國立政治大學亞太研究英語博士學位學程

International Doctoral Program in Asia-Pacific Studies

National Chengchi University

論貨幣政策與資產價格

Essays on Monetary Policy and Asset Prices

博士論文

Ph.D. Dissertation

指導教授：林左裕 博士

Supervisor: Dr. Tsoyu Calvin Lin

研究生：寇菲力 撰

Candidate: Philipp Klotz

中華民國一百零三年三月

論貨幣政策與資產價格

Essays on Monetary Policy and Asset Prices

A Dissertation

by

Philipp Klotz

Submitted to National Chengchi University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Chair of Committee	Dr. Tsoyu Calvin Lin 林左裕 博士
Committee Members	Dr. Chung-Rou Fang 方中柔 博士
	Dr. Shih-Hsun Hsu 徐士勛 博士
	Dr. Che-Chun Lin 林哲群 博士
	Dr. Tzu-Chin Lin 林子欽 博士
	Dr. Tony Shun-Te Yuo 游舜德 博士

中華民國一百零三年三月

Abstract

This thesis consists of two essays on the relationship between monetary policy and asset price dynamics. The first essay examines the extent to which Greece, Ireland, Portugal and Spain experienced property bubbles and investigates the role of European Central Bank's (ECB) monetary policy in the formation of these bubbles in the period from 1999 to 2012. The analysis shows that Spain and Ireland experienced the largest bubble formation followed by Portugal and Greece. Cointegration tests and VEC impulse responses indicate a significant long- and short-run relationship between ECB's monetary policy and bubble formation in Greece, Ireland and Spain.

The second essay examines long- and short-run dynamics between global commodity prices, economic activity and monetary policy of China in the period from 1998M01 to 2012M12. While Toda and Yamamoto (1995) type Granger causality tests provide no evidence for a long-run relationship between monetary policy and commodity prices, VAR generalized impulse responses suggests that agricultural commodity prices overshoot in response to a drop in the real interest rate. The analysis further finds evidence that industrial metals prices tend to be higher when China's exchange rate regime is relaxed.

Table of Contents

List of Abbreviations

BGS	British Geological Survey
BIS	Bank for International Settlements
BP	British Petroleum
CBOT	Chicago Board of Trade
CME	Chicago Mercantile Exchange
COMEX	Commodity Exchange
DCE	Dalian Commodity Exchange
EA	Euro Area
ECB	European Central Bank
EIA	Energy Information Administration
EMF	European Mortgage Federation
Euribor	Euro Interbank Offered Rate
FAO	Food and Agriculture Organization of the United Nations
GIRF	Generalized Impulse Response Function
GVA	Gross Value Added
HAC	Heteroskedasticity and Autocorrelation Consistent
ICE	Intercontinental Exchange
KCBOT	Kansas City Board of Trade
LME	London Metal Exchange
LTV	Loan-to-Value
NYBOT	New York Board of Trade
NYMEX	New York Mercantile Exchange
OECD	Organization for Economic Co-operation and Development
OTC	Over-the-Counter

PBC	People's Bank of China
RMB	Renminbi
S.D.	Standard Deviation
SFE	Shanghai Futures Exchange
T&Y	Toda and Yamamoto
USD	US Dollar
USITC	United States International Trade Commission
VAR	Vector Auto Regression
VEC	Vector Error Correction
WACC	Weighted Average Cost of Capital
WFE	World Federation of Exchanges
WTO	World Trade Organization
Y-o-Y	Year-on-Year
ZCE	Zhengzhou Commodity Exchange

List of Figures

List of Tables

1. Introduction

Asset prices across different regions and markets experienced large movements before and during the recent global financial and Eurozone crisis. Being a critical component in the economic and financial system, these asset price fluctuations have attracted a lot of attention from academia and practitioners. Monetary policy has been frequently identified as a major driver of asset price booms and busts as well as an instrument to mitigate the possibly severe consequences on economic and financial stability.

The literature on the transmission mechanism of monetary policy to asset price dynamics is extensive. The mainstream view, focusing on the effect of liquidity, has its roots in the theories of Keynes and was essentially coined by Monetarist economists. Friedman (1970), well known for his statement[1] "*inflation is always and everywhere a monetary phenomenon*", argues that changes in the quantity of money have a dominant impact on nominal income, prices and output. Thereby, the effect of a change in the rate of change in the quantity of money first shows up in nominal income then in output followed by a lagged effect on inflation. The transmission of the monetary change to the nominal income involves portfolio adjustment and change in relative prices, which have a direct impact on asset prices (Friedman, 1970; Friedman & Schwartz, 1965).

Following the monetarist theory, a monetary policy induced rise in the quantity of money increases the amount of cash people and businesses have relative to other assets. The excessive cash is used to adjust their portfolios by buying existing assets such as bonds, equities, real estate, and other physical capital. As one man's spending

[1] In this context, Friedman (1970) understands monetary phenomenon as an increase in the quantity of money that exceeds output. The effect on how the general price level is affected by the increase of the quantity of money, however, is not a direct one; it is rather part of the process how monetary changes are transmitted to economic changes.

is another man's receipt and market participants attempt to change their cash balance, the effect spreads from one asset to another. In this regard, Tobin (1969) illustrates the mechanism how monetary changes impact different asset classes. Accordingly, an increase in the supply of any asset alters the structure of rates of return on this and other assets so that it induces market participants to hold the new supply. If the rate of the asset is fixed, as in the case of money, the adjustment process works through reductions in other rates or increases the price of other assets. A substitution from assets with high return towards assets with lower returns is carried out as returns on the former decline relative to the latter. The portfolio adjustment not only tends to increase prices of assets across different categories but also reduces interest rates. The positive price effect on assets paired with the negative effect on interest rates in turn encourages spending to produce new assets and gives an incentive for spending on current services rather than buying existing assets. Through this process the initial effect on portfolio adjustment translates into an effect on income and spending. In a later stage, as spending and price inflation move up, demand for loans as well as discrepancy between real and nominal interest rates increases, leading to an upward movement of the interest rate later on.

An alternative view on the relationship between monetary policy and asset prices is provided by the Austrian business cycle theory developed by Mises (1912) and Hayek (1935). The theory has been carried forward to the modern discussion on asset price booms (Bordo & Landon-Lane, 2013; Bordo & Wheelock, 2004) and incorporated in the BIS view (Borio, 2012; Borio, English, & Filardo, 2003; Borio & Lowe, 2002). In contrast to the monetarist view (Friedman, 1970) which regards the quantity of money as the key element of monetary policy in the context of asset price dynamics, the Austrian view pays special attention to interest rates and credit. In this view, changes in interest rates are not merely side effects of portfolio adjustment and of changes in relative prices triggered by an increase in the quantity of money, but rather a key element driving asset prices and entire business cycles.

The Austrian business cycle theory argues that an increase in money supply lowers interest rates below its natural rate[2], inducing a credit-financed investment boom which bids up prices of capital goods relative to consumption goods. Thereby, prices of capital goods rise faster than consumption goods because entrepreneurs spend the increased amount of money loaned by banks on capital goods. While prices of capital goods rise first, prices of consumption goods rise only moderately at the rate as they are increased by money loaned by consumption goods. Soon after, as the loan rate rises and approaches the natural rate, the movement reverts and prices of consumption goods rise while prices of capital goods decline. This reverse movement can be temporarily countered by monetary intervention which increases money supply and holds interest rates below the natural rate. The reason why credit is channeled into capital goods after a drop of the interest rate below its natural rate is because interest rates play an important role in the economy as a coordinator of investment and production across time. When consumers prefer to consume in the future rather than today, they will increase savings; this in turn will lead to an interest rate decline, giving producers a signal to engage in capital-intensive investments and sell their products in the future. The reverse holds true when consumers prefer to consume today rather than in the future.

When monetary policy comes into play, the coordinating function of interest rates might become misleading. An increase in money supply which forces the interest rate

[2] The natural rate, also called equilibrium rate, describes the interest rate which would prevail without monetary intervention. This rate would be determined by demand for and the supply of savings. If the money rate of interest coincides with the natural rate, the rate remains neutral on its effects on the prices of goods (Hayek, 1935, p. 23-24).

below its natural level signals producers to engage in capital investments rather than on production of consumption goods. As consumer preferences as well as total resources remain unchanged, the remaining resources are directed into unwanted long-term product development where some of the capital investments cannot be completed. Ultimately, with the depletion of the subsistence fund or end of easing monetary policy these misallocated resources are liquidated, prices fall and the economy bursts.

Although the two views presented above have several similarities, they are intrinsically different (Bordo & Landon-Lane, 2013; Bordo & Wheelock, 2004). Both theories regard monetary policy as a driver of asset prices; however, while the focus of the monetarist view is on changes in liquidity, i.e. money supply, the Austrian view focuses on the effect of interest rates and credit supply which have its source in alterations of the quantity of money. Another key difference is the role asset prices play in the transmission of monetary policy to the economy as a whole. In the monetarist view, the role of asset prices has a passive character as a channel transmitting monetary policy changes into the economy. As such, asset price changes are considered as a harbinger of future inflation of the general price level. In contrast, the Austrian view attributes a more active role to asset prices being an inherent element of economic cycles. Thereby, an asset price boom, whatever its cause, can turn into a bubble if accommodative monetary policy allows credit to rise to fuel the credit-financed investment boom. Unless monetary policy hinders credit-financed investment booms, a crash which may turn in serious recession might be inevitable.

