

# Time-frequency relationship between U.S. output with commodity and asset prices

Aviral K. Tiwari<sup>\*</sup>, Claudiu T. Albuлесcu<sup>\*\*</sup> and Rangan Gupta<sup>\*\*\*</sup>

## Abstract

Commodity and asset prices have a well-documented effect on economic growth, manifested through various channels. At the same time, the business cycle influences the commodity and asset prices. Whereas empirical evidence on the effect of commodity and asset prices on the long-run economic growth is ambiguous, most of the previous researches highlight a positive correlation in the short-run. The aim of this paper is to disentangle the short- and long-run co-movements between U.S. historical business cycles and commodity and asset prices, over the period 1859-2013. For this purpose we use a time-frequency approach and we test the historical influence of oil, gold, housing and stock prices, over the output growth. Different from other studies, we control for the effect of other prices and monetary conditions, using the wavelet partial coherency. In line with the previous works, we discover that co-movements between economic growth and commodity and assets prices manifest especially in the short-run. We also find that stock returns and housing prices have a more powerful effect on the U.S. economic growth rate than the oil and gold prices. The long-run co-movements are documented especially around the World War II. Finally, when controlling for the influence of the interest rate, inflation and other commodity and asset prices, co-movements become weaker in the short-run. In general the oil and housing prices lead the GDP growth, the U.S. output lead the gold prices, while there is no clear causality direction between business cycle and stock prices.

**Keywords:** Commodity and asset prices, economic growth, U.S. business cycle, historical co-movements, wavelets.

**JEL codes:** E32, C22, N11, N12.

## 1. Introduction

The impact of commodity prices, as well as the impact of real and financial asset prices on the economic growth is well-documented by the literature. The influence of different commodity prices, real estate prices and stock prices is heavily investigated. However, the empirical evidence on the short- and long-run effects of commodity and asset prices on the economic growth remains ambiguous. Therefore, given the strong fluctuation of these prices, a clear understanding of their correlation with the business cycle is crucial for anticipating the state of the economy.

The existing literature provides unambiguous link between economic growth, and commodity and asset prices. Several questions remain without a clear answer. Which are the similarities between the historical and the present co-movements of economic growth and commodity and asset prices? Is the influence of commodity and asset prices on the economic

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<sup>\*</sup> Faculty of Management, IBS Hyderabad, IFHE University, Dontanpalli, Hyderabad, Pin-501203, India. E-mail: [aviral.eco@gmail.com](mailto:aviral.eco@gmail.com); [aktiwari@ibsindia.org](mailto:aktiwari@ibsindia.org).

<sup>\*\*</sup> Management Department, Politehnica University of Timisoara, P-ta. Victoriei No. 2, 300006, Timisoara, Romania. E-mail: [claudiu.albulescu@upt.ro](mailto:claudiu.albulescu@upt.ro), [claudiual@yahoo.com](mailto:claudiual@yahoo.com).

<sup>\*\*\*</sup> Department of Economics, University of Pretoria, Pretoria, 0002, South Africa. Email: [rangan.gupta@up.ac.za](mailto:rangan.gupta@up.ac.za).

growth the same at different time-frequencies? Which are the commodities and assets prices with the strongest impact on the economic growth? Do the monetary conditions influence the link between commodity and asset prices and the economic growth? We attempt to provide answers to all these questions, analyzing the time-frequency historical impact of different commodity and asset prices (oil, gold, housing and stock prices) on the U.S. economic growth over the period 1859-2013.

The influence of commodity and asset prices on the economic growth is assessed by different strands of literature. A first strand tests the relationship between commodity prices and economic growth (Deaton and Miller, 1996; Brückner and Ciccone, 2010; Céspedes and Velasco, 2012; Collier and Goderis, 2012; Camacho and Perez-Quiros, 2014), with a focus on oil prices (Jayaraman and Choong, 2009; Le and Chang, 2012; Difiglio, 2014; Narayan et al. 2014) and gold prices (Pierdzioch et al., 2014). A second recent strand of literature pays importance to the role of housing prices in explaining the business cycle fluctuations (Miller et al., 2011; Pan and Wang, 2013; Loutskina and Strahan, 2015). A third strand investigates the role of financial asset prices on economic growth, with accent on stock prices (Liu and Sinclair, 2008; Panopoulou et al., 2010; Lyócsa, 2014; Peress, 2014). The monetary conditions are also associated with the business cycle fluctuations by Gilchrist and Leahy (2002), Caballero et al. (2008) or by Bordo et al. (2010).

However, none of these papers makes a historical analysis of time-frequency linkages between different commodity and assets prices and the U.S. economic growth. Consequently, our paper aims to provide three main contributions to the literature. First, we extend the existing literature on the impact of commodity and asset prices on economic growth, combining the time-series analysis with the frequency-domain analysis. We resort thus to wavelets to assess the co-movements of oil prices, gold prices, housing prices and stock prices, with the U.S. economic growth. Despite the growing literature using wavelets in economics and finance, the attention paid to simultaneous movements in commodity and asset prices and business cycles is limited. Using the wavelet coherency, we are able to assess the role of commodity and asset prices in explaining the economic growth dynamics at different frequencies and specific moments in time. At the same time, we are able to indicate the direction of the causality between commodity and asset prices and economic growth at different moments in time, i.e., if a shock is transmitted from the commodity and asset prices to the U.S. economic growth or conversely.

Second, in contrast to the bulk of the literature that uses wavelets to assess the link between GDP growth rate and different categories of commodity and asset prices, we also consider the potential influence of other factors impacting the business cycle, as the monetary conditions (interest and inflation rates). Therefore, in order to make abstraction of the influence of other elements (including the simultaneous influence of considered commodity and asset prices), we use a new approach, namely the wavelet partial coherency, which allows the analysis of co-movements between the economic growth and each considered category of prices, while controlling for the influence of other prices and monetary conditions on the business cycles – commodity and asset prices nexus.

Finally, we contribute to the existing literature as we perform a historical investigation of the impact of commodity and asset prices on business cycles. The empirical evidence on the linkages between commodity and asset prices and the long-run growth is ambiguous, but most of the existing works find that the boom of commodity and asset prices raise income in the short-run. As far as we know, our paper is the first attempt which assesses the historical co-movements in the short- and long-run (that is high- and low-frequencies). The studies closest in spirit to ours are the papers by Benhmad (2013) and Li et al. (2015). Benhmad (2013) investigates the cyclical co-movements between crude oil prices and the U.S. economic growth using wavelets, but only over the recent period and does not make

abstraction of other variables' influence on business cycles. The paper by Li et al. (2015) performs a time-frequency historical analysis of the relationship between the U.S. housing and stock markets prices. However, this paper does not address the influence of asset prices on the U.S. economic growth.

Our results show that co-movements between business cycles and commodity and asset prices appear in the short-run, for the 1-2-years frequency cycle. However, when controlling for the influence of other categories of commodity and asset prices, interest rate and inflation rate, co-movements are weaker in the short-run and manifest only for the 2-4-years frequency cycle, in general around the World War II. These co-movements are stronger in the case of asset prices as compared to the commodity prices.

The rest of the paper is organized as follows. Section 2 outlines the outcomes of the literature on asset prices – business cycle co-movements. Sections 3 and 4 present the methodology and comment the empirical results of our analysis. Section 5 concludes the paper.

## **2. Literature review**

A large volume of literature deals with the co-movements of commodity asset prices and business cycles. Commodity prices, including the oil prices, are usually found to have a long-run positive effect on economic growth, especially for countries disposing of natural resources (Sala-i-Martin et al., 2004; Alexeev and Conrad, 2009). Other studies document however, a negative impact of commodity prices fluctuations on economic growth (Gylfason, 2001; Sachs and Warner, 2001; Berk and Yetkiner, 2014). However, more and more recent studies report a nonlinear behavior between commodity and asset prices and economic growth (Jimenez- Rodriguez and Sanchez, 2005; Cerra and Saxena; 2008; Kilian and Vigfusson, 2011a).

