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The Evolution of Housing-Macro Nexus in Time-Frequency Space: The Case of Korea*

시간-빈도 공간상에서 거시 경제와 주택 시장의 연계: 한국의 경우

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< Abstract >

As well noted during the recent global financial crisis, the interdependence between housing markets and the macroeconomy has become increasingly important. Unfortunately, most studies on housing market fluctuations and macro-housing nexus are conducted in the time domain and often fail to incorporate critical time-varying features observed in data. In this paper, we use wavelet analysis to identify important changing time-frequency properties of housing price dynamics in Korea and their dynamic relationships with other variables.

We find that: (i) both the volatility and the length of housing price cycles have recently decreased; (ii) however, housing price fluctuations are, by and large, loosely associated with housing fundamentals, and their coherencies are found only at low frequencies, with such patterns disappearing in recent times; and (iii) instead, several housing price booms are associated with the increase in liquidity measures at high frequencies, whose specific features are time-varying as well.

Keyword : Housing Prices, Wavelet Analysis, Business Cycles, Housing-Macro Nexus

I. Introduction

In most industrialized economies, the housing sector constitutes a significant share of total expenditure and wealth and is closely intertwined with a range of other parts of the macroeconomy, including household consumption, taxation, residential investment, and housing finance, among others. Furthermore, as well noted during the global financial crisis of 2007-2009 (largely driven by real estate boom-bust cycles), this interdependence between housing markets and the macroeconomy has become even more important, indicating that it is critical to grasp the nature of the housing-macro nexus and its implications, both for analysis of housing market dynamics and designing related policies.

At the same time, an increasing body of evidence suggests that most macro variables (including housing market indicators) have exhibited various types of structural changes in their time series properties in the past several decades (see, for example, Igan et al., 2011; Ng and Wright, 2013). The housing market in Korea is not an exception to these observations, and

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recent studies provide evidence that Korean housing markets have also undergone notable structural changes in several aspects (Kim, 2004; Hwang et al., 2006; Kim and Park, 2016).

This study is concerned with the changing nature of housing price dynamics in Korea over time and aims to provide new insights on the issue from a macro perspective. In this context, the Korean housing market provides an interesting and useful case in several dimensions.[1] First, along with economy-wide privatization and deregulation occurring since the Asian financial crisis, substantial changes have also been observed in the Korean housing sector in the past decades with respect to underlying magnitudes and mechanisms. One example is a range of structural and institutional changes in housing finance markets, characterized by deregulation of the primary mortgage markets and their substantial growth, along with the emergence of a secondary mortgage market. In addition, the chonsei system, a housing lease contract unique to Korea, has become less important as a financing mechanism in recent years, as monthly rental contracts and mortgage financing have become more popular. Another notable feature is that, unlike other industrialized countries, Korean policymakers have a long history of actively implementing macroprudential policies (including adjustment of loan-to-value (LTV) ratios and debt-to-income (DTI) limits in recent times) to either stabilize or stimulate the real estate sector.

A novel feature of this paper is that we explore the time-varying features of the housing price fluctuations from a frequency perspective as well as over time. Despite the vast and growing literature on the linkages between housing markets and the macroeconomy,[2] the studies in this line are largely limited in the sense that they focus almost exclusively on the time domain in their analyses, with little attention to the frequency properties of data and their possible time-varying nature. However, both theoretical and empirical rationales suggest that the dynamic housing-macro nexus is likely to differ over horizons (i.e., short run versus long run and cycles versus trends) as well as over time (Igan et al., 2011; Simo-Kengne et al., 2015; Kishor and Marfatia, 2017). Hence, in the study of housing markets, it is crucial to distinguish the frequency scale of the data from the time scale as well as properly address their changing nature over time, and focusing on only one domain may result in the neglect of other important information in the data.

Methodologically, this study borrows several tools from wavelet analysis, a flexible approach that allows us to analyze the changing features of time series data in time-frequency space. Unlike the conventional Fourier transform, where the time-varying features of a series of interest are lost or averaged out, wavelet analysis, which can be seen as a general version of a Fourier transform, allows us to explore when and how the frequency domain properties of a series and its dynamic relationship with other variables have changed.

Although relatively newly introduced in economics, wavelet transform has been used in several studies with a wide range of applications, including business cycle analysis (Yogo, 2008; Rua, 2010; Aguiar-Conraria and Soares, 2011a), effects of monetary policy (Aguiar-Conraria et

1) For comprehensive reviews on the Korean housing market, see Kim (2004), Kim and Cho (2010), Renaud et al. (2016), and Kim and Park (2016)

2) The list of such studies is long and expanding. Recent examples include Igan et al. (2011), Bracke (2013), Simo-Kengne et al. (2015), Zimmer (2015), and Kishor and Marfatia (2017), among others. They all show that housing market dynamics and/or their interactive nexus with the macroeconomy exhibit a number of changing features over time as well as over business cycle phases

al., 2008), international co-movements of stock market returns (Rua and Nunes, 2009), the relationship between oil prices and industrial production (Aguiar-Conraria and Soares, 2011b), and the link between money growth and inflation (Rua, 2012a). However, despite its increasing popularity in other fields, applications of wavelet analysis in housing literature are essentially nonexistent.[3)]

In this study, we utilize a wavelet transform to explore the housing price dynamics in Korea and their relationships with a number of indicators of potential importance to housing markets (including macro and liquidity/credit indicators as well as asset prices) for the period of 1986 to 2017. We find important empirical evidence regarding the time-varying aspects of housing price fluctuations and the housing-macro nexus in time-frequency space.

The main results are as follows. First, there have been significant changes in housing price dynamics both in terms of the volatilities and the lengths of cycles. Specifically, the overall volatilities have significantly diminished in recent periods at low as well as high frequencies. At the same time, frequency regions with strong wavelet power have recently shifted from a medium/low frequency range to a higher one over time, indicating that housing price cycles have shortened. In particular, relatively long-run cycles seem to have largely disappeared since the 2000s.

Second, regarding the dynamic relationship between housing price and other relevant variables, the results suggest that the evolution of housing prices is, by and large, loosely linked with housing market fundamentals (such as industrial production and chonsei prices) as well as other asset prices (such as short-term interest rates, stock prices, and exchange rates). With these indicators, except for the two crisis periods, strong co-movements are found at low frequencies only, and such associations seem to have disappeared recently.

Third, on the contrary, we find that, at high and business cycle frequencies, housing price changes are more closely linked with liquidity indicators, such as narrowly defined money and short-term assets. In particular, several episodes of housing price booms or hikes during the 2000s are accompanied by increases in these liquidity measures, with specific components and their lead-lag relationships changing over time.

Overall, the evidence suggests that the evolution of housing price dynamics in Korea is largely asynchronous with the overall macro cycles and housing market fundamentals. Instead, it seems that housing prices may have their own cycles, whose short-run dynamics (especially booms) are usually accompanied or even driven by increases in liquidity measures alone, suggesting that the housing market may be in an unhealthy state and vulnerable to potential risks.

The remainder of this paper is structured as follows. Section 2 briefly describes wavelet analysis and related toolkits, which will serve as background reading for the following material. Section 3 presents the empirical results on housing price dynamics, first in a univariate perspective, followed by bivariate analysis, which will help us understand the dynamic relationship between housing prices and other relevant indicators. Section 4 concludes the paper.

3) A few recent exceptions are Kang et al. (2018) and Fan et al. (2019), where the dynamics of housing prices in major (international) cities are explored based on wavelet analysis. However, these studies do not explore how the housing prices are associated with macro fundamentals and other potential drivers of housing markets over time

II. Wavelet: An Intuitive Introduction

As wavelet analysis is a relatively newly introduced method in economics, we briefly describe its key ideas and main tools in this section before presenting the empirical results.[4] In doing so, we will focus on its idea and intuition, referring interested readers to other references for more advanced or technical discussions. In addition, since most economists are, to some extent, familiar with Fourier analysis, on which traditional spectral analysis is based, the discussion compares and contrasts the two (Fourier and wavelet analyses) when appropriate.