Besides the theory, there are many empirical studies that look at the relationship between monetary policy and asset price cycles. For instance, Detken and Smets (2004) identify asset price booms since the early 1970s and characterize what happens during the boom, just before and immediately following it. The authors look specifically at the relationship between monetary policy and prices of equity, commercial and private real estate. Monetary policy is captured by changes in short term interest rates, money and credit aggregates as well as deviations from the Taylor rule; an asset price boom is defined as a period when real asset prices are more than 10 percent above their recursively estimated trend. The analysis further distinguishes between booms that are followed by a large recession (high-cost booms) and those that are not (low-cost booms). The analysis concludes that high-cost booms seem to follow very rapid growth in the real money and real credit stocks and that high-cost booms are associated with significantly looser monetary policy conditions over the boom period. Another recent study (Bordo & Landon-Lane, 2013) focuses on the effect of monetary policy on housing, stock and commodity price dynamics. Looking at the time interval from 1920 to 2011, the study uses a panel of up to 18 OECD and determines the effect of loose monetary policy on the asset price dynamics in the housing, stock and commodity market. This analysis uses deviation of a short term interest rate from the optimal Taylor rule rate and the deviation of the money growth rate from the target growth rate as measure of monetary policy. Thereby, loose monetary policy is defined as having an interest rate below or money growth rate above the respective target rate. The empirical findings show that loose monetary policy is increasing asset prices. The results furthermore indicate that the loose monetary policy effect is strengthened during periods of fast price increases and the subsequent market correction across multiple asset classes and different specifications. The two essays presented in the following two chapters contribute to this literature by investigating the relationship between monetary policy and asset price dynamics in two specific markets.

The first essay presented in chapter two examines the impact of the monetary policy of the European Central Bank (ECB) on real estate price bubbles in Greece, Ireland, Portugal and Spain. The main motivation to look at these countries is that these countries stand in the epicenter of the ongoing financial crisis in Europe. These countries strongly relied on the construction sector, making them particularly vulnerable to the collapse of the real estate sector. This study attempts to determine the extent to which these countries experienced property bubbles and to examine the role of ECB's monetary policy in the formation of these bubbles. The analysis builds on the theory on asset bubbles developed by Stiglitz (1990) and applies the direct capitalization approach through weighted average cost of capital (WACC) to identify real estate bubbles in the period from the inception of the single monetary policy in the Eurozone in 1999 to 2012. Thereby, the essay looks at two critical monetary policy variables, the loan-to-GDP ratio as a measure of bank lending activities and the 3-month Euribor as proxy for the key interest rates set by the ECB. The short-run and long-run dynamics between monetary policy variables of the ECB and the real estate bubble in the four countries are investigated by applying cointegration tests, Vector Autoregression (VAR) and Vector Error Correction (VEC) models.

The second essay presented in chapter three focuses on the link between the monetary policy of the People's Bank of China (PBC) and global commodity price dynamics. In light of China's emergence as world's second largest economy and dominant player in commodity markets, the main motivation is to gain an understanding of its monetary policies on global commodity prices. Thereby, the preposition is that not only China's economic activity as suggested by past literature but also the monetary policy of the PBC has a significant impact on global commodity prices. The analysis draws from the commodity price overshooting theory developed by Frankel (1986, 2008) and examines the long- and short-run dynamics between global commodity prices of the agriculture, energy, industrial metals, livestock and precious metals sector, economic activity and real interest rate of China in the period from 1998M01 to 2012M12. The time period starts at the point when China accelerated banking sector reforms and officially replaced its credit quota system by a target system and interest rates started to be increasingly determined by market forces. In order to account for the exchange rate regime change in China, the analysis further considers a dummy variable capturing the move of China from a fixed exchange rate regime to a managed floating exchange rate regime in 2005M07. To investigate the long- and short-run dynamics between the variables, this study applies Toda and Yamamoto (1995) type Granger causality tests on lag augmented VAR models and generalized impulse response function analysis.

The last chapter summarizes the key points of the two essays on monetary policy and asset price dynamics and derives a short conclusion.

2. Monetary Policy and Real Estate Bubbles

2.1. Introduction

The four European countries[3] Greece, Ireland, Portugal and Spain stand in the epicentre of the current financial crisis in Europe. As for Ireland and Spain, there is broad consent that the housing market played an important role in putting them into financial distress. In the case of Greece and Portugal, the economic downturn was mainly associated with structural issues, high government spending as well as an inefficient administrative system. Although the roots of the ongoing Eurozone crisis differ across these countries, they share several characteristics.

The most apparent similarity is that the economies of these four countries have become particularly weak in the course of the Eurozone crisis. Another important similarity is that these four countries relied strongly, above Eurozone average, on the construction sector. The initial boom in the construction sector across most of these countries came to an abrupt end when the real estate sector collapsed in the late 2008. The economic downturn in the construction sector went hand in hand with falling housing prices in Greece, Ireland and Spain right after the crisis followed by further massive price declines across all four countries at the end of 2012 (Igan & Loungani, 2012).

Table 2.1 gives an overview of the gross value added (GVA) of the construction sector as a share of total GVA in the four countries relative to the Eurozone average. The data shows that the weight of the construction sector in all of the four countries

[3] Due to their relatively weak and unstable economy, these four countries were often referred to as "PIGS" countries in the discussion related to the ongoing financial crisis in Europe. Originally this acronym was used to describe the four south European countries Greece, Italy, Portugal and Spain. In the course of the outbreak of the European sovereign-debt crisis Ireland replaced Italy in the group of the so called "PIGS" countries.

was above the Eurozone average in the time period from the inception of the single monetary policy in the Eurozone in 1999[4] to the collapse in 2008. While the weight of the construction sector in Greece and Portugal was around 1-2% above the Eurozone average, Ireland displayed temporarily and Spain constantly values above 10%, putting them much above the Euro area average. In the extreme case of Spain, the size of the construction sector was for some time twice as large as the Eurozone average. This strong reliance on the construction sector made the economies of the four countries particularly vulnerable to the downturn in the housing market.

Table 2.1: GVA of the Construction Industry as a Share of Total GVA

Year	Euro Area	Greece	Ireland	Portugal	Spain
1999	N/A	7.24%	6.90%	7.93%	N/A
2000	5.89%	7.17%	7.32%	8.19%	10.30%
2001	5.94%	7.46%	7.61%	8.35%	10.86%
2002	5.96%	6.17%	7.43%	8.20%	11.54%
2003	6.06%	6.56%	7.90%	7.69%	12.08%
2004	6.18%	6.61%	9.02%	7.69%	12.67%
2005	6.39%	6.98%	10.22%	7.47%	13.59%
2006	6.64%	8.87%	11.06%	7.25%	14.17%
2007	6.68%	7.79%	9.50%	7.32%	13.86%
2008	6.75%	6.77%	7.09%	7.29%	13.61%
2009	6.60%	5.13%	2.95%	6.70%	13.00%
2010	6.06%	3.47%	1.89%	6.25%	10.67%
2011	5.93%	2.49%	1.68%	5.84%	9.50%
2012	5.77%	2.12%	1.56%	5.07%	8.56%

Note: Data is sourced from the Eurostat database (Eurostat, 2013). Construction gross value added (GVA) is used instead of gross domestic product (GDP) because there are no GDP figures on individual economic sectors available. The GVA can be calculated as GDP+ subsidies- taxes on products. The ratio shown gives an indication on the size of the construction sector relative to the entire economy. *Euro Area (EA) country aggregate includes the countries which were part of the Eurozone at the respective point in time (EA11-2000, EA12-2006, EA13-2007, EA15-2008, EA16-2010, EA17).

Table 2.2 illustrates the Y-o-Y growth rate of the total and construction sector gross value added (GVA). The table emphasizes two central points. First, in the booming years, the economic growth in three of the four countries, namely Greece, Ireland and

[4] While Ireland, Portugal and Spain became part of the Eurozone on 01 January 1999, Greece was admitted two years later on 01 January 2001 as a member of the Eurozone.

Spain propelled the economy much faster than the Eurozone average as well as other sectors as indicated by Y-o-Y growth rates in the total GVA. Second, in the years after the collapse of the real estate sector, the construction sector in all of the four countries fell much faster than the Eurozone average. This sharp drop in the economic activity in the construction sector had a spillover effect on the economy as a whole, contributing strongly to the slowdown of the broad economy.

Table 2.2: Y-o-Y Growth of Total GVA and Construction GVA

	Total GVA					Construction GVA				
Year	EA	Greece	Ireland	Portugal	Spain	EA	Greece	Ireland	Portugal	Spain
1999	N/A	6.8	13.5	7.8	N/A	N/A	9.3	21.4	9.2	N/A
2000	N/A	18.4	17.2	7.9	N/A	N/A	17.2	24.4	11.5	N/A
2001	6.9	5.9	11.1	5.7	8.4	7.8	10.1	15.4	7.8	14.3
2002	3.5	7.9	10.3	4.2	7.2	3.9	-10.7	7.7	2.3	13.8
2003	2.9	10.9	7.6	1.9	6.9	4.6	18.0	14.4	-4.4	11.9
2004	4.0	7.9	5.8	4.1	7.0	6.1	8.6	20.8	4.1	12.2
2005	3.3	3.6	8.2	2.3	7.4	6.8	9.5	22.7	-0.6	15.2
2006	4.7	6.4	9.0	3.7	7.9	8.7	35.2	18.0	0.7	12.5
2007	5.8	6.5	8.3	5.7	7.9	6.5	-6.4	-7.1	6.6	5.5
2008	2.9	4.8	-4.5	2.1	5.4	4.1	-8.9	-28.6	1.8	3.5
2009	-2.5	0.4	-9.3	-0.4	-2.5	-4.7	-24.0	-62.3	-8.5	-6.9
2010	2.5	-5.2	-1.0	1.8	-1.8	-6.0	-35.8	-36.4	-5.0	-19.4
2011	2.9	-6.2	3.1	-1.3	0.5	0.7	-32.7	-8.4	-7.8	-10.5
2012	0.6	-6.9	-1.0	-3.3	-1.6	-2.1	-20.7	-8.3	-16.1	-11.3

Note: Data is sourced from the Eurostat database (Eurostat, 2013). GDP and construction GVA Y-o-Y growth rates are calculated on the basis of the GDP and construction GVA at current market prices respectively. *Euro Area (EA) country aggregate includes the countries which were part of the Eurozone at the respective point in time (EA11-2000, EA12-2006, EA13-2007, EA15-2008, EA16-2010, EA17).