Crude oil is one of the main energy sources and therefore one of the main drivers of economic growth. At the same time, crude oil is one of the most traded commodity and its prices are extremely volatile, especially during the last years (Regnier, 2007). Much of the research on the economic growth – oil price nexus focuses on the U.S. (see Narayan et al., 2014). In this context, a series of studies document a negative impact of oil prices' shocks on economic growth (Rasche and Tatom, 1981; Lee et al., 1995; Hamilton, 2003; Jimenez-Rodriguez and Sanchez, 2005; Kilian, 2008). In the same line, Kilian and Vigfusson (2011b) notice a decline of the economic growth in response to unexpected increases in the real price of oil. However, there are also papers which show that oil prices shocks positively affect the output growth, in particular for oil-exporting countries. Using a Vector Autoregressive (VAR) setting, Berumen et al. (2010) find that oil prices' increase have a statistically significant and positive effect on the output of most of the selected Middle East and North Africa (MENA) countries. Similar, Jayaraman and Choong (2009) apply the Autoregressive Distributed Lag (ARDL) bounds testing methodology to investigate the link between economic growth and oil prices in small Pacific Island countries. The authors discover that both in the long- and short-run, there is a unidirectional relationship from oil prices and international reserves to economic growth. Nevertheless, performing a historical analysis on oil prices – economic growth co-movements, Difiglio (2014) shows that for developed countries, oil prices' shocks are invariably followed by 2-3 years of weak economic growth and weak economic growth is almost always preceded by an oil prices shock. Consequently, the relationship between economic growth and oil prices is not well established and requires further clarifications.

Even if most of papers focus on the impact of oil prices on economic growth, a reverse causality is also expected. During economic growth periods the consumption increases in general, for all goods and services. The phenomenon is transmitted to oil products and therefore an increase of their prices might arise. However, the impact of economic growth on oil prices is expected to manifest especially in the long-run.

At the same time, other categories of commodities might have an influence on business cycles. The existing literature gives a special emphasis to the gold prices and its role on business cycles fluctuations (Pierdzioch et al., 2014). As Le and Chang (2012) state, “*gold carries important psychological weight, and any jump in its price tends to make headlines*”. Furthermore, the gold is considered the leader in the precious-metals market and an increase of gold prices determines parallel movements of other precious metals prices (Sari et al., 2010) or asset prices (Reboredo, 2013; Apergis, 2014; Arouri et al., 2015). Therefore the movement in gold prices does not affect only the commodity prices as the oil prices, but also the macroeconomic variables, including the business cycle (for a detailed analysis see Arouri et al., 2012). However, given the gold role of reserve asset, its prices increase in general in financial turbulence periods, when the international investors lost their confidence in financial markets and find gold as an alternative for their investment. Thus, we also expect to find a business cycle influence on gold prices.

The impact of housing prices on business cycle has also attracted the attention of researchers during the last years. Especially for the U.S. economy, the role of the real estate market is extremely important because the housing market signals the state of the economy as a whole (Pan and Wang, 2013). The relationship between housing prices and economic growth is mainly explored in the context of the recent subprime mortgage crisis. In this line, Loutskina and Strahan (2015) reveal a multitude of channels for the housing prices – economic growth pass-through. The transmission channels from housing prices through economic growth are represented by the wealth effect and by the renters’ saving effect. The housing wealth effect during the economic boom fuels the consumption (Benjamin et al., 2004; Lettau and Ludvigson, 2004; Case et al., 2005; Campbell and Cocco, 2007; Kishor, 2007; Mian and Sufi, 2011), but also the firm investment (Chaney et al., 2011). The effect of renters’ saving is documented *inter-alia* by Sheiner (1995) and Engelhardt (1996).

Without exploring a particular transmission channel, more recently, Loutskina and Strahan (2015) show that financial integration amplified the positive effect of housing prices’ shocks on the U.S. economy before 2007. Similar, using quarterly data for all 379 metropolitan statistical areas in the U.S. from 1980 to 2008, Miller et al. (2011) show that housing prices’ changes have significant effects on the output growth. However, none of the above mentioned papers document differences in the intensity of housing prices – economic growth pass-through, at different frequencies and at different moments in time. Moreover, the role of economic growth on the increase in housing prices is not sufficiently explored. During growth periods, the investments’ confidence increases and the credit activity is in expansion, which favors the growth of real estate prices.

The impact of stock prices on business cycle is also intensively debated in the empirical literature. The stock market allows investors to interact and share efficiently their costly private signals, which contributes to raising total factor productivity and therefore to economic growth (Peress, 2014). Starting with Fama (1990), noteworthy papers find that movements in stock prices generally reflect real economic activities (Cheung and Ng, 1998; Choi et al., 1999; Mauro, 2003; Lyócsa, 2014). At the same time, a series of papers indicate that stock prices are influenced by the real economic activity (Jefferis and Okeahalam, 2000; Shirai, 2004). A bilateral influence of stock prices and economic growth is documented by Nasseh and Strauss (2000) and Hassapis and Kalyvitis (2002). Similar results are reported by Panopoulou et al. (2010) which uses non-parametric procedures to account for the impact of

long-lagged observations and discover that correlation between growth and stock prices returns in the G7 countries is detected at larger horizons than those typically employed in parametric studies.

Nevertheless, many more studies find that the relation between stock prices and economic growth is non-linear and is frequently asymmetric (Domian and Louton, 1997; Binswanger, 2004). For example, Liu and Sinclair (2008) find in the case of China, a one-way causality running from growth to stock prices in the long-run and running from stock prices to economic growth in the short-run. However, none of these papers explores the time-frequency dynamics of the stock returns – growth nexus for the U.S.

The co-movements between economic growth and commodity and asset prices are directly or indirectly influenced by the monetary conditions. On the one hand, with large movements in asset prices, many scholars question the legitimacy of monetary policy makers' interventions, to respond to asset prices volatility (Gilchrist and Leahy, 2002). On the other hand, the decline in interest rates favors a boom of commodity and asset markets, with impact on the business cycle. This happened during the subprime crisis when, in the context of low real interest rates, U.S. households were encouraged to take on more risk than they could bear (Caballero et al., 2008).

The interest rate may interfere in the relation between stock prices and output growth for example. Peiró (1996) investigates the relationships between stock returns, changes in production, and changes in interest rates in Western European countries and shows that the influence of changes in production on stock returns diminishes substantially when contemporaneous changes in interest rates are considered. The inflation rate has in its turn a non-negligible influence in the commodity and asset prices – business cycle nexus. In this line, Chatrath et al. (1997) and Canova and De Nicoló (2000) analyze the empirical interdependencies among asset returns, real activity, and inflation. Other studies assess the link between oil prices, gold prices and inflation rate (Shafiee and Topal, 2010), or between oil prices, inflation and economic growth (Doroodian and Boyd, 2003). Finally, Stock and Watson (2003) show that some asset prices predict inflation or output growth in several OECD countries, in some periods.

We notice that different commodity prices, the interest rate, and also the inflation rate impact the output growth. Consequently, in order to assess the pure influence of oil, gold, housing and stock prices on the U.S. business cycles, different from other studies, we control for the simultaneous effect of other commodity and asset prices, but also for the effect of monetary conditions, using the wavelet partial coherency.

### 3. Methodology

The wavelet analysis is meant to determine the frequency content of a variable in order to extract the temporal variation of this frequency content (Heil and Walnut, 1989; Labat, 2005). A wavelet is a function with zero mean, localized both in time ( $\Delta t$ ) and frequency ( $\Delta \omega$ ), which fluctuates within a limited period (Fan and Gançey, 2010). Therefore, this function shall obey the conditions that  $\int \psi(\eta) d\eta = 0$  and  $\int |\psi(\eta)|^2 d\eta = 1$  (representing the mother and the father wavelet).

