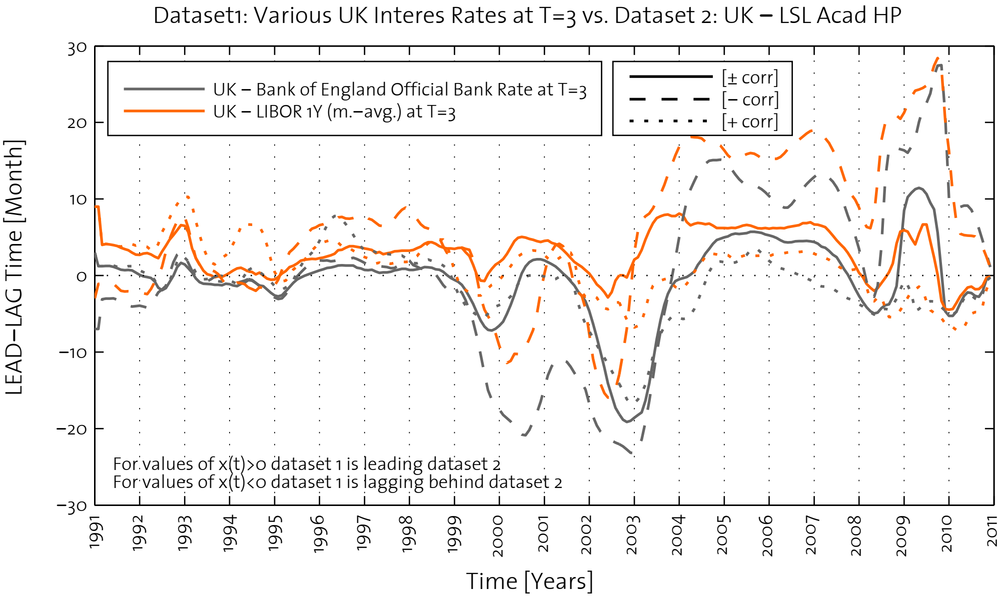

Figure 28: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

IV.3.2. INTEREST RATES AND LOANS APPROVED

Another important indicator for the real estate market in the United Kingdom is the amount of loans approved for the purchase of house. It measures the availability of financing options for potential future house owners and thus, should be strongly tied to interest rate guidelines issued by the Bank of England. In addition, it should drive the real estate prices because it is a proxy for demand in an inelastic market.

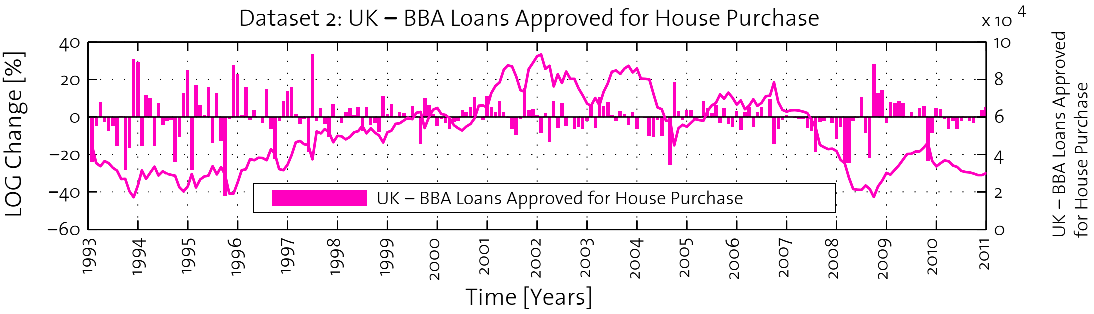

Figure 29: Number of approved loans for house purchases in the UK published by the British Bankers Association (BBA) between January 1993 and March 2011.

Figure 29 shows the dataset available from the British Bankers Association between 1993 and 2011. Despite strong seasonal fluctuations, we see a constant increase of issued loans between 1994 and 2002, followed by a gradually decline with some steep drops in 2004 and 2007. It is especially interesting to see that the peak of the amount of loans issued in the UK was well before the time when house prices reached their maximum.

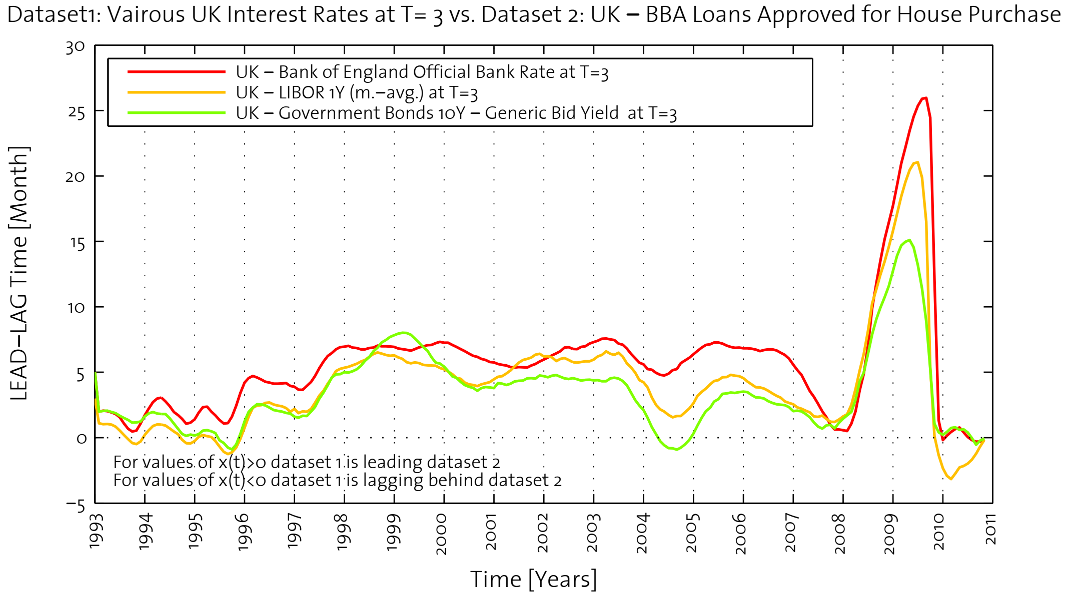

Figure 30: Lead-Lag dependence $x(t)$ between between the returns of various UK interest rates and the change of the number of approved loans for house purchases in the UK published by the British Bankers Association (BBA) on a monthly level at temperature T=3

The theoretical assumption that interest rates lead the amount of issued loans is proven by analysing the interrelation between the two types of time series. Figure 30 shows a continuous positive lead of around 5 months, which peaks to an almost 20-month lead in 2009. This strong divergence coincides with the first signs of the central bank's expansionary monetary policy. The massively reduced base interest rates allowed mortgage providers to increase the amount of approved loans, thus supporting the stricken real estate market, which showed some small signs of recovery by the end of 2009. However, the direction of correlation is less obvious as can be seen in Figure 31.

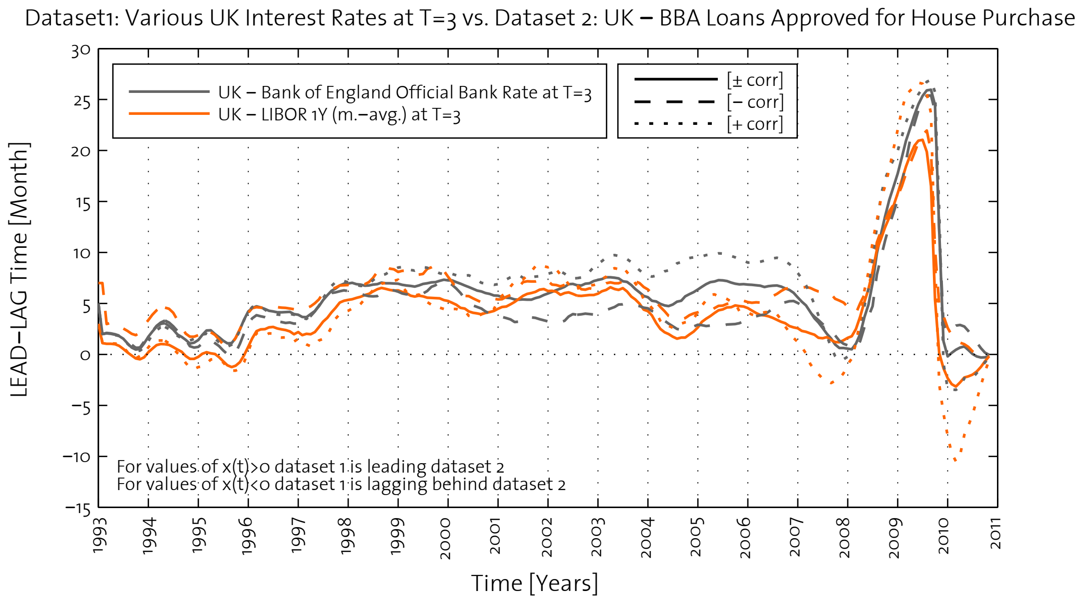

Figure 31: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

IV.3.3. HOUSE PRICE INDEX AND LOANS APPROVED

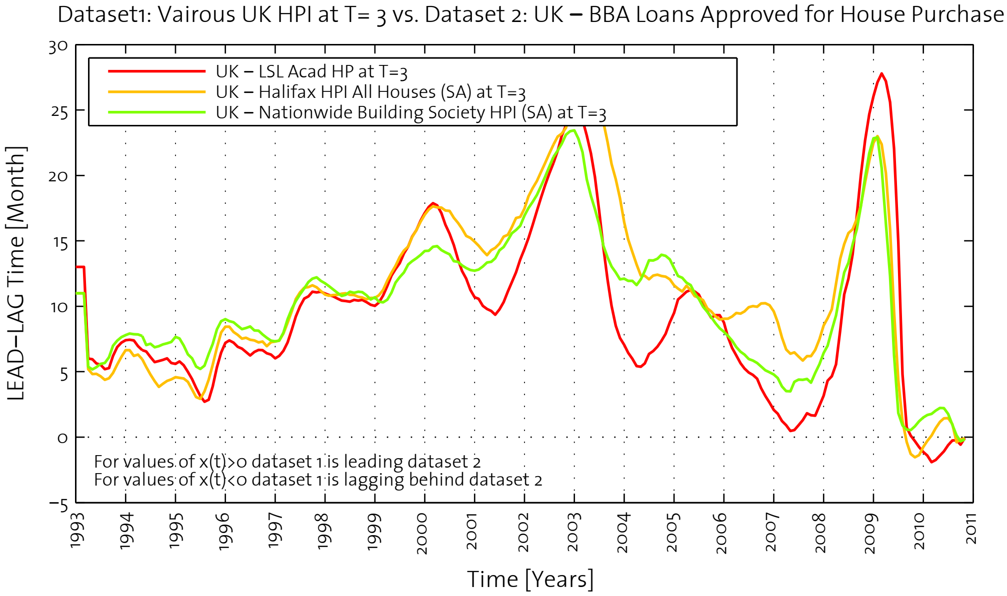

Figure 32: Lead-Lag dependence $x(t)$ between between the returns of various UK House Price Indices and the change of the number of approved loans for house purchases in the UK published by the British Bankers Association (BBA) on a monthly level at temperature T=3

In a further analysis for the UK, we compare the three major house price indices with the amount of approved mortgages. The data used for the analysis was already presented in Figure 20, Figure 23, Figure 26 and Figure 29. As expected, the TOP method analysis seen below in Figure 32 encourages that the house prices lag behind changes in the amount of approved mortgages. The result is a strictly positive lag between roughly 5 and 20 month. This long time delay is however surprising since loans are usually issued after identifying the object to purchase. Thus, one explanation for this prolonged lag might be found in the time it takes to acquire, construct and publish the necessary data.

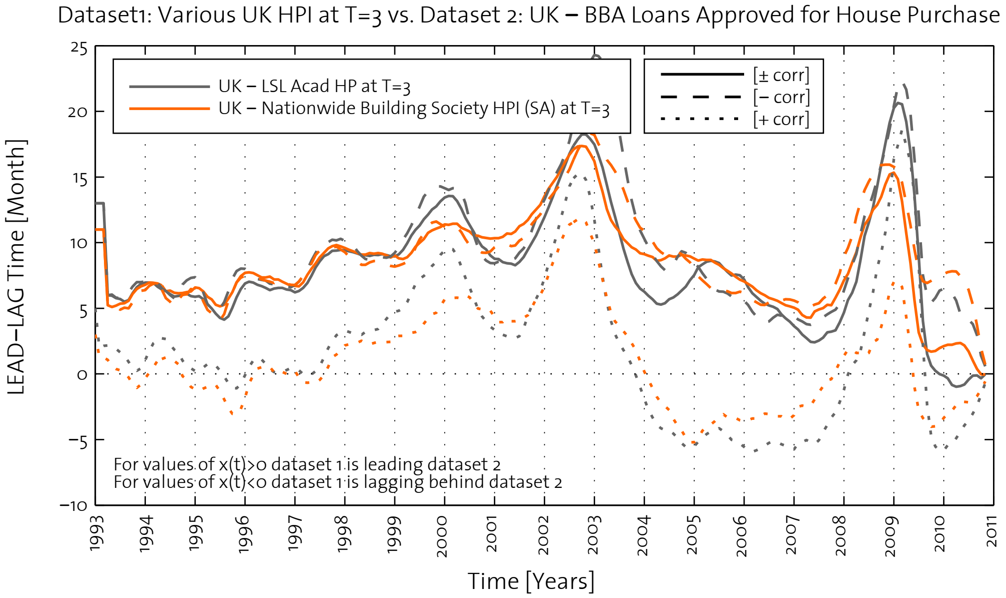

Figure 33: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

Figure 33 shows a clear negative correlation between the price level of houses and the amount of approved mortgages. This suggests that an increase in real estate prices lead to a reduction in approved mortgages for house purchase. This might be explained by the fact that increasing house prices lead to a reduction of the affordability of real estate and thus to a shrinking volume of mortgages.

IV.3.4. MONEY AGGREGATES AND HOUSE PRICES

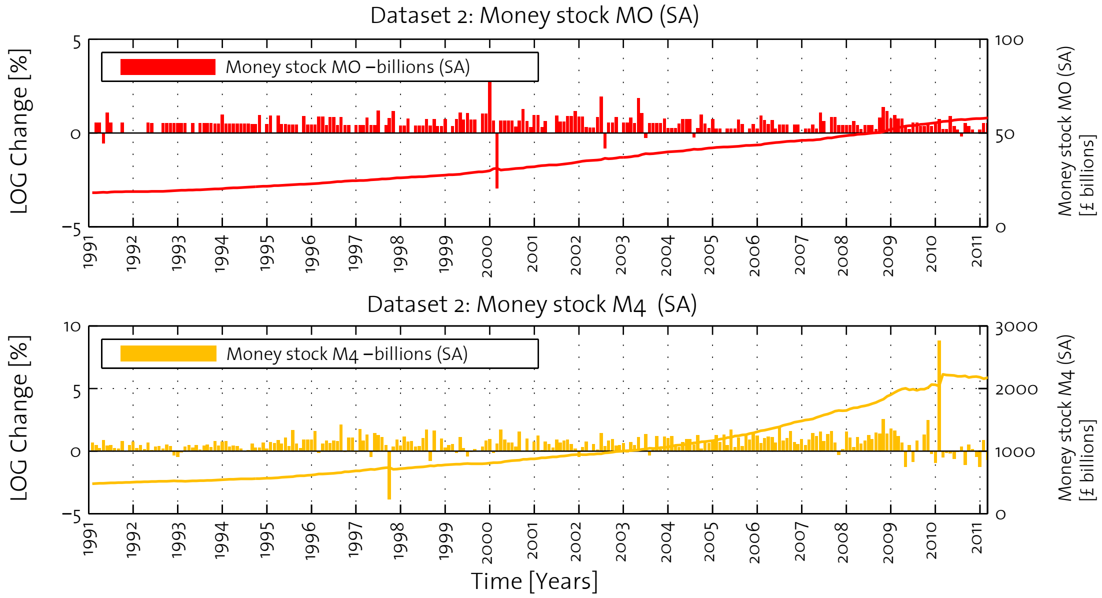

Figure 34: Monthly money supply measure by the two seasonal adjusted money aggregates M0 and M4 published by the Bank of England between January 1991 and March 2011.

Our last analysis aims to discover the empirical interdependence between money supply and house price development. The theoretical implication was already explained in the previous chapter and supposes that an increase in money supply will support growing demand and output, which in turn should lead to increasing real estate prices.

