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# The nexus between housing and GDP re-visited: A wavelet coherence view on housing and GDP for the U.S.

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## Abstract

Does the U.S. housing market lead the U.S. GDP? This paper contributes to this ongoing debate but is different from its predecessors: Using continuous wavelets and U.S. quarterly data between 1991 and 2014, the paper finds evidence of a significant time-varying lead-lag relationship between GDP and house prices. In particular, the main findings are: First, we show that housing leads the business cycle only in times of the recent economic crisis but does not significantly contribute to growth during time of expansion. Second, we find that housing shocks are predominantly short-lived during the times of the recent economic crisis.

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# 1 Motivation

Since the "Great Recession", many politicians and economists believe that the housing market plays a decisive economic role. Housing contributes substantively to total economic wealth. According to Kim (2004), housing represents 30% of the world's wealth. The relevant literature has identified two relevant channels which both suggest that house prices affect economic growth. First, the collateral channel states that increasing housing prices relax an agent's borrowing constraint in a world of ex-ante financially constrained agents. As a direct consequence, consumption increases and finally, economic growth is stimulated. Second, the wealth channel states that an unexpected housing shock increases homeowners' wealth which in turn stimulates economic growth. According to these theories, one can conjecture that house prices lead the GDP.

In this contribution we employ the continuous wavelet methodology[1] and re-visit the nexus of housing and GDP, which has so far drawn much academic interest. Generally spoken, the wavelet analysis combines both, the time as well as the frequency domain. More precisely, the wavelet transform has the appealing attribute that it measures low frequency movements by stretching into a long wavelet function and measures high frequency movements by compressing into a short wavelet function (Aguiar-Conraria and Soares (2011a)).

The wavelet analysis can be directly applied to non-stationary time series as well as to the analysis of markets, which like the housing market, exhibit complicated patterns over time, such as abrupt changes during the economics crisis. Compared to standard and established time-series methods, e.g. linear VAR models, the wavelet transform is able to capture local events in time (Fan and Gençay (2010, p.1307)) and is, as we will see later, a suitable instrument to detect time-varying leading effects of housing and GDP.

Using data for the U.S. economy, we find, first, evidence for a time-varying leading effect of housing and GDP during the years of the housing bubble and the recent economic crisis. This finding is clearly at odds to the great majority of linear time-series methods, which have been employed so far to investigate the GDP-housing link and which, in

[1] Although the idea of employing continuous wavelets for the analysis of economic time series is not new, the number of articles is still limited (see for instance, Caraiani (2012), Aguiar-Conraria and Soares (2011a, 2011b, 2012 and 2014), Reboredo and Rivera-Castro (2013) and Tiwari et al. (2013).

contrast to our suggested method, are unable to detect such time-varying effects satisfactorily. Second, as the wavelet analysis also takes frequency dimension of the housing and GDP nexus into account, for the recent economic crisis we can show that housing shocks are predominantly significantly short-lived. Lower frequencies however, seem to be less relevant, particularly at later stages of the crisis period.

The plan of the paper is as follows. Section 2 provides a literature review. Section 3 introduces some elements of the continuous wavelet methodology, Section 4 presents the results, and, Section 5 concludes.

## 2 Literature Review

It is not astonishing that since the beginning of the recent economic crisis, a large number of theoretical[2] as well as empirical studies focus directly on the GDP-housing nexus. Meanwhile, there is broad consensus that much of the strength of the U.S. economy in the mid-2000s can be directly traced back to the U.S. housing boom (Jurgilas and Lansing (2013)). Moreover, Sutton (2002), for the UK, Canada, Ireland, The Netherlands, Australia and the U.S., and Égert and Mihaljek (2007) for the OECD countries found that GDP was the most significant contributor to the observed house price dynamics. Finally, Briscoe (2007), p. 2 points out that "*[...] the domestic property market is important to economic policy makers. When the housing market is strong, growth is boosted and inflation can threaten. A bursting property bubble ranks highly among the most important threats - easily being able to drag a country into recession.[...]*".
However, referring to the empirical literature, the relationship between house prices and GDP appears to be ambiguous. For England and Wales, Ortalo-Magné and Rady (2004) found a positive correlation of income and housing prices over the business cycle. For the U.S., Iacoviello (2004) shows that housing prices drive consumption fluctuations. Green (1997) performs a Granger-causality analysis (Granger (1969)) of housing investments and GDP for the U.S. His findings suggest that housing leads the U.S. business cycle and, in particular, for Northern California, Green (2002) finds evidence for a pro-