Thus, the continuous wavelet transform (CWT) of a series  $x(t)$  is:

$$W_x(s, \tau) = \langle x(t), \psi(t) \rangle \equiv \int_{-\infty}^{\infty} x(t) \circ \frac{1}{\sqrt{s}} \psi\left(\frac{t-\tau}{s}\right) dt, \quad (1)$$

where:  $s$  and  $\tau$  are the scale and location parameters respectively;  $\psi((t - \tau)/s)$  is the mother wavelet function, which can take complex values; the symbol  $\circ$  is the convolution operator.

There are several families of wavelet functions. A complex wavelet function, as the Morlet wavelet, is useful in economic analyses as it gives information on local phase. Besides, the Morlet wavelet function can be shown to achieve an optimal localization between the resolution in time and in frequency due to its Gaussian envelop. This property is guaranteed by Heisenberg's uncertainty theorem stating that there is a lower limit to the product of time and frequency resolution. Thus, to achieve optimal balance, we employ the Morlet wavelet function given by:

$$\psi_0(\eta) = \pi^{-1/4} e^{i\omega_0\eta} e^{-\frac{1}{2}\eta^2}, \quad (2)$$

where:  $\omega_0$  is dimensionless frequency and  $\eta$  is dimensionless time.

For an optimal balance, we set  $\omega_0 = 6$  as suggested by Torrence and Compo (1998). Since the idea behind the CWT is to apply the wavelet as a band pass filter to the time series, the wavelet is stretched in time by varying its scale  $s$ , so that  $\eta = s \cdot t$  and normalizing it to have unit energy. For the Morlet wavelet, the Fourier period ( $\lambda_{wt}$ ) is almost equal to the scale ( $\lambda_{wt} = 1.03$ )s. The wavelet transform also inherits this property. The discretized version of Equation (1) for time series  $\{x_n : n = 1, \dots, N\}$  is given by

$$W_m^x(s) = \frac{\delta t}{\sqrt{s}} \sum_{n=0}^{N-1} x_n \cdot \psi^* \left( (m - n) \frac{\delta t}{s} \right), \quad m = 1, 2, \dots, N - 1 \quad (3)$$

where:  $\delta t$  is the uniform step size. From the expression above, the wavelet power that measures the variability in the time series both in time and in frequency is defined as  $|W_m^x(s)|^2$ .

For this discretized version, the complex argument of  $W_m^x(s)$  can be interpreted as the local phase. Specifically, if  $W_m^x(s)$  is complex-valued, then it can be separated into real  $\Re\{W_m^x(s)\}$  and imaginary  $\Im\{W_m^x(s)\}$  parts, allowing for the calculation of the phase angle,  $\varpi_x = \tan^{-1}(\Im\{W_m^x(s)\}/\Re\{W_m^x(s)\})$  parameterized in radians ranging from  $-\pi$  to  $\pi$ . The CWT suffers from edge effects caused by a discontinuity at the edge because wavelet is not completely localized in time. To cope with this challenge, the cone of influence (COI) has been introduced. The COI earmarks the area where edge effects cannot be ignored and determines the set of CWT coefficients influenced by the value of the signal at a specified position. Outside COI, edge effects are predominant and can distort the result. Here we take the COI as the area in which the wavelet power drops to  $e^{-2}$  of the value at the edge.

Since our intention is to measure the extent of synchronization between two given time series, it is informative to use coherence between them. Wavelet coherence is a time-frequency counterpart of the time-domain coefficient of determination and shares property with traditional correlation coefficient. Aguiar-Conraria et al. (2008) defines wavelet coherence as “the ratio of the cross-spectrum to the product of the spectrum of each series, and can be thought of as the local (both in time and frequency) correlation between two time-series”. Following Torrence and Webster (1999), we define the wavelet coherence between two time series as

$$R_m^2(s) = \frac{|S(s^{-1}W_m^{xy}(s))|}{S\left(s^{-1}|W_m^x|^{\frac{1}{2}}\right) \cdot S\left(s^{-1}|W_m^y|^{\frac{1}{2}}\right)}, \quad (4)$$

where:  $S$  is a smoothing operator and  $W_m^{xy} = E[W_m^x \tilde{W}_m^y]$  is the cross-spectrum, with  $\tilde{W}_m^y$  as the complex conjugate of  $W_m^y$ .

Notice that  $0 \leq R_m(s) \leq 1$  while for the traditional correlation coefficient ( $\rho$ )  $0 \leq \rho \leq 1$ . Without smoothing coherency is identically 1 at all scales and times. We may further write the smoothing operator  $S$  as a convolution in time and scale:

$$S(W) = S_{scale}(S_{time}(W_m(s))), \quad (5)$$

where:  $S_{scale}$  denotes smoothing along the wavelet scale axis and  $S_{time}$  denotes smoothing in time.

The time convolution is done with a Gaussian and the scale convolution is performed with a rectangular window (see, for more details, Torrence and Compo, 1998). For partial continuous wavelet transform, Aguiar-Conraria and Soares (2011) define coherence as

$$R_m^2(s)_{x,y|z} = \frac{|Q_{XY}^M|^2}{Q_{XX}^M Q_{YY}^M}, \quad (6)$$

where:  $Q_{XY}^M$ ,  $Q_{XX}^M$  and  $Q_{YY}^M$  are the minors associated with the smoothed cross wavelet transforms  $|S(s^{-1}W_m^{XY}(s))|^2$ ,  $S\left(s^{-1}|W_m^X(s)|^2\right)$  and  $S\left(s^{-1}|W_m^Y(s)|^2\right)$  respectively in a  $3 \times 3$  matrix  $Q$ .

This trivariate model was used in Ng and Chan (2012) and is a specific form of the multivariate case, where the effects of all other variables are removed from the coherence between  $x$  and  $y$ . It is important to conceptualize the lead-lag relationship between two time series. This is achieved by computing the phase difference given by:

$$\phi_{x,y} = \tan^{-1} \frac{\Im\{W_m^{xy}\}}{\Re\{W_m^{xy}\}}, \quad \phi_{x,y} \in [-\pi, \pi] \quad (7)$$

where:  $\Im$  and  $\Re$  are the imaginary and real parts of the smooth power spectrum respectively.

Phase differences are useful to characterize phase relationship between any two time series. A phase difference of zero indicates that time series move together at the specified frequency. If  $\phi_{x,y} \in [0, \pi/2]$ , then the series are in-phase, with the time-series  $y$  leading  $x$ . On the other hand, if  $\phi_{x,y} \in [-\pi/2, 0]$  then  $x$  is leading. We have an anti-phase relation (analogous to negative covariance) if we have a phase difference of  $\pi$  (or  $-\pi$ ) meaning  $\phi_{x,y} \in [-\pi/2, \pi] \cup [-\pi, \pi/2]$ . If  $\phi_{x,y} \in [\pi/2, \pi]$  then  $x$  is leading, and the time series  $y$  is leading if  $\phi_{x,y} \in [-\pi, -\pi/2]$ .

#### 4. Data and results

The U.S. economy experienced several episodes of high output volatility (see Fagan et al., 2013). Economic historians provide different explanations of low volatility of output from the mid-1980s up to 2008 (the Great Moderation period), and of an increased output volatility characterizing the late 1960s and 1970s (the Great Inflation period), but also from 1879 to the start of World War I (Gold Standard era). Our analysis provides a clarification on the

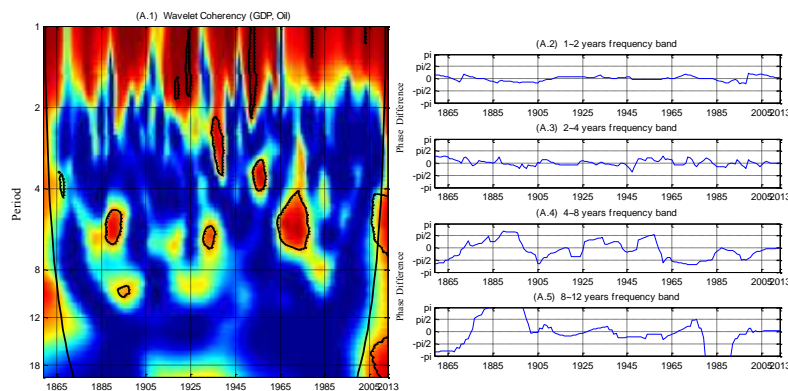
historical role of asset prices in explaining the U.S. business cycles, considering this nexus at different frequencies, and different classes of assets.