Figure 34 shows the development of the two money aggregates M0 and M4 over the last 20 years. Both indicators increased steadily since 1991 more than doubling the UK money supply until today. In 1999, 2007, 2009 and 2010 the growth of the money aggregate M4 was slowed down for some time as a possible reaction on the previous and on-going financial crisis.

The outcome of the dynamic interrelation analysis of the three house price indices and the monetary aggregate M0 is presented in Figure 35. The patterns of lead-lag structure are heterogenic and do not allow for a clear interpretation. On the one side, the NBS HPI seems to lead the change in money aggregates. On the other side, we see that the Halifax HPI lags behind it and the LSL Acad HPI is somewhere in between. When conducting the same analysis with the money aggregate M4, presented in Figure 34, we get similar results. This leads us to the conclusion that there is no clear relationship between changes in the house price indices and in the money supply in the UK.

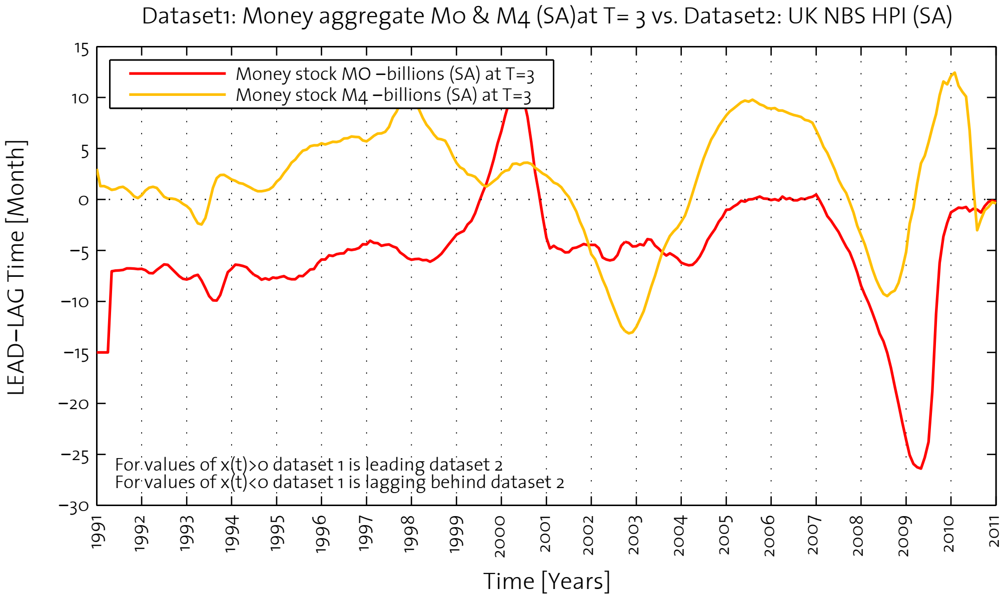

Figure 35: Lead-Lag dependence $x(t)$ between the money aggregates M0 and M4 measured by the Bank of England and the change of the National Building Society House Price Index on a monthly level at temperature T=3

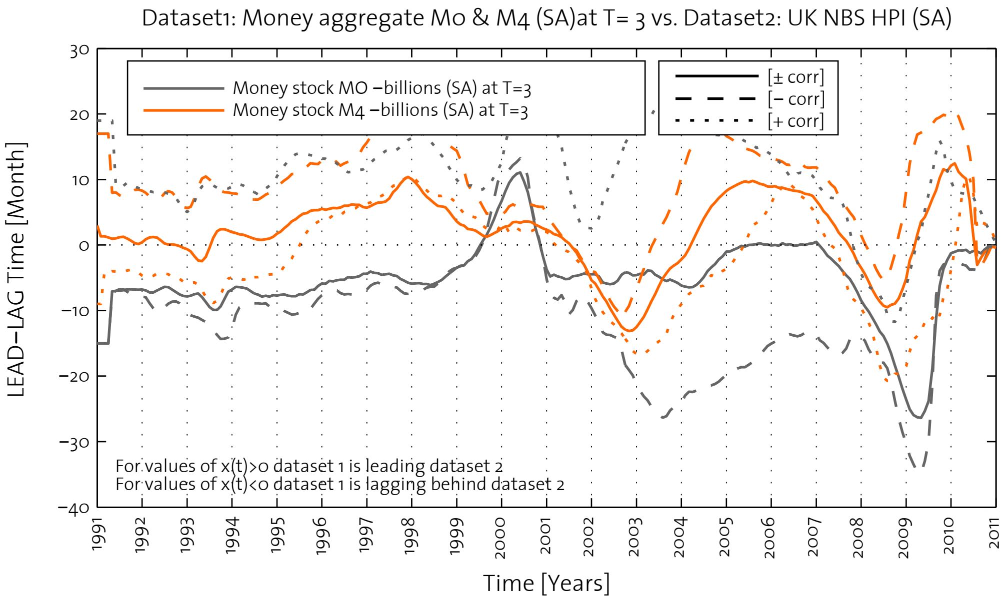

Figure 36: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

The most particular findings of the analysis are the peaks within the lead-lag patterns in mid 2000 and the end of 2008. Both peaks can be directly associated with the two major financial crisis and are homogeneously formed across the three house price indices. During the period of the dotcom bubble in 2000, which had only minor effects on the development of real estate prices, we can identify an oscillation towards a leading role of the real estate price development on the money supply. In the case of the second crisis in 2008, which was essentially triggered by a bust of a real estate bubble, we observe that the money supply is a reaction to these changes of real estate prices. As can be seen in Figure 36, for both cases the direction of correlation remains positive.

IV.4. UNITED STATES

For the case of the United States, the seasonal adjusted house price indices (HPI) published by the Federal Housing Finance Agency (FHFA), the Standard &Poor's Case-Shiller Index and the Bloomberg Real Estate Operating Company Index is compared with the effective Federal Funds Rate, the 1-year dollar LIBOR and the 10-year Treasury Bill. As shown in Figure 37, the FHFA HPI is available starting from January 1991 while the data of the S&P Case-Shiller HPI starts in January 2000.

In addition, the interrelation between the amount of new single-family houses sold in the US and the three abovementioned interest rates as well as the impact of the amount of new single-family houses for sale on the development of the two major house price indices described above is analysed.

Finally, the influence of the development of money supply measured as the money aggregates by the Federal Reserve on the real estate prices is investigated. The latest data point selected for every analysis is April 2011.

IV.4.1. INTEREST RATES AND HOUSE PRICES

The first dataset in Figure 37 shows the development of US interest rates over two centuries. Three periods of decreasing interest rates, which were led by the target rate of the Federal Reserve (FFR) can be identified. This change in interest rate on a level of monetary policy was triggered by periods of economic recessions, namely the US Savings and Loans Crisis between 1990 and 1991, the dotcom bubble that climaxed in March 2000, together with the shock of the 9/11 terrorist attacks in 2001 and the most recent Subprime mortgage crisis which caused a global financial crisis beginning in late 2007. Each period preceding the crisis was characterised by economic recovery with slow constant rises in Federal Reserve Target Rate. In general, during the last two decades the interest rate level has decreased significantly for all these types of maturity, resulting in historical lows today.

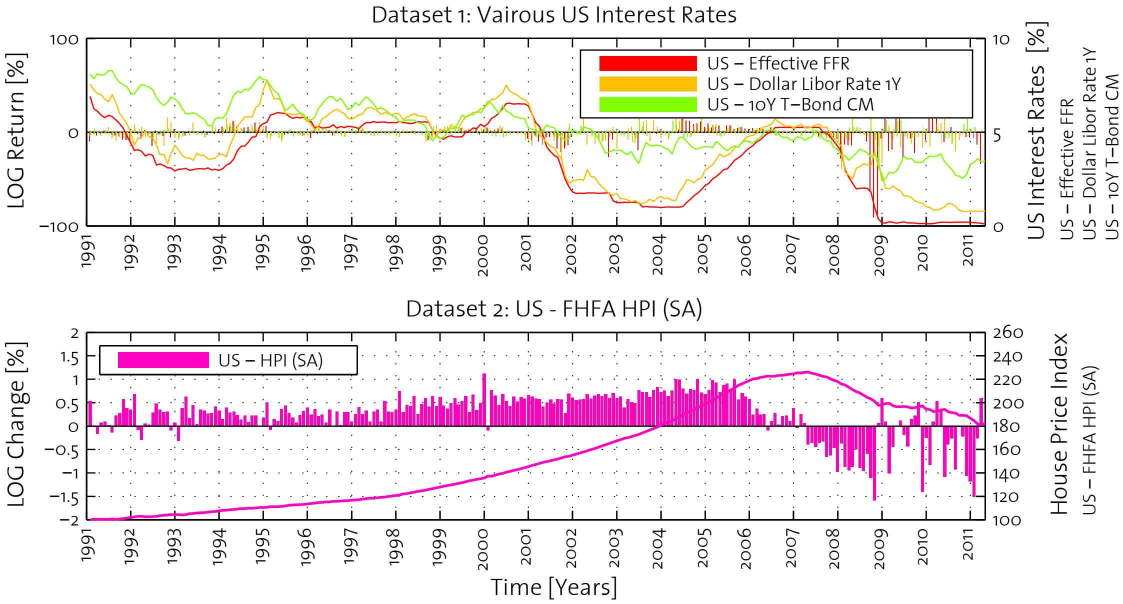

Figure 37: Monthly US interest rate data of the Effective FFR, the 1-year US Dollar LIBOR and the 10-Year Treasury Bond as well as the US house price development according to the FHFA House Price index between January 1991 and April 2011.

The development of house prices in the United States, represented by the FHFA House Price Index is characterised by a strong, almost exponential, growth since the early 1990s which peaked 2007. The consequences of this development are explained in the previous chapter and have their counterpart in the decline in interest rates in late 2007. It is also important to note that the house price time series is obviously non-stationary and even the logarithmic returns seem to have three different regimes, one until 1997-1998 with small growth, another until 2007 with increasing growth rates and until the end of 2010 strong decay.

The results of the TOP Method analysis between the various US interest rate proxies and the Federal Housing Finance Agency's House Price Index are presented in Figure 38. It shows a stable relationship between the interest rates and the housing data between 1991 and 2002, followed by some disturbance and a regime shift between 2003 and 2007. For the first decade in the analysis, the three interest rates lead the growth of house prices, measured by the FHFA HPI, with an average time difference of roughly 10 months. In the subsequent period until 2006, which was characterized by extensive growth in house prices, the analysis reveals a perturbation of this stable regime. As a result, we see in mid 2007 (roughly at the climax of US house prices) a change in regime towards all three interest rates following the development of house prices with about a 5-month average time difference.

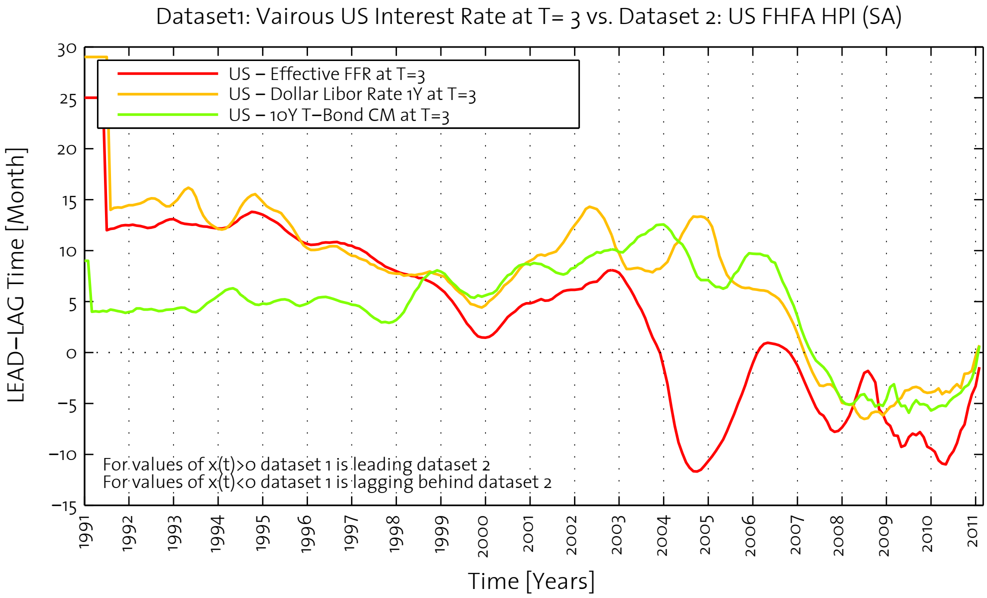

Figure 38: Lead-Lag dependence $x(t)$ between the returns of various US interest rates and the returns of the US FHFA House Price Index on a monthly level at temperature T=3

In Figure 39 the variations of the lead-lag patterns in regard to the "a priory" assumptions of correlation is displayed. Between 1991 and 1999, it is possible to identify relatively stable regimes. The non-monotonic lead-lag structure of the US FFR seems to be negatively correlated to the development of the house prices, while the 10-year Treasury Bond Yields suggest a positive correlation during that time. With the beginning of the economic turbulences, caused by the bust of the dotcom bubble, these stable relationships disappear. Later, the lead-lag pattern of the FFR somehow follows a negative correlation but finally leaves the path in 2004 towards a positive correlation in regard to the development of house prices. For the 10-year T-Bond a trend towards a positive correlation until 2004 is observed, devolving into a period of strong disturbances which hinders a clear interpretation.

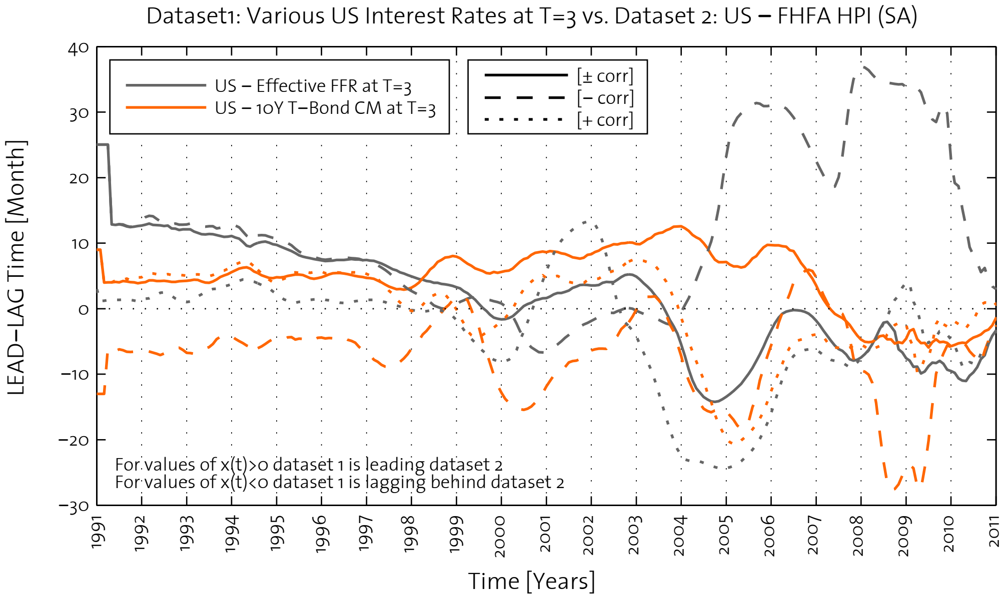

Figure 39: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

The direction of causality we discovered, especially for the FFR is found to be in line with the theory previously presented. Until 2004, the Central Banks' low interest rate policy was driving the increase in house prices. But as house prices start to climax and eventually collapsed, the dependence turned around towards a lead of house prices on interest rate levels based on a positive correlation. This implies that as soon as the Federal Reserve realized the danger of an overheating in the real estate market, it increased its Target Rate. But, as the bubble collapsed and the house prices started falling, the Central Bank tried to stop the development by massively decreasing the interest rates. The 1-year US Dollar LIBOR, which has been left out in this analysis to allow better readability, follows the same changes in dynamics as the FFR. For the case of the 10-year Treasury Bond Yield, the positive correlation to the house price development during the first decade of the analysis is surprising. In theory, lower Treasury Bond yields would correspond to decreasing fixed rate mortgage rates, which in turn would lead to an increase in real estate prices.