1. Frequency Domain Analysis

While a majority of research on time series data is conducted in the time domain (i.e., in terms of a sequence of data of interest), spectral analysis in the frequency domain provides information that is analogous yet informative from the frequency perspective (i.e., in terms of frequencies of the series' changes). The main toolkit in the frequency domain analysis is the Fourier transform. For a (discrete) time series x_t, its Fourier transform is given by:

$$x(\omega) = \sum_{t=-\infty}^{\infty} x_t e^{-i\omega t}, \quad (1)$$

where $i = \sqrt{-1}$ and ω is the (angular) frequency. This operation transforms a series, a function of time t, to a complex-valued function of frequency ω. Specifically, noting Euler's formula, that is, $e^{-i\omega t} = \cos(\omega t) - i \cdot \sin(\omega t)$, the spectral representation above implies that x_t is the sum of an infinite number of simple random components, represented by sines and cosines, each associated with a particular frequency ω.

Since the period, denoted by λ, is the amount of time it takes a wave to go through a whole cycle and is related to ω by $\lambda = 2\pi/\omega$, ω can be seen as the angular speed measured in radians. It is seen that low (high) frequencies are associated with cycles of long (short) periods, that is, with infrequent (frequent) shifts from a peak to a trough. Hence, trend components are represented in the low frequencies of the spectrum and irregular, short term, and/or transient fluctuations in the high frequencies.

One useful quantity in frequency domain analysis is the spectral density, defined as the Fourier transform of the autocovariance function:

$$S(\omega) = \frac{1}{2\pi} \sum_{j=-\infty}^{\infty} \gamma_j e^{-i\omega j}, \quad (2)$$

where $\gamma_j = Cov(x_t, x_{t-j})$ is jth autocovariance. The spectral density, or periodogram, decomposes the variance of the series into uncorrelated components at each frequency ω, and its interpretation is analogous to a standard probability density.

The above definitions and interpretations of spectral density for a univariate process can be easily extended to multivariate cases, that is, a vector of stochastic processes. For example, for two series x_t and y_t, we can define the cross-spectral density between the two series at frequency ω as

$$S_{xy}(\omega) = \sum_{t=-\infty}^{\infty} Cov[x_t y_{t-j}] e^{-i\omega j}, \quad (3)$$

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4) The discussion in this section is largely based on survey papers such as Crowley (2007), Ramsey (2012), Rua (2012), and Aguiar-Conraria and Soares (2014), all of which provide excellent reviews on wavelet analysis, with a focus on economics and finance. For a more advanced and rigorous treatment on wavelet analysis, one may refer to these articles and references therein

and a measure of the strength of the relationship between two series is given by the squared coherency:

$$Co(\omega) = \frac{|S_{xy}(\omega)|^2}{S_x(\omega)S_y(\omega)}, \tag{4}$$

where $|\ |$ indicates the real part (or the modulus) of a complex number. The coherency is the frequency domain version of the correlation coefficient, with large (small) values indicating stronger or tighter (weaker) co-movements (at frequency ω).

2. Wavelet Analysis

One of the shortcomings of the Fourier transform is its time-invariant nature. That is, while useful in revealing the frequency features of the series, the Fourier transform does not allow such content of data to change over time, and it therefore may not properly characterize data that have time-varying features.[5)]

In contrast, the wavelet transform uses flexible local base functions that can be scaled and translated (defined below) in both frequency and time. Specifically, in a wavelet transform, the time resolution is automatically adjusted to the frequency with the window width, narrowing when focusing on high frequencies while widening when assessing low frequencies. Allowing for windows of different sizes can improve the frequency resolution of the low frequencies and the time resolution of the high frequencies. This means that a certain high frequency component can be located better in time than a low frequency component, and vice versa. As it enables a more flexible approach to time series data, wavelet analysis can be seen as a refinement of Fourier analysis.

In line with recent studies that apply wavelet analysis to economics and finance, such as Aguiar-Conraria et al. (2012, 2014) and Rua (2012), we consider the continuous wavelet transform.[6)] The continuous wavelet transform of a time series x_t can be written as

$$W_x(\tau,s) = \int_{-\infty}^{\infty} x_t \psi^*_{\tau,s}(t)dt, \tag{5}$$

where * denotes the complex conjugate. The wavelet transform decomposes a time series x_t in terms of some basis functions (i.e., wavelets), $\psi^*_{\tau,s}(t)$, which is analogous to the use of sines and cosines in Fourier analysis, that is, $e^{-i\omega t} = \cos(\omega t) - i \cdot \sin(\omega t)$; see equation (1).

These basis functions are derived from the so-called mother wavelet, $\psi_{\tau,s}(t)$, and are defined as

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right), \tag{6}$$

where s is a scaling, or dilation, factor that controls the width of the wavelet, τ is a translation parameter controlling its location, and $1/\sqrt{s}$ is a normalizing factor to ensure unit variance and allows for wavelet transformations to be comparable across scales and time. Scaling a wavelet means stretching it (if $|s| > 1$,

5) This is similar to the case that a standard regression, assuming fixed model parameters, may not capture the possible change in the parameters over time. To overcome such limitations, the windowed, or short-time Fourier transform has been suggested. As the name suggests, its basic idea is to apply a short time window to the series and perform the Fourier transform within this window as it slides across all the data. The idea is similar to a rolling window estimation in a standard regression. The problem with the short-time Fourier transform is that there is a trade-off between time and frequency resolution, and both cannot be simultaneously known to an arbitrarily high precision, which is also analogous to the Heisenberg uncertainty principle in quantum physics

6) Alternatively, "discrete" wavelet transform has also been widely used in the past. For a comparison and discussion on merits and disadvantages of the two approaches, see Aguiar-Conraria and Soares (2014)

suitable for detecting lower frequencies) or compressing it (if $|s|<1$, suitable for detecting higher frequencies), while translating it means shifting its position in time. Consequently, these waves can be adjusted on the time scale by changing the dilation parameter (stretching or squeezing) to generate cycles that fit the actual data.

To be a mother wavelet, the basis function $\psi_{\tau,s}(t)$, must meet certain criteria called admissibility conditions. Although there are a number of functions that can be used for this purpose, the most commonly used mother wavelet for the continuous wavelet transform is the Morlet wavelet, which, in its simplified form, can be written as

$$\psi_{\omega_0} = \pi^{-1/4} e^{i\omega_0 t} e^{-t^2/t}, \qquad (7)$$

It can be shown that the Morlet wavelet consists of a complex sine wave within a Gaussian envelope. One of the main advantages of the Morlet wavelet is that it has an optimal joint time-frequency concentration, with the uncertainty attaining the minimum possible values.7)

The parameter ω_0 controls the number of oscillations within the Gaussian envelope. By increasing (decreasing) ω_0, one achieves better (poorer) frequency localization but poorer (better) time localization. In practice, setting ω_0 to 6 provides a good balance between time and frequency localization. Furthermore, with this value, the wavelet scale s is almost equal to the Fourier period, which thus eases the interpretation of wavelet analysis as well as allows us to use both terms (i.e., scale and period) interchangeably.

3. Wavelet Tools

As in Fourier analysis, several interesting quantities can be defined in the wavelet analysis. For instance, one can define the wavelet power spectrum as $|W(\tau,s)|^2$, which measures the relative contribution to the variance of the series at each scale and at each time.

Another quantity of interest is the cross-wavelet spectrum, which captures the covariance between two series in time- frequency space. Specifically, given the two time series x_t and y_t, with their continuous wavelet transforms, $W_x(\tau,s)$ and $W_x(\tau,s)$, respectively, the cross-wavelet spectrum is defined as $W_{xy}(\tau,s) = W_x(\tau,s)\, W_y^*(\tau,s)$, where $W_y^*(\tau,s)$ is the complex conjugate. The wavelet (squared) coherency is then given by

$$R^2(\tau,s) = \frac{S(W_{xy}(\tau,s))}{\sqrt{S(|W_x(\tau,s)|^2) S(|W_y(\tau,s)|^2)}}, \qquad (8)$$

where $S(.)$ denotes smoothing in both time and scale.8)

Thus, the wavelet cross-correlation is defined as the wavelet cross-covariance divided by the square root of the product of the wavelet power spectra of the two series. The $R^2(\tau,s)$ is between 0 and 1, with a high (low) value indicating a strong (weak) relationship.