For this purpose, we use data with an annual frequency, covering the period 1859-2013. Data for real GDP, nominal stock price (SP500), Winans International house price, and West Texas Intermediate (WTI) oil price are extracted from the Global financial Database. Nominal gold price is obtained from kitco.com. The consumer price index (CPI) is used to deflate the nominal asset and commodity prices to obtain the corresponding real values, and is obtained from the website of Robert Sahr (<http://oregonstate.edu/cla/polisci/sahr/sahr>). Inflation is computed as the first-differences of the natural logarithms of the CPI, expressed in percentages. The data on the short-term interest rate is obtained from Homer and Sylla (2005) over 1859-1870, and thereafter from the online data segment on Robert J. Shiller's website (<http://www.econ.yale.edu/~shiller/data.htm>).

The analysis is made considering four frequency cycles. The first two cycles (1-2-years cycle and 2-4-years cycle) are associated with the short-run, or with high-frequency bands. The last two cycles (4-8-years cycle and 8-12-years cycle) are intended for the long-run analysis (that is, low-frequency bands).

We first present the co-movements between the output growth and international oil prices, using the wavelet coherency (Fig. 1).

**Fig. 1. Wavelet coherency between the growth rate and international oil prices**



*Note: Wavelet Coherency between GDP and oil prices. The black contour designates the 5% significance level estimated from the Monte Carlo simulations based on an ARMA(1,1) Null. The color code for power ranges from blue (low power) to red (high power). If phase difference is lies between  $[0, \pi / 2]$ , then the series are in-phase, with the time-series oil prices leading GDP. On the other hand, if phase difference lies  $[-\pi / 2, 0]$  then GDP is leading. If we find evidence that phase-difference lies between  $[\pi / 2, \pi]$  then GDP is leading, and the time series oil prices is leading if phase difference lies between  $[-\pi, -\pi / 2]$  whiles both series have an anti-phase relationship.*

In the short-run, we notice strong co-movements for the 1-2-years cycle, starting form 1859 up to present. This means that the relation between output growth and oil prices is very strong for high-frequencies (when the variables experience high variations). These co-movements are stronger around the World War I and after the World War II, in the 1950s. A co-movement spike also appears in the 1970s, and from 2008 up to present, when strong



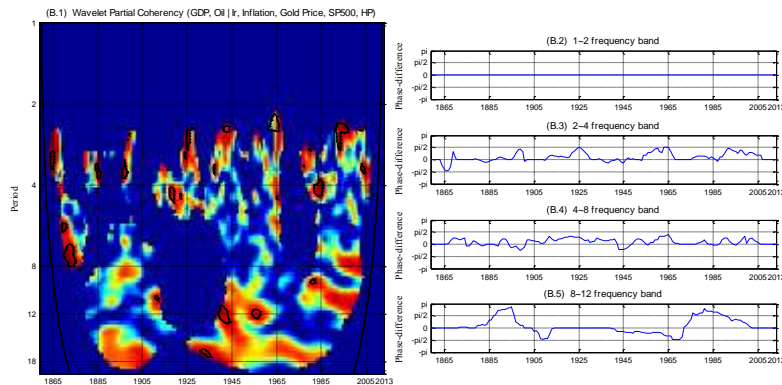
variations in oil prices are accompanied by strong movements in the growth rate. However, noticeable differences in co-movements appear for the 2-4-years cycle as compared with the 1-2-years cycle. For the 2-4-years cycle we clearly observe two periods of strong co-movements at these particular frequency cycles in 1930 and the second part of the 1950s. In the second part of the 1950s, the U.S. GDP growth rate fluctuated considerably from one year to another, in a range of 0.4% and 9%. In the same time, the international oil prices remained relatively stable. This period was not characterized by economic boom and prices bubbles, either by severe recession. According to the phase-difference, the variables are in-phase (they co-move in the same direction), but it is not very clear if in the short-run oil prices are leading the U.S. GDP growth rate or conversely.

In the long-run, the output growth – oil prices co-movements are isolated. For the 4-8-years cycle, three periods of co-movements can be identified. The first period ranges between 1885-1890 when the oil prices had a relatively stable evolution while the second period of co-movements is identified around the 1930s. Once again, co-movements seem to be stronger in normal periods. This result can be explained by the fact that spikes in oil prices are followed by a sharp drop in the GDP, with a certain lag (Difiglio, 2014). However, for the third period of co-movements in the long-run, from 1965 up to 1975, we see that an increase in international oil prices with a pick around the 1973 oil crisis, is followed by an increase in the U.S. output, the U.S. being one of the main oil producers. Different from the short-run, in the long-run the phase difference shows clear period in which oil prices are leading the U.S. GDP. For the 4-8-years cycle a first period appears from 1875 to 1900 and the variables are in-phase. Other similar periods appear before and immediately after the World War II. However, around the 1973 oil crisis and in the 2000, the U.S. economic growth is leading international oil prices. However, the long-run results are somehow different for the 8-12-years cycle. First, the variables are out-of-phase between 1875 and 1900 (the phase difference lies between  $[\pi/2, \pi]$ ) and oil prices are leading. Second, between 1980 and 1990 the variables are also out-of-phase and oil prices are lagging.

Nevertheless, these results can be influenced by the evolution of asset prices, monetary conditions or by the other commodity prices. Therefore, we proceed to the computation of wavelet partial coherency, controlling for the influence of these additional variables (interest rate, inflation rate, gold prices, stock prices and housing prices). When eliminating the impact of these variables on the oil prices – economic growth nexus, we notice a relatively different situation (Fig. 2).

First, short-run co-movements are observed only for the 2-4-years cycle and are weaker than in the previous case. They are located around the World War II and between 1980 and 2005. Oil prices and U.S. business cycle co-move in the same direction ( $[-\pi/2, \pi/2]$ ) and in most of the cases oil prices are leading, except for 1859-1870. During the recent period, it is clear that oil prices have a noticeable influence on the U.S. economic growth rate. Second, in the long-run for the 4-8- and 8-12-years cycle, significant co-movements appear around the World War II, when both oil prices and U.S. GDP fluctuated a lot, but also in the 1880s and 1990s. The variables are in-phase for the 4-8-years cycle and oil prices are leading. However, for the 8-12-years cycle the variables are out-of-phase in two periods (1890s and 1980s) and oil prices are also leading. This means that in these two specific periods, an increase in oil prices lead to a contraction of the U.S. business cycle.