The booming years in Greece, Ireland and Spain went hand in hand with a strong increase in housing prices. On the contrary, not only Portugal's construction industry grew much slower than the other countries but also its price. Particularly in the case of Ireland and Spain it has been often argued that these countries experienced price increases that cannot be explained by actual, consumption-driven, demand. In fact, as Table 2.3 shows, house prices in Greece, Ireland and Spain increased much faster than rent and income.

Table 2.3: House Prices, Rent and Income

Year	Greece			Ireland			Portugal			Spain		
	House Price	Rent	Income	House Price	Rent	Income	House Price	Rent	Income	House Price	Rent	Income
1999	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2000	108.52	105.49	109.04	128.45	113.40	109.30	110.86	102.66	107.23	112.85	105.17	110.03
2001	120.46	109.68	112.11	144.36	129.67	128.63	116.87	105.34	113.31	123.97	109.44	120.69
2002	134.05	115.09	N/A	154.44	136.26	N/A	117.57	108.77	N/A	143.49	114.07	N/A
2003	143.62	121.10	129.23	176.40	135.25	153.93	118.89	111.36	N/A	168.75	118.94	N/A
2004	150.37	127.55	139.28	196.09	132.14	162.91	119.63	114.29	130.98	198.21	123.81	137.97
2005	170.46	132.95	148.30	210.64	134.79	169.43	122.35	117.02	136.27	225.77	129.12	139.65
2006	192.65	138.76	155.12	239.19	142.61	178.07	124.90	119.98	138.47	249.26	134.77	148.80
2007	199.97	145.07	160.63	238.09	157.65	198.87	126.57	123.20	143.43	263.62	140.65	155.58
2008	205.10	150.71	170.08	216.41	165.29	207.26	131.56	126.93	154.22	265.54	146.62	168.71
2009	199.09	156.16	181.04	186.85	141.84	202.30	132.08	130.35	156.86	245.77	151.13	171.76
2010	185.80	159.98	188.39	157.81	134.34	184.88	134.49	133.08	164.36	236.31	154.45	169.23
2011	171.90	161.32	172.99	138.08	134.37	177.79	134.23	134.32	159.28	223.11	156.08	161.92
2012	155.14	157.96	149.81	120.39	136.57	N/A	131.33	137.02	157.63	203.59	156.85	159.92

Note: Data on housing prices is sourced from the property price database of the European Central Bank (ECB, 2013b) and the Bank for International Settlements (BIS, 2013b). Population and income data is sourced from the Eurostat database (Eurostat, 2013). Income is the figure on median equalized net income. To allow for comparability, the quarterly house price and rent indices are transformed to annual data by calculating the arithmetic average of the quarterly values of the respective year and all of the time series are further adjusted so that 1999=100.

Only in the case of Portugal, the development of the house price relative to rent and income was more balanced with fundamental factors.

Relatively high owner occupancy rates[5] in all of the four countries further show a strong preference for buying versus renting (EMF, 2012), partially explaining the divergence between actual and investment demand.

Looking at the supply side of residential housing further strengthens the point that the price increase, particularly in Greece, Ireland and Spain cannot be explained by actual, consumption-driven, demand. Table 2.4 provides an overview of the yearly development of the total housing stock in the four countries relative to the number of households. The key figure- dwelling per household, in this table is calculated on the basis of the total dwelling stock and number of households in the respective country. Thereby, a value below one indicates housing shortage and a figure above one indicates oversupply. Two key observations can be attained on the basis of the figure on dwellings per household. First, all of the four countries display an oversupply in housing. As of 2010, Greece shows the largest oversupply with 1.56 dwelling per household, followed by Spain with 1.51, Portugal with 1.47 and Ireland with 1.19. The figure presented in Table 2.4 is further confirmed by figures on vacant conventional dwellings as a percentage of total dwelling stock shown in a report on housing statistics in the European Union (Dol & Haffner, 2010). The report indicates vacancy rates of 33.2% for Greece in 2001, 21.9% for Spain in 2004, 10.6% for Portugal in 2001 and 12% for Ireland in 2002. Second, all of the four countries showed an upward trend in the dwellings per household, indicating a constantly increasing oversupply of housing.

[5] While the owner occupancy rate of the EU 27 average of the latest figures was at 68.9%, this rate stood in 2010 at 80.1% in Greece, 74.5% in Ireland and 74.9% in Portugal and in 2008 at 85% in Spain.

Table 2.4: Total Dwelling Stock and Number of Households

Country	Year	Dwelling Stock	Population	Household Size (Average)	Households	Dwellings per Household
Greece	2000	5,476,000	10,903,757	N/A	4,038,429	1.36
	2001	5,581,000	10,931,206	N/A	4,048,595	1.38
	2002	5,705,000	10,968,708	N/A	4,062,484	1.40
	2003	5,829,000	11,006,377	N/A	4,076,436	1.43
	2004	5,947,000	11,040,650	2.70	4,089,130	1.45
	2005	6,136,000	11,082,751	2.70	4,104,723	1.49
	2006	6,257,000	11,125,179	2.70	4,120,437	1.52
	2007	6,357,000	11,171,740	2.70	4,137,681	1.54
	2008	6,434,000	11,213,785	2.70	4,153,254	1.55
	2009	6,493,000	11,260,402	2.70	4,170,519	1.56
	2010	6,545,000	11,305,118	2.70	4,187,081	1.56
	2011	6,572,000	11,123,392	2.60	4,278,228	1.54
Ireland	2000	1,406,000	3,777,565	N/A	1,302,609	1.08
	2001	1,448,000	3,832,783	N/A	1,321,649	1.10
	2002	1,506,000	3,899,702	N/A	1,344,725	1.12
	2003	1,575,000	3,964,191	N/A	1,366,962	1.15
	2004	1,652,000	4,028,851	2.90	1,389,259	1.19
	2005	1,733,000	4,111,672	2.80	1,468,454	1.18
	2006	1,841,000	4,208,156	2.80	1,502,913	1.22
	2007	1,919,000	4,340,118	2.80	1,550,042	1.24
	2008	1,971,000	4,457,765	2.80	1,592,059	1.24
	2009	1,997,000	4,521,322	2.70	1,674,564	1.19
	2010	2,012,000	4,549,428	2.70	1,684,973	1.19
	2011	N/A	4,570,881	2.70	1,692,919	N/A
Portugal	2000	5,007,000	10,249,022	N/A	3,660,365	1.37
	2001	5,107,000	10,330,774	N/A	3,689,562	1.38
	2002	5,232,000	10,394,669	N/A	3,712,382	1.41
	2003	5,324,000	10,444,592	N/A	3,730,211	1.43
	2004	5,398,000	10,473,050	2.80	3,740,375	1.44
	2005	5,473,000	10,494,672	2.80	3,748,097	1.46
	2006	5,539,000	10,511,988	2.80	3,754,281	1.48
	2007	5,603,000	10,532,588	2.80	3,761,639	1.49
	2008	5,659,000	10,553,339	2.70	3,908,644	1.45
	2009	5,708,000	10,563,014	2.70	3,912,227	1.46
	2010	5,751,000	10,573,479	2.70	3,916,103	1.47
	2011	N/A	10,572,721	2.60	4,066,431	N/A
Spain	2000	20,376,000	40,049,708	N/A	14,833,225	1.37
	2001	21,058,000	40,476,723	N/A	14,991,379	1.40
	2002	21,762,000	41,035,278	N/A	15,198,251	1.43
	2003	22,425,000	41,827,838	N/A	15,491,792	1.45
	2004	23,175,000	42,547,451	2.70	15,758,315	1.47
	2005	23,918,000	43,296,338	2.80	15,462,978	1.55
	2006	24,626,000	44,009,971	2.70	16,299,989	1.51
	2007	25,377,000	44,784,666	2.70	16,586,913	1.53
	2008	26,231,000	45,668,939	2.70	16,914,422	1.55
	2009	26,769,000	46,239,273	2.70	17,125,657	1.56
	2010	26,953,000	46,486,619	2.60	17,879,469	1.51
	2011	26,998,000	46,667,174	2.60	17,948,913	1.50

Note: Data on total dwelling stock and population as well as average household size is sourced from the European Mortgage Federation (EMF, 2012) and the Eurostat database (Eurostat, 2013) respectively. Prior to 2004, no data on average household size is available, thus the 2004 figure is used.

Although the four countries experienced an increase in dwellings per household, housing prices, particularly in Greece, Ireland and Spain increased dramatically. This pattern indicates that the housing price increase in the four countries cannot be entirely explained by an increase in housing demand for living purpose. It rather indicates that the price increase in these countries throughout the observed period is investment driven.