The idea behind wavelet coherency is similar to that of coherency in Fourier analysis. Wavelet coherency measures the strength of the localized correlation coefficient between the two series in time-frequency space, while coherency in Fourier analysis only allows one to assess it in frequency domain only. Hence,

7) Theoretically, the time-frequency resolution of the continuous wavelet transform is bounded by the Heisenberg box, which describes the trade-off relationship between time and frequency. The area of the Heisenberg box is minimized with the Morlet wavelet. See Aguiar-Conraria and Soares (2014) for further details and advantages of the Morlet wavelet

8) As in Fourier analysis, smoothing is also required; otherwise squared coherency would be always equal to one

by observing the plot of wavelet coherency, one can distinguish the regions where the link is stronger in time-frequency space where the link is stronger and identify both time- and frequency-varying features of the series.

Finally, one can also compute the wavelet phase, which captures the lead-lag relationship between the variables in the time-frequency space. The wavelet phase difference is defined as

$$\phi_{xy}(\tau,s) = \tan^{-1}\left[\frac{I(W_{xy}(\tau,s))}{R(W_{xy}(\tau,s))}\right], \quad (9)$$

where R and I denote the real and imaginary parts, respectively. The resemblance with the analogous measure in Fourier analysis, $\phi(\omega) = \tan^{-1}[I(S_{xy}(\omega))/R(S_{xy}(\omega))]$ and its interpretation are clear. The phase difference gives us information on the degree of synchronization, or the lead-lag relationship between the time series as a function of time and scale/frequency. Specifically, a phase-difference of zero indicates that the two series move together at the specified time-frequency: if $\phi_{xy} \in (0,\pi/2)$, then the series move in phase, but the time series x leads y; if $\phi_{xy} \in (-\pi/2,0)$, then y is leading. A phase-difference of π (or $-\pi$) indicates an anti-phase relation; if $\phi_{xy} \in (\pi/2,\pi)$, y is leading; if $\phi_{xy} \in (-\pi,-\pi/2)$, x is leading. Note again that besides providing information about the lead-lag relationship across frequencies as in Fourier analysis, the wavelet phase also allows one to assess how and when such a lead-lag relationship has changed over time.

III. Empirical Results

This section presents the empirical results of the wavelet analysis applied to Korean data. We begin by presenting the univariate results on housing prices and then explore their time-varying relationships with a range of other relevant variables. These indicators are grouped as follows:[9]

- Macro variables: industrial production index and consumer price index (CPI)
- Asset prices: interest rate (3-year corporate bond yield, AA-), stock price (KOSPI index), and exchange rate (KRW/USD)
- Monetary aggregates: monetary base (MB), M1, and M2
- Other housing prices: chonsei price, housing price in Seoul, and US housing price

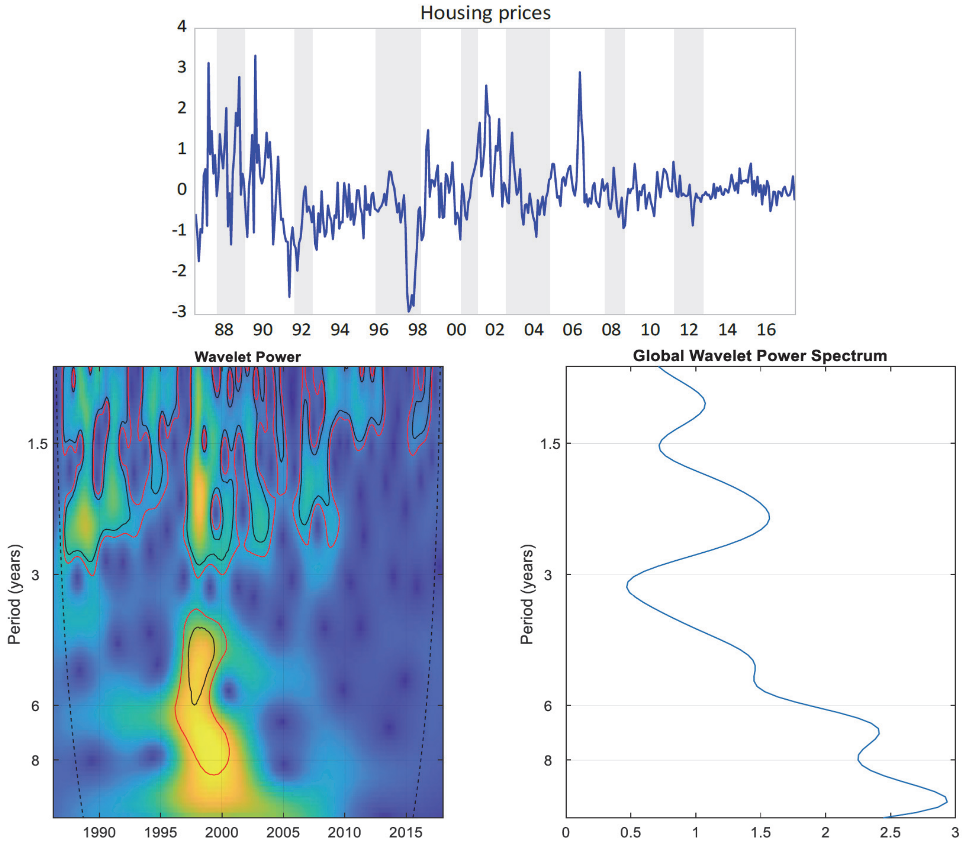
All the data are monthly series, spanning 1986:1 through 2017:12, and are obtained from the Bank of Korea, except for housing prices, which are collected from the Kookmin Bank database and the Federal Reserve Economic Data. All series are deflated by the CPI (except for industrial production) and are transformed as log differences, that is, growth rates (except for interest rate), before they are used in the wavelet transform. All the series except for the asset prices data are seasonally adjusted.

1. Evolution of Housing Prices

<Figure 1> plots the time series of real housing price growth rates (along with recession periods, shaded) and two (unconditional and wavelet) power spectra.

9) The selection of variables is partly based on the availability of data. For example, we use corporate bond yields for interest rates, mainly because popular short rates, such as call rates, are available only from 1991. Since the movement of the two series are largely similar, the results with the call rate are largely unchanged. In addition, regarding liquidity indicators, although mortgage market related data, rather than monetary aggregates, are more relevant, such data are available only from the mid-2000s. Finally, data for the corporate bond yield and the US housing prices start from 1987:1

<Figure 1> Housing prices and the wavelet power spectrum



Note: The top graph plots the monthly growth rate of real housing prices and official recession periods are shaded. In the wavelet power spectrum (the bottom left), the horizontal axis represents time and the vertical axis gives us the period. The power is given by the color. The color ranges from blue to red, with warm (cold) colors representing areas of high (low) power. The black and red contours respectively stand for the 1% and 5% significance levels. Dotted lines represent "the cone of influence," which indicates the region affected by edge effects, that is, border distortions at the beginning and the end of the time series. The bottom right figure is global wavelet power spectrum.

The black and red contours respectively stand for the 1% and 5% significance levels. Dotted lines represent "the cone of influence," which indicates the region affected by edge effects, that is, border distortions at the beginning and the end of the time series. The bottom right figure is global wavelet power spectrum.

One can see that there were approximately threemajor episodes of housing market booms in Korea in the time period considered. The first spans 1988-1990 and is followed by a decade-long sluggish market until the economy was smashed by the Asian financial crisis of 1997-1999 and weathered out its impacts. Recovering from the crisis, the second boom occurred over the period 2002-2003. The most recent boom occurred during 2006-2007, and since then the housing sector has remained more or less stable until the recent years.

However, it does not seem that these housing price cycles are tightly synchronized with the overall macro cycles. For example, except for the period of the Asian financial crisis, there are several recession episodes when housing prices tended to rise rather than fall or remain steady. At the same time, housing prices have experienced sluggish growth and even showed declines in a few expansion regimes, all of which indicate that the housing market may have its own cycles.

The unconditional, or global, power spectrum (in which the time-varying features are averaged out) in the bottom-right panel of <Figure 1> illustrates that the housing price fluctuations are mainly concentrated in low frequencies (peaking around ten years), along with relatively short-run cycles (around two years).

While informative, this alone fails to provide full information regarding how the nature of housing price cycles may have changed over time in terms of frequency.