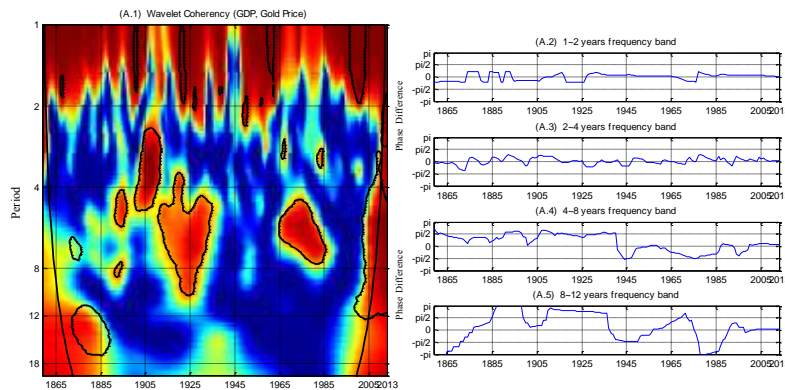
**Fig. 2. Wavelet partial coherency between the growth rate and international oil prices**



*Note: Wavelet Partial Coherency between GDP and oil prices after controlling for interest rate, inflation, gold prices, stock prices and housing prices. The black contour designates the 5% significance level estimated from the Monte Carlo simulations based on an ARMA(1,1) Null. The color code for power ranges from blue (low power) to red (high power). If phase difference is lies between  $[0, \pi / 2]$ , then the series are in-phase, with the time-series oil prices leading GDP. On the other hand, if phase-difference lies  $[-\pi / 2, 0]$  then GDP is leading. If we find evidence that phase-difference lies between  $[\pi / 2, \pi]$  then GDP is leading, while oil prices are leading if phase-difference lies between  $[-\pi, -\pi / 2]$  whiles both series have an anti-phase relationship.*

In the case of gold prices, the short-run co-movements look similar to the previous case, with a large intensification in the 2000s (Fig. 3). For the 2-4-years cycle, a co-movement period appears around 1900s. In the short-run the variables are in-phase (an increased in gold prices is associated with an increase in the U.S. output), and it is not evident which variable is leading. In the long-run (4-8-years cycle), two co-movement periods are noticed between 1910 and 1930 and 1965 and 1985. This result appear to be strange given the fact that during this last period the fold prices had not considerable fluctuations. As expected, after the World War II, the economic growth leads the gold prices for the 4-8-years cycle. Finally, during the recent financial crisis strong co-movements are observed both in the short- and long-run, but it is not clear which variables is leading.

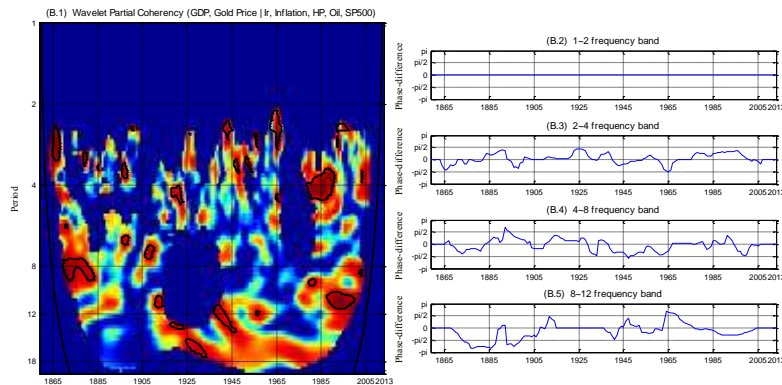
**Fig. 3. Wavelet coherency between the growth rate and gold prices**



*Note: Wavelet Coherency between GDP and gold prices. The black contour designates the 5% significance level estimated from the Monte Carlo simulations based on an ARMA(1,1) Null. The color code for power ranges from blue (low power) to red (high power). If phase-difference lies between  $[0, \pi / 2]$ , then the series are in-phase, with the time-series gold prices leading GDP. On the other hand, if phase-difference lies between  $[-\pi / 2, 0]$  then GDP is leading. If we find evidence that phase-difference lies between  $[\pi / 2, \pi]$  then GDP is leading, while the time-series gold prices is leading if phase-difference lies between  $[-\pi, -\pi / 2]$ , while both series have an anti-phase relationship.*

These results might be distorted by the simultaneous influence of other variable or by the monetary conditions. Consequently, we compute the wavelet partial coherency for the U.S. GDP – gold prices relation (Fig. 4). In this moment the short-run co-movements are not very evident and can be noticed only for the 2-4-years cycle. However, in the 1980s co-movements appear at the 4-years cycle. In the long-run strong co-movements can be noticed in the 1990s for the 4-8-years cycle. This corresponds to the period of the Great Moderation. The variables are in-phase and in general the business cycle is leading the gold prices.

**Fig. 4. Wavelet partial coherency between the growth rate and gold prices**

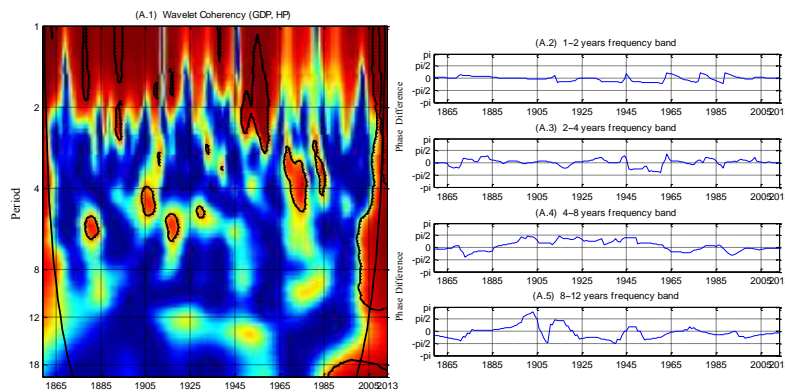


*Note: Wavelet Partial Coherency between GDP and gold prices after controlling for interest rate, inflation, housing prices, oil prices and stock prices. The black contour designates the 5% significance level estimated from the Monte Carlo simulations based on an ARMA(1,1) Null. The color code for power ranges from blue (low power) to red (high power). If phase-difference ranges between  $[0, \pi/2]$ , then the series are in-phase, with the time-series gold prices leading GDP. On the other hand, if phase-difference lies between  $[-\pi/2, 0]$  then GDP is leading. If we find evidence that phase-difference lies between  $[\pi/2, \pi]$  then GDP is leading, and the time-series gold prices is leading if phase-difference lies between  $[-\pi, -\pi/2]$  whiles both series have an anti-phase relationship.*

We further assess the influence of housing prices on the business cycle. We expect that a crash in the real estate market will slow down the economic growth and conversely, due to the wealth effect. From Fig. 5 it appears that co-movements between housing prices and economic growth are stronger in the short-run than those between oil prices and the economic growth in the U.S. Two periods of strong co-movements are identified after the World War II, but also in the context of the recent financial crisis, in 2009-2012. Another period of co-movements can be identified for the 1-2-years cycle in 1870. However, in the long-run, no clear period of co-movements is identified.

The variables are in-phase in the short-run, and periods when housing prices lead the economic growth are followed by periods when the U.S. GDP is leading. Thus, cyclicity is noticed regarding the bi-directional causality between U.S. housing prices and economic growth. In the long-run, for the 4-8-years cycle, starting with 1890 until 1965, housing prices leads the economic growth. Opposite, in 1970 and 1990 the U.S. GDP leads the housing prices.