In response to the global financial and ongoing Eurozone crisis, it has been often pointed out that monetary policy plays a crucial role in the determination of asset price bubbles across different asset classes. For instance, in a general report on asset price bubbles and monetary policy, the ECB (2010) pointed out that money and credit indicators help to predict booms and busts cycles in asset prices. In regard to property bubbles, a member of the Executive Board of the ECB stated that simple money and credit aggregates deviations from a trend that exceeds a given threshold provide a useful predictor of costly boom and bust cycles (Praet, 2011). Another member of the Executive Board of the ECB emphasized in a speech on Ireland that ballooning credit and spending excesses overheated the economy and misdirected resources during the booming years before the crisis (Asmussen, 2012).

The purpose of this essay is to address three questions. First, to what extent did Greece, Ireland, Portugal and Spain experience real estate bubbles in the period from entering the Eurozone and the end of 2012? Second, what is the role of the single monetary policy of the ECB in the formation of property bubbles in these countries? Third, why does the monetary policy of the ECB have a diverging effect on the formation of real estate bubbles in these countries? The rest of this essay is grouped into five parts. In the first part, the literature review gives a short overview on the literature on real estate bubble and the role of monetary policy in the formation of bubbles. The following two parts then move to the framework and data section. The framework draws from Stiglitz's (1990) theory on asset bubbles and applies the direct capitalization approach through weighted average cost of capital (WACC) to identify real estate bubbles in the four countries. In the empirical part, Vector Autoregression (VAR) and Vector Error Correction (VEC) models are set up and impulse response analysis applied to investigate the relationship between the monetary policy of the ECB and property bubbles in the four countries. Finally, the findings from the analysis are discussed and a summary of the central arguments of this essay presented.

2.2. Literature Review

2.2.1. Real Estate Bubbles

The definition of a bubble is simple. A bubble describes the situation where the market price is higher than the fundamental value or not justified by fundamental factors (Stiglitz, 1990). Although there is common consent about the definition of a bubble, the measurement of the fundamental value is a difficult task. In the literature, there are several approaches on how to determine the fundamental value of real estate. The fundamental value is derived in one approach from an equilibrium model and usually contains a number of variables such as income, employment, construction cost and interest rates. For example, Hui and Yue (2006) applies a comparative study on housing price bubbles in Hong Kong, Beijing and Shanghai and uses disposable income, the stock of vacant new dwellings and local GDP as market fundamentals. Mikhed and Zemcik (2009) investigate whether the recently high and rapidly decreasing US house prices have been justified by fundamental factors. In their structural model of the housing market, personal income, population, house rent, stock market wealth, building costs, and mortgage rate are used as fundamentals.

Another approach is the user cost framework developed by Poterba (1984). The key concept behind this framework is that individuals base their decision of owning or renting a house on the relative cost. Thereby the cost of owning a house is calculated by adjusting the house price by the user cost of housing[6]. Under the long-run housing market equilibrium, the cost of owning a house equals the cost of renting. Individuals adjust its consumption preference until the equilibrium is reached. For instance, if the cost of owning a house is high relative to the cost of renting it, house prices must fall or rents must rise to calibrate the market equilibrium. Related to the user cost approach of Poterba (1984) is the present-value approach. This approach focuses on the present value of the expected stream of future cash-flow. The idea is that the market is in equilibrium when the housing price equals the present value of the future cash-flow. There are several studies applying different variations of this approach. Many studies (Bjoerklund & Soederberg, 1999; Chan, Lee, & Woo, 2001; J. D. Hamilton, 1985; Hatzvi & Otto, 2008; Smith & Smith, 2006; Xiao & Tan, 2007) model the fundamental value as the sum of the expected rental income discounted at a constant rate of return. Unlike the equilibrium model outlined above, this approach does not rely on other macroeconomic variables and thus does not need a lot of data. Mikhed and Zemcik (2009) also focuses on the rent as determinant of the cash-flow associated with owning a house. In their analysis, however, the rent-to-price ratio is used to detect the discrepancy between fundamental and market value. Smith and Smith (2006) acknowledge that rental savings are the central factor determining the fundamental value of an owner-occupied home but they emphasize that other factors such as transaction costs, down payment, insurance, maintenance costs, property taxes,

[6] Following Poterba (1984), the user cost of housing includes the foregone interest that the homeowner could have earned by investing in an alternative risk-free asset known as “opportunity cost”, the cost of property taxes, tax deductibility of mortgage interest and property taxes, maintenance cost, expected capital gain or loss and an additional risk premium to compensate homeowners of the higher risk of owning versus renting.

mortgage payments, tax savings, and the proceeds if the home is sold at some point have an impact on the cash flow. Black et. al. present (2006) another variation of the present-value approach which is based on the present value of real disposable income to determine the fundamental value of housing.

Another representation of the present-value approach is the state-space model which can be used to empirically estimate the size of housing bubbles. This time series model includes one or more unobservable (state) variables and represents its dynamics in a state equation. The model further consists of the observation equation that captures the relationship between the observed variables and unobserved variables. In a recent study, Teng et. al. (2013) build on the state-space model of Alessandri (2006) on stock market and apply it to the context of real estate markets in Taipei and Hong Kong. In their model, the state equation captures the movement of the bubble and allows the bubble price to move at time varying rates determined by the bubble price and risk-free rate in the previous period. The observation equation captures the market price and contains the rent, risk-free interest rate and the bubble as unobservable component. The combination of these two equations form the state-space model which is used to separate the deviation of the observed market price from the fundamental price into measurement error and the bubble price, whose evolution is driven by lagged bubble price and interest rate. The underlying concept of Teng et. al.'s (2013) state-space model is the same as the simple present-value framework. This state-space model is just another more sophisticated representation of the present-value approach which allows separating the deviation of the observed market price from the fundamental price into measurement error generated by a white noise process and the bubble price which is driven by lagged bubble price and interest rate. Instead of the state-space representation of the present-value approach, the following analysis applies a simple present-value approach that takes, through the weighted average cost of capital, financial leverage into account. This approach is used because it is widely applied by practitioners in real estate markets and can be readily understood by a broad audience.

2.2.2. Monetary Policy and Property Bubbles

Several papers analyze the relationship between monetary policy variables and housing prices. For instance, Ahearne et. al. (2005) examine the rise and fall of real house prices since the 1970 in 18 major industrialized countries including Ireland and Spain. The analysis shows that real house prices are typically preceded by a period of easing monetary policy. Another recent study (Adams & Füss, 2010) applies panel cointegration analysis to a sample of 15 OECD countries, including Ireland and Spain, over the period of 30 years to study the macroeconomic determinants of international housing markets. The analysis shows that besides the economic activity and construction cost, the long-term interest rate also has a significant inverse impact on housing prices. As for Ireland and Spain, this inverse relationship is significant at the 1% level.

There are also several studies in the literature specifically looking at the relationship between monetary policy variables and housing bubbles. In this regard, Tsai and Peng (2011) analyze house prices in four cities in Taiwan. The empirical result of the panel unit root and cointegration test shows that bubble-like behavior of house prices in Taiwan after 1999 was primarily related to the mortgage rates. The study concludes that expansionary monetary policy, which leads to speculations and lower mortgage rates, is the key driver for housing bubbles. Another study (Agnello & Schuknecht, 2011) looks into the determinants of housing market booms and busts in eighteen industrialized countries, including Ireland and Spain, from 1980 to 2007. The estimates from the multinomial probit model indicate that domestic credit and interest rates have a significant impact on the probability of booms and busts. The evidence indicates that regulatory policies which slow down money and credit growth reduce boom probabilities.

Confrey and Gerald (2010) show with the example of Ireland and Spain that the introduction of the single monetary policy under the ECB and its monetary policy was a main factor causing real estate bubbles in the booming periods. Specifically, the analysis points out that the regime change brought about a substantial reduction in the real cost of capital for households in many Eurozone countries. In the case of Ireland and Spain, the reduction was particularly strong which in turn supported households in these countries to finance their investment in the housing market. The regime change not only lowered the real cost of capital but also made it much easier for the domestic financial system in Ireland and Spain to fund the dramatic investment surge of households.

In sum, monetary policy variables play a crucial role in the rise of real estate prices and the formation of bubbles. This study contributes to this literature by analyzing the relationship between the bubble formation in Greece, Ireland, Portugal and Spain and the monetary policy of the ECB, the top authority controlling money supply and key interest rates in the European monetary union. This essay further sheds light on the reasons of diverging bubble formation across these countries.