In fact, the wavelet power spectrum, shown in the bottom-left panel of <Figure 1>, depicts a much richer picture and shows the overall frequency properties are mainly attributed to only a subsample.[10] Specifically, the low frequency cycles are largely due to the movements during the period 1995-2005, surrounding the Asian financial crisis. In contrast, the short-run fluctuations (i.e., one- to three-year frequencies) are scattered throughout the sample.

Another notable feature is the decline in overall volatilities of housing prices. Long-run volatilities have essentially disappeared since the early 2000s, and short-run fluctuations also seem to diminish after 2010. That is, undergoing the crisis, the housing price cycles seem to have somewhat shortened over time, accompanied by reduced variabilities.

2. Dynamic Relationships with Other Variables

Given that housing prices have experienced significant changes over time, this section attempts to uncover the possible mechanism behind the above findings. Specifically, by exploring the dynamic co-movements between housing prices and a range of other relevant indicators, we identify which indicators are mainly associated with the movements in housing prices, explore how and when such empirical properties have changed over time, and draw implications based on them. The analysis is based on wavelet coherency and phase difference, which can be easily calculated using bivariate wavelet analysis.

1) Macro variables

<Figures 2 and 3> plot the housing price wavelet coherencies and phase differences between the industrial production index (<Figure 2>) and CPI inflation (<Figure 3>).[11]

In the case of industrial production, while there are strong low frequency (i.e., over six to eight years) co-movements up until late 1990s, such patterns have essentially disappeared since then. At relatively high frequencies (i.e., around one to three years), housing prices tend to strongly co-move with industrial production during the periods around the Asian financial crisis and, to a somewhat lesser degree, the global financial crisis. However, other than these episodes, the two series seem largely

10) In the wavelet power spectrum, the horizontal axis represents time, and the vertical axis represents the period. To ease interpretation, the period is converted to time units (in years). The power is given by the color. The color ranges from blue to red, with warm (cold) colors representing areas of high (low) power. The black and red contours respectively stand for the 1% and 5% significance levels. To obtain the results, we first fit an ARMA(2,1) model with a GARCH(1,1) specification on disturbance and then construct new samples by bootstrapping. Dotted lines represent "the cone of influence," which indicates the region affected by edge effects, that is, border distortions at the beginning and the end of the time series

11) The wavelet coherencies show the degree of co-movements between two variables of interest, and the interpretation is basically the same as the wavelet power spectrum. In the right panel, we provide the phase-relations over two bands of high (i.e., less than one and a half years) and conventional business cycle frequency (i.e., one and a half to six years) and the unconditional coherency

unrelated. In particular, note that during several housing price booms (i.e., 1988-1990, 2002-2003, and 2006-2007), the coherencies at high frequencies are very low.

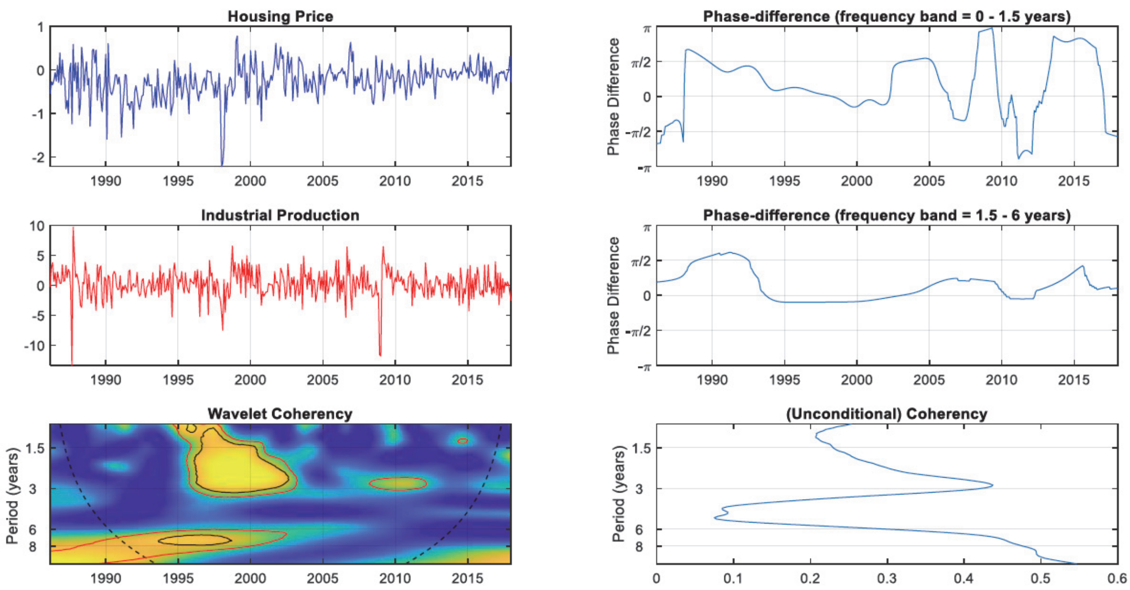
For CPI inflation, the global coherency shows that

the two series co-move at around three- and six-year frequencies (as well as virtually contemporaneously, which is natural, due to the deflation using CPI). However, the wavelet coherency shows that these features are only observed over roughly half of the entire sample period; coherencies at these frequencies are largely limited to the middle of the sample (including the Asian financial crisis period), although other episodes of strong coherency are found at medium frequencies (two to three years) during the late 2000s and around the end of the sample.

The phase relations of housing prices with these indicators are also intriguing. For industrial production, while the two series overall co-move simultaneously around the times of the Asian financial crisis, housing prices seem to occasionally lead industrial production, with the two series being in out-of-phase (in particular, at a high frequency). It is also notable that housing prices seem to lead inflation prior to 2005; in particular, between 1995 and 2005, the two series are in anti-phase for both frequency bands considered. This finding implies that housing may have played a limited role as an inflation-hedging asset.

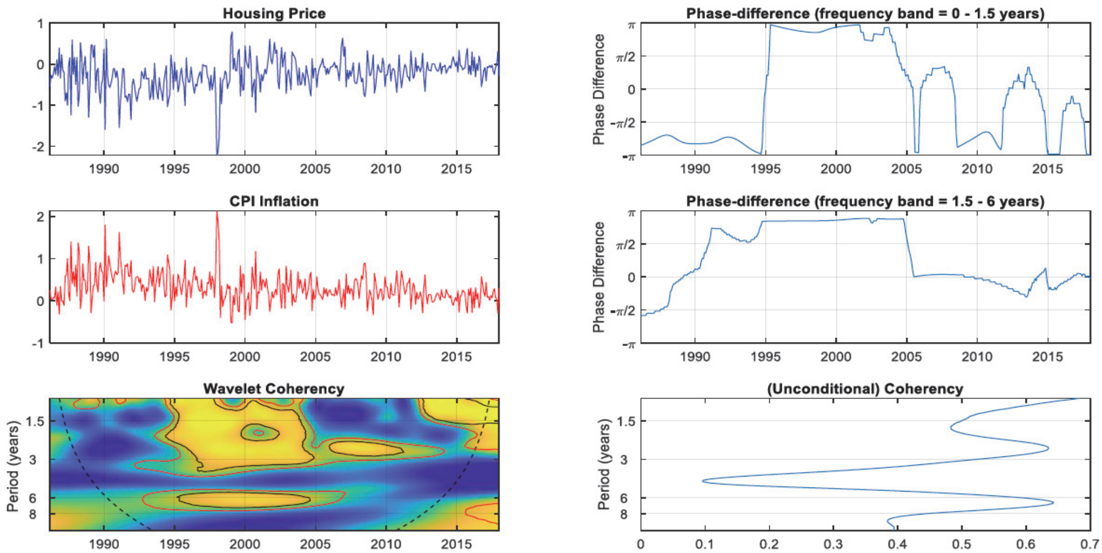
While it is not straightforward to fully explain these (changing) lead-lag behaviors, some of which are not consistent with conventional economic rationale, these results suggest that housing market dynamics are not strongly associated with the developments of the overall aggregate economy.

<Figure 2> Wavelet coherency and phase difference: housing price and industrial production



Note to Figures 2 to 10: The first two figures in the left panel show monthly growth in housing price and the various economic indicators (See section 3). The bottom figure plots wavelet coherency, where the strength is given by the color. The color ranges from blue to red, with warm (cold) colors representing areas of high (low) power. The black and red contours stand for the 1% and 5% significance levels, respectively. Dotted lines represent "the cone of influence." In the right panel, the phase differences for the two frequency bands (0 to 1.5 years and 1.5 to 6 years, the first two figures) and the unconditional coherency (the bottom figure) are provided.