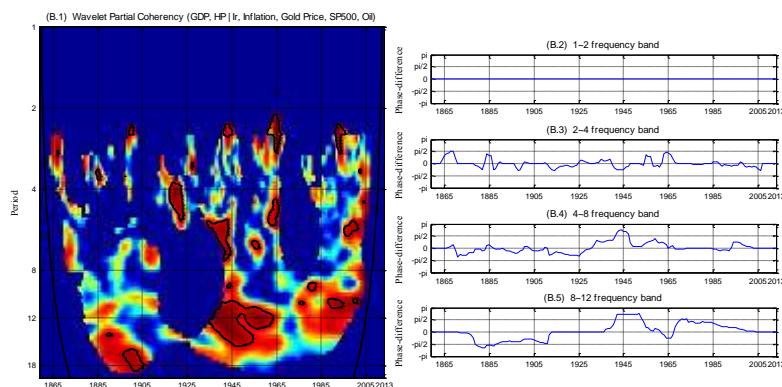
**Fig. 5. Wavelet coherency between the growth rate and housing prices**



*Note: Wavelet Coherency between GDP and housing prices. The black contour designates the 5% significance level estimated from the Monte Carlo simulations based on an ARMA(1,1) Null. The color code for power ranges from blue (low power) to red (high power). If phase-difference lies between  $[0, \pi/2]$ , then the series are in-phase, with the time-series housing prices leading the GDP. On the other hand, if phase-difference lies between  $[-\pi/2, 0]$  then GDP is leading. If we find evidence that phase-difference lies between  $[\pi/2, \pi]$  then GDP is leading, and housing prices are leading if phase-difference lies between  $[-\pi, -\pi/2]$ , while both series have an anti-phase relationship.*

In what follows, we control for the influence of interest rate, inflation, gold prices, stock prices and oil prices (Fig. 6). When eliminating these influences, co-movements are less evident in the short-run and are located in the 1960s and 1990s. The variables are in-phase, but it is not clear which variable is leading. Furthermore, strong co-movements appear in this moment in the long-run, both for the 4-8- and 8-12-years cycles, between 1940 and 1945, during the World War II. Another episode of co-movements in the long-run is documented after the outburst of the recent financial crisis, when both the output and the housing prices dropped. The variables are in-phase in the long-run (except for a short period immediately after 1945), and the housing prices are leading in general.

**Fig. 6. Wavelet partial coherency between the growth rate and housing prices**

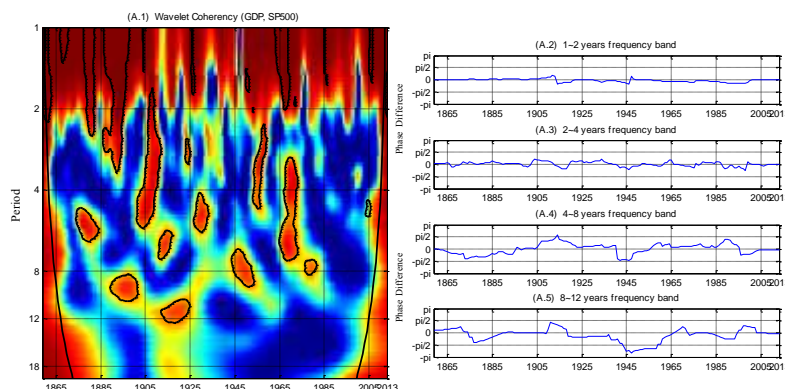


*Note: Wavelet Partial Coherency between GDP and housing prices after controlling for interest rate, inflation, gold prices, stock prices and oil prices. The black contour designates the 5% significance level estimated from the Monte Carlo simulations based on an ARMA(1,1) Null. The color code for power ranges from blue (low power) to red (high power). If phase-difference lies between  $[0, \pi/2]$ , then the series are in-phase, with the time-series housing prices leading GDP. On the other hand, if phase-difference lies  $[-\pi/2, 0]$  then GDP is leading. If we find evidence that phase-difference lies between  $[\pi/2, \pi]$  then GDP is leading, and the time-series housing prices is leading if phase-difference lies between  $[-\pi, -\pi/2]$ , whiles both series have an anti-phase relationship.*

The last part of our analysis assesses the historical co-movements between the U.S. GDP growth rate and stock prices (Fig. 7). From Fig. 7 it appears that in this case also, there are strong co-movements in the short-run, for the 1-2-years cycle, for the entire analyzed time-span. Strong co-movements are noticed in the 1880s and during the 1960s. In the case of the 2-4-years cycle, important co-movements are noticed around 1900s and 1970s. Furthermore, in the long-run, for the 4-8- and 8-12-years cycles, co-movements between stock returns and economic growth are mainly observed in the beginning of the 20<sup>th</sup> century.

In the short-run the variables co-move in the same time (none of the two variables is leading). However, in the long-run, in general the stock prices lead the economic growth, except for the World War II period, when the opposite applies. We can thus state then shocks in stock prices are transmitted to the U.S. economic growth.

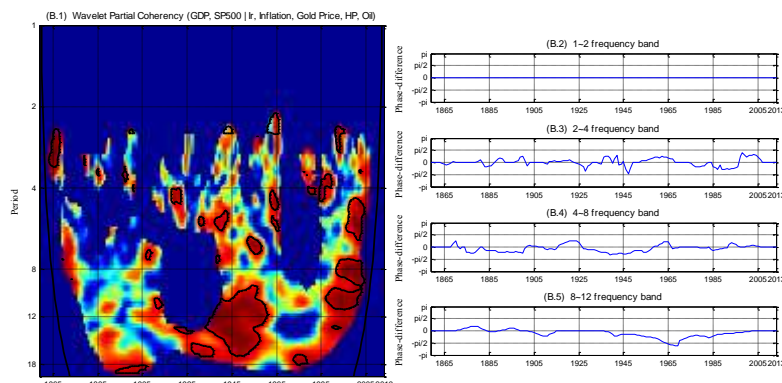
**Fig. 7. Wavelet coherency between the growth rate and stock prices**



*Note: Wavelet Coherency between GDP and stock prices. The black contour designates the 5% significance level estimated from the Monte Carlo simulations based on an ARMA(1,1) Null. The color code for power ranges from blue (low power) to red (high power). If phase-difference lies between  $[0, \pi / 2]$ , then the series are in-phase, with the time-series stock prices leading the GDP. If phase-difference lies between  $[-\pi / 2, 0]$  then GDP is leading. If we find evidence that phase-difference lies between  $[\pi / 2, \pi]$  then GDP is leading, and the stock prices are leading if phase-difference lies between  $[-\pi, -\pi / 2]$ , while both series have an anti-phase relationship.*

In order to avoid the simultaneous influence of interest rate, inflation and other commodity and asset prices on the output growth – stock returns nexus, we compute the wavelet partial coherency (Fig. 8). Similar to the previous case, co-movements are noticed in the short-run for the entire time horizon, in the case of 2-4-years cycle, but are less strong. Noticeable co-movements appear in the 1980s, when the “Black Money” took place, but it is not evident which variable is leading. In the long-run, at 4-8-years cycles, co-movements between the stock market and the output are documented around the World War II and during 2000s. However, for the 8-12-years cycle, strong co-movements are noticed between 1940 and 1950 on the one hand, and between the 1990 and 2005 on the other hand. However, different from other commodity and asset prices investigated above, in the case of economic growth – stock prices relationship, there is no clear evidence about the leading variable, even in the long-run. This result proves that stock prices are highly correlated with the economic activity in the U.S.

**Fig.8. Wavelet partial coherency between the growth rate and stock prices**



*Note: Wavelet Partial Coherency between GDP and stock prices after controlling for interest rate, inflation, gold prices, housing prices and oil prices. The black contour designates the 5% significance level estimated from the Monte Carlo simulations based on an ARMA(1,1) Null. The color code for power ranges from blue (low power) to red (high power). If phase-difference lies between  $[0, \pi / 2]$ , then the series are in-phase, with the time-series stock prices leading GDP. On the other hand, if phase-difference lies between  $[-\pi / 2, 0]$  then GDP is leading. If we find evidence that phase-difference lies between  $[\pi / 2, \pi]$  then GDP is leading, and the time-series stock prices is leading if phase-difference lies between  $[-\pi, -\pi / 2]$ , while both series have an anti-phase relationship.*

All in all, our results state that: (i) the co-movements between assets prices and economic growth manifest especially in the short-run, for the 1-2-years frequency cycle; (ii) when controlling for the influence of other commodity and asset prices, as well for the influence of monetary conditions, the short-run co-movements are noticed over the entire time-span, but only starting with the 2-years frequency cycle, and they prove weaker this time; (iii) the asset prices have a more powerful effect on the U.S. economic growth than the commodity prices; (iv) most of co-movements appear around the World War II, but also in normal-times episodes; (v) in general the oil and housing prices lead the GDP growth, the U.S. output lead the gold prices, while there is no clear causality direction between business cycle and stock prices.