[2]For instance, see Iacoviello (2005), Davis and Heathcote (2005), Fisher (2007) for the investigation of the importance of housing in the business cycle.

nounced wealth effect. Sutton (2002) and Égert and Mihaljek (2007) showed that GDP contributes most to the house price dynamics. Kim (2004) could not confirm the findings made by Green (1997) for Korea. Within a VARX approach, Edelstein and Lum (2004) fail to confirm that changes in private house prices have an impact on aggregate consumption. Based on U.S. metropolitan data, Miller et al. (2011) observe that house price changes significantly affect the growth rate of per capita GDP. Finally, Bostic et al. (2009) find a reverse wealth effect by showing that a 10 percent reduction in housing wealth directly reduces real GDP growth by 1 percentage point. Based on a rich micro data-set, Campbell and Cocco (2005) find a large positive effect of house prices on consumption for old households who are homeowners, but find no evidence for a wealth effect for the cohort of young households who rent a home.

Recently, there are doubts that the housing-GDP causality does not change over time. In other words, a proper investigation of the housing-GDP causality requires a methodology, which is able to take into account this asymmetry. As a reflex to that, one small strand of literature investigates the housing-GDP link with a Markov-Switching VAR (MS-VAR) approach[3]. Although this approach is able to test whether or not the housing-GDP causality does change over time, it also has some limitations: First, it requires that variables are stationary and, second, it completely leaves out the frequency domain. Instead, the validity of the wavelet approach neither requires the stationary of variables or assumes a linear relationship. In contrast to standard time-series methods, it further provides us with new insights regarding the housing-GDP causality, if we take the frequency domain into consideration.

Some authors further argue that the house sector's leading effect on GDP disappears, if one controls for monetary aggregates (Smeets (2007)). There is strong evidence that monetary transmission affects the housing market (see e.g. Del Negro and Otrok (2007), Iacoviello and Minetti (2008), Iacoviello (2005) and Goodhart and Hofmann (2008)). However, based on a MS-VAR model for the U.S., Lee and Chen (2014) have recently shown that the leading effect of the housing market on GDP remains strong even if monetary aggregates are included. Hence, the inclusion of monetary aggregates affect but do not replace the leading behavior of the housing market.

[3]For recent contributions in this direction see Lee and Chen (2014) for the U.S. and Chowdhury and Maclennan (2014)) for the UK.

As the literature overview suggests, the great majority of the existing empirical literature employ linear VAR or error correction models to investigate the housing-GDP nexus. Inter-alia, this implies that the housing-GDP causality does not change over time. As we will see later, the wavelet methodology enables us to investigate whether or not we find a significant time-varying causality between housing and GDP. The next section introduces some basic concepts of the employed wavelet methodology.

## 3 The continuous wavelet methodology: Some relevant tools

In this section we provide the reader with some key elements of the continuous wavelet transform (CWT). A superb introduction into this methodology is given by Aguiar-Conraria and Soares (2011a, 2011b, 2012 and 2014). For an easier interpretation we often refer to the notation of the former mentioned authors. Intuitively, a wavelet transform of a discrete time series can be described as a simultaneous mapping of the time series into a time and frequency function. More precisely, for a discrete time series $z(t) \in \mathscr{L}^2(\mathbb{R})$, the CWT with respect to the wavelet $\psi$ is given by the following function of two variables $\tau$ and $s$:

$$W_z(\tau, s) = \int_{-\infty}^{+\infty} z(t) \frac{1}{\sqrt{|s|}} \hat{\psi}\left(\frac{t-\tau}{s}\right) dt. \tag{1}$$

The time domain position of the wavelet is denoted by $\tau$, whereas its position in the frequency domain is given by $s$. $\tau$ controls the location of the wavelet. If $|s| > 1$, the wavelet is stretched, whereas for $|s| < 1$, the wavelet is compressed. Contrary to the Fourier transform, the CWT provides us with a time localization of the time series. Finally, the $\hat{}$ denotes the use of complex conjugation.

The choice of the so-called mother wavelet $\psi(t)$ is important. The relevant literature suggests several wavelet functions which offer different characteristics (e.g. Mexican Hat, Haar, Morelet etc.). The choice of the "correct" wavelet depends on the application the researcher has in mind. In the present study, we are particularly interested in the synchronism between GDP and housing. Hence, we have to search for a complex-valued wavelet because we are primarily interested in both, the phase and the amplitude of the time series. Being the most popular complex-valued wavelet, we choose the Morlet

wavelet as advised by Aguiar-Conraria and Soares (2011b) because this features some pleasant attributes which considerably simplify the interpretation of the result[4] derived below.