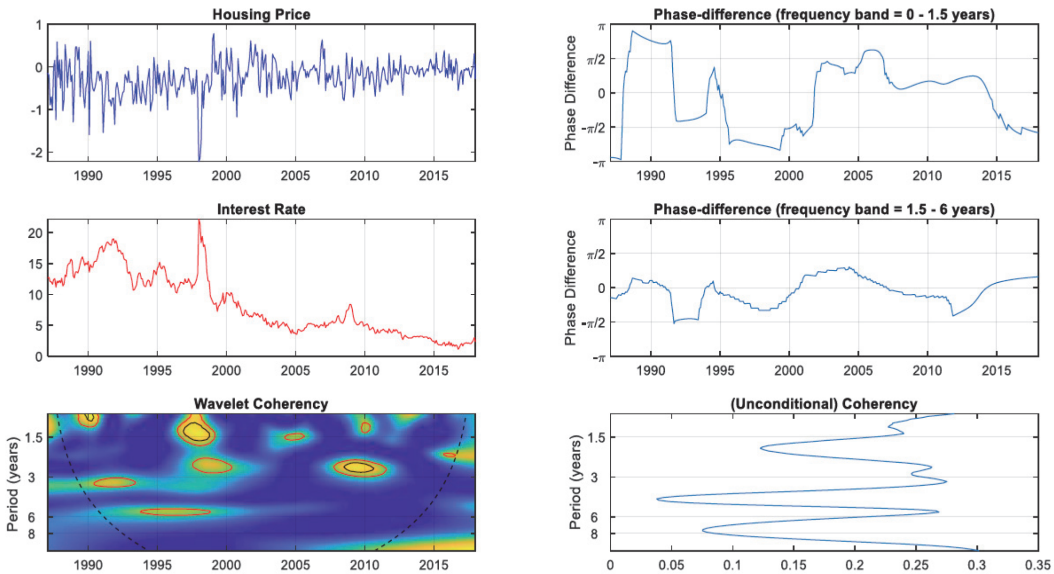
<Figure 3> Wavelet coherency and phase difference: housing price and CPI



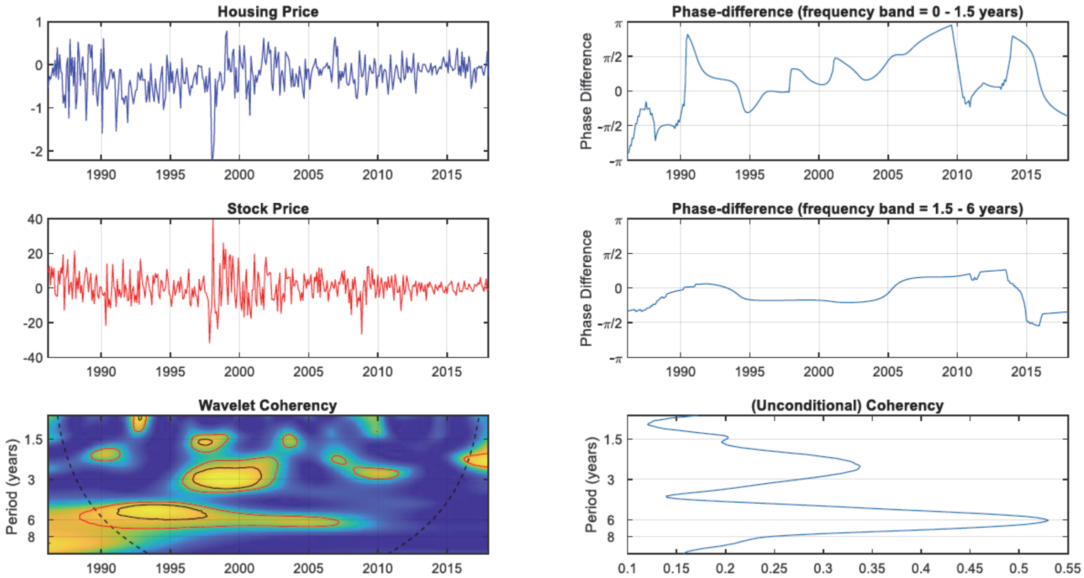
2) Interest Rate and Asset Prices

The wavelet coherency between housing prices and other asset prices (short-term interest rate, stock price, and exchange rate) are shown in <Figures 4-6>. First, for the interest rate, although the unconditional coherency shows that the two series co-move at several frequencies, the wavelet coherency reveals that their relationship seems to be, by and large, sporadic and loose. Except for the two crises, most episodes of their co-movements are short-run, transient, and found at frequencies of less than two years. In addition, such episodes rarely correspond to the housing market

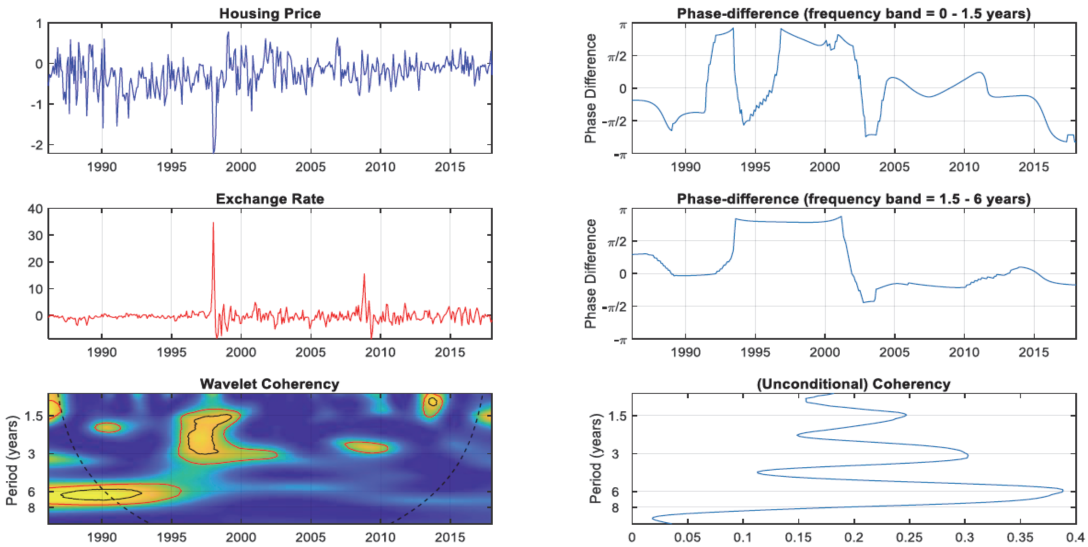
<Figure 4> Wavelet coherency and phase difference: housing price and interest rate



<Figure 5> Wavelet coherency and phase difference: housing price and stock prices



<Figure 6> Wavelet coherency and phase difference: housing price and exchange rate



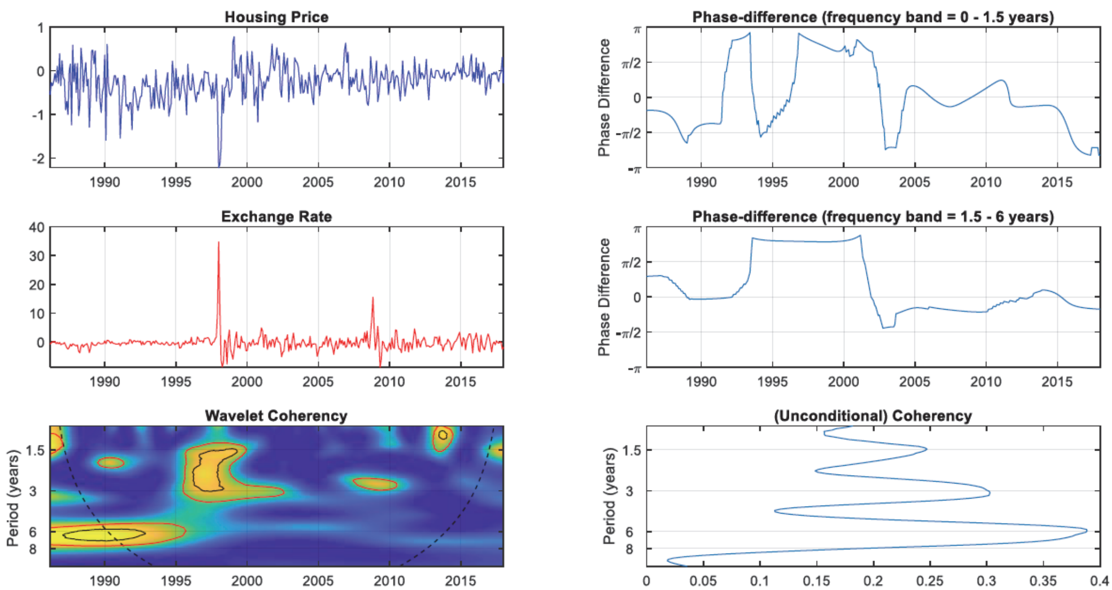
booms. One exception is the episode of 1989-1990, during which housing prices tend to lead the interest rate, but they are in out- of-phase. The overall loose association implies that there is not an effective link between housing price dynamics and the interest rate, as noted in traditional or credit-view channels of monetary policy. This is further supported by the phase relation, where the housing price overall seems to lead interest rate during the housing market booms.