2.3. Framework

2.3.1. Property Bubble Determination

An asset bubble, as defined by Stiglitz (1990), describes the situation where only investor's expectations of higher selling prices instead of the fundamental factors determine the high price today. In such a situation, investors ignore the fundamental value and bid prices up, assuming that other investors will push prices further. The bubble is created by a form of speculation which does not rely on future income streams but on expected bullish behavior of other investors. Such a situation is inherently unstable and referred to as the greater fool theory of investing. As soon as the pool of greater fools dries up, the market turns bearish and corrects towards its fundamental value. Accordingly, an asset bubble exists when the market price (MV) is higher than the fundamental value (FV).

$$\mathrm{MV} > FV \tag{1}$$

While it is simple to identify the market price, it is a difficult task to determine the fundamental value. As discussed in the literature review, there are several approaches to determine the fundamental value. This essay applies the present-value approach to determine the fundamental value. In this case, the fundamental value is determined by the present value of the anticipated cash flow from the property investment (Mikhed & Zemcik, 2009). A real estate investor receives rent payments and will make a profit or loss from selling the house. Consequently, the fundamental value should be close to the flow of future rent payments discounted back by the required rate of return. Although the rent is the central factor in the calculation of the cash-flow, there are also other variables which affect the future flow of payments as transaction costs, insurance, maintenance costs, property taxes and tax savings (Smith & Smith, 2006). Due to data availability and simplicity, however, the fundamental value is treated as the discounted future rent. Most present-value models apply a constant discount rate; however, it is crucial to use the appropriate modelling of the discount rate or else a bubble could be identified when in fact, there is no discrepancy between the market and fundamental value (Black et al., 2006). Hence this study applies a time-varying discount rate. Furthermore, most studies using present-value models employ a risk-free rate of return, i.e. long-term yields of government bonds, as a proxy for the required rate of return. In practice, however, most residential properties in the Euro area are bought by individual investors financing their property via mortgage loans (ECB, 2009). The concept of weighted average cost of capital (WACC)[7] allows considering this feature by incorporating both the cost of equity and debt. The loan-to-value ratio (L/V) adjusts the proportion of the cost of debt ($\mathrm{i_{Djt}}$) and equity ($\mathrm{i_{Ejt}}$) which is used to finance the house purchase. The subscript j is for the country and t for the time. The average interest rate for deposits with agreed maturity of up to 1 year at a domestic bank as the opportunity cost of equity and the average interest rate for house purchase as the cost of debt are used. The following analysis assumes that the typical loan-to-value ratio is 0.7[8].

$$\mathrm{WACC_{jt}} = \left[\frac{\mathrm{L}}{\mathrm{V}} \times \mathrm{i_{Djt}}\right] + \left[\left(1 - \frac{\mathrm{L}}{\mathrm{V}}\right) \times \mathrm{i_{Ejt}}\right] \tag{2}$$

The fundamental value of residential real estate is the rent discounted by the WACC. In the following definition $\mathrm{FV_{jt}}$ is the fundamental value, $\mathrm{RENT_{jt}}$ the rent, and $\mathrm{WACC_{jt}}$ the weighted average cost of capital.

$$\mathrm{FV_{jt}} = \frac{\mathrm{RENT_{jt}}}{\mathrm{WACC_{jt}}} \tag{3}$$

Referring back to formula (1), a positive property bubble exists when the market price of real estate is higher than the fundamental value. Thus, the bubble in percentage terms is calculated as following.

$$B_{jt} = \left(\frac{\mathrm{MV_{jt}} - \mathrm{FV_{jt}}}{\mathrm{FV_{jt}}}\right) \times 100 \tag{4}$$

A positive bubble indicates that the market price is higher than the fundamental value and vice versa.

---

[7] For simplicity, other factors, such as risk premium are not considered in the calculation of the WACC.
[8] The data section shows a simulation of the bubble under five different LTV scenarios.

2.3.2. Monetary Policy Transmission

Real estate bubbles are basically linked to monetary policy through two different channels. First, house prices are sensitive to the interest rate on other financial assets such as bonds or deposits at a bank. Zeno and Füss (2010) point out that increasing long-term interest rates do not change the actual demand for housing space directly but rather change the investment demand for housing. An increase in the policy interest rate increases the return on other fixed-income assets relative to the return of real estate; hence it shifts the demand away from real estate into other assets. The opposite holds true for low interest rates which reduce the return on equity and thus provide incentives for real estate investment. While the actual need for housing for living purpose remains the same, the investment demand goes up and artificially drives up the demand for residential real estate and housing prices.

Second, interest rates and money supply affect the debt financing conditions of borrowers. As pointed out by Zeno and Füss (2010), an increase in long-term interest rate is reflected in higher mortgage rates, which reduces the demand for real estate. On the opposite, low interest rates reduce the cost of mortgage loans, which increases the availability and accessibility to house purchasing loans and thus demand.

The interplay of both channels increases the demand for housing relative to the demand for rental housing. The unbalanced development of the demand in the two markets manifests, in a widening gap, between the market and fundamental value. The simplified relationship between property bubbles and the two channels of monetary policy can be expressed as following.

$$B_{jt} = f(IR_t, HL_t) \tag{5}$$

This expression shows that the bubble $B_{jt}$is a function of the interest rate IR_t and the lending for house purchase-to-GDP HL_t. In this case, the interest rate reflects both interest rates on equity, i.e. returns gained from alternative financial assets such as bonds or deposits at a bank, as well as debt, i.e. mortgage rate. In order to approximate the interest rate effect on the bubble, this analysis applies the 3-month Euribor (Euro Interbank Offered Rate) which proxies the key interest rate set by the ECB. Hereby, the main refinancing operation is the most important monetary policy tool of the ECB. It provides liquidity through the national central banks to the domestic banking system in the member states of the Eurozone. The interest rate for this instrument is set in a tender procedure where the domestic banks make a bid and receive a short-term loan with maturity of one week. The domestic banks receive the loan and provide financial assets as a guarantee. After the transaction is completed, the domestic banks pay interests to the central bank and receive the provided collateral in return. The interest rate set in the tender procedure is subject to a minimum bid rate. The minimum bid rate is set on a monthly basis by the Governing Council of the ECB. In the tender procedure, the total amount of funds to be allocated is defined by the ECB. Domestic banks that make the highest bid are served first until the full amount is allocated. Domestic banks unable to obtain liquidity through this mechanism have to borrow funds in the money market. Money market interest rates as the 3-month Euribor are usually very close to the minimum bid rate of the main refinancing operations set by the ECB (ECB, 2013a). The loan-to- GDP ratio is commonly used as a measure of bank lending activities (Oikarinen, 2009).

Based on the theory of the two channels above, it is suggested that IR_t is negatively and HL_t positively related to the bubble in the short-run. In the long-run, however, the relationship between the bubble and IR_t might be positive. This is because the long-run low interest rate may enhance investors' confidence in housing investment, and consequently bolster the housing prices as well as the bubble.

In the empirical part, VAR and VEC models are applied to analyze dynamics between the bubble, Euribor and the lending for house purchase-to-GDP ratio.

2.4. Data

For Ireland, Portugal and Spain, the analysis covers the time period from the inception of the single monetary policy in the Eurozone in 1999 to the third quarter of 2012. As Greece entered the Eurozone two years later, the analysis starts in 2001.

As for the house price, price indices on residential property from the property price database of the ECB and the Bank for International Settlements (BIS) are used. In the case of Ireland, there is no complete time series on house prices for the entire period available. In order to cover the full time period, two overlapping time series are consolidated into a single item. The rent index is sourced from the ECB and available for the entire period. For the calculation of the WACC, due to data availability, data from two separate data sets is used. Historical quarterly data on retail interest rates is sourced from Eurostat and covers the time period from 1999 to 2003. The second data set is sourced from the Monetary Financial Institute (MFI) database from the ECB and covers the period from 2003 to 2012. In order to allow the analysis of the full time period, both data sets are consolidated. As for the cost of debt, the average interest rate for housing loans is used. Regarding the cost of equity, the average interest rate on deposits of up to one-year maturity is used. For Ireland, the average rate for overnight deposits is used as a proxy for the cost of equity as the previously mentioned interest is not available for this country. The data on the Euribor and the lending for house purchase-to-GDP is also sourced from Eurostat and available for the entire period.

The following figure shows the bubble[9] in the four countries according to the definition in (4). Ireland, Portugal and Spain experienced an increase in the bubble at the beginning of the 2000s, followed by a decrease up to 2005 in Portugal and a returning upward trend in Ireland and Spain in 2003. After a sharp drop in 2001, the bubble in Greece developed steadily before increasing at the end of 2005.

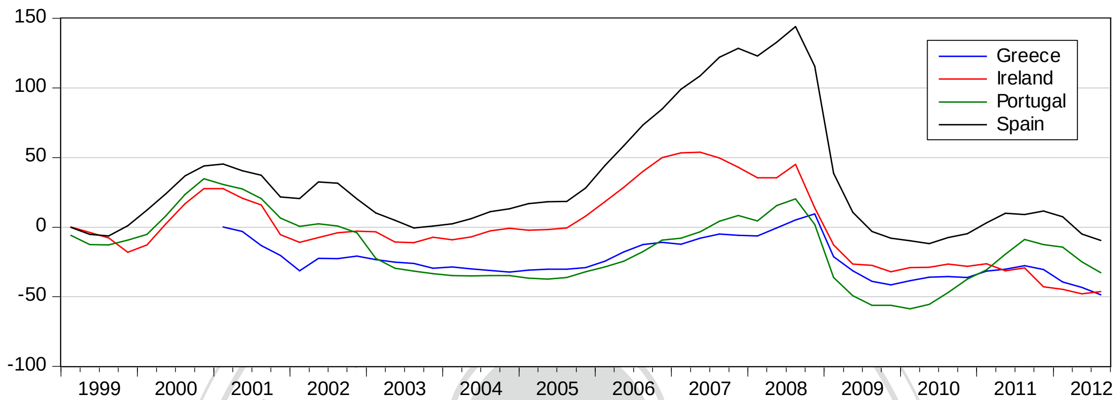

Figure 2.1: Residential Property Bubbles with LTV Ratio of 70%

Figure 2.2 shows the simulation of the bubble in the four countries under five different scenarios assuming LTV ratios of 0.5, 0.6, 0.7, 0.8, and 0.9. Two interesting observations can be made from this simulation. First, it can be observed that the higher the LTV ratio the bigger the bubble. This is because the interest rate on equity is usually smaller than the interest rate on debt, implying that an increase in the loan-to-value ratio gives more weight to cost of debt, resulting in a higher WACC. Reverting back to formula (3) the fundamental value of residential real estate decreases when the WACC increases. Hence the bubble increases with an increase in the WACC.