For a time series $\{z_k, k = 0, 1, ..., K-1\}$ with $K$ observations, we obtain the discrete version of equation (1) with time step $\delta t$ as:

$$W_l^z(s) = \frac{\delta t}{\sqrt{s}} \sum_{k=0}^{K-1} z_k \hat{\psi}\left((k-l)\frac{\delta t}{s}\right), \text{ for } l = \{0, 1, ..., K-1\}. \tag{2}$$

The wavelet-power spectrum can be computed as $|W_k^z|^2$. For two time series, $z_k$ and $y_k$, the cross wavelet transform can be analogously represented as:

$$W_k^{zy} = W_k^z \hat{W}_k^y, \tag{3}$$

whereas the cross wavelet power is defined as $|W_k^{zy}|$. For a univariate time series environment, economic turbulences, such as the recent economic crisis should be directly associated with higher wavelet power as the wavelet power spectrum reflects the variance of the time series.

For our analysis, we require an instrument which quantifies and detects appropriately the relationship between two variables, namely the coherence between housing and GDP. The wavelet coherence, defined as

$$R_k(s) = \frac{|S(s^{-1}W_k^{zy}(s))|}{S(s^{-1}|W_k^z|)^{0.5} S(s^{-1}|W_k^z|)^{0.5}} \tag{4}$$

helps us to shed light into the frequency-time dependencies between those two variables. $S$ represents a smoothing parameter, both in scale and time (see Aguiar-Conraria et al. (2008)).

Finally, to find out whether the housing market leads the GDP or vice versa, we employ the concept of phase difference as this provides us with the delay of the oscillations of our two time series as a function of frequency (see Bloomfield et al. (2004)). The phase

[4]The introduction of the Morlet wavelet can be traced back to the work accomplished by Goupillaud, Grossman and Morlet (1984).

difference reads as:

$$\phi_{z,y} = \arctan\left(\frac{\mathcal{I}(W_k^{zy})}{\mathcal{R}(W_k^{zy})}\right), \tag{5}$$

with $\phi_{z,y} \in [-\pi, \pi]$. If the two time series move together at a given frequency, the phase difference turns out to be zero. For $\phi_{z,y} \in \left[0, \frac{\pi}{2}\right]$, two time series move in phase, whereas y leads z. If $\phi_{z,y} \in \left[-\frac{\pi}{2}, 0\right]$, $z$ leads $y$. For $\phi_{z,y} \in \left[\frac{\pi}{2}, \pi\right]$, $z$ leads $y$, for $\phi_{z,y} \in \left[-\pi, -\frac{\pi}{2}\right]$, $y$ leads $z$. A phase difference of $|\pi|$ shows anti-phasing. Intuitively, the phase difference helps us to clearly identify the delay between the oscillations of two time series. In the broad sense, this can be interpreted as an alternative for conducting a Granger-causality analysis.

## 4 Results

We draw on quarterly data for the U.S. economy between 1991 and the second quarter of 2014. The choice of the sample period is dictated by the housing boom phase and the recent economic crisis. From Federal Reserve Economic Data (FRED) we obtain data for the real GDP. Like Glaeser et. al. (2010), we use the Federal Housing Finance Agency (FHFA) price index which is deflated with the GDP deflator[5]. Both series are seasonally adjusted. We follow (Iacoviello and Minetti (2008)) and use the house price as a cyclical housing market indicator.

For the continuous wavelet analysis, we rely on the toolbox *ASTool* developed by Luís Aguiar-Conraria and Maria Joana Soares[6]. As mentioned above, the empirical literature is ambiguous regarding the causal direction between GDP and housing. With the wavelet coherency and phase-difference analysis it is possible to investigate the synchronicity between housing and GDP. Figure (1) presents the wavelet coherency between housing and GDP as well as the corresponding phase differences between $1-4$ and $4-8$ year frequencies.

[5]Alternatively, one can refer to the S&P/Case-Shiller home price index, which is available, e.g. on Robert Shiller's website: http://www.econ.yale.edu/ shiller/data.htm. It turns out that the derived results are not sensible regarding the choice of the house price index.