Because of the availability of a second US proxy for housing prices, the S&P's Case-Shiller House Price Index, we have the opportunity to verify our previously gained results. In Figure 40, the three interest rates together with the development of the S&P's Case-Shiller index are displayed between January 2000 and April 2011. As already stated for FHFA HPI, we can identify a strong growth period between 2000 and 2006 with a brought peak during 2006-2007, which is an early sign of the real estate bubble when compared with Figure 37. After 2007, we see the same crash in housing prices followed by a stabilisation of price levels in mid 2009.

It is important to indicate that this analysis only covers half of the time period presented in Figure 38.

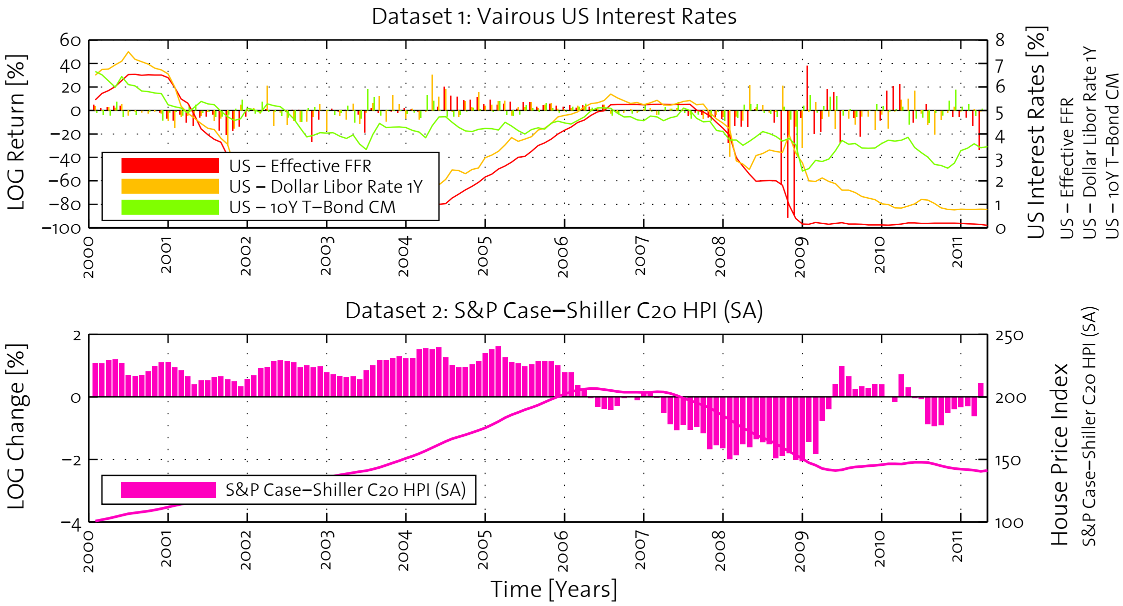

Figure 40: Monthly US interest rate data of the Effective FFR, the 1-year US Dollar LIBOR and the 10-Year Treasury Bond as well as the US house price development according to the S&P's Case-Schiller House Price index between January 2000 and April 2011.

Figure 41 is able to prove some of our previous findings gained in Figure 38. We see the same patterns as before, namely a stable plateau of roughly 10-month average lag of the house prices compared to the changes in interest rates until 2006 followed by a regime-changing period. However, this time the results beyond 2007 are not as stable any more. On the one side, the analysis of the US effective FFR and the 1-year Dollar LIBOR suggests a lead of the house prices compared to the interest rate in the magnitude of roughly five month. On the other side, the influence on the 10-year Treasury Bond is not as stable and allows no clear conclusion.

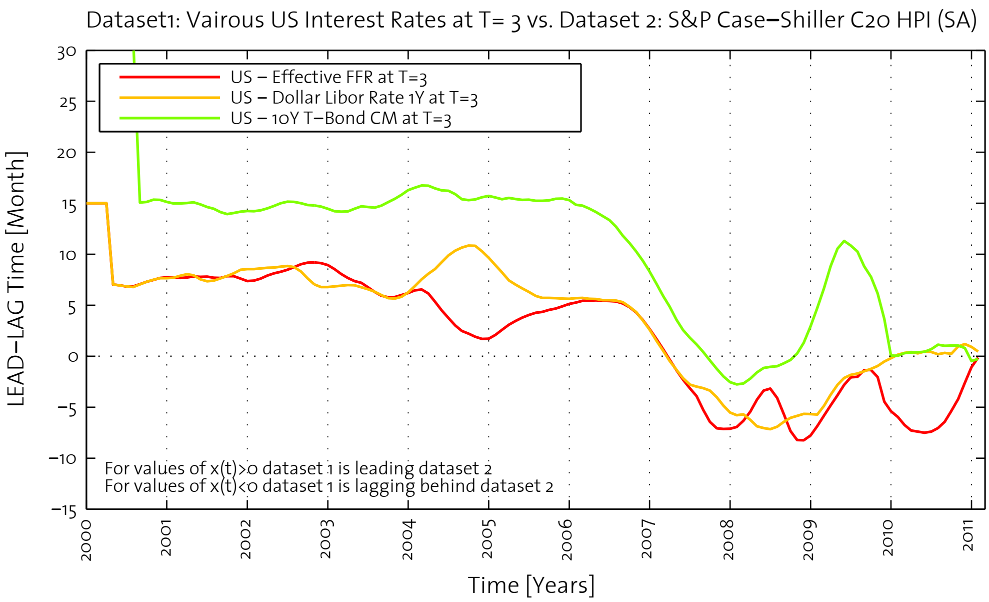

Figure 41: Lead-Lag dependence $x(t)$ between the returns of various US interest rates and the returns of the US S&P's Case-Schiller House Price Index on a monthly level at temperature T=3

The results of the variation analysis of the lead-lag structure, in regard to the underlying correlation of the two time series, show a slightly different picture than we have seen in Figure 39. However, it is important to mention again that the plot covers only the period between

2000 and 2011. Within this period, we see that the US FFR first leads, based on a positive correlation, the development of house prices measured by the S&P Case-Shiller HPI until 2007. This relationship is reversed later on, but a positive correlation still exists. From 2007 onward this is essentially the same result as we have identified for the FHFA HPI and the FFR. The results for the 10-year Treasury Bond, in contrast to the previous findings, suggest a lead with a negative correlation until 2007. Thereafter, this interdependence is disturbed and no clear interpretation is possible. Despite being contradictory to what we have identified previously, this result is more in line with the theoretical background presented in this study because it would suggest that low 10-year T-Bonds would lead to higher real estate prices.

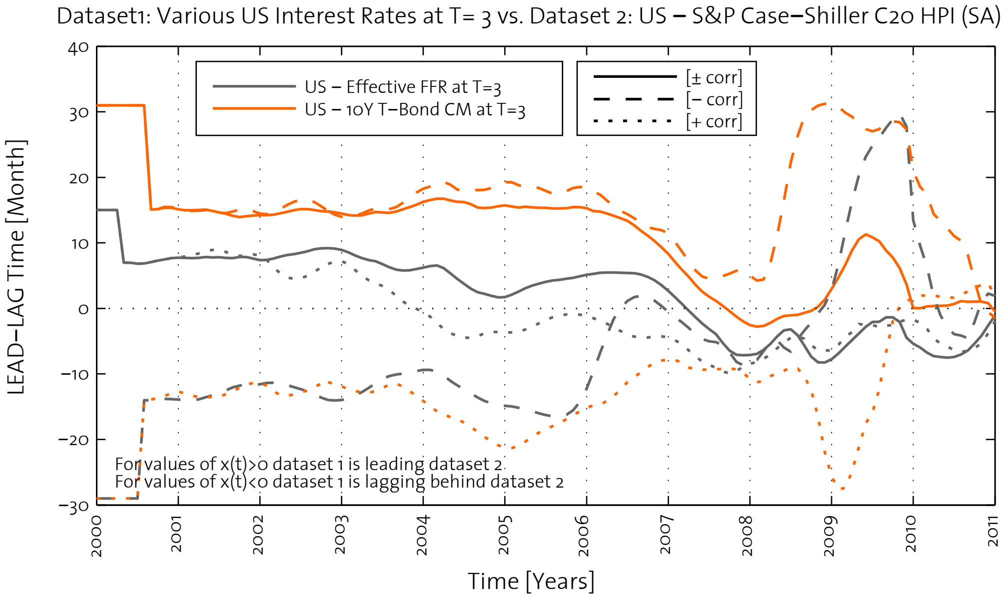

Figure 42: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

Finally, we compare the Real Estate Operating Company Index (REOCI) introduced by Bloomberg with the development of the three US interest rates with different maturities. The Bloomberg index represents publicly-traded Real Estate Operating Companies that specialise in the professional management of real estate. The Index, as seen in Figure 43, behaved similar to the house price indices presented above. There was a strong price increase during mid 2000 with a moderation period starting from 2005 and a peak in 2007. Thereafter, prices decreased rapidly, thus leading to the lowest values for over one decade.

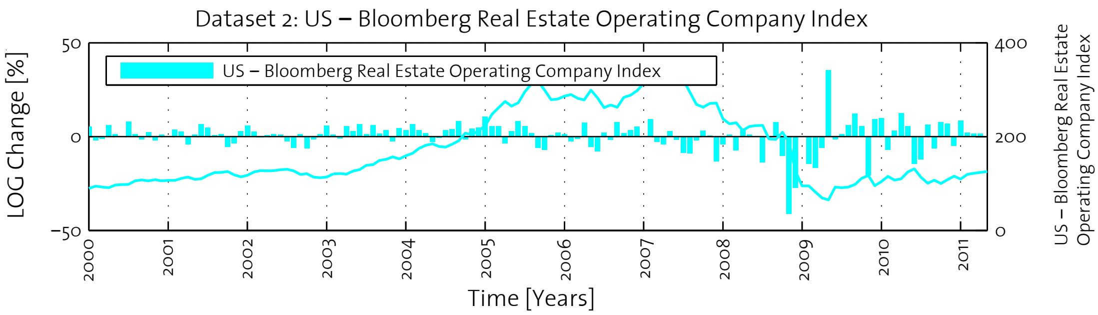

Figure 43: Monthly development of the Bloomberg Real Estate Operating Company Index between January 2000 and April 2011.

The lead-lag analysis between the US interest rate data and the Bloomberg REOCI is presented in Figure 44. Once again, it provides similar results, showing that until 2008 short- to long-term interest rates lead the development of house prices. In mid 2007, this relationship is disturbed and drops towards a lagging relationship for roughly one year.

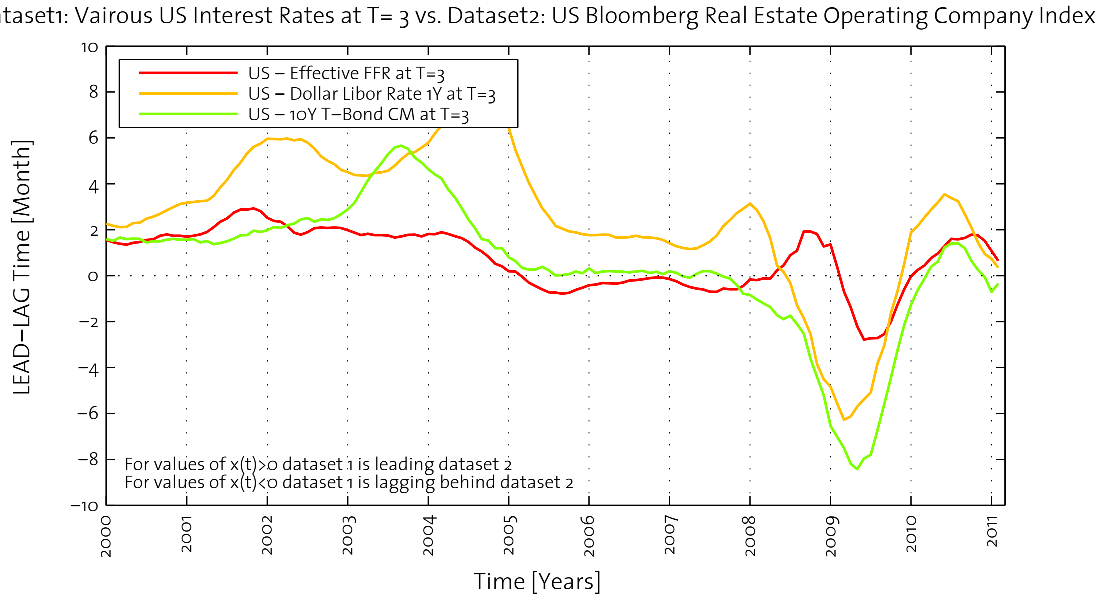

Figure 44: Lead-Lag dependence $x(t)$ between the returns of various US interest rates and the returns of the Bloomberg Real Estate Operating Company Index on a monthly level at temperature T=3

Figure 45 visualizes the variations in lead-lag patterns between the US interest rates and the Bloomberg REOCI under the three correlation conditions. While the FFR roughly follows the path of positive correlation (especially after 2004), we see that the 10-year T-Bond is directly related more to the negative correlation. The results are less pronounced but qualitatively similar to the findings in the last two analyses, which allows us to adopt the previous interpretations.

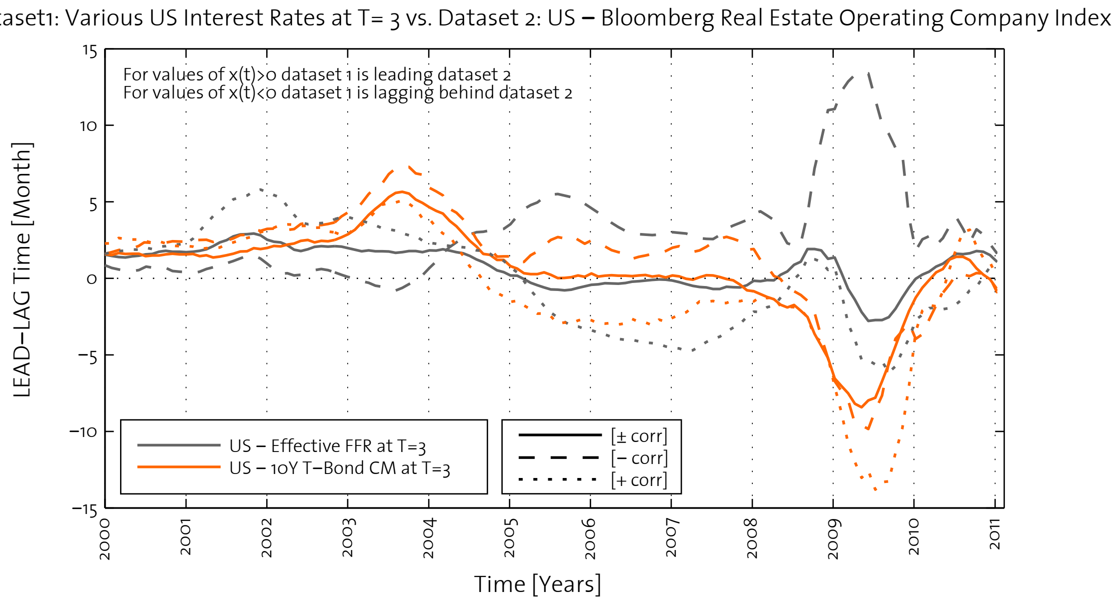

Figure 45: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

In summary, our findings are a great source for verifying the theoretical dependence between interest rates and house prices in the United States. As stated in the previous chapters, the US mortgage market is traditionally composed of fixed rate mortgages that are using long-term government bond yields such as the 10-year T-Bond plus some risk premium as a guideline for their mortgage rate levels. This is exactly what we see in Figure 38,Figure 41 and Figure 44, where the 10-year Treasury Bond is leading house price development with a negative correlation. This implies that a reduction of T-Bond Yield will have a positive effect on the development of the real estate price levels. In addition, the US real estate market is reacting sensibly to the changes in Federal Funds rate. The negatively-correlated lead of the FFR over the house prices between 1991 and 2000 might be due to the fact that penalties for early repayment of loans are relatively low in the US and therefore refinancing of mortgages, in the case of dropping interest rate levels, is a common practice. In contrast, the change of this lead-lag path towards a positive correlation and even a lead of the development of house prices over the FFR level in 2000 could be a sign of the growing importance of the real estate sector for monetary policy decisions. In short, this means that the Federal Reserve reacted on both, the overheating of the real estate market and the later decline in houses prices, by increasing respectively decreasing its FFR.

IV.4.2. Interest Rates and Houses Sold

When comparing the lead-Lag structure of interest rates and house prices it is also interesting to see the impact of interest rate movements on the change in property sale statistics. As already described in the introduction, homeowners are sensitive to changes in house prices and are reluctant to sell their homes at a loss (or below their asking price). Therefore, a drop in total sales volume should be experienced during periods of declining house prices and the opposite in periods of house price booms.