[9] The starting value of the rent has been adjusted so that fundamental value equals the market value in the base period. The base period is set according to the point when the respective country entered the Eurozone. Therefore, the base period is 2001Q1 in the case of Greece and 1999Q1 for the other countries. This adjustment does not imply that the fundamental value is equal to the fundamental value in the base period; it rather defines the respective year as the reference point. What matters in the subsequent analysis is the movement or the trend of the bubble.

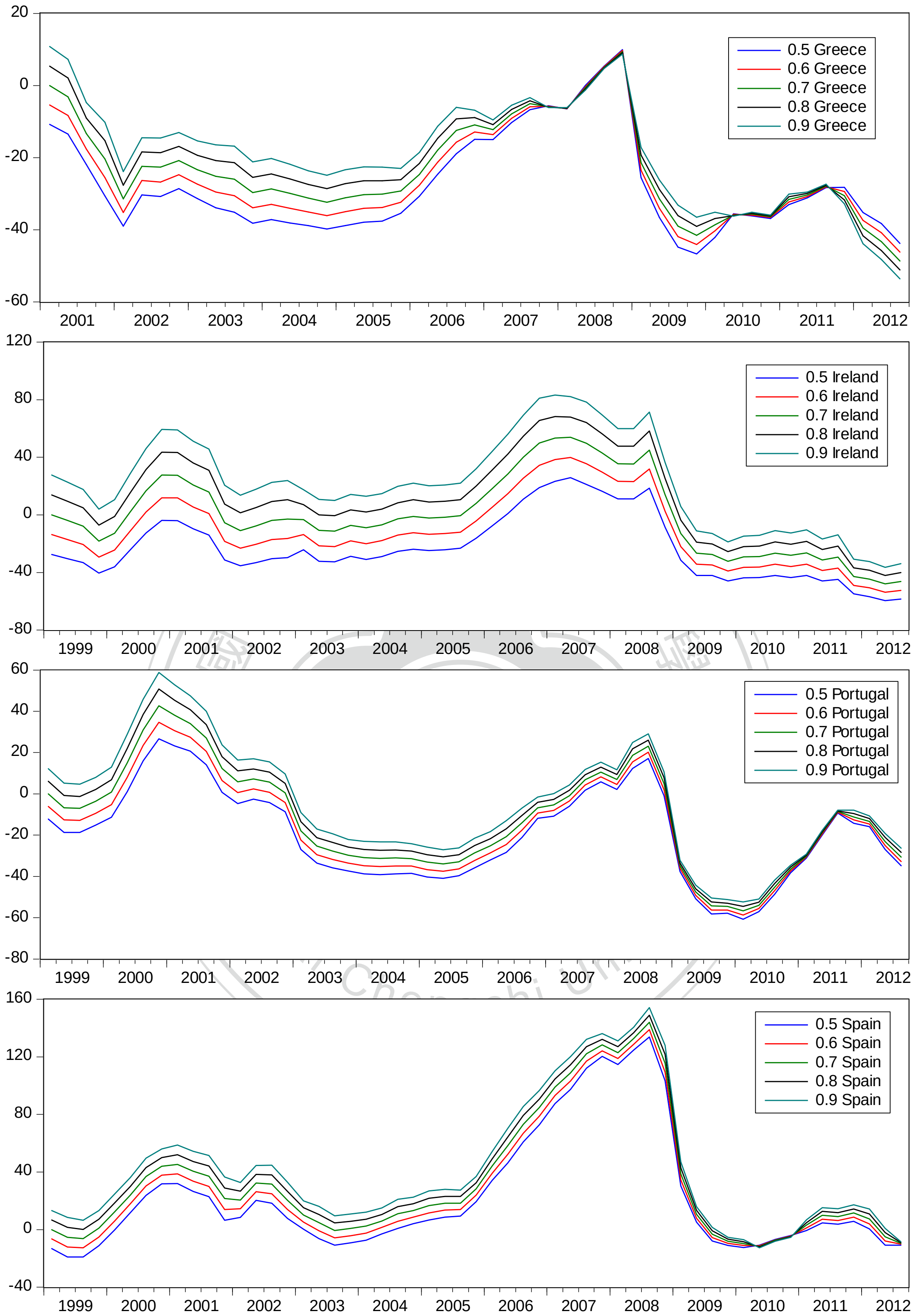

Figure 2.2: Residential Property Bubble Simulation under Varying LTV Ratios

Second, the trend of the bubble does not change with an adjustment of the loan-to-value ratio. This point is important because the subsequent analysis builds on the movement or trend of the bubble rather than its absolute value.

Figure 2.3 compares the minimum bid rate for main refinancing operations set by the ECB with the 3-month Euribor money market interest rate. It is obvious that the money market rate is closely related to the key interest rate of the ECB. In the subsequent analysis the 3-month Euribor is used as proxy for the interest rate on the main refinancing operations of the ECB.

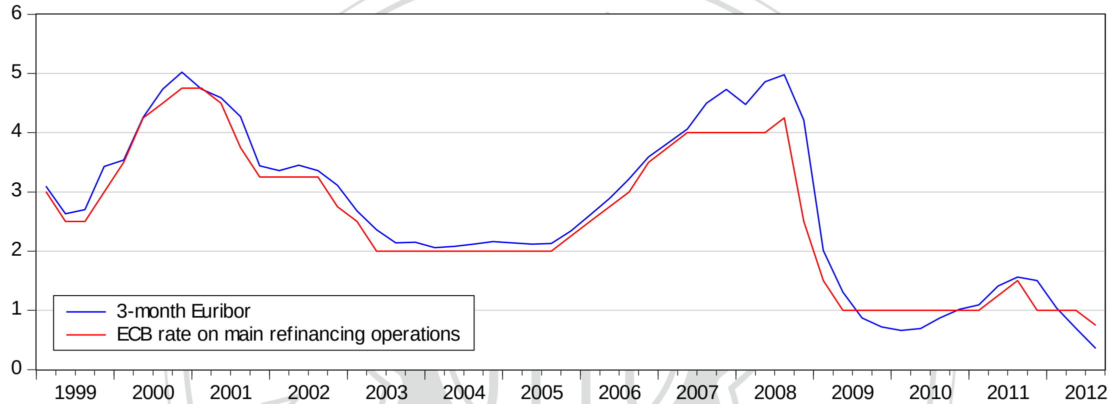

Figure 2.3: 3-Month Euribor and Key Policy Rate of the ECB

Figure 2.4 shows the ratio of lending volume for house purchase-to-quarterly GDP in the Eurozone. Except for a drop at the end of 2000, the ratio increased strongly in the period from 1999 to 2007. From the year 2007 onward, the ratio increased much slower.

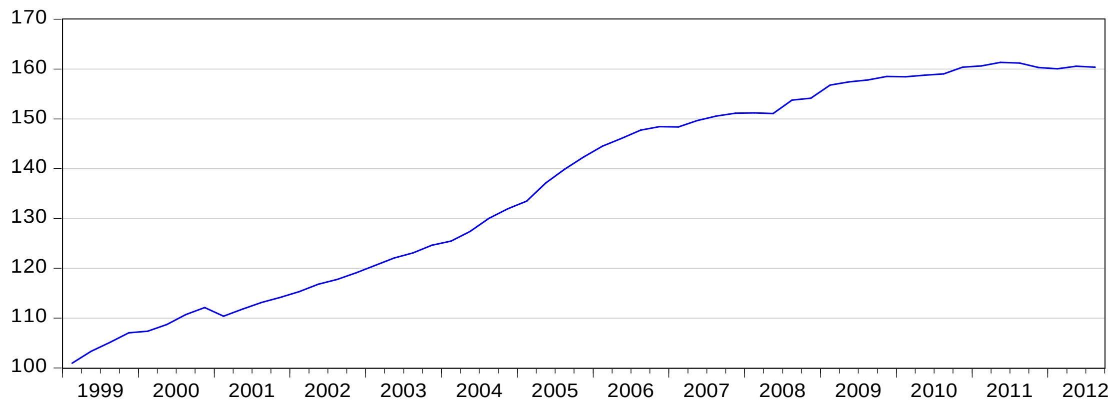

Figure 2.4: Lending for House Purchase-to-Quarterly GDP in the Eurozone

In order to select the appropriate model for the following analysis, the augmented Dickey and Fuller (1979) (ADF) test is applied to determine the order of integration of the variables. A variable is said to be integrated of order n when it achieves stationarity after taking its n-th difference. As shown in Table 2.5, the ADF test statistic indicates at a significance level of 10% that all of the variables in its level contain a unit root.

Table 2.5: ADF Unit Root Tests

Variable	Level t-value	p-value	Lags	Difference t-value	p-value	Lags	Result
B_{Greece} [c]	-2.17	0.22	1	-4.87	0.00	0	I(1)
IR [c]	-2.06	0.26	1	-3.44	0.01	0	I(1)
HL [ti]	1.32	1.00	0	-4.77	0.00	0	I(1)
$B_{Ireland}$ [c]	-1.84	0.36	1	-4.15	0.00	0	I(1)
$B_{Portugal}$ [c]	-2.78	0.07	1	-3.51	0.01	0	I(1)
B_{Spain} [c]	-2.61	0.10	1	-3.52	0.01	0	I(1)
IR [c]	-1.85	0.35	1	-3.89	0.00	0	I(1)
HL [ti]	1.07	1.00	0	-5.44	0.00	0	I(1)

Note: The results of the upper and lower panel are based on data covering the period from 2001Q1 to 2012Q3 and 1999Q1 to 2012Q3 respectively. The number of lags included in the ADF test is decided by the automatic lag length selection criteria based on SIC with maximum lag length of 10. [c] indicates that a constant term and [ti] indicates that a constant term as well as a linear time trend have been included in the model.