[6]See `https://sites.google.com/site/aguiarconraria/joanasoares-wavelets/the-astoolbox`.

### 4.1 Wavelet coherency analysis

Figure (1.1) provides information regarding the strength of local correlation between housing and GDP. The black (grey) contour shows whether or not this correlation is significant at the 5% (10%) level.

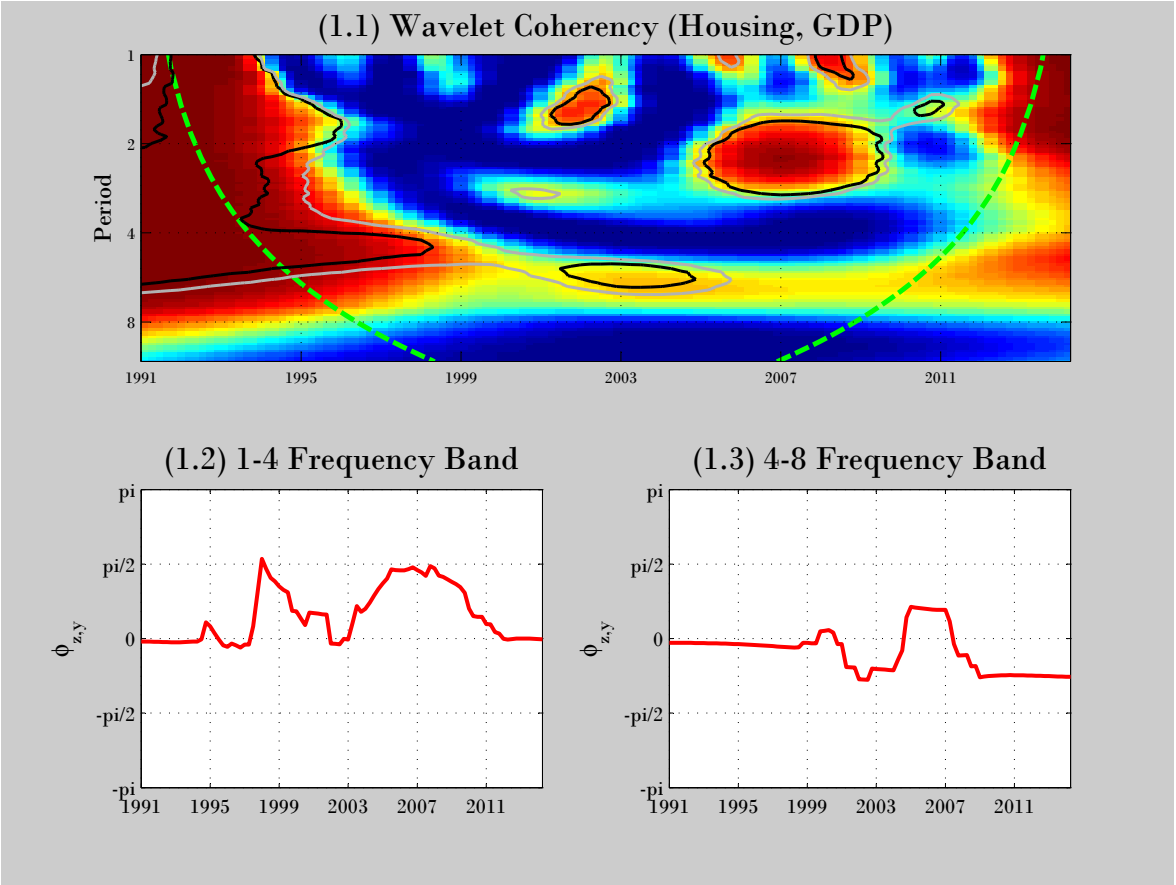


**Figure 1**: The relationship between housing and GDP through wavelet coherence: (1.1) Wavelet coherency between housing and GDP. The black (grey) contour lines indicates the 5% (10%) level of significance estimated by Monte Carlo simulations (500 trials). The coherency color spectrum ranges from blue (low choerency) to red (high coherency). The cone of influence, which shows the region affected by so-called edge effects, is the outside region of the thick-dotted, green line. (1.2) Phase difference at $1-4$ years frequency band. (1.3) Phase difference at $4-8$ years frequency band.