In Figure 46 the seasonal adjusted sales volume of new Single-Family homes is displayed for a period between January 1991 and April 2011. As expected, we can see that the sales volume closely followed the development of house prices illustrated in Figure 37 and Figure 40. However, it is also noticeable that the peak of houses sold was in end of 2006, roughly half a year before the peak in house prices.

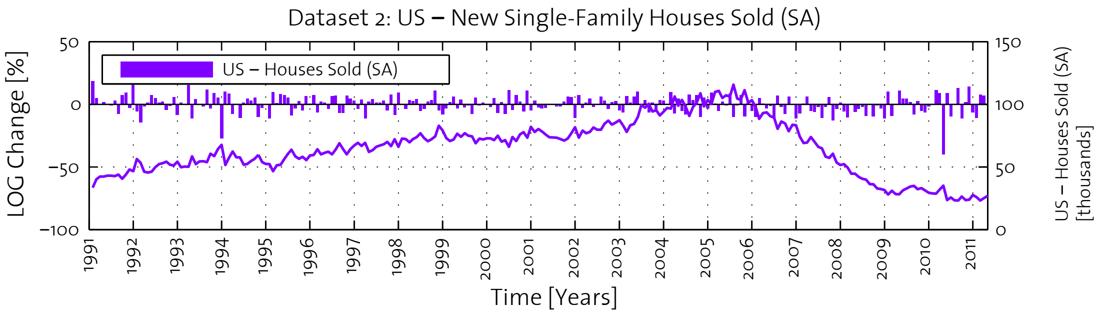

Figure 46: Seasonally adjusted data of houses sold during the period of January 1991 and April 2011. (Number of housing units in thousands)

The dynamic interdependence between the three types of interest rate data and the total amount of houses sold is represented in Figure 47. The analysis shows that over the past two decades returns of interest rates lead the changes in the volume of house sales and therefore, confirm our theoretical assumption. Again, we see a more or less stable relation between 5-12 month time difference during the first decade and thereafter some disturbances, especially after the peak of the real estate bubble.

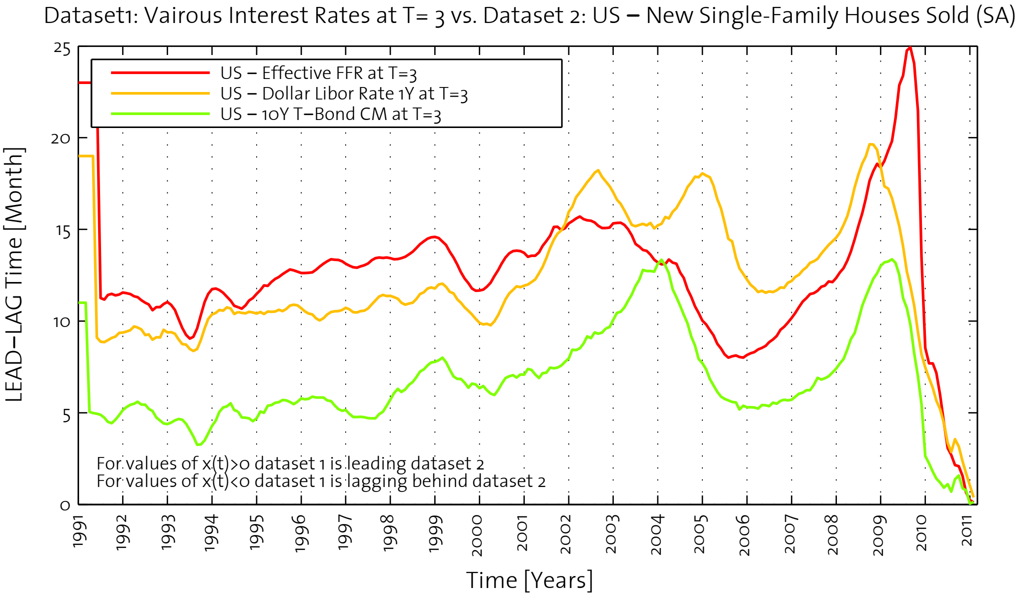

Figure 47: Lead-Lag dependence $x(t)$ between the returns of various US interest rates and the change in sold houses in the US on a monthly level at temperature T=3.

To identify the causal direction of this lead, the variation analysis of the lead-lag pattern is presented in Figure 48. Based on the results, we find that until 2004 the FFR has a positive correlation with the development of the amount of houses sold while the 10-year T-Bond yields are negatively correlated. Thereafter the correlation seems to be reversed under the same lead-lag pattern. This outcome allows no clear interpretation until 2004. However, from 2004 to 2011 the results are in line with our previous findings.

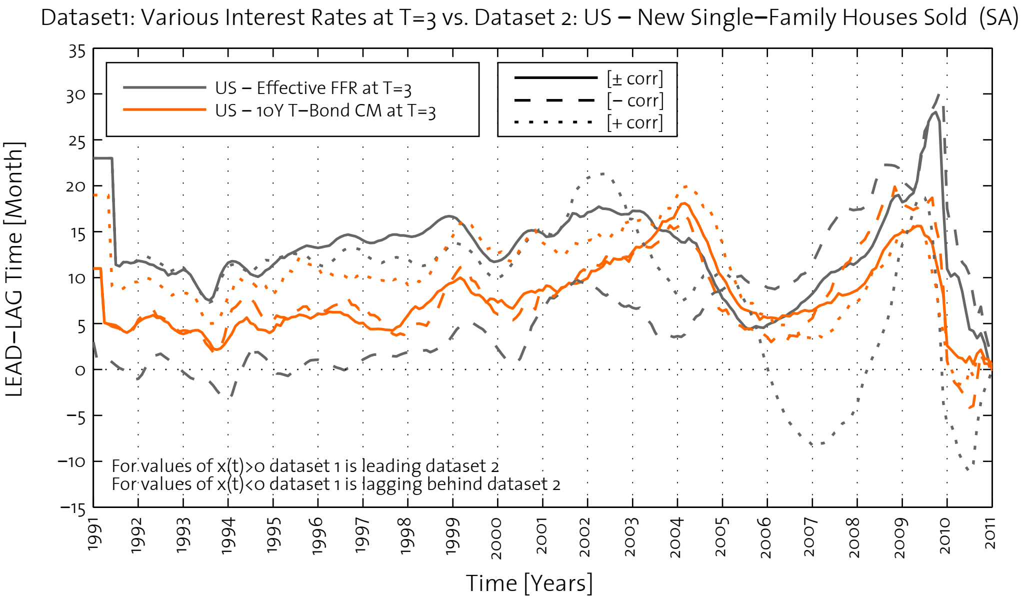

Figure 48: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

IV.4.3. House Prices and Houses for Sale

In a separate analysis shown in Figure 49, Figure 50 and Figure 51, we compare the two proxies for the US house prices with the amount of houses for sale within the US. As expected, according to common economic theory, we can prove that the development of house prices leads the change in houses for sale following a positive causal relationship. The lead-time is relatively stable between 4 and 10 month.

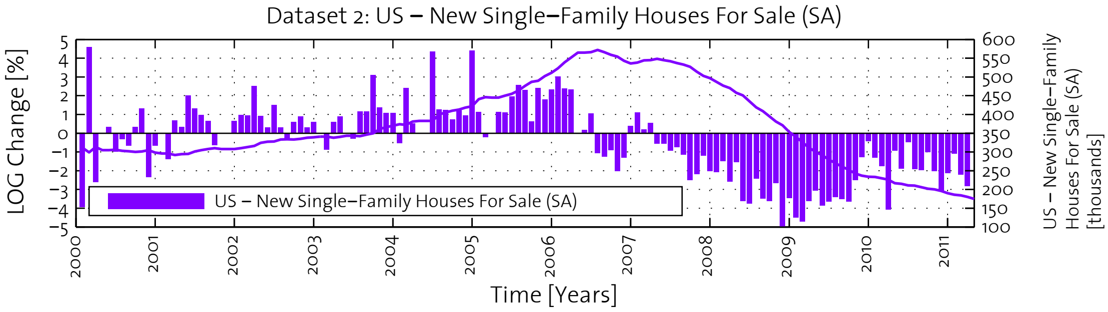

Figure 49: Seasonally adjusted data of houses for sale during the period of January 2000 and April 2011. (Number of housing units in thousands)

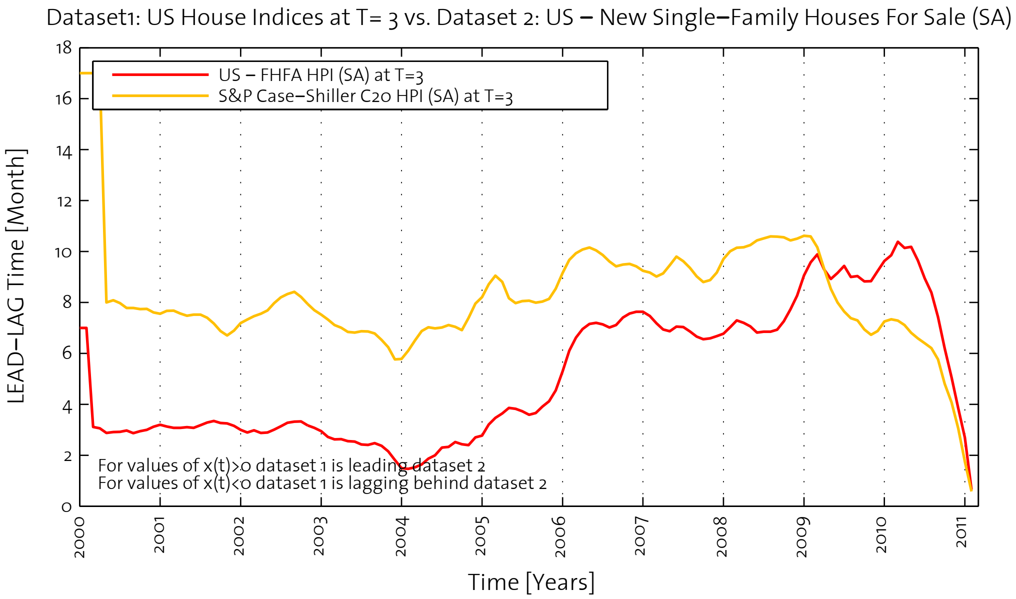

Figure 50: Lead-Lag dependence $x(t)$ between the returns of the two major house price indices and the change in houses for sale in the US on a monthly level at temperature T=3.

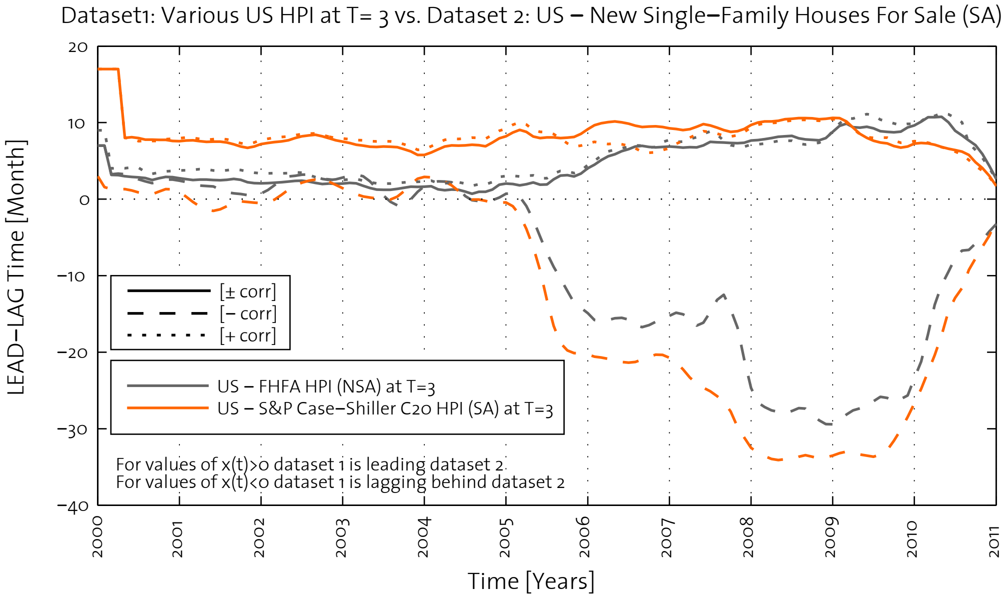

Figure 51: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

IV.4.4. Money Aggregates and House Prices

To complete the set of analysis, we publish the TOP Method results of the comparison between the United States Monetary Aggregates M1 respectively M2 and the two main House Price Indices. Figure 52 visualises the development of the United States money supply. The money aggregates are showing an almost continuous growth rate over the entire two decades, which is only interrupted by some minor decreases during 1994-1997 and 2006-2008.

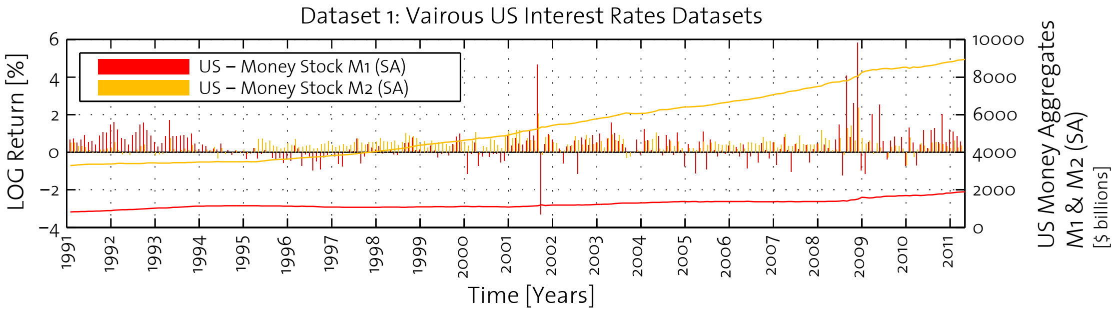

Figure 52: Monthly development of the money aggregates M1 and M2 published by the United States Federal Reserve

The findings of the lead-lag relationship presented in Figure 53 are mixed. On the one side, the results suggest that the Money Aggregate M2 was leading the house price development over the period between 1991 and 2007. On the other side, this cannot be confirmed by the Money aggregate M1, which allows no clear interpretation. However, in the aftermath of the financial crisis in 2008 both Money Aggregates are lagging behind the interest rate development.

The results of variation analysis presented in Figure 54 are not able to provide additional information. For both Money Aggregates M1 and M2 the non-monotonic result is strongly fluctuating between a positive and a negative correlation, thus the direction of causality cannot be determined.