These findings present however several limits. First, we assess the influence of individual commodities, while most recent works use country-specific commodity export price indexes (see Deaton and Miller, 1996; Collier and Goderis, 2012; Gruss, 2014). Indeed, the U.S. is one of the largest oil and gold producers but, at the same time, non-commodity price influences cannot be appropriately assessed for individual items. Second, we have controlled only for the effect of monetary conditions and other commodity and asset prices. However, in the long-run, the economic growth – commodity and asset prices nexus might be also influenced by the trade openness or credit facilities. Third, we have noticed strong co-movements not only during distress periods, but also in normal times. Therefore, factors which explain these co-movements should be identified.



## Conclusions

In this paper we examine the economic growth – commodity and asset prices nexus from an historical perspective, considering the U.S. case from 1859 up to 2013. Many analysts now argue that in the short-run, the economic growth and commodity and asset prices co-move. However, a considerable uncertainty surrounds this relationship in the long-run. Therefore, one salient feature of our paper is the fact that it draws a comparison between the short- and long-run co-movements, relying on a time-frequency approach. More precisely, we test the link between business cycles and the oil, gold, housing and stock prices, using wavelets. Moreover, we control for the influence of monetary conditions and the other commodity and asset prices, considering the wavelet partial coherency.

We conjecture that the response of the U.S. business cycles to different categories of assets is frequency-dependent and changes during the analyzed time-span. In line with previous researches, co-movements manifest especially in the short-run, but we highlight the fact that these co-movements are stronger for the housing and stocks prices, than those for international oil and gold prices. In addition, the long-run co-movements are notice in general around the World War II. Furthermore, co-movements are in general strong during the recent financial crisis. Finally, we state that when controlling for the simultaneous influence of other variables, on the one hand, the short-run co-movements appears only starting with the 2-years frequency cycle and are weaker, while for the long-run, additional co-movements episodes appear, also localized around the World War II.

Even if co-movements between stock prices and economic growth are strong, it is not clear which variables is leading. This proves for a high dependence between financial markets and economic growth in the U.S. However, the oil and housing prices lead the economic growth in general, while the opposite applies in the case of gold prices.

Nevertheless, the results caution against the assessment of particular categories of assets, while making abstraction of the effects of other categories of commodities for example. Therefore, future works can be extended toward including into analysis an aggregate commodity price index. At the same time, we have controlled for the effect of interest rate, inflation and other commodity and asset prices, but the trade openness or financial intermediation condition may also impact the investigated relationships. In this context, a deeper analysis of the transmission channels between commodity and asset prices and the business cycles is suitable.

## References

- Aguiar-Conraria, L., Azevedo, N. and Soares, M.J., 2008. Using Wavelets to Decompose the Time-Frequency Effects of Monetary Policy. *Physica A: Statistical Mechanics and its Applications*, 387, 2863–2878.
- Aguiar-Conraria, L. and Soares, M.J., 2011. Business cycle synchronization and the Euro: A wavelet analysis. *Journal of Macroeconomics*, 33, 477–489.
- Alexeev, M. and Conrad, R., 2009. The elusive curse of oil. *The Review of Economics and Statistics*, 91, 586–598.
- Apergis, N., 2014. Can gold prices forecast the Australian dollar movements? *International Review of Economics and Finance*, 29, 75–82.
- Arouri, M.E.H., Hammoudeh, S., Lahiani, A. and Nguyen, D.K., 2012. Long memory and structural breaks in modeling the return and volatility dynamics of precious metals. *The Quarterly Review of Economics and Finance*, 52, 207–218.
- Arouri, M.E.H., Lahiani, A. and Nguyen, D.K., 2015. World gold prices and stock returns in China: Insights for hedging and diversification strategies. *Economic Modelling*, 44, 273–282.

- Benhmad, F., 2013. Dynamic cyclical comovements between oil prices and US GDP: A wavelet perspective. *Energy Policy*, 57, 141–151.
- Benjamin, J.D., Chinloy, P., and Jud, G.D., 2004. Real estate versus financial wealth in consumption. *Journal of Real Estate Finance and Economics*, 29, 341–354.
- Berk, I. and Yetkiner, H., 2014. Energy prices and economic growth in the long run: Theory and evidence. *Renewable and Sustainable Energy Reviews*, 36, 228–235.
- Berumen, M.H., Ceylan, N.B. and Dogan, N., 2010. The Impact of Oil Price Shocks on the Economic Growth of Selected MENA Countries. *The Energy Journal*, 31, 149–177.
- Binswanger, M., 2004. Stock returns and real activity in the G-7 countries: did the relationship change during the 1980s? *The Quarterly Review of Economics and Finance*, 44, 237–252.
- Bordo, M.D., Landon-Lane, J. and Redish, A., 2010. Deflation, Productivity Shocks and Gold: Evidence from the 1880–1914 Period. *Open Economies Review*, 21, 515–546.
- Brückner, M. and Ciccone, A., 2010. International commodity prices, growth and the outbreak of Civil War in Sub-Saharan Africa. *The Economic Journal*, 120, 519–534.
- Caballero, R., Farhi, E. and Gourinchas, P-O., 2008. Financial Crash, Commodity Prices, and Global Imbalances. *Brookings Papers on Economic Activity*, Fall, 1-55.
- Camacho, M. and Perez-Quiros, G., 2014. Commodity Prices and the Business Cycle in Latin America: Living and Dying by Commodities? *Emerging Markets Finance and Trade*. 50, 110–137.
- Campbell, J.Y. and Cocco, J.F., 2007. How do house prices affect consumption? Evidence from micro data. *Journal of Monetary Economics*, 54, 591–621.
- Canova, F. and De Nicolo, G., 1995. Stock returns and real activity: a structural approach. *European Economic Review*, 39, 981–1015.
- Case, K.E., Quigley, J.M. and Shiller, R.J., 2005. Comparing wealth effects: the stock market versus the housing market. *Advances in Macroeconomics*, 5, 1–34.
- Cerra, V., and Saxena, S., 2008. Growth Dynamics: The Myth of Economic Recovery. *American Economic Review*, 98, 439–457.
- Céspedes, L.F. and Velasco, A., 2012. Macroeconomic Performance During Commodity Price Booms and Busts. NBER Working Papers, No. 18569.
- Chaney, T., Sraer, D. and Thesmar, D., 2011. The collateral channel: how real estate shocks affect corporate investment. *American Economic Review*, 102, 2381–2409.
- Chatrath, A., Ramchander, S. and Song, F., 1997. Stock prices, inflation and output: evidence from India. *Applied Financial Economics*, 7, 439–445.
- Cheung, Y. and Ng, L., 1998. International evidence on the stock market and aggregate economic activity. *Journal of Empirical Finance*, 5, 281–296.
- Choi, J.J., Hauser, S. and Kopecky, J., 1999. Does the stock market predict real activity? Time series evidence from the G-7 countries. *Journal of Banking and Finance*, 23, 1771–1792.
- Collier, P. and Goderis, B., 2012. Commodity Prices and Growth: An Empirical Investigation. *European Economic Review*, 56, 1241–1260.
- Deaton, A. and R. Miller, 1996. International Commodity Prices, Macroeconomic Performance and Politics in Sub-Saharan Africa. *Journal of African Economies*, 5, 99–191.
- Difiglio, C., 2014. Oil, economic growth and strategic petroleum stocks. *Energy Strategy Reviews*, 5, 48–58.
- Domian, D.L. and Louton, D.A., 1997. A threshold autoregressive analysis of stock returns and real economic activity. *International Review of Economics and Finance*, 6, 167–179.
- Doroodian, K. and Boyd, R., 2003. The linkage between oil price shocks and economic growth with inflation in the presence of technological advances: a CGE model. *Energy Policy*, 31, 989–1006.
- Engelhardt, G.V., 1996. House prices and home owner saving behavior. *Regional Science and Urban Economics*, 26, 313–336.
- Fagan, G., Lothian, J.R. and Mcnelis, P.D., 2013. Was the gold standard really destabilizing? *Journal of Applied Econometrics*, 28, 231–249.
- Fama, E., 1990. Stock returns, expected returns and real activity. *Journal of Finance*, XLV, 1089–108.
- Fan, Y. and Gençay, R., 2010. Unit root tests with wavelets. *Econometric Theory*, 26, 1305–1331.