If we focus on the entire sample period, it is apparent that we observe a strong coherency of housing and GDP at a $1-8$ year frequency from 1991 until 1995. After 1995 it seems that first, the coherency between GDP and housing becomes weaker and, second, concentrates on the $5-8$ years period frequency band until 2001. From 2001 until 2010

we observe high power regions, indicating a strong relationship both at $1-4$ years frequencies and $4-8$ years frequencies. Interestingly, in times of the U.S. housing bubble, housing and GDP exhibit a significantly strong coherence pattern at $1-4$ years frequencies. Also apparent, we further detect a changing behaviour of coherence in the years between the housing bubble and the recent economic crisis: in particular between 2001 and 2005, GDP and housing are synchronized at a 5% significance level at $4-6$ frequencies, whereas over the years of the recent crisis, GDP and housing become even stronger synchronized at a 5% significance level at $2-4$ year frequencies. Hence, the most striking aspect is this obvious change in the predominant frequencies during the years of the housing bubble and the recent economic crisis, which we will discuss in more detail below.

### 4.2 Phase difference

Figure (1.2) and (1.3) show the phase difference ($1-4$ and $4-8$ years frequency, respectively). We observe that the phase difference $\phi_{z,y}$ is always in the $\phi_{z,y} \in \left[-\pi, -\frac{\pi}{2}\right]$ range, which indicates that both series are positively correlated for the entire sample. However, the leading pattern of housing and GDP changes several times[7]. For an economic interpretation of this behavior, we will come back to this point later.

### 4.3 Implications

In this section we link economic intuition to our aforementioned results. For this purpose we concentrate on the time span $2001-2011$, which comprises the housing bubble as well as the recent economic crisis. If we first focus on the period of the U.S. housing bubble $2001-2006$, we find significantly strong coherency at the 4-8 years frequency (figure (1.1)). Further the phase-difference is between $-\frac{\pi}{2}$ and 0 (figure (1.3)), suggesting that GDP increases anticipated upswings in the housing sector not only in the longer run (at $4-8$ years frequency) but also in the shorter run (at $4-8$ years frequency), at least in the early stage of the housing bubble from 2001-2003. Thus, in times of the housing bubble, we cannot find evidence for a leading behavior of the housing variable.

[7] Note that for $\phi_{z,y} \in \left[0, \frac{\pi}{2}\right]$ it turns out that $z$ leads $y$, whereas for $\phi_{z,y} \in \left[-\frac{\pi}{2}, 0\right]$, $y$ leads $z$.

If we now focus on the times of the economic crisis ($2007-2011$), we observe that the significantly strongest region of high coherency is in the $1-4$ years frequency band (1.2)). Now, the phase difference is located between 0 and $\frac{\pi}{2}$, which is in line with the idea that negative housing shocks anticipate downturns of GDP. Interestingly, from a point of significance, we cannot confirm this finding for the $4-8$ years frequency band. In particular, during the observed period of the economic crisis, there is clear evidence that housing significantly leads GDP.

### 4.4 Discussion

This subsection discuss the results in the light of existing studies and further highlights some important differences compared to our findings. From our analysis above, we can derive the following results: First, in the years of the economics crisis, our causality analysis directly suggests that housing leads output. This finding is echoed by Green (1997), Coulson and Kim (2000), Leamer (2007), Case and Quigley (2008) and Strauss (2013) who emphasize the role of the housing sector on imminent recessions (Leamer (2007)). Thus, in times of the financial crisis, we can confirm a (negative) wealth effect. Second, in the years of the housing bubble, however, this picture is completely reversed. In the early stages of this period, it seems that in particular short-term positive income shocks increased the demand for housing, which translates directly into a sharp price increase as both, GDP as well as the housing variable are significantly positively correlated. However, this can be interpreted as a transitory phenomenon, as it disappears in the later stages of the booming phase. Thus, we do not find evidence for a wealth effect in those times. From our wavelet analysis we might further conjecture that housing leads the business cycle only in times of recessions but does not significantly contribute to growth during times of expansion.

In a nutshell, our results suggests that the relation between housing and gpd is obviously asymmetrically time-varying. This finding is in line with findings made by Stock and Watson (2003) who emphasize that leading indicators for GDP are not stable over time. Taking Stock and Watson (2003) seriously, this might explain why empirical results of the leading role of housing markets for the U.S. economy are mixed. Before the economic crisis, it was common to employ linear regression models to study the relationship

between house prices, housing markets and the macro-economy, also for the U.S. economy[8]. Some studies, such as Ghent and Owyang (2010), used regional U.S. data and employed a linear VAR model to investigate whether or not housing leads the business cycle. While Ghent and Owyang (2010) found no leading behavior of housing, others e.g. Rapach and Strauss (2007, 2009), Vargas-Silva (2008) and Stock and Watson (2004) report evidence that economic aggregates, such as income, predict movements in house prices. However, as our results indicate that the housing-output causality may vary over time, results based upon linear (VAR) regression models should be interpreted with care.