The results regarding equity price and the exchange rate are also interesting. As with the macro indicators, strong long-run co-movements between housing prices and these asset prices have largely disappeared after the Asian financial crisis, in the case of exchange rate, and the mid-2000s, in the case of stock prices. While several episodes of short-run co-movements are found over the entire sample (including the times of two crises) at one- to three-year frequencies, it appears that housing prices overall do not have strong co-movements with these two series at high frequency, particularly during the housing price booms, indicating that they may not be close substitutes for housing assets.[12]

3) Liquidity Measures

We now turn to the relationship between housing prices and several liquidity measures, depicted in <Figures 7-9>. In doing so, rather than directly looking at the relationship between housing prices and commonly used monetary aggregates such as M1 and M2, we separate out additional components included in these broad measures of money to focus on their role in housing price cycles.[13] Specifically, we construct the two series of M1 less MB and M2 less M1 and look at their relationship with the housing price. The former consists of demand deposits and transferable savings deposits, while the latter includes savings deposits, time deposits, and marketable financial instruments (e.g., money market funds, beneficiary certificates, certificates of deposit), all with maturities of less than two years. These assets, with varying liquidities, are closely linked to housing finance markets; they can be used as either direct funds

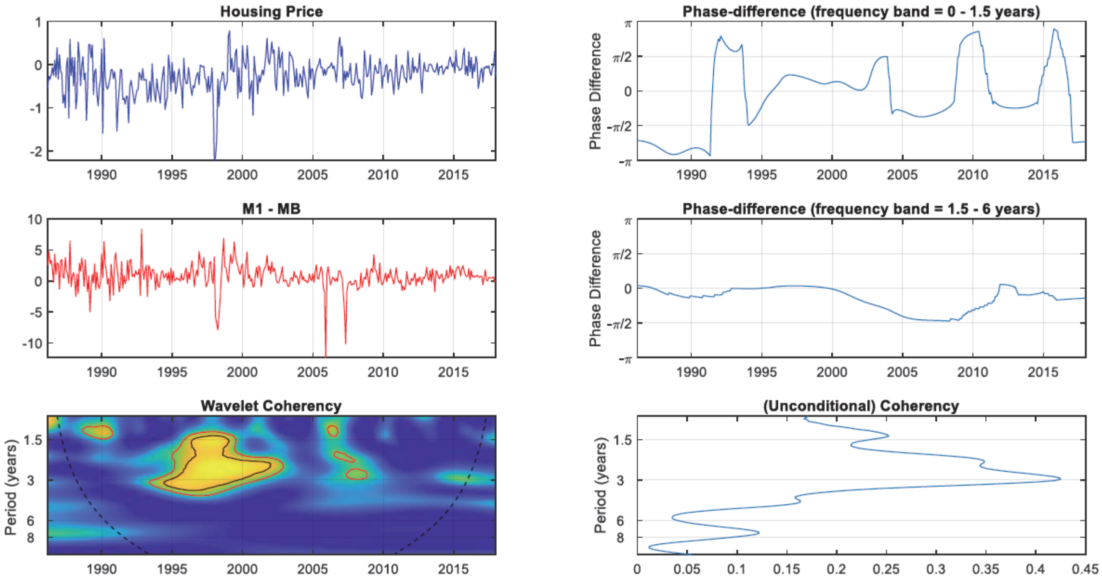
<Figure 7> Wavelet coherency and phase difference: housing price and MB



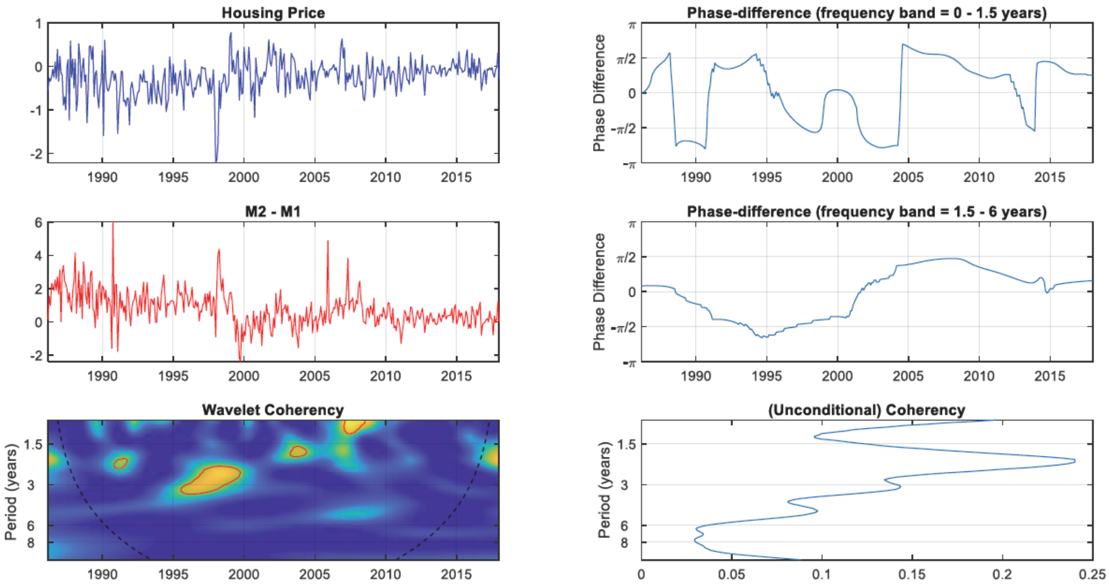
12) In fact, low correlation between price changes in the stock and housing, at least in the short-run, has been often reported in several other countries as well (e.g., Eichholtz and Hartzell, 1996; Quan and Titman, 1999). This is partly due to the low liquidity of housing assets and its provision of dwelling services, which other assets lack. See Shiller (2015) for potential cross feedback between stock and housing markets

13) The appendix provides the wavelet coherency for M1 and M2, whose results are often unclear. For example, while the results for M1 less MB are similar to those for M1, the wavelet coherency with M2 shows that its relationship with housing price is weak, having two very transient episodes (during 1989-1990 and the Asian financial crisis) with only moderate coherency at high frequencies

<Figure 8> Wavelet coherency and phase difference: housing price and M1 less MB



<Figure 9> Wavelet coherency and phase difference: housing price and M2 less M1



for financing housing or serve as close short-term substitutes for housing asset investments. In yet another way, the levels of these liquidity indicators are often affected by housing prices, for example, via home-equity loans.

First, in the case of MB, it can be seen that, in addition to strong co-movement at low frequencies (which essentially disappears after 2000), there is another episode with strong coherency at frequencies of one to three years during 2001-2003, which corresponds to the second housing market boom.

Next, the results for M1 less MB and M2 less M1 are largely similar. In both cases, there is virtually little coherency found at frequencies beyond four years throughout the sample. Instead, their co-movements are by and large located over relatively high frequencies only and scattered over several sporadic episodes. Specifically, their short-run co-movements are found in several episodes such as 1989-1990, 2000-2002, and 2006-2007, all of which essentially correspond to the periods of housing market booms (as well as the Asian financial crisis where medium frequency coherencies are also found).