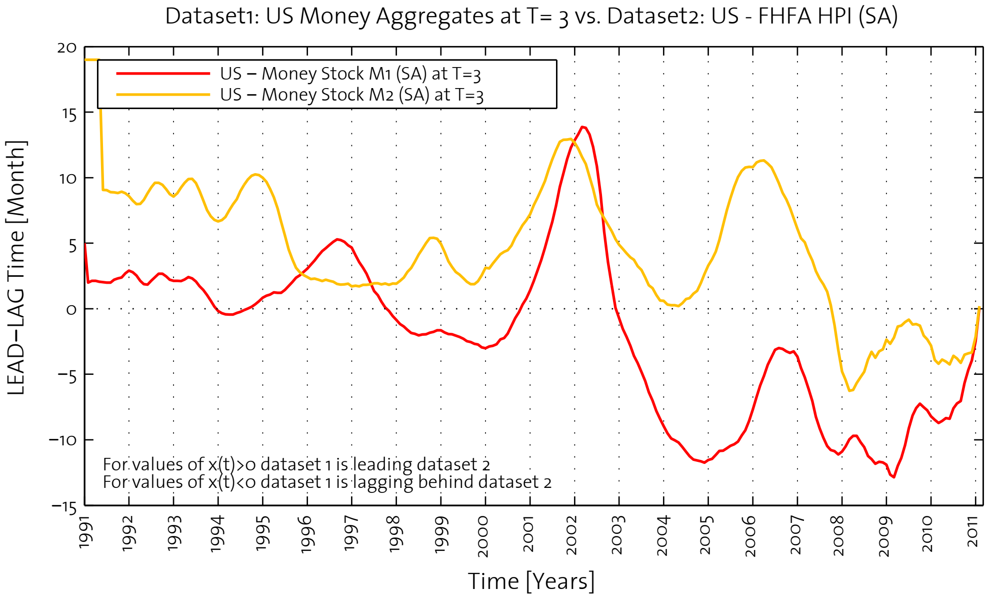

Figure 53: Lead-Lag dependence $x(t)$ between the returns of the two United States money aggregates and the returns of the US FHFA House Price Index on a monthly level at temperature T=3

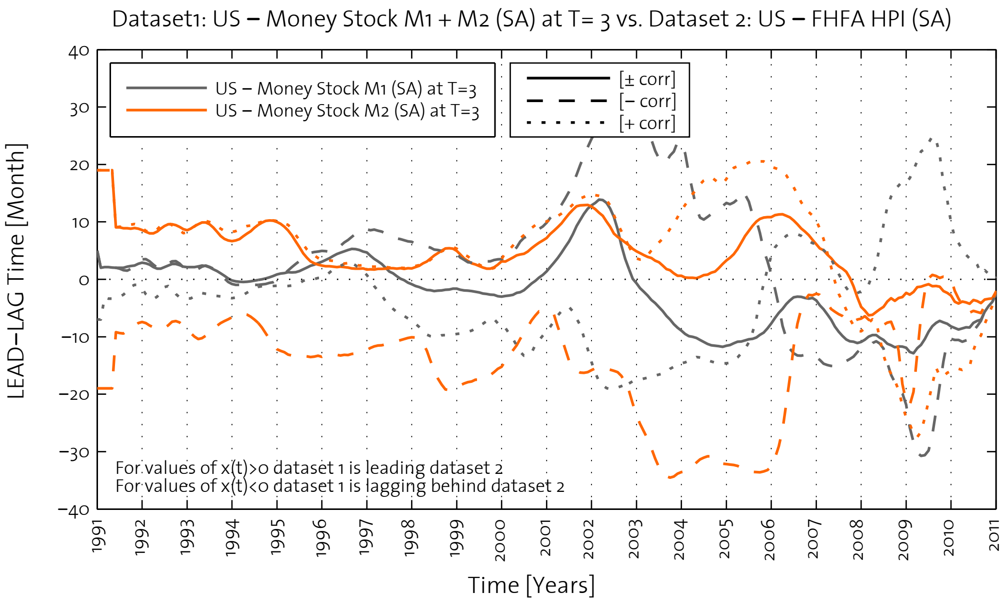

Figure 54: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

When conducting the same analysis with both, the S&P Case-Shiller HPI as well as the Bloomberg REOCI, we get qualitatively similar results. Even though the analysis allows no clear interpretation, it is similar to the results we gathered in the UK. Again, Figure 53 illustrates that during periods of financial busts we see stronger disturbances. For the dotcom crisis in 2000 we see a reaction towards Monetary Aggregates leading House Prices and during the Credit Crunch in 2008 we can observe the opposite.

IV.5. SWITZERLAND

In Switzerland we analyse the correlation between three different maturity interest rates and real estate prices represented by the Swiss Property Price Indices for residential flats as well as single family houses. The interest rate data is composed of the Swiss National Bank Cash Rate reported by the IMF, the 12-month Swiss Franc LIBOR and the 10-year Government Bond Yields. All data is given between 1994 and 2011 on a quarterly basis.

In addition, we report the interdependency analysis between the three Money Aggregates M1, M2 and M3, published by the Swiss National Bank and the development of the Swiss real estate prices.

IV.5.1. INTEREST RATES AND HOUSE PRICES

Swiss house prices boomed during the late 1980s and the early 1990, which forced the Swiss National Bank (SNB) to raise the interest rate level, thus counteracting the development of a bubble. Consequently, house prices began to fall but as a side-effect the whole Swiss economy was slowing down, facing a 3 year recession until 1993, which led to a small shrinkage of the economy and a rise in unemployment rates.

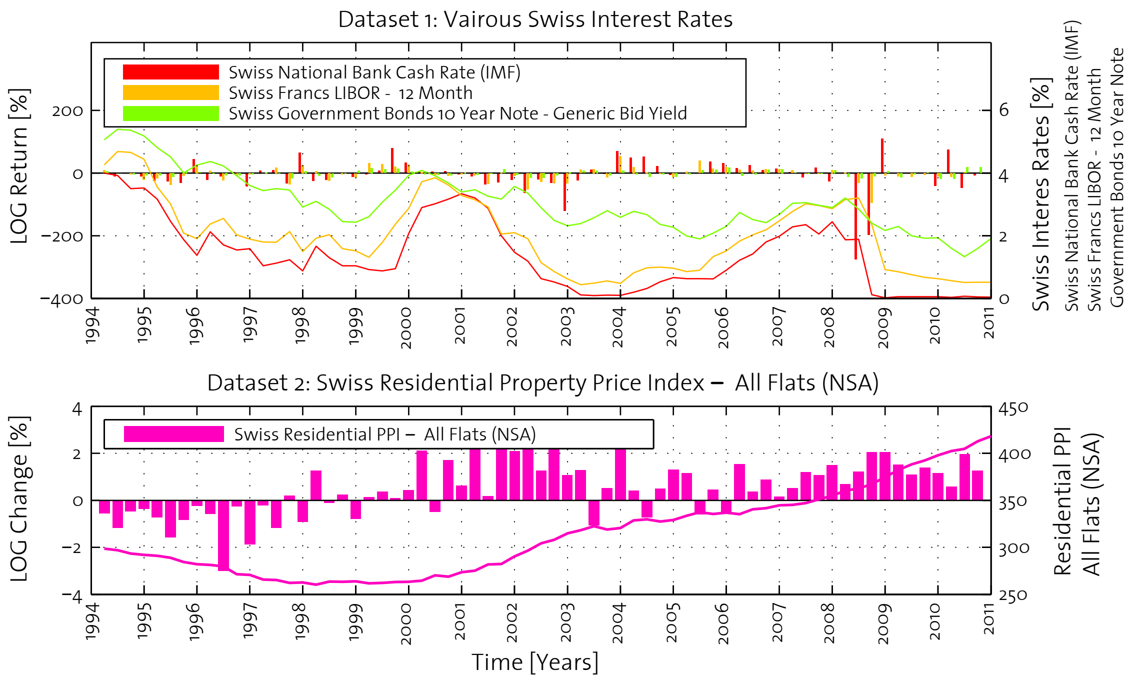

Figure 55: Quarterly Swiss interest rate data of the Swiss National Bank Call Rate (IMF - Swiss FFR), the Swiss Francs 12 month LIBOR and the 10-Year Government Bond as well as the house price development according to the Swiss Residential Property Price index for all Flats between first quarter of 1994 and last quarter of 2011.

In Figure 55 we see that Swiss interest rates, represented by the SNB Cash Rate, the Swiss Francs 12-month LIBOR and the 10-year Government Bond Yields continuously deceased in the aftermath of the house price peak and the economic recession until 1999. Thereafter, interest rates were brought back to higher levels because authorities feared the risk of increasing inflation and economic overheating. This period was, however, of a short duration because in 2000 the dotcom crisis hit the US and Europe, which together with the after effects of the 9/11 terrorist attacks led to an economic downswing in 2001. The SNB reacted upon this development with massive decrease in targeted cash rate level until 2003. In mid 2003 the economy started to recover again, which allowed the SNB once again to slowly increase the interest rate levels. This development was suddenly stopped in 2008 as the result of the US credit crunch, which also had strong effects on the Swiss economy, forcing the SNB to bring interest rate levels down to a historical low.

In the lower part of Figure 55, we see the development of the Swiss Residential Property Price Index (PPI) for all flats (not seasonally adjusted (NSA)). As described above, house prices were declining until 1999 when the market turned around, allowing for a modest but continuous growth until today (with the small exception of a plateau in 2003-2004).

The results of the lead-lag analysis between the three Swiss interest rates and the residential PPI are presented in Figure 56. For both medium and long-term interest rates the lead-lag time is always positive. This means that the return of Swiss Francs 12-month LIBOR and the 10-year Government Bond Yields have been leading the changes in property prices within Switzerland over more than one decade. This leading relationship is stable for both interest rates at around one to two quarters of a year until 2004. After that, some disturbances increase the lead of the Government Bond Yield up to one year, while the LIBOR lead vanishes only to return to previous values in 2008. The Swiss National Bank's Cash Rate shows a completely different pattern. The analysis suggests that it follows the development of property prices by one to two quarters of a year until 2006, with the exception of the period between 1997 and 2000. After 2006, the SNB Cash Rate flips towards a leading role over the PPI between 2006 and 2009.

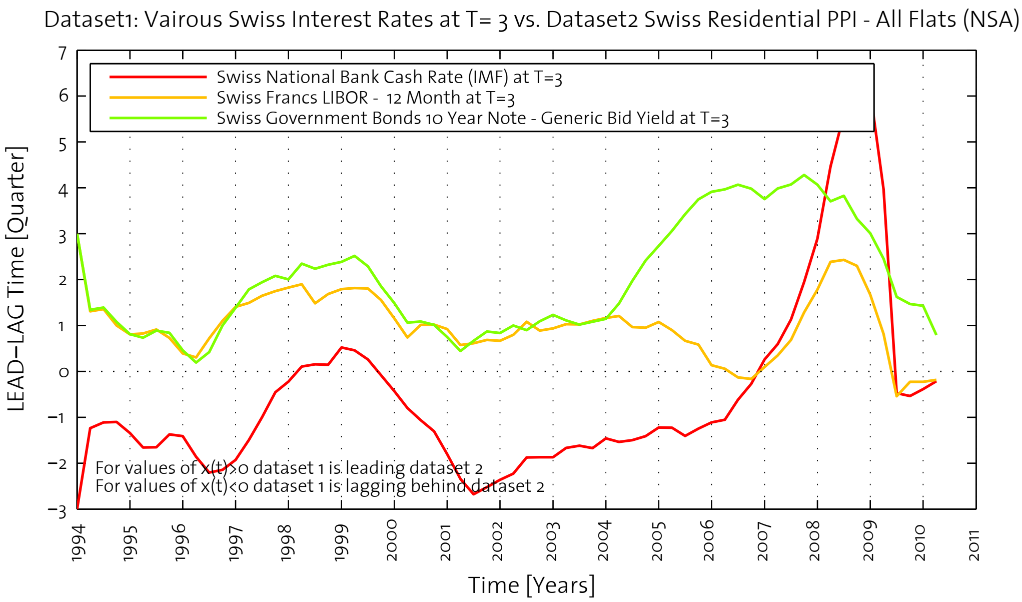

Figure 56: Lead-Lag dependence $x(t)$ between between the returns of various Swiss interest rates and the returns of the Swiss Residential Property Price Index for all flats on a quarterly level at temperature T=3

Figure 57 gives additional information about the direction of the lead-lag relationship. The graph shows that both non-monotonic determined interrelations clearly follow the path of the negative correlation. The result for the 10-year Government Bond Yield implies that a reduction in this long-term interest rate measure will lead to an increase of the real estate price level. For the SNB Cash Rate a positive correlation, together with a lagging relationship, suggests that a decrease in house prices would lead to an increase in the target rate of Central Banks. However, this is counterintuitive as we would expect the opposite to take place. Only in the aftermath of the financial crisis in 2007, we see results that follow the common theory. The result for the 1-

year Swiss Francs LIBOR, which is similar to one of the 10-year Government Bond Yield, is not presented in the analysis for the sake of the graphical representation.

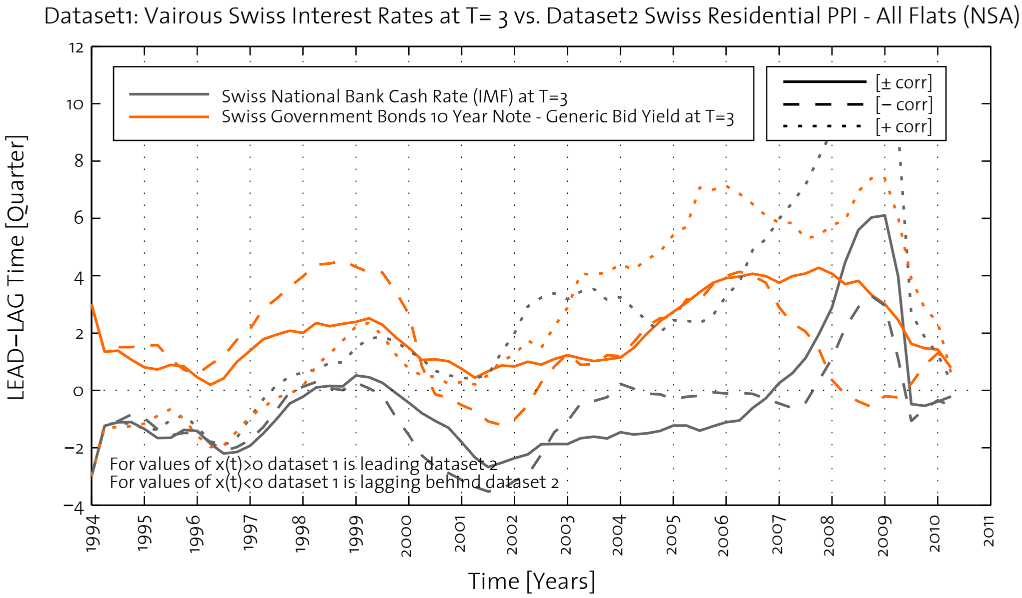

Figure 57: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

To verify our previous outcome, we conduct the same analysis using the Swiss Property Price Index for all one family houses. Figure 58 shows the development of the index over the same period between 1994 and 2011. The graph is the same as the PPI for all flats, with decreasing prices until 1999 followed by a continuous growth until today.

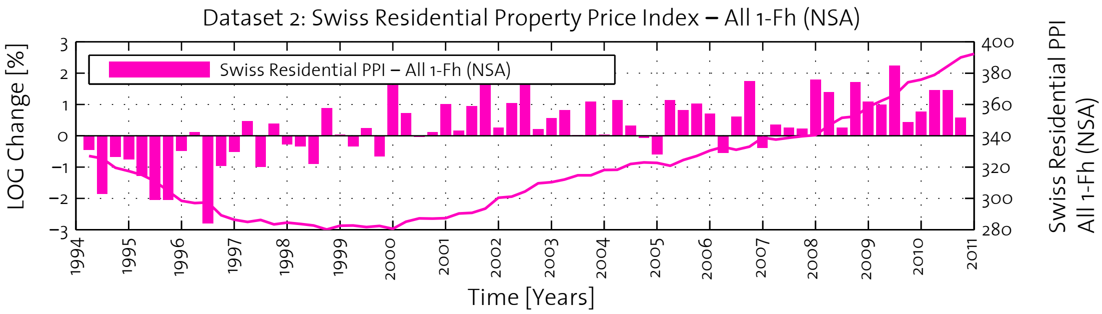

Figure 58: Quarterly Swiss house price development according to the Swiss Residential Property Price index for all one family houses between first quarter of 1994 and last quarter of 2011.

Figure 59 describes the dynamic dependence between the returns of the PPI and the changes in interest rates. Again we see that both changes in medium and long-term interest rates lead the development of Swiss property prices by roughly one to two quarters during the whole timeframe of the analysis. Only the SNB Cash Rate is lagging behind the house prices during the first period but it becomes unstable in the beginning of the 2000-century and finally changes towards leading over the PPI. The results are therefore similar to the ones we have seen in Figure 56.