The test further indicates that the first difference of all variables is stationary at the same level of significance. Thus it can be concluded that all of the variables are integrated of order one, or I(1).

2.5. Empirical Analysis

2.5.1. Long-Run Dynamics

Engle and Granger (1987) show that a linear combination of two or more non-stationary variables may be stationary. Such a linear combination of non-stationary variables is referred to as cointegration. Following the definition, the components of the vector $x_t = [x_{1t}, x_{2t}, \ldots, x_{nt}]'$ are said to be cointegrated if all components of x_t

are I(1) and a vector $\beta = [\beta_1, \beta_2, \dots, \beta_n]'$ exists such that the linear combination $\beta' x_t = \beta_1 x_{1t} + \beta_2 x_{2t} + \dots + \beta_n x_{nt}$ is stationary, or I(0). The stationary linear combination is the cointegration equation and may be interpreted as the long-run relationship among the variables in the model.

To test for cointegration amongst the variables in each system the Johansen Methodology illustrated by Enders (2010) is applied. In the first step, undifferenced data is used and a separate VAR model for each country estimated to determine the appropriate maximum lag length of the respective model. Each VAR model includes three variables- the respective bubble, *IR* and *HL*. The maximum lag length is chosen on the basis of the sequential modified LR test statistic. Including four lags in the lag specification, the tests indicate a lag length of two for Portugal and four for Greece, Ireland and Spain.

In the next step the third model considered by Johansen (1995) is estimated to determine the rank of integration. This model allows the time series to have linear deterministic trends and includes an intercept but no trend in the cointegration equation. The cointegration vector in this model removes the linear deterministic trend of the time series as it removes the unit roots so that the cointegration equation does not contain any trend. A cointegration equation without a linear trend is close to the idea of the cointegrating vector defining an equilibrium relationship. There are two possible test statistics, considering different alternative hypotheses, to determine the number of cointegration relationships, i.e. the rank of cointegration (r). Table 2.6 presents the corresponding results.

Both test statistics indicate on a significance level of 5% that the variables in the model of Greece, Ireland and Spain are cointegrated of order one. In the case of Portugal, neither the Trace nor the Maximum-Eigenvalue test statistics show cointegration. Thus, it can be concluded that there is a long-run relationship between the bubble and the two variables representing monetary policy in Greece, Ireland and Spain. In the case of Portugal, however, the results do not indicate such relationship.

Table 2.6: Johansen Cointegration Tests

		Trace Test				Maximum-Eigenvalue Test				
Country	Lag	H0	λtrace	5% critical value	p-Value	H0	λmax	5% critical value	p-Value	Result
Greece	4	r=0	33.35	29.80	0.02	r=0	22.04	21.13	0.04	r=1
		r≤1	11.31	15.49	0.19	r=1	6.47	14.26	0.55	
Ireland	4	r=0	60.54	29.80	0.00	r=0	46.17	21.13	0.00	r=1
		r≤1	14.37	15.49	0.07	r=1	10.83	14.26	0.16	
Portugal	2	r=0	19.93	29.80	0.43	r=0	13.89	21.13	0.37	r=0
		r≤1	6.04	15.49	0.69	r=1	4.30	14.26	0.83	
Spain	4	r=0	36.26	29.80	0.01	r=0	25.71	21.13	0.01	r=1
		r≤1	10.55	15.49	0.24	r=1	7.81	14.26	0.40	

Note: r is the rank of cointegration. λtrace is the Trace statistic, testing the null hypotheses r=0 and r≤1 against the alternative hypotheses r>0 and r>1. λmax is the Maximum-Eigenvalue statistic, testing the null hypothesis r=0 and r=1 against the alternative hypotheses r=1 and r=2.

The analysis of the estimated cointegration relation helps to understand the direction and magnitude of the long-run relationship in the three countries where cointegration was found. The upper panel of Table 2.7 summarizes these results.

Table 2.7: Estimated Cointegration Relationships

	Greece			Ireland			Spain		
	B	IR	HL	B	IR	HL	B	IR	HL
Coeff.	1	-11.04*	-0.22*	1	-26.31*	-0.98*	1	-38.21*	-1.90*
Std. Error		0.47	0.04		-1.09	-0.07		-1.51	-0.10
t-statistic		-23.39	-5.75		-24.22	-14.31		-25.27	-19.61
Adj. speed	-0.57	0.03	0.04	0.37*	0.02*	0.07*	0.10	0.01	0.07*
Std. Error	0.31	0.02	0.07	0.13	0.01	0.02	0.22	0.01	0.02
t-statistic	-1.82	1.19	0.61	2.86	3.80	4.27	0.44	1.33	3.92

Note: * denotes significance at the 95% confidence interval. The critical value for the t-test is 1.96. Coeff. is the normalized cointegration coefficient; Adj. speed is the speed-of-adjustment coefficient and Std. error the respective standard error.

The normalized cointegration coefficients of the Euribor and the bubble indicate a significant positive relationship in all of the three countries. As already pointed out in the framework, the long-run relationship between the interest rate and the bubble might be positive. One possible explanation for this is that the long-run low interest rate enhances investors' confidence in housing investment and consequently bolsters the housing prices as well as the bubble. The relationship between *HL* and the bubble is also significantly positive in all three countries.

2.5.2. Short-Run Dynamics

In the next step, the short-run dynamics between the variables in the models are analyzed. In the case of Portugal, the Johansen cointegration test indicates no cointegration relationship. Therefore, a VAR model in first differences as specified below is set up. x_t is the 3×1 vector of the three variables included in the model. A_0 is the 3×1 vector of intercept terms, A_i the 3×3 matrix of coefficients and ε_t the 3×1 vector of error terms.

$$\Delta x_t = A_0 + A_1 \Delta x_{t-1} + \cdots + A_p \Delta x_{t-p} + \varepsilon_t \qquad (6)$$

In the case of Greece, Ireland and Spain, the same model is used for the Johansen cointegration test. The model includes a constant but no trend in the cointegration vector. This model removes the linear deterministic trend of the time series as it removes the unit roots so that the cointegration equation does not contain any trend. This specification is close to the idea of the cointegrating equation defining an equilibrium relationship. The model is specified below where x_t is the 3×1 vector of the variables included in the model, A_0 is a 3×1 vector of constant terms, $(\beta_0 + \beta' y_{t-1})$ the cointegrating equation, α the speed of adjustment, A_i the 3×3 matrix of coefficients and ε_t the 3×1 vector of error terms.

$$\Delta x_t = A_0 + \alpha(\beta_0 + \beta' x_{t-1}) + A_1 \Delta x_{t-1} + \cdots + A_{p-1} \Delta x_{t-p+1} + \varepsilon_t \qquad (7)$$

The speed-of-adjustment coefficient indicates how the variables adjust to any discrepancies from the long-run equilibrium relationship. Given the positive value of the cointegrating equation, a positive coefficient indicates that the variable will go up and a negative coefficient indicates that the variable will decrease. The lower panel of Table 2.7 shows the estimates. In the short-run, the bubble in Ireland responds with an increase and the bubble in Greece with a decrease to a deviation from the long-run equilibrium; the implication is that in the short-run the bubble tends to depart from the long-run equilibrium in Ireland but tends to approach the long-run equilibrium in Greece. In the case of Spain, the speed-of-adjustment coefficient is not significant at the 5% level of significance.

Based on the VAR model for Portugal and the VEC model for the other three countries, the dynamic effects of innovations in the money market interest rate and lending for house purchase-to-GDP and the bubble are analyzed by computing orthogonalized impulse responses. Hereby the standard Choleski decomposition (C. Sims, 1980) is used to derive the impulse responses. The ordering used is *B-HL-IR* and aligned to the specification used by Hofmann (2004) and Oikarinen (2009). Following the ordering, it is assumed that the bubble does not respond instantly to innovations in lending for house purchase-to-GDP and the Euribor. The lending for house purchase does not respond instantly to a shock in the interest rate, and the interest rate is rather flexible because the ECB and the domestic banking system can respond immediately with an interest rate change to alterations of the former two variables. Thus, the bubble may be affected within a quarter by the other two variables. The chosen ordering of the variables is common in the literature on monetary policy transmission and reflects the assumption that interest rate changes are transmitted to the economy with a lag. The following figures (Figure 2.5, Figure 2.6, Figure 2.7, Figure 2.8) illustrate the impulse responses up to 20 quarters from the shock. As outlined above, differenced data is used in the case of Portugal and data in its levels for the other three countries. Therefore the results of the following analysis cannot be compared directly with the other three countries.

Figure 2.5 shows the response of the bubble in Portugal to an innovation in *IR* and *HL*. The impulse response function of Portugal reveals that the response of the bubble to a positive innovation of the two variables is positive but very weak. The effect vanishes after 10 quarters.