- Gilchrist, S. and Leahy, J.V., 2002. Monetary policy and asset prices. *Journal of Monetary Economics*, 49, 75–97.
- Gruss, B., 2014. After the Boom—Commodity Prices and Economic Growth in Latin America and the Caribbean. IMF Working Paper, No. 154.
- Gylfason, T., 2001. Natural resources, education, and economic development. *European Economic Review*, 45, 847–859.
- Hamilton, J. 2003. What Is an Oil Shock? *Journal of Econometrics*, 113, 363–398.
- Hassapis, Ch. and Kalyvitis, S., 2002. Investigating the links between growth and real stock price changes with empirical evidence from the G-7 economies. *The Quarterly Review of Economics and Finance*, 42, 543–575.
- Heil, C.E. and Walnut, D.F., 1989. Continuous and discrete wavelet transforms. *SIAM review*, 31, 628–666.
- Homer, S., and Sylla, R. (2005). *A History of Interest Rates*, 4th Edition. Wiley Finance.
- Jayaraman, T.K. and Choong, C-K., 2009. Growth and oil price: A study of causal relationships in small Pacific Island countries. *Energy Policy*, 37, 2182–2189.
- Jefferis, K. and Okeahalam, C., 2000. The impact of economic fundamentals on stock markets in Southern Africa. *Development Southern Africa*, 17, 23–51.
- Jimenez-Rodriguez, R. and Sanchez, M., 2005. Oil price shocks and real GDP growth: empirical evidence for some OECD countries. *Applied Economics*, 37, 201–228.
- Kilian, L., 2008. Exogenous oil supply shocks: how big are they and how much do they matter for the U.S. economy? *Revue of Economics and Statistics*, 90, 216–240.
- Kilian, L. and Vigfusson, R.J., 2011a. Are the responses of the US economy asymmetric in energy price increases and decreases? *Quantitative Economics*, 2, 419–453.
- Kilian, L. and Vigfusson, R.J., 2011b. Nonlinearities in the oil price–output relationship. *Macroeconomics Dynamics*, 15, 337–363.
- Kishor, N.K., 2007. Does consumption respond more to housing wealth than to financial market wealth? If so, why? *Journal of Real Estate Finance and Economics*, 35, 427–448.
- Labat, D., 2005. Recent advances in wavelet analyses: Part 1. A review of concepts. *Journal of Hydrology*, 314, 275–288.
- Le, T-H. and Chang, Y., 2012. Oil price shocks and gold returns. *International Economics*, 131, 71–104.
- Lee, K., Ni, S. and Ratti, R.A., 1995. Oil Shocks and the Macroeconomy: The Role of Price Variability. *Energy Journal*, 16, 39–56.
- Lettau, M. and Ludvigson, S., 2004. Understanding trend and cycle in asset values: reevaluating the wealth effect on consumption. *American Economic Review*, 94, 276–299.
- Li, X-L., Chang, T., Miller, S.M., Balcilar, M. and Gupta, R., 2015. The co-movement and causality between the U.S. housing and stock markets in the time and frequency domains. *International Review of Economics and Finance*, forthcoming
- Liu, X. and Sinclair, P., 2008. Does the linkage between stock market performance and economic growth vary across Greater China? *Applied Economics Letters*, 15, 505–508.
- Loutskina, E. and Strahan, P.E., 2015. Financial integration, housing, and economic volatility. *Journal of Financial Economics*, 115, 25–41.
- Lyócsa, Š., 2014. Growth-returns nexus: Evidence from three Central and Eastern European countries. *Economic Modelling*, 42, 343–355.
- Mauro, P., 2003. Stock returns and output growth in emerging and advanced economies. *Journal of Development Economics*, 71, 129–153.
- Mian, A. and Sufi, A., 2011. House prices, home equity-based borrowing and the US household leverage crisis. *American Economic Review*, 101, 2132–2156.
- Miller, N., Peng, L. and Sklarz, M., 2011. House Prices and Economic Growth. *Journal of Real Estate Finance and Economics*, 42, 522–541.
- Narayan, P.K., Sharma, S., Poon, W.C. and Westerlund, J., 2014. Do oil prices predict economic growth? New global evidence. *Energy Economics*, 41, 137–146.
- Nasseh, A. and Strauss, J., 2000. Stock prices and domestic and international macroeconomic activity: a cointegration approach, *The Quarterly Review of Economics and Finance*, 40, 229–245.

- Ng, E.K.W. and Chan, J.K.L., 2012. Geophysical applications of partial wavelet coherence and multiple wavelet coherence. *Journal of Atmospheric and Oceanic Technology*, 29, 1845–1853.
- Pan, H. and Wang, C., 2013. House prices, bank instability, and economic growth: Evidence from the threshold model. *Journal of Banking and Finance*, 37, 1720–1732.
- Panopoulou, E., Pittis, N. and Kalyvitis, S., 2010. Looking far in the past: revisiting the growth–returns nexus with non-parametric tests. *Empirical Economics*, 38, 743–766.
- Peiró, A., 1996. Stock prices, production and interest rates: comparison of three European countries with the USA. *Empirical Economics*, 21, 221–334.
- Peress, J., 2014. Learning from Stock Prices and Economic Growth. *Review of Financial Studies*, 27, 10, 2998–3059.
- Pierdzioch, C., Risse, M. and Rohloff, S. 2014. The international business cycle and gold-price fluctuations. *The Quarterly Review of Economics and Finance*, 54, 292–305.
- Rasche, R.H. and Tatom, J.A., 1981. Energy Price Shocks, Aggregate Supply and Monetary Policy: The Theory and International Evidence. *Carnegie-Rochester Conference Series on Public Policy*, 14, 125–142.
- Reboredo, J.C., 2013. Is gold a safe haven or a hedge for the U.S. Dollar? Implications for risk management. *Journal of Banking and Finance*, 37, 2665–2676.
- Regnier, E. 2007. Oil and energy price volatility. *Energy Economics*, 29, 405–427.
- Sachs, J.D. and Warner, A.M., 2001. The curse of natural resources. *European Economic Review*, 45, 827–838.
- Sala-i-Martin, X., Doppelhofer, G. and Miller, R.I., 2004. Determinants of long-term growth: a Bayesian averaging of classical estimates (BACE) approach. *American Economic Review*, 94, 813–835.
- Sari, R., Hammoudeh, S. and Soytas, U., 2010. Dynamics of oil price, precious metal prices, and exchange rate. *Energy Economics*, 32, 351–362.
- Shafiee, A. and Topal, E., 2010. An overview of global gold market and gold price forecasting. *Resources Policy*, 35, 178–189.
- Sheiner, L., 1995. Housing prices and the savings of renters. *Journal of Urban Economics*, 38, 94–125.
- Shirai, S., 2004. Testing the three roles of equity markets in developing countries: the case of China. *World Development*, 32, 1467–1486.
- Stock, J.H. and Watson, M.W., 2003. Forecasting Output and Inflation: The Role of Asset Prices. *Journal of Economic Literature*, 41, 788–829.
- Torrence C. and Compo G.P., 1998. A Practical Guide to Wavelet Analysis. *Bulletin of the American Meteorological Society*, 79, 605–618.
- Torrence C. and Webster P., 1999. Interdecadal Changes in the ENSO-Monsoon System. *Journal of Climate*, 12, 2679–2690.