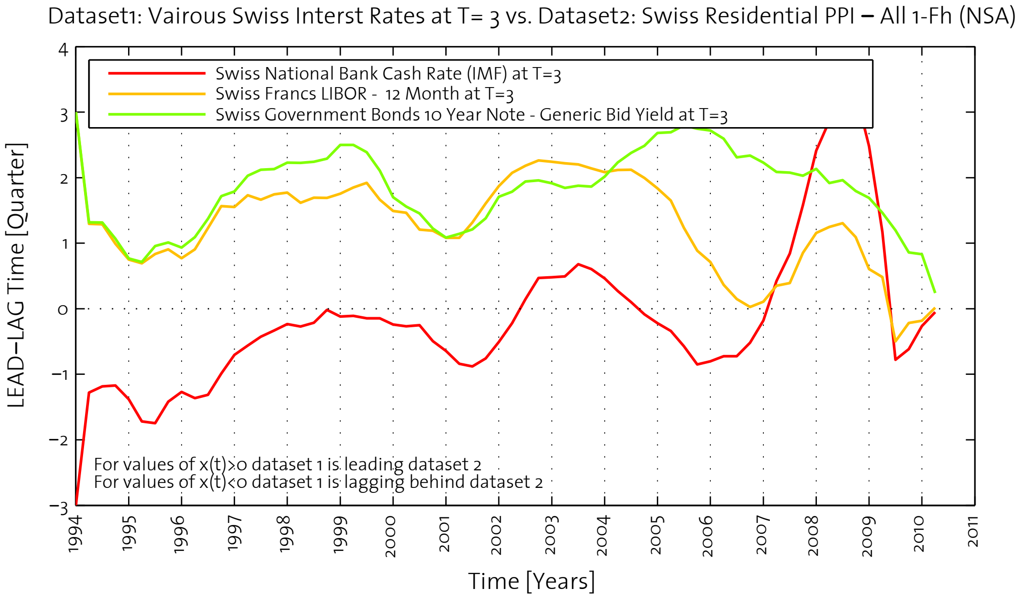

Figure 59: Lead-Lag dependence $x(t)$ between between the returns of various Swiss interest rates and the returns of the Swiss Residential Property Price Index for all one family houses on a quarterly level at temperature T=3

Figure 60 shows the variation of the lead-lag patterns, which is analogue to the findings in Figure 57. However, this time the results suggest, especially after 2000, a higher tendency of the SNB Cash Rate to be leading the development of real estate prices with a negative correlation.

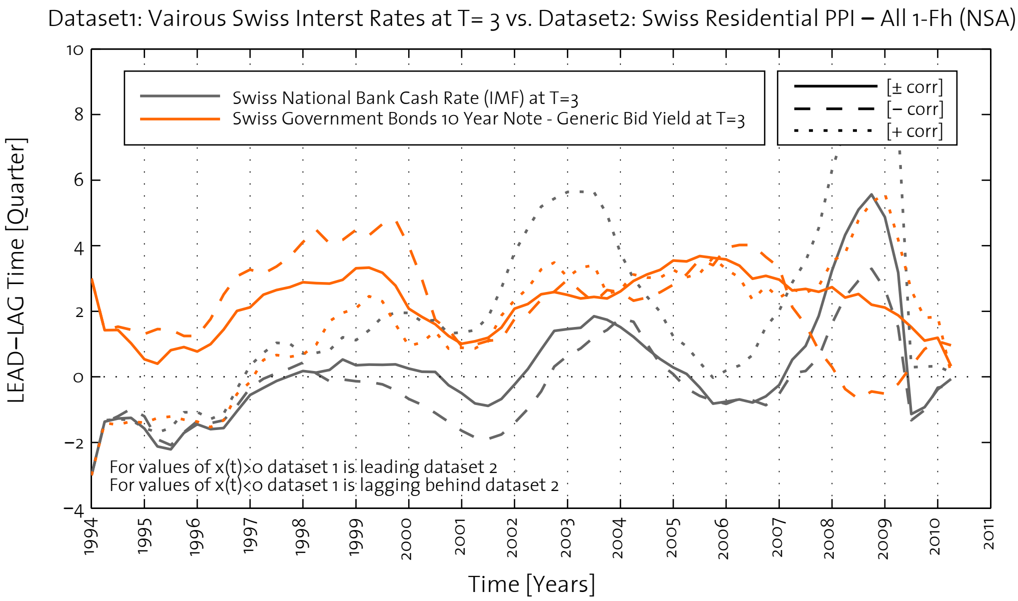

Figure 60: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$))

Summing up the results from the past two analyses, the medium-and long-term interest rates are found to be leading the development of both residential price indices by between one to two quarters and three to four quarters respectively. The short-term interest rates presented by the Swiss National Bank Cash Rate generally lag behind the development of the Property Price Index. These findings are strongly congruent with the theoretical background of the interdependence between real estate prices and monetary policy. In Switzerland, residential properties are mostly financed by mortgages, which can be based on fixed or adjustable rates.

While adjustable mortgages use medium term interest rates such as the 12-month LIBOR as a proxy for adjusting their rates, fixed mortgages are usually following the development of long term government bond yields. The availability of mortgages in Switzerland, which is dependent on the interest rate levels, can be seen as one of the limiting factors for demand and therefore real estate prices, as supply is inelastic. The Swiss National Bank's Cash Rate on the other hand, which serves as one of the tools for monetary policy, is lagging behind the development in house prices. In theory this is not surprising as the SNB is focused on the development of the real estate market because it had already experienced a sever bubble in the late 1980s. However, the direction of the correlation is counter intuitive and thus prevents a clear interpretation. Only in the aftermath of the global financial crisis of the late 2000s, we see that the Cash Rate is leading house price development, again showing a negative correlation. This can be explained by the reduced interest rates that put additional stimulus in the already prospering real estate market.

IV.5.2. MONEY AGGREGATES AND HOUSE PRICES

The following analysis investigates the dynamic dependency between the Swiss Money Aggregates and the residential Property Prices. Figure 61 illustrates the steady increase of the Swiss money supply over more than 20 years. Only during the periods of recessions, namely the early 1990s, the dotcom bubble in 2000 and the most recent financial crisis, a decline in money supply can be seen on all three levels. With the beginning of economic recovery during 2002 and especially in late 2008, monetary authorities drastically increased the supply of money again.

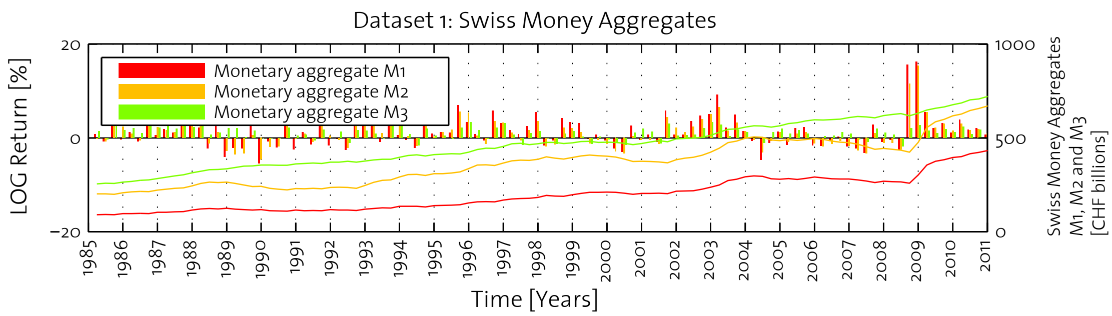

Figure 61: Quarterly development of the Swiss Monetary Aggregates M1, M2 and M3 published by the Swiss National Bank between the first quarter of 1085 and the last quarter of 2010

The representation of the dynamic lead-lag relationship can be seen in Figure 62 and Figure 63. In the first part of the analysis until the early 1990s, the results suggest that the level of property prices was leading the changes in Swiss Money Aggregates. Thereafter, the interdependence moves towards a lead of the money supply over the real estate prices, with the exception of the M3 Money Aggregate (which includes M2 as well as bank's time deposits). In addition to the analysis presented here, we also applied the TOP method to the time series of the residential PPI for all Flats. The results are similar in the qualitative structure, however they are shifted along the y-axis. The outcomes of the first decade between 1985 and 1995 are ambiguous, also considering the fluctuation in the causal direction, while during the period of 2000 to 2011 all datasets showed similar interdependences with a tendency towards a negative correlation. The major characteristic that is present in all three analyses is the disturbed lead-lag relationship in 2008, where suddenly the lead-lag structure moves toward a lead of the Money Aggregates over the house prices. This perfectly matches the time of the expansionary monetary policy of the Swiss National Bank, which supported the recovery of the Swiss economy and simultaneously a further increase in real estate prices. However, as the direction of causality cannot be finally determined, the results remain weak in their power to explain.

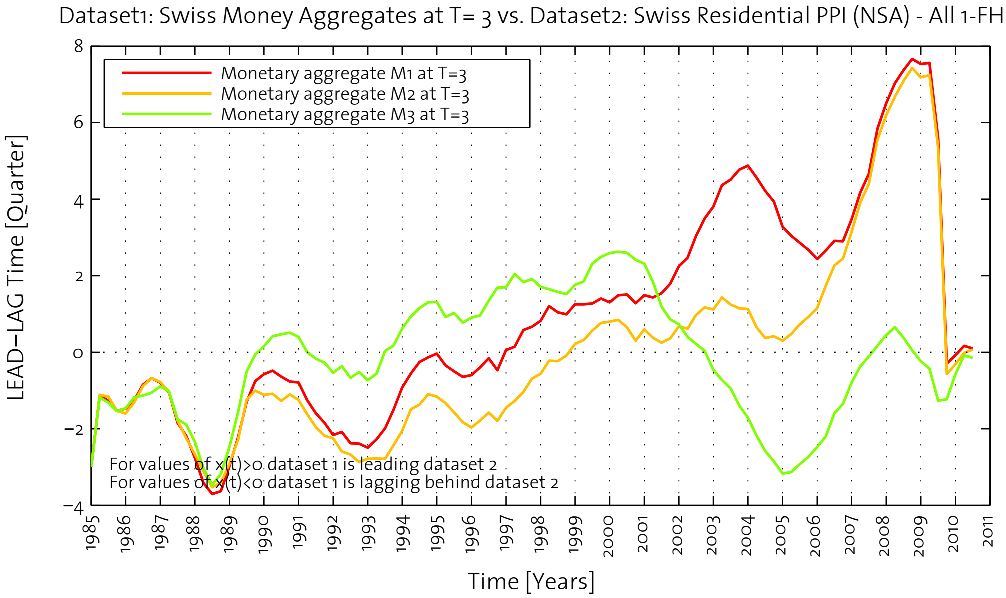

Figure 62: Lead-Lag dependence $x(t)$ between between the returns of three Swiss Monetary Aggregates and the returns of the Swiss Residential Property Price Index for all one family houses on a quarterly level at temperature T=3

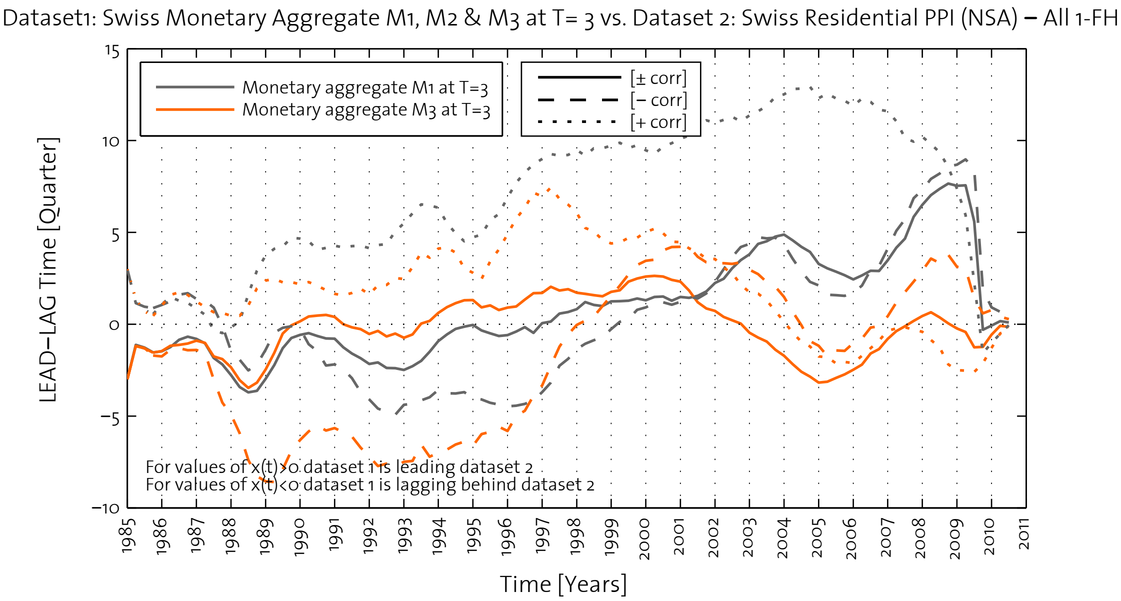

Figure 63: Variation of the Lead-Lag dependence $x(t)$ relative to the assumption of strict monotonic (negative correlation (ϵ_+) and positive correlation (ϵ_-)) as well as non-monotonic behaviour (negative/positive correlation ($\epsilon_\pm$)

V. DISCUSSION

In theory, the influence of monetary policy on the development of real estate prices is well described. Using its two main instruments, target interest rates and money supply, monetary authorities should be able to stimulate distressed economies or even disarm economic overheating. The target interest rate level is therefore of utmost importance, because it directly determines the conditions of money lending and therefore liquidity in the financial market. The same is also true for the money supply, which allows central banks not only to tame inflation but also to enhance output and consumption. Furthermore, the real estate sector contributes to the wellbeing of the global economy by stimulating household's wealth (Tobins' q theory) and thus consumption.[49,33]

The real estate market, being a market of the largest single assets owned by households and firms, is strongly dependant on external financing options. Such options are usually in the form of mortgages, especially for private residential real estate, which are provided by banks or other financial institutions. The costs of these mortgages are indirectly correlated to the base rate of central banks. Depending on type of mortgage, whether it is based on fixed or adjustable rates, the terms depend on market values of medium- and long-term interest rates. These interest rate levels are usually represented by the 1-year LIBOR or 1-year Government Bond yields respectively 10-year Government Bond yields that in theory are based on the future discounted expected Target Central Bank interest rates with some inflation adjustments[127].

Consequently, when the Central Bank lowers target interest rates, real estate financing options become more affordable. This in turn leads to a shift in the demand for owning a house, which impacts the prices of real estate[128]. Despite most of the exogenous supply and demand factors of property prices (location, building stock respectively income, demographics, etc.), interest rates[129]are equal across a country, allowing for a homogeneous increase in price levels. Similar effects are expected when monetary authorities increase the money supply, which should lead to an increasing demand in real estate. However, while empirical evidence for the causal relationship between interest rates and house prices is well established[8,14,15,43,95], similar studies for the influence of money supply are more controversial[96,97,130].

These macroeconomic interdependences are also known as transmission channels, which can be summarized into a "financial accelerator" mechanism and a "risk-taking channel". Both theories underline the mutual relationship between the real estate and the credit market. On one side, lower interest rates will result in rising prices for real estates and collateral values because of higher discounted future costs, which lead to increasing net worth of households as well as expanding debt capacities and a simultaneously decreasing default risks of banks[43,95,131]. On the other side, low interest rates force financial institutions to target riskier assets to remain at a certain rate of return, leading to property valuations that further depart from their fundamentals and increasing lending activates of banks[132,133].

Using the Thermal Optimal Path Method to discover the dynamic interdependence between real estate markets and monetary policy, we confirm parts of the described theory and its mechanism. Despite the heterogeneity of the datasets comprising Australia, China, the United Kingdom, the United States and Switzerland, we are able identify common patterns in the lead-lag structure. The analysis focuses on five major types of datasets. For the real estate market we use house price indices based on different methodologies, housing statistics and stock market indices as a proxy for development of the real estate sector. The open market operations of monetary authorities are modelled by interest rates covering three different maturities (Base Rate, 1-year LIBOR and 10-year Government Bond yields) and the monetary aggregates monitored by the central banks.

The lead-lag analyses between house prices and interest rates reveal a relatively stable interrelation of the real estate market and monetary policy during periods of prospering economic activity. The results suggest that prior to the economic turbulences caused by the bust of the dotcom bubble, changes in interest rates lead the development of real estate prices based on a negative correlation. These findings are in line with most of the literature regarding this topic.[8,14,15,43,95]. However, the results illustrate that this relationship only exists with respect to the type of interest rate that is a relevant proxy for a country's mortgage market. In particular, our study indicates that the correlation effects of Central Banks Base Rate or 1-year LIBOR are more pronounced than of the 10-year Government Bond Yields. This is especially true for Australia and the United Kingdom that are dominated by real estate financing options based on adjustable rate mortgages (ARM) and therefore show a strong linkage to the short- and medium-term rates (see also Jäger and Voigtländer[134]). The real estate prices in the United States, based on theory, should be strongly related to the 10-year Treasury Bill yields, but our results suggest the short-term Federal Fund Rate to be more meaningful. For the case of China we find all interest rates to be leading the development of house prices. In average, the lead-lag patterns are found to exhibit a time delay of roughly six to twelve month, depending on the country and the maturity of the interest rates.

In the aftermath of the bust of the dotcom bubble and its economic downswing, an interest rate shock leads to disturbances in the lead-lag structure as well as in the direction of correlation between interest rates and house prices. This shock is particularly significant for the results of Australia and the United Kingdom, which as described above have a mortgage market that is mainly based on ARMs. The finding harmonises with previous literature that has shown that countries with dominating ARM contracts are increasingly prone to the influences of monetary shocks[134,95], caused by changes in interest rates[135].