At the same time, their phase relations turn out to be rather different. While housing prices tend to slightly lag M1 less MB, they lead M2 less M1, particularly during the two booms in 2000s, indicating these findings are partly in line with the changing features in the housing finance market over time, as noted above.

4) Other Housing Prices

In this section, we examine the dynamic relationship with other housing prices, such as ***chonsei*** prices and housing prices in Seoul and the US, which may further reveal the nature of housing price dynamics.

The chonsei price (also called "key money") in a chonsei contract is an up-front lump-sum deposit from the tenant to the owner for the use of the residence (usually for two years) with no additional requirement for periodic rent payments. While the deposit is fully refunded at the end of the lease, the landlord then can make a return by investing the deposit in other assets and keeping interest earned. Since the chonsei prices mainly reflect the residence's value-in-use and are far less likely to be affected by psychological or speculative factors, they can be regarded as, at least approximately, fundamental prices of the housing service.

It is also worthwhile to explore the relationship between Korea's national housing price and those of Seoul and the US. The former is interesting in that it is suspected that the national housing market booms have often originated from housing price hikes in Seoul, while the latter offers a chance to explore the issue in the context of an international housing price co-movement, although in a limited way.[14)]

As shown in <Figure 10>, in the case of chonsei price, the unconditional coherency shows that co-movements between the two series concentrate at low frequencies (i.e., around 6 years), indicating their long-run cointegrated relationship. However, as illustrated in the wavelet coherency, there are again non-negligible changes in their relationship over time. The long-run co-movement seems to have weakened since 2010, and the coherency over high to medium frequencies (i.e., one to four years) are largely centered on the middle of the sample period and are since then essentially non-existent.

The results with housing prices in Seoul (<Figure A3> in the Appendix) are similar to those with chonsei prices, although the coherencies tend to be more spread over time and frequencies.[15)] In addition, the phase relation shows that, during the two recent episodes, Seoul prices indeed seem to lead at a high frequency. Finally, in the case of the US housing prices (<Figure A4> in the Appendix), a few episodes with strong coherencies are found at low as well as high frequencies, which largely correspond to the US recession periods (rather than Korea's), most notably, the global financial crisis.

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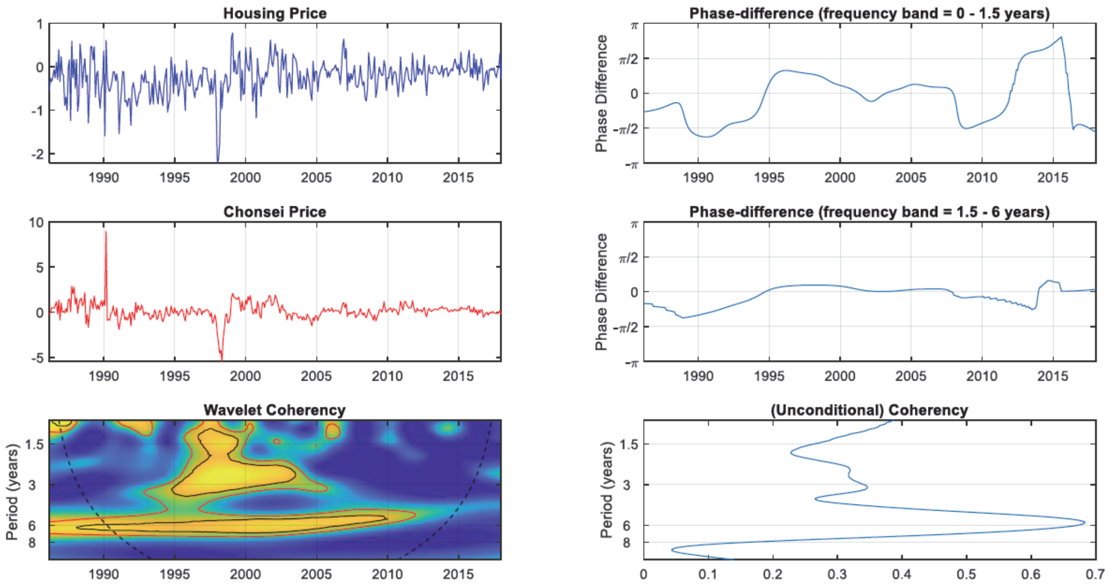
14) The results for housing prices in Seoul and the US are provided in the Appendix

15) We obtain very similar results with the housing prices in Gangnam district, Seoul's prime submarket, which is one of the most expensive neighborhoods in Korea

<Figure 10> Wavelet coherency and phase difference: housing price and *chonsei* price



3. Summary of Findings and Discussion

The empirical findings can be summarized as follows. First, there have been notable changes in the housing price dynamics of Korea over time, both in terms of volatilities and the length of cycles. Second, apart from the major recessions (in particular, the Asian financial crisis), the housing prices are by and large loosely connected with the indicators reflecting housing fundamentals (such as industrial production and chonsei prices) as well as other asset prices. Third, on the contrary, there seems to be strong coherency between housing price and the liquidity indicators at short-run frequencies and most of such episodes are tightly associated with housing price booms.

These findings suggest that the housing price booms, perhaps triggered by shocks to non-fundamental factors (including the expectations of appreciation in housing prices) and/or to credit supply, may have been spurred by housing price-credit spirals. Further, their changing patterns are also partly in accordance with structural changes in housing finance markets, including the expansion of mortgage credit and the shift from chonsei to monthly rental markets, among others.

It should be noted that the empirical link between credit and real estate prices has been extensively explored for Korea (Kim, 2004; Park et al., 2008) as well as for other countries (Igan et al., 2011; Igan and Loungani, 2012; Cerutti et al., 2015), and these studies find similar results to ours. Yet, the findings in this paper deliver much richer messages, depicting specifically when and how their relationship has changed over time with the evolution of housing price dynamics.

Given that our approach is not structural, caution is needed in interpreting these findings. However, overall evidence suggests that dynamic links between housing prices and several indicators reflecting their fundamentals have largely been loose and weakening. It seems instead that several short-term housing booms are accompanied by, or even spurred by, non-fundamental factors such as various liquidity measures, which in turn are suspected to have been more or less triggered by widespread expectations of rising housing prices.

All in all, these observations may signal a potentially unhealthy state of the housing market, and there might be non-negligible risk of downward adjustment in housing prices in the future. Moreover, along with the housing sector's potential vulnerability, given the large and increasing household debt (including home-equity loans) in Korea, (abrupt) depreciation in housing prices, in itself or in conjunction with an otherwise mild economic downturn, may have prolonged and aggravating consequences on the overall macroeconomy.[16]

IV. Concluding Remarks

Utilizing wavelet transform, this paper explores the time-varying features of housing prices of Korea and their dynamic relationship with other indicators from a macro perspective. We reveal that the housing prices have undergone important structural changes over time, in terms of both the volatilities and the length of cycles. Furthermore, their relationships with other variables exhibit significant time-varying features in several important aspects as well.

While informative, this study, with a focus on the housing market in Korea, is essentially descriptive and explanatory, lacking in rigorous theoretical discussion of a range of the findings presented. In addition, we neglect several important dimensions of the housing sector, including demographic shifts, detailed analysis of demand/supply sides in regional sub-markets, and evaluations on a variety of enacted policies, among others.

Thus, one natural future research agenda is to investigate these issues in a more analytical way (i.e., employing rigorous theoretical models), taking into account the time-varying features of housing prices reported in this paper. Another avenue worth exploring is to apply the wavelet tools, which are found to be flexible as well as useful, to international housing market data, which would uncover important features in data beyond what conventional econometric methods can offer and draw richer implications.

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16) In this regard, the ceilings on the LTV and DTI ratio, recently established as a key policy instrument, are noteworthy. However, their full impacts need yet to be fully investigated (Igan and Kang, 2011; Jerome and Mitra, 2015).