As shown above, the wavelet approach takes this non-linear behavior into account and can be therefore seen as a promising alternative to recently published empirical literature which recognize the asymmetric impact of housing on the macro-economy by estimating predominantly Markov-Switching models[9], applying asymmetric Granger tests[10] or employ asymmetric error correction models like Abelson et al. (2005) for Australia. Although Markov-Switching models can detect the asymmetric impact of housing on macro-economic variables, nevertheless, they remain silent to the question whether or not cycles at different frequencies contribute equally to the total variance of the house price change. Instead, our methodology is not only able to show that negative housing shocks anticipate downturns of GDP during the economic crisis. Further, it can answer the question, whether or not the shock pattern itself changes over time, i.e. whether or not housing-shocks are short-lived during the economic crisis. In particular, during the observed period of the economic crisis, we show that housing-shocks are significantly short lived.

Finally, there is a strand of medium and large scale VAR literature with a important focus on the interplay of housing and credit markets and the macro-economy. The results are mixed. For instance, based on a medium scale VAR for several European countries, Iacoviello and Minetti (2008) highlight the important role the housing sector plays in creating a significant credit channel for monetary policy endeavors. This important find-

[8] See Englund and Ioannides (1997), Tsatsaronis and Zhu (2004) who each focuses on a sample of OECD countries, which also includes the U.S.A.

[9] For the U.S., see Corradin, Fillat, and Vergara-Alert (2014). For Europe, refer to Corradin and Fontana (2013), and for UK regions see Chowdhury and Maclennan (2014)).

[10] For U.S. regions refer to Kim and Bhattacharya (2009).

ing is supported by the VAR studies conducted by Iacoviello (2005) and Del Negro and Otrok (2007) who underpin the important role of monetary transmission effects for the evolution of the housing market. In a recent contribution, Luciani (2015) employs a large scale dynamic factor model for the U.S. economy to investigate the role of monetary policy for the evolution of the U.S. housing market. The author points out that the FED's monetary policy between 2002 and 2004 does only marginally contribute to the housing cycle and, further, a restrictive policy smooths the cycle but does not prevent the economy from a recession. With respect to our methodology, one reason for the mixing results mentioned above could be the fact that monetary policy affects the housing sector different at different frequencies, which also implies that the existence of a credit channel in this context is also a question of investigated frequencies. We leave this issue for further research.

One drawback of our approach is that we do not control for possible regional house price heterogeneity. However, this would imply to focus on regional housing markets which is beyond the scope of this contribution. Nevertheless, it is worth mentioning that using the wavelet analysis for a sample of U.S. regions, Flor and Klarl (2015) investigate in a recent contribution, whether or not regional house price cycles at different frequencies tend to be more synchronized after the burst of the U.S. housing bubble in 2007. In particular they find evidence for geographic club convergence at 2-4 years frequency, and thus fail to confirm that all regional housing markets are significantly synchronized with the U.S. housing market after the burst of the housing bubble. The authors further confirm that some regions drive the evolution of the U.S. wide housing market significantly more than others.

## 5 Concluding comments

The investigation of the causal link between GDP and housing has been subject of numerous theoretical as well as empirical research. The present analysis shows that wavelets, in contrast to a simple Granger-causality analysis allows for a deeper investigation of the causal link between GDP and housing. With wavelets at hand, we are able to identify transient relations between GDP and housing as well as different relations of these

variables that occur at the same time but at different frequencies. The main findings are: First, we show that housing leads the business cycle only in times of the recent economic crisis but does not significantly contribute to growth during time of expansion. Hence, we find evidence for a time-varying leading effect of housing and GDP. Second, our wavelet analysis shows further that housing shocks are predominantly short-lived during the times of the recent economic crisis, which implies a change of expected returns of housing assets, and, hence, leads to a sudden reallocation of capital into alternative assets. Longer frequencies however seem to be less relevant. Thus, using wavelets can be regarded as a valuable extension to the (non-linear)Granger-causality approach, as it focuses on both the time as well as the frequency dimension of the housing and GDP nexus.

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