With the recovery of the affected economies and the turning of monetary authorities towards expansionary monetary policy we observe that the lead-lag patterns return to their previous state. In the following years, until late 2006, the results suggest a similar lead relationship of the interest rates over the real estate prices. However, for China and the United States, this behaviour cannot be observed. Both countries move towards a lead of house prices over the development of interest rate levels based on a positive correlation, especially for the Central Banks Base Rate. In the United States, this can already be identified in mid 2004, correlating with an almost exponential growth in the real estate sector[136]. Therefore, the results visualise attempts of the central banks to cope with an overheating real estate market by increasing their target interest rate, which is in line with recent findings in literature.[4,130,137,138]

The last period of analysis between 2006 and today produces more controversial results. While in Australia, the United Kingdom and Switzerland the lead-lag patterns suggest a lead of the interest rates over the changes in house prices with only minor bumps towards a lag during the time of the US house price crash, the outcomes for United States and China remain on the level as described above.

In a simplified view we can summarise our findings and identify three types of lead-lag regimes between interest rates and house prices. First, the results suggest some kind of post crisis periods of economic recovery that are combined with decreasing or stably low interest rates that lead the real estate market based on a negative correlation, resulting in continuous house prices increases. The second type is characterized by healthy economic conditions, which allow central banks to return to higher interest rate levels. These periods similarly show a leading relationship of the interest rates over the house prices, except for the countries that experience an overheating of the real estate sector. Finally, there are periods of economic crises that are based on two substantially different economic conditions. On one side, a crisis like the dotcom bubble, which was primarily affecting the level of the stock markets, forced central banks to react on the contraction of the economy by lowering target rates and increasing money supply. This positively impacted the housing market, which was already prospering by that time. On the other side, the most recent crisis triggered by the bust of the housing bubble in the US and the following credit crunch was more severe in its nature because it affected all classes of assets. However, for countries that did not cope with a real estate bubble, the most recent crisis behaved like the previous financial market crisis and lead to a further appreciation of housing prices. This effect is also documented by Ott et al.[139] who described the international financial linkage as a cause for propagation of the economic downswing.

For the case of the United Kingdom and the United States a second part of the analysis focuses on the impact of monetary policy on the variations in housing statistics. In theory, the level of house prices should have a direct impact on the amount of houses for sale[140]. Homeowners generally have a reservation value for their property, which is quite insensible compared to changes in the market value. When prices fall, real estate owners are more likely to withdraw from the market (if they are not facing severe financial constraints) because they are reluctant from selling at a loss. Comparing the theory with our results, we see that in the US it was changes in prices that led the fluctuation of houses for sale during the last decade. This has a positive correlation with a time delay of between 4 and 10 month and it increases around the years of the credit crunch. This seems to be reasonable[141] in the light of insecure real estate market perspectives.

Going a step further, we also investigated the relationship between changes of interest rate level and the amount of houses sold. From the theoretical perspective this is similar to the previous considerations because, as shown above, we find interest rates being a driver for the development of real estate prices[142]. Yet, the fluctuation of houses sold additionally depends on the availability of financing options and therefore on the demand for housing. Again, the result can partly prove the theory as shown by the 5 to 12 month lead between US interest rate levels and the amount of single family houses sold. Especially interesting to observe in the dynamics of the lead-lag patterns is the increase of the lead relationship during 2003, at the point when the US housing boom picked up in speed and the following reduction of the lead relationship, which is directly associated to the increase in interest rate levels to counteract the formation of a real estate bubble. This analysis clearly demonstrates the sensitivity of housing markets towards changes of the general interest rate levels.

As a last step we conducted an analysis of the relationship between interest rate levels and house price changes and the development of approved loans within the United Kingdom. With the mortgage market being the main source of real estate financing, the implications are straightforward. Both low interest rates and high property prices are expected to result in an increased amount of approved loans[143]. The background for this behaviour is essentially the homeowner's wealth effect and the financial accelerator mechanism as described above. The results suggest that for both cases, the amount of approved UK mortgages is lagging behind the UK interest rate changes and the UK house price index with a time delay of roughly 5 month. The direction of correlation is ambiguous for the interest rate levels and negative for the house prices, which hinders a clear interpretation. However, once again we observe strong reactions of the lead-lag pattern during the times of financial crises, especially in 2008's credit crunch. Unfortunately, we could not compare these findings with other countries because of the limited availability of such data.

Coming back to the influence of monetary policy on real estate prices, we investigate the interdependence of the development of the money supply on the housing market. However, the results vary inconsistently between countries and over time. For Australia and Switzerland, the returns of house prices lead the changes in money aggregates by 6 to 12 month until the beginning of the 21st century, followed by a regime shift towards a lead of the house price indices. For the United States, this relationship seems to be reversed, while the interdependence within the United Kingdom does not allow a conclusion et al. As interest rates are the dominant instrument of monetary authorities and are also essential for the control of the money supply, we conclude that the majority of the lead-lag information of this dataset is already covered in the analysis of the dependency towards the interest rates. Nevertheless, the results once more show strong signs of perturbations of the lead-lag patterns during the times of economic disturbances and realignment of monetary policy.

Finally, in a last dataset the dynamic correlation between volatility of Stock Market Real Estate Indices and the changes of interest rates are analysed. While in the study we only present the case of Australia, we additionally conducted similar analysis for the US and the European market. All outcomes show a qualitatively similar pattern, which is a continuous lead of the stock market index based on a positive correlation over the development of interest rate levels. This finding is in accordance with Guo et al.[122] who found similar results for the dependence of US S&P 500 Stock Market Index and various US interest rates. The main explanation provided for this finding is that, especially in times of economic uncertainty, the Federal Reserve is increasingly mindful about the stock market behaviour. This directly translates to the housing market, which is regarded as one of the most important assets in today's economies.

Summing up these findings, we can say that the volatility of the lead-lag path seems to have changed over the last two decades. Part of this can be explained by the increasing amount of global interconnection of capital markets[139], which eases international propagation of economic shocks[32,34]. Therefore, economies and the monetary policies of their central banks are not depending solely on the regional market development any more. For the case of the housing market especially the securitization of real estate caused such an increasingly strong interconnection[144]. When looking at the results gained from this study, we see that countries that did not have their own housing bubble now have to deal with further increasing real estate prices, which are even amplified through a reduction in interest rate levels because that country's banking sector suffered from the US credit crunch.

VI. CONCLUSION

Using the Thermal Optimal Path (TOP) Method introduced by Sornette and Zhou[119], we investigate the dynamic lead-lag interdependence between the real estate market and monetary policy for the case of five exemplary countries. Our study enhances previously existing literature by providing a time resolution to the correlation analysis between the datasets. This allows for the first time to have an instantaneous representation of the effects on the lead-lag structure for the case of regime changes within the underlying data. The study suggests that models that assume a constant-correlation, both in direction of correlation and causality as used in the majority of empirical studies, may be insufficient when describing the relationship between monetary policy and the real estate market.

Based on the in-depth discussion of the individual results gained by the lead-lag analysis of each country, we observed common denominators that seem to be valid for the entire study.

- During periods of economic recoveries with stable low interest rate levels or prospering economies accompanied by rising interest rates, a lead-lag pattern with only minor fluctuations can be observed. The results of these periods suggest a lead of the interest rates over the returns of house prices based on a negative correlation with approximately 6 to 12 month time delay.
- This lead is especially pronounced in relation to Central Banks Base Rate and 1-year LIBOR in markets that are dominated by adjustable rate mortgage.
- Economic contractions that are followed by realignments of monetary policy cause great fluctuations in the lead-lag relationship. This represents strong market insecurities, as the movements of monetary authorities are less foreseeable[5]. The direction of the lead-lag perturbation as well as the direction of correlation depends strongly on the causes of the crisis.
- Concerning the interaction of real estate markets and monetary policy, there seems to be a difference between the most two recent crises that struck world economy. An economic downswing that is correlated with on-going depreciations in the real estate market tends to lead to a regimes shift of the lead-lag relationship towards a lead of the housing market over the interest rate levels. In the case of only temporary losses or even no impact on the housing values, the lead-lag relationship often exhibits only a small disturbance before it returns to the initial setup.
- The influence of money supply on changes in real estate prices is ambiguous. Because our results cannot provide a homogeneous picture, we conclude that most of the monetary authorities' intention concerning real estate markets is already included in the movements of target interest rates.

However, since the direction of correlation and therefore the predictive relationship changes frequently over time, further studies are needed to understand the factors that drive these dynamics within the interrelations on a regional level.

VII. Acknowledgments

The completion of this Master Thesis represents the end of my studies at the ETH Zürich. I am very grateful for the help and encouragement of Professor Sornette who initiated this project allowing me to join his skilful team at the Chair of Entrepreneurial Risks. I also want to thank Qunzhi Zhang and Peter Cauwels for the support during the research process.

REFERENCES

1 Stock, J.H., Watson, M.W., 2003. Forecasting output and inflation: the role of asset prices. Journal of Economic Literature 41, 788–829.

2 Bernanke, B., Gertler, M., Gilchrist, S., (1994). The financial accelerator and the flight to quality. Review of Economics and Statistics 78, 1–15.

3 Aoki, K., Proudman, J., & Vlieghe, G. (2004). House prices, consumption, and monetary policy: a financial accelerator approach. Journal of Financial Intermediation, 13(4), 414–435. Elsevier.

4 Borio, C., and P. Lowe (2004), Securing Sustainable Price Stability: Should Credit Come Back from the Wilderness?, Paper presented at the ECB Workshop on 'Asset Prices and Monetary Policy', 11–12 December 2003, Frankfurt.

5 Adam, K., Kuang, P., & Marcet, A. (2011). House Price Booms and the Current Account. CEP Discussion Papers. Centre for Economic Performance, LSE.

6 Bordo M. D. and Jeanne O. (2002). Monetary Policy and Asset Prices: Does 'Benign Neglect' Make Sense?, International Finance, 5, 2, 139-164.

7 Goodhart, C., and B. Hofmann (2003), 'Deflation, Credit, and Asset Prices', forthcoming in P. Siklos and R. Burdekin, The Anatomy of Deflation, Cambridge: Cambridge University Press.

8 Giuliodori, M. (2005): Monetary Policy Shocks and the Role of House Prices across European Countires, Scottish Journal of Political Economy, 52, 519– 543.

9 Demary, M. (2009). The Link between Output, Inflation, Monetary Policy and Housing Price Dynamics. MPRA Paper. University Library of Munich, Germany.

10 Jarocinsky, M. and F. Smets (2008), House Prices and the Stance of Monetary Policy. Federal Reserve Bank of St. Louis Review, July-August 2008; 90(4): 339-65

11 Dreger, Ch. and J. Wolters (2009a), Geldpolitik und Vermögensmärkte. Vierteljahreshefte zur Wirtschaftsforschung 78(1): 56-65.

12 Assenmacher-Wesche, K. and S. Gerlach (2009), Financial Structure and the Impact of Monetary Policy on Asset Prices. Working Paper, Swiss National Bank & Goethe Univer- sity Frankfurt.

13 Luciani, M. (2010). Monetary Policy, the Housing Market, and the 2008 Recession: A Structural Factor Analysis. Working Papers, 1–41. Doctoral School of Economics, Sapienza University of Rome.

14 Hume, M and Sentance, A (2009), The global credit boom: challenges for macroeconomics and policy, Journal of International Money and Finance, Volume 28, Issue 8, pages 1,426-61.

15 Sa, F., Towbin, P., & Wieladek, T. (2011). Low interest rates and housing booms: the role of capital inflows, monetary policy and financial innovation. Bank of England working papers. Bank of England.

16 Oikarinen, E., Hoesli, M., & Serrano, C. (2010). Response speeds of direct and securitized real estate to shocks in the fundamentals. Discussion Papers. Aboa Centre for Economics.

17 Diamond, D and Rajan, R (2009), `The credit crisis: conjectures about causes and remedies', American Economic Review: Papers and Proceedings, Vol. 99, Issue 2, pages 606-10.

18 Zhu, H. (2005). The importance of property markets for monetary policy and financial stability. BIS Papers chapters, 21, 9–29. Bank for International Settlements.

19 Hendershott, P., (1994). Rental Adjustment and Valuation of Real Estate in Overbuilt Markets: Fundamental versus Reported Office Market Values in Sydney Australia. NBER Working Paper 4775.

20 Herring, R., Wachter, S., (1999). Real Estate Booms and Banking Busts: an International Perspective. The Wharton Financial Institutions Centre. Working Paper 99-27.

21 Borio, C, N Kennedy and S Prowse (1994): Exploring aggregate asset price fluctuations across countries: measurement, determinants and monetary policy implications, BIS Economic Papers, no 40.

[22] Bank for International Settlements (1993): Asset prices and the management of financial distress, 63rd Annual Report, Basel, pp 155-81.

[23] Khor, Martin. (1998) The Economic Crisis in East Asia: Causes, Effects, Lessons. Third World Network.

[24] Kane, E.J. (1989)The S&L Insurance Mess: How Did It Happen? Washington, D.C.: Urban Institute Press,.

[25] Tsatsaronis, K. and Zhu, H. (2004), What drives housing prices dynamics: cross country evidence, BIS, Quarterly Review,

[26] McCarthy, and Peach, R. (2002), Monetary policy transmission to residential investment, FRB New York, Economic Policy Review.

[27] Bessone, A.-J., Heitz, B. and Boissinot, J. (2005), Are we seeing a bubble on the French housing market?, INSEE

[28] Martínez Pagés, J. and L. Ángel Maza, (2003), Analyses of house prices in Spain, Banco de España, Documento de trabajo.

[29] Terrones M. and Otrok C. (2004), The global house price boom, IMF, World Economic Outlook

[30] Bandt, O., Barhoumi, K., & Bruneau, C. (2010). The International Transmission of House Price Shocks. (O. Bandt, T. Knetsch, J. Peñalosa, & F. Zollino, Eds.) Housing Markets in Europe: A Macroeconomic Perspective (pp. 129–158). Berlin, Heidelberg: Springer Berlin Heidelberg

[31] Ortalo-Magné, F., & Prat, A. (2010). Spatial Asset Pricing: A First Step. CEPR Discussion Papers. C.E.P.R. Discussion Papers.

[32] Vansteenkiste, I., & Hiebert, P. (2009). Do house price developments spill over across euro area countries? Evidence from a Global VAR. Working Paper Series. European Central Bank.

[33] Goodhart, C., & Hofmann, B. (2008). House prices, money, credit, and the macroeconomy. Oxford Review of Economic Policy, 24(1), 180–205.

[34] Kiyotaki, N., Michaelides, A., & Nikolov, K. (2011). Winners and Losers in Housing Markets. Journal of Money, Credit and Banking, 43, 255–296. Blackwell Publishing.

[35] Fry, R., Martin, V. L., & Tang, C. (2008). A New Class Of Tests Of Contagion With Applications To Real Estate Markets. CAMA Working Papers. Australian National University, Centre for Applied Macroeconomic Analysis.

[36] Mun, S. (2005). Contagion and the Real Estate Markets of the Pacific Rim Countries, PhD Thesis submitted to the University of Auckland.

[37] Hatemi-J, A., & Roca, E. (2010). The Impact of the US Real Estate Market on Other Major Markets During Normal and Crisis Periods. Discussion Papers in Finance. Griffith University, Department of Accounting, Finance and Economics.

[38] Costello, G., Fraser, P., & Groenewold, N. (2010). House Prices, Non-Fundamental Components and Interstate Spillovers: The Australian Experience. Economics Discussion / Working Papers. The University of Western Australia, Department of Economics.

[39] Sommervoll, D. E., Borgersen, T.-A., & Wennemo, T. (2010). Endogenous housing market cycles. Journal of Banking & Finance, 34(3), 557–567. Elsevier.

[40] Rouwendal, J., and Longhi, S. (2007). The Effect of Consumers' Expectations in a Booming Housing Market. Tinbergen Institute Discussion Papers. Tinbergen Institute.

[41] Leamer, E. E. (2007). Housing is the business cycle. Proceedings, 149–233. Federal Reserve Bank of Kansas City.

[42] Ahearne, A. G., Ammer, J., Doyle, B. M., Kole, L. S., & Martin, R. F. (2005). Monetary policy and house prices: a cross-country study. International Finance Discussion Papers. Board of Governors of the Federal Reserve System (U.S.).