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<국문요약>

시간-빈도 공간상에서 거시 경제와 주택 시장의 연계: 한국의 경우

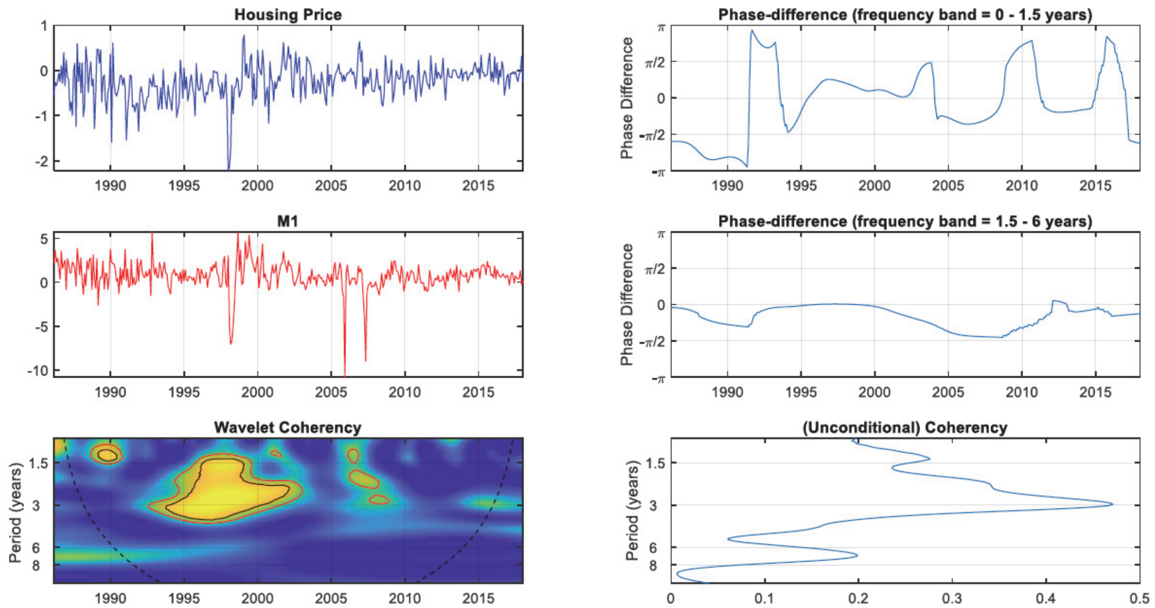
황 영 진 (Hwang, Youngjin)

최근의 글로벌 금융 위기의 사례에서 잘 나타났듯이, 거시 경제와 주택 시장의 상호 연관성은 점차 중요해지고 있다. 하지만, 주택시장과 관련된 대부분의 실증 연구는 시계열 공간(time-domain)상에 국한되어 있으며, 데이터에 나타나는 여러 시변적(time-varying) 속성을 간과한 측면이 있다. 이 논문은 웨이블렛(wavelet) 분석을 한국의 주택 가격 데이터에 적용하여 거시 경제와 주택 시장의 상호 연관성이 시간-빈도 공간(time-frequency domain)상에서 어떻게 변화해 왔는 지 분석하였다. 주요 결과를 요약하면 다음과 같다. 첫째, 주택 가격의 사이클은 길이와 변동성이 모두 감소한 것으로 나타났다. 둘째, 주택 가격의 변동은 주요 거시 변수 등 주택 가격의 주요 펀더멘탈과는 연관성이 약한 것으로 나타났다. 셋째, 대부분의 주택 시장 호황은 고빈도상에서 단기 유동성과 밀접한 관련이 있는 것으로 나타났다.

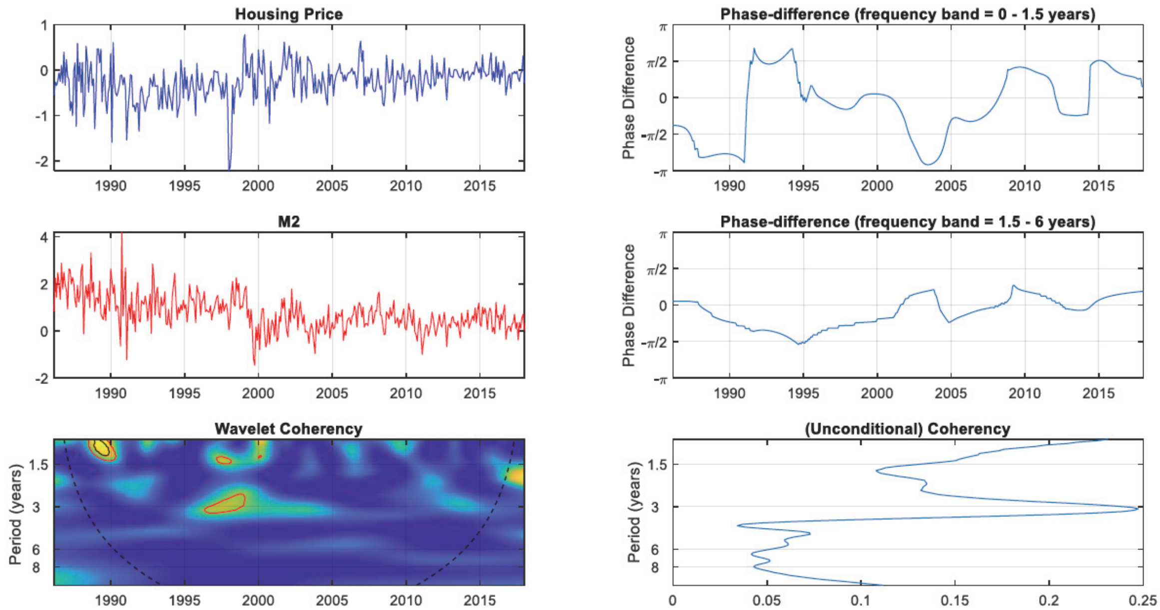
주 제 어 : 주택가격, 웨이블렛 분석, 경기변동, 거시경제-주택시장 연계

<Appendix: Additional Figures>

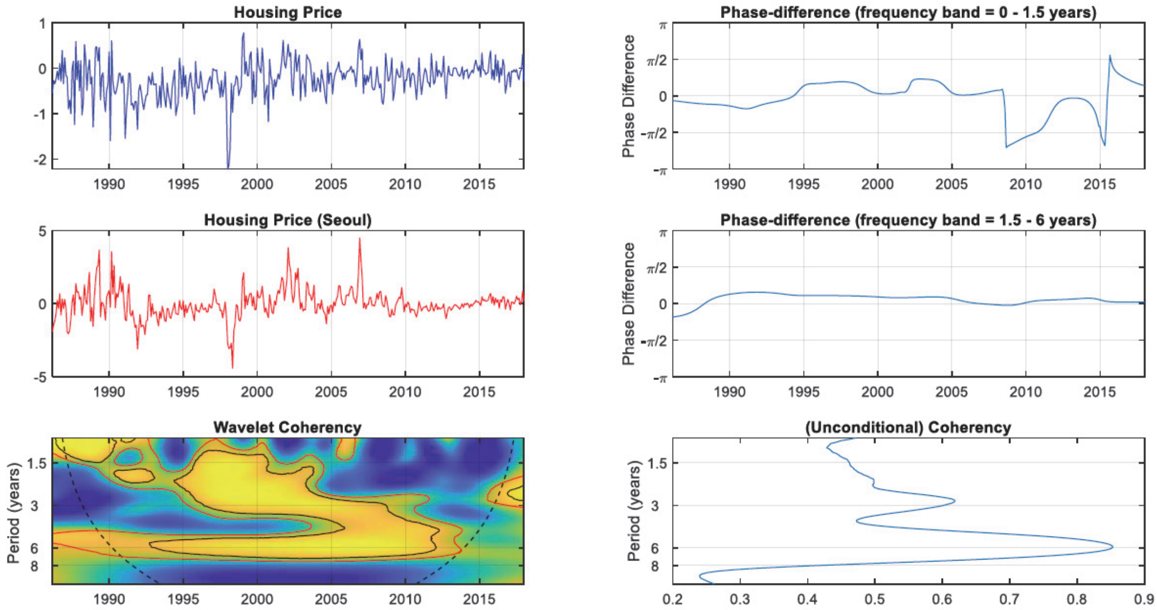
<Figure A1> Wavelet coherency and phase difference: housing price and M1



<Figure A2> Wavelet coherency and phase difference: housing price and M2



<Figure A3> Wavelet coherency and phase difference: housing price (national and Seoul)



<Figure A4> Wavelet coherency and phase difference: housing price (Korea and US)