[43] Iacoviello, M. (2005). House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. American Economic Review, 95(3), 739–764. Boston College Department of Economics.

[44] Ando, A., and F. Modigliani (1963), "The ''Life Cycle'' Hypothesis of Saving: Aggregate Implications and Tests", American Economic Review, 53, 55–84.

45 Deaton, A. (1992), Understanding Consumption. Oxford: Oxford University Press.

46 Muellbauer, J. (1994), The Assessment: Consumer Expenditure, Oxford Review of Economic Policy, 10, 1–41.

47 Goodhart, C., and B. Hofmann, (2000), Do Asset Prices Help to Predict Consumer Price Inflation, The Manchester School, 68(Supplement), 122–40

48 Goodhart, C., and B. Hofmann, (2000), Financial Variables and the Conduct of Monetary Policy, Sveriges Riksbank Working Paper No. 112.

49 Tobin, J. (1969), A General Equilibrium Approach to Monetary Theory, Journal of Money, Credit and Banking, 1, 15–29.

50 Kennedy, N., and P. Andersen (1994), Household Saving and Real House Prices: An International Perspective, BIS Working Paper No. 20.

51 Case, K., J. Quigley and R. Shiller (2001), Comparing Wealth Effects: The Stock Market versus the Housing Market, Cowles Foundation Discussion Paper No. 1335, Yale University.

52 Kiyotaki, N., and J. Moore (1997), Credit Cycles, Journal of Political Economy, 105, 211–48

53 Bernanke, B., and M. Gertler (1989), Agency Costs, Collateral and Business Fluctuations, American Economic Review, 79, 14–31

54 Bernanke, B., M. Gertler and S. Gilchrist (1998), The Financial Accelerator in a Quantitative Business Cycle Framework, NBER Working Paper No. 6455

55 Fisher, I. (1933), The Debt-Deflation Theory of Great Depressions, Econometrica, 1, 337–57.

56 Daglish, T., (2009). What motivates a subprime borrower to default? Journal of Banking and Finance 33, 681–693.

57 Niinimaki, J.-P., (2009). Does collateral fuel moral hazard in banking? Journal of Banking and Finance 33, 514–521.

58 Koetter, M., & Poghosyan, T. (2010). Real estate prices and bank stability. Journal of Banking & Finance, 34(6), 1129–1138. Elsevier.

59 Bernanke, B. S., & Gertler, M. (1995). Inside the Black Box: The Credit Channel of Monetary Policy Transmission. Journal of Economic Perspectives, 9(4), 27–48. American Economic Association.

60 Allen, F., Gale, D., (2001). Comparing Financial Systems. MIT Press, Cambridge.

61 Collyns, C., & Semlali, A. S., (2002), Lending Booms, Real Estate Bubbles and The Asian Crisis, IMF Working Papers, International Monetary Fund

62 Chen, N. -K. (2001), Bank Net Worth, Asset Prices and Economic Activity, Journal of Monetary Economics, 48, 415–36

63 Keynes, J. (1931), The Consequences for the Banks of the Collapse in Money Values, in Essays in Persuasion, London: Macmillan

64 Hacker, J. S. (2006). The Great Risk Shift: The New Economic Insecurity and the Decline of the American Dream

65 Lea, D. M. (2010). Alternative Forms of Mortgage Finance: What Can We Learn From Other Countries? Retrieved June 23, 2011, from http://www-rohan.sdsu.edu/~realest/images/Harvard-Lea.pdf

66 Borio, C. E. V. (1995). The structure of credit to the non-goverment sector and the transmission mechanism of monetary policy: a cross-country comparison. BIS Working Papers. Bank for International Settlements.

67 Structural factors in the EU housing markets. (2003, March). Structural factors in the EU housing markets. European Central Bank.

68 Deep, Akash and Dietrich Domanski (2002): Housing markets and economic growth: lessons from the US refinancing boom, BIS Quarterly Review, September.

69 George Lefcoe (2009), Real Estate Transactions, Finance, and Development, 6th ed., LexisNexis.

70 Borio, Claudio, Craig Furfine and Philip Lowe (2001): Procyclicality of the financial system and financial stability: issues and policy options, BIS Papers, no 1.

71 G10 Contact Group on Asset Prices (2002): Turbulence in asset markets: the role of micro policies.

72 Barkham, R. and D. Geltner. 1995. Price Discovery in American and British Property Markets. Real Estate Economics 23: 21-44.

73 Maddaloni, A., & Peydró, J.-L. (2010). Bank risk-taking, securitization, supervision and low interest rates: Evidence from the euro area and the U.S. lending standards. Working Paper Series. European Central Bank.

74 BIS (2004) Bank Failures in Mature Economies. Basel Committee on Banking Supervison, Working Paper No. 13.

75 Levitin, A., & Susan, W. (2010). Explaining the Housing Bubble (pp. 1–81). University of Pennsylvania Institute for Law & Economics Research Paper No. 10-15, Georgetown Public Law Research Paper No. 10-60, Georgetown Law and Economics Research Paper No. 10-16.

76 John B. Taylor (2009), Getting off track: How government actions and interventions caused, prolonged, and worsened the financial crisis

77 Pinto, E. (2009). Acorn and the Housing Bubble. The Wall Street Journal; Wallison, P. J. (2009). The True Origins of This Financial Crisis. The American Spectator; Sowell, T. (2009, May). Housing Boom and Bust. nationalreview.com

78 DellAriccia, G., Igan, D., & Laeven, L. (2008, April). Credit Booms and Lending Standards: Evidence from the Subprime Mortgage Market. IMF Working Paper

79 Eggert, K. (2009). The Great Collapse: How Securitization Caused the Subprime Meltdown. Connecticut Law Review, Vol. 41, No. 4, 2009.

80 Bhardwaj, G., & Sengupta, R. (2008). Where's the smoking gun? a study of underwriting standards for US subprime mortgages. Working Papers. Federal Reserve Bank of St. Louis

81 Demyanyk, Y., & Van Hemert, O. (2007). Understanding the subprime mortgage crisis. Supervisory Policy Analysis Working Papers. Federal Reserve Bank of St. Louis

82 Keys, B. J., Mukherjee, T., Seru, A., & Vig, V. (2008, April). Did Securitization Lead to Lax Screening? Evidence From Subprime Loans

83 Mian, A., & Sufi, A. (2008). The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis

84 Shiller, R. J. (2006), Irrational Exuberance (2nd edition)

85 Brunnermeier, M. K., & Julliard, C. (2007). Money Illusion and Housing Frenzies. Review of Financial Studies, 21(1), 135–180

86 Green, R. and S. Malpezzi, (2003), A Primer on US Housing Markets and Housing Policy, Urban Institute Press

87 Halvorsen, R. and H. O. Pollakowski (1981): Choice of functional form for hedonic price equations, Journal of Urban Economics, 10, pp 37-49.

88 Shiller, R. J. (1993): Measuring asset values for cash settlement in derivative markets: hedonic repeated measures indices and perpetual futures, Journal of Finance, 68(3), pp 911-31, July.

89 Case, B. and J. M. Quigley (1991): The dynamics of real estate prices, Review of Economics and Statistics, 73(1), pp 50-8.

90 IMF (2005) World Economic Outlook, Chapters I and II, Economic Outlook, September, International Monetary Fund, Washington D.C., USA.

91 BIS (2005) 75th Annual Report, Chapters IV and VIII, Report, Bank of International Settlements, Basel, Switzerland.

92 de Lucia, C. (2007). Did the FED Inflate a Housing Price Bubble? A Cointegration Analysis between the 1980s and the 1990s. ISAE Working Papers. ISAE - Institute for Studies and Economic Analyses - (Rome, ITALY).

93 Adrian, T., and H. S. Shin, (2009) —Money, Liquidity, and Monetary Policy, American Economic Review 99 (2), 600–605.

94 De Nicolo, G., G. Dell'Ariccia, L. Laeven, and F. Valencia, (2010) —Monetary Policy and Risk Taking, IMF Staff Position Note No. 2010/09.

95 Calza, A., Monacelli, T., & Stracca, L. (2009). Housing Finance and Monetary Policy. Working Paper Series. European Central Bank.

96 Borgy, V., Clerc, L., & Renne, J.-P. (2010). House price Boom/Bust Cycles: Identification Issues and Macro-prudential Implications. (O. Bandt, T. Knetsch, J. Peñalosa, & F. Zollino, Eds.)Housing Markets in Europe: A Macroeconomic Perspective (pp. 359–383). Berlin, Heidelberg: Springer Berlin Heidelberg.

97 Belke, A., Orth, W., & Setzer, R. (2008). Sowing the seeds for the subprime crisis: does global liquidity matter for housing and other asset prices International Economics and Economic Policy, 5(4), 403–424. Springer.

98 Berlemann, M., & Freese, J. (2010). Monetary Policy and Real Estate Prices: A Disaggregated Analysis for Switzerland. Working Paper. Helmut Schmidt University, Hamburg.

99 Leamer, E. (2007), Housing is the business cycle, NBER, Working Paper, No. 13428.

100 Essaadi, E., & Boutahar, M. (2008). A Measure of Variability in Comovement for Economic Variables : a Time-Varying Coherence Function Approach. Post-Print. HAL.

101 Takens, F. (1981). Detecting strange attractors in turbulence. In D. Rand & L.-S. Young (Eds.), Lecture Notes in Mathematics (Vol. 898, pp. 366–381). Springer Berlin / Heidelberg SN

102 Marwan, N., Thiel, M., & Nowaczyk, N. R. (2002). Cross recurrence plot based synchronization of time series. Nonlinear Processes in Geophysics, 9, 325–331.

103 Marwan, N., Kurths, J. (2002) Nonlinear analysis of bivariate data with cross recurrence plots. Physics Letters A 302, 299—307.

104 Marwan, N., CARMENROMANO, M., Thiel, M., & Kurths, J. (2007). Recurrence plots for the analysis of complex systems. Physics Reports, 438(5-6), 237–329.

105 Forni, M. (2002). Using Stationarity Tests in Antitrust Market Definition. CEPR Discussion Paper, (3236).

106 Granger, C.W.J., (1969). Investigating causal relations by econometric models and cross-spectral methods. Econometrica 37 (3), 424–438

107 Engle, R. F., & Granger, C. W. J. (1987). Co-integration and Error Correction: Representation, Estimation, and Testing. Econometrica, 55(2), 251–76. Econometric Society.

108 Campos, J., Ericsson, N. R., and Hendry, D. F. (1996). Cointegration tests in the presence of structural breaks. Journal of Econometrics, 70, 187–220.

109 Kremers, J. J. M., Ericsson, N. R., and Dolado, J. J. (1992). The power of cointegration tests. Oxford Bulletin of Economics and Statistics, 54, 325–348.

110 Kiviet, J. F., and Phillips, G. D. A. (1992). Exact similar tests for unit roots and cointegration. Oxford Bulletin of Economics and Statistics, 54, 349–367.

111 Banerjee, A., J. J. Dolado, J. W. Galbraith, and D. F. Hendry (1993). Co-integration, Error Correction and the Econometric Analysis of Non-Stationary Data. Oxford: Oxford University Press.

112 Hjalmarsson, E., & Österholm, P. (2009). Testing for cointegration using the Johansen methodology when variables are near-integrated: size distortions and partial remedies. Empirical Economics, 39(1), 51–76. Springer.

113 Brockwell, P. J. & Davis, R. A. (1991) Time Series: Theory and Methods (Springer, NY)

114 Priestley, M. B. (1989) Spectral Analysis and Time Series (Academic Press, London)

115 Hudgins, L., Friehe, C., & Mayer, M. (1993). Wavelet transforms and atmopsheric turbulence. Physical Review Letters, 71(20), 3279–3282.

[116] Torrence, C., & Compo, G. P. (1998). A Practical Guide to Wavelet Analysis. Bulletin of the American Meteorological Society.

[117] Torrence, C. and P. J. Webster (1999). Interdecadal changes in the enso-monsoon system. Journal of Climate 12(8), 2679–2690.

[118] H. Gish and D. Cochran. (1988). Generalized coherence. In International Conference on Acoustics, Speech, and Signal Processing, pages 2745–2748

[119] Sornette, D., & Zhou, W.-X. (2005). Non-parametric determination of real-time lag structure between two time series: the “optimal thermal causal path” method. Quantitative Finance, 5(6), 577–591

[120] Zhou, W.-X., & Sornette, D. (2006). Non-parametric determination of real-time lag structure between two time series: The “optimal thermal causal path” method with applications to economic data. Journal of Macroeconomics, 28(1), 195–224.

[121] Zhou, W.-X., & Sornette, D. (2006, July 22). Lead-lag cross-sectional structure and detection of correlated-anticorrelated regime shifts: Application to the volatilities of inflation and economic growth rates.

[122] Guo, K., Zhou, W.-X., Cheng, S.-W., & Sornette, D. (2011). The US stock market leads the Federal funds rate and Treasury bond yields. Quantitative Finance Papers.

[123] Wang, X.-H., Havlin, S., & Schwartz, M. (1999). Directed polymers at finite temperatures in 1+1 and 2+1 dimensions. The Journal of Physical Chemistry, 104(16), 3875–3880.

[124] Jaccard, I. (2006). House Prices, Real Estate Returns and the Business Cycle. Swiss Finance Institute Research Paper Series. Swiss Finance Institute.

[125] Pavlov, A., & Wachter, S. (2010). REITs and Underlying Real Estate Markets: Is There a Link University of Pennsylvania Law School, Law & Economics Research Paper Series. Retrieved September 15, 2011

[126] http://www.abs.gov.au/

[127] Fisher I (1930) The theory of interest. Macmillan, New York, NY

[128] Adams, Z., & Füss, R. (2010). Macroeconomic determinants of international housing markets. Journal of Housing Economics, 19(1), 38–50. Elsevier.

[129] Muellbauer, J. und A. Murphy (2008): Housing Markets and the Economy: The Assessment, Oxford Review of Economic Policy 24, S. 1-33.

[130] Xu, L., & Ye, Y. (2011). Monetary policy rules and house price in Chinese economy, 935–938. IEEE. doi:10.1109/ICCIT.2010.5711194

[131] Davis, E. P., & Zhu, H. (2009). Commercial property prices and bank performance. The Quarterly Review of Economics and Finance, 49(4), 1341–1359. Elsevier.

[132] Rajan, R. (2005), Has financial development made the world riskier?, paper presented at “The Greenspan Era: Lessons For the Future” – A symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 25-27.

[133] Borio, C., H. Zhu (2008), Capital regulation, risk-taking and monetary policy: a missing link in the transmission mechanism?, BIS Working Paper 268.

[134] Jäger, M. and M. Voigtländer (2006), ”Immobilienfinanzierung”, IW-Analysen No. 22, Institut der deutschen Wirtschaft Köln.

[135] International Monetary Fund. September 2004. World Economic Outlook: The Global Demographic Transition. : http://www.imf.org/external/pubs/ft/weo/2004/02/index.htm.

[136] http://thesecreteconomist.blogspot.com/2010/01/monetary-policy-and-house-prices_29.html

[137] Dokko, J., Doyle, B., Kiley, M. T., Kim, J., Sherlund, S., Sim, J., & Van den Heuvel, S. (2009). Monetary policy and the housing bubble. Finance and Economics Discussion Series. Board of Governors of the Federal Reserve System (U.S.).

138 Mishkin, F. S. (2007). Housing and the monetary transmission mechanism. Finance and Economics Discussion Series Working Paper. Board of Governors of the Federal Reserve System (U.S.).

139 Ott, H. (2007). Three Empirical Essays on House Prices in the Euro Area. Munich Dissertations in Economics. University of Munich, Department of Economics.

140 Kodrzycki, Y. K., & Gerew, N. (2006). Using state and metropolitan area house price cycles to interpret the U. S. housing market. Public Policy Brief. Federal Reserve Bank of Boston.

141 Oikarinen, E. (2009). The reaction speeds of prices and transaction volume in the Finnish housing market to demand shocks. Discussion Papers. Aboa Centre for Economics.

142 http://www.americanprogress.org/issues/2011/05/debt_ceiling_housing.html

143 Glaeser, E. L., Gottlieb, J. D., & Gyourko, J. (2010). Can Cheap Credit Explain the Housing Boom NBER Working Papers. National Bureau of Economic Research, Inc.

144 Bredin, D., O'Reilly, G., & Stevenson, S. (2010). Monetary policy transmission and real estate investment trusts. International Journal of Finance & Economics, 16(1), 92–102.