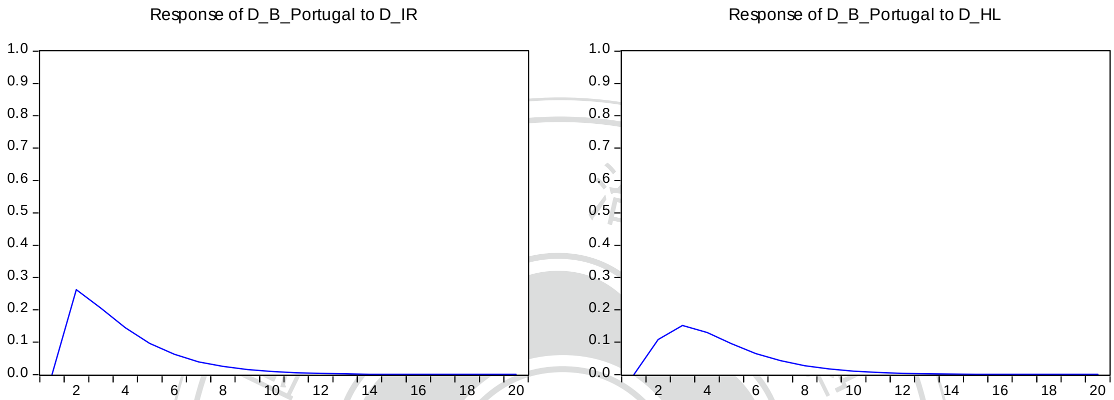

Figure 2.5: Portugal's Bubble Response to Cholesky One S.D. Innovations

As illustrated in Figure 2.6, the response of the bubble in Greece to a one standard deviation in *IR* is also positive, but relatively weak. The response to an innovation in *HL* becomes positive and relatively strong after a few lags.

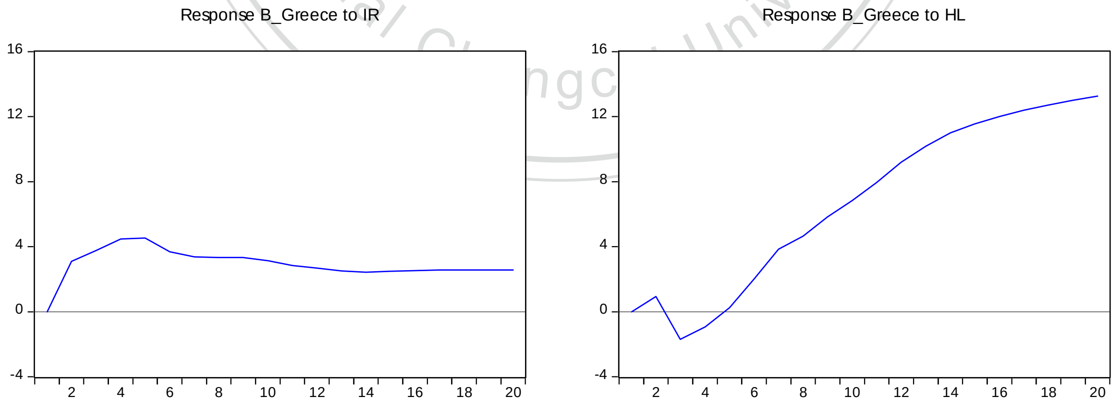

Figure 2.6: Greece's Bubble Response to Cholesky One S.D. Innovations

As shown in Figure 2.7 and Figure 2.8, a positive one standard deviation shock in *IR* has temporarily no effect in Ireland and a slightly positive effect in Spain before turning strongly negative. The initial positive response of Spain to a positive shock in

IR can be explained by the effect of the WACC on the fundamental value and bubble. An increase in the Euribor leads to an increase in the WACC. With an increase in the WACC, the fundamental value decreases, the gap to the market price widens and the bubble increases. The response of the bubble in Spain to a positive innovation in the *IR* turns strongly negative and is negative in Ireland because the investment demand of real estate is affected by higher interest rates. One possible reason for the different response of Portugal and Greece to an unexpected innovation of the interest rate might be that the bubble in these countries reacts only to the effect of the WACC on the fundamental value but not to its effect on investment demand and thus the market price.

As for Ireland and Spain, in the case of a positive interest rate shock, mortgage borrowers become increasingly overwhelmed by the debt burden, and in the worst case default on their mortgage loans. Investors lose interest in real estate and start to switch to other assets where interest rates increase. This decreases the demand for property as well as the market price, thus resulting in a decreasing bubble.

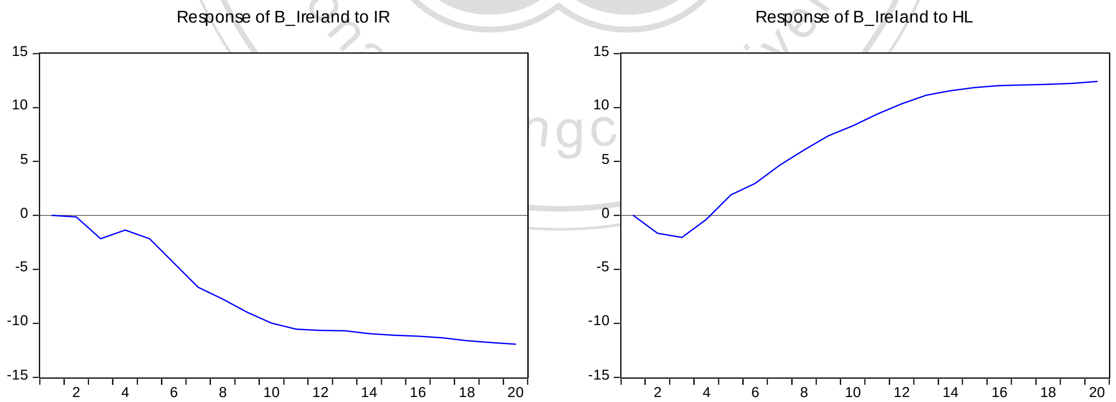

Figure 2.7: Ireland's Bubble Response to Cholesky One S.D. Innovations

Similar to the bubble in Portugal and Greece, the bubble in Ireland and Spain also respond positively to a positive shock in *HL*. However, unlike the bubble in Portugal the bubble in Greece, Ireland and Spain responds much stronger and with a lag to an innovation in *HL*.

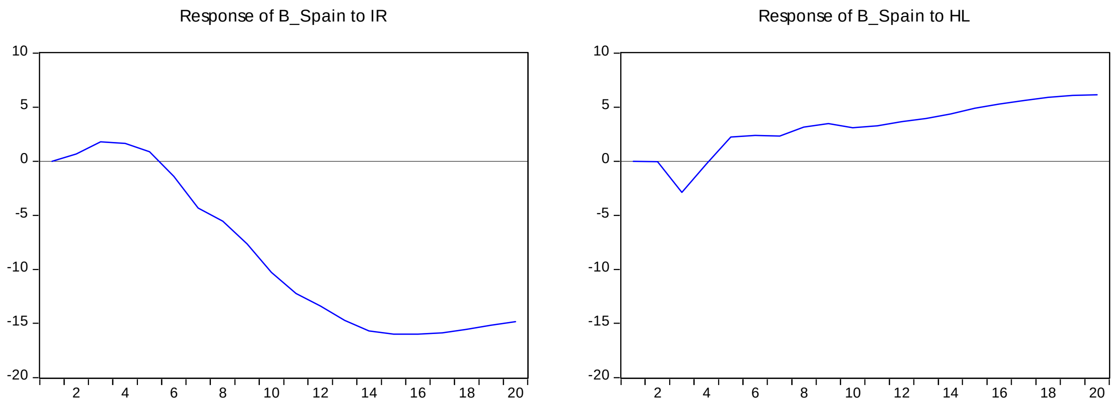

Figure 2.8: Spain's Bubble Response to Cholesky One S.D. Innovations

The variance decomposition in Table 2.8 shows that almost no variance of Portugal's bubble can be explained by the short-run dynamics of *IR* and *HL*. In Greece and Ireland, both, *IR* and *HL* account for a large proportion of the variance in the bubble. For instance, at lag 10, *IR* explains around 20% of the bubble variance in Greece and around 31% in Ireland. At the same lag, *HL* accounts for around 21% of the variance of Greece's and around 40% of Ireland's bubble. In Spain, most of the variance in the bubble is primarily explained by *IR*. For example, at lag 10, around 16% in Spain's bubble is explained by *IR* and only around 1% by *HL*. It is interesting to note that while the ECB's monetary policy variables explain only a minor proportion in the bubble of Portugal, the variables explain a large proportion of the variance in the bubble of Greece, Ireland and Spain. Another interesting observation is that the explanatory power of *IR* and *HL* tends to increase with the number of lags. This illustrates the lagged effect of monetary policy on the formation of real estate bubbles.

Before moving on to the discussion part, the residual Portmanteau test for autocorrelations is applied to each model. The null hypothesis of this test is that the residuals exhibit no autocorrelations up to a specified lag. A maximum lag length of 20 is chosen and the test for the model of each country applied. The null hypothesis cannot be rejected at the 10% level of significance in Portugal and Spain meanwhile at the 5% level of significance in Ireland. In the case of Greece, however, the null cannot be rejected at several lags even at the 1% level of significance. Therefore, the empirical results of Greece should be interpreted with caution.

Table 2.8: Decomposition of Property Bubble Variance

	Portugal		Greece		Ireland		Spain	
Period	ΔIR	ΔHL	IR	HL	IR	HL	IR	HL
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.09	0.01	18.48	1.64	0.15	2.39	0.00	0.10
3	0.13	0.04	24.56	3.83	3.79	3.13	0.00	2.17
4	0.15	0.06	32.70	3.42	4.30	2.47	0.08	2.19
5	0.15	0.07	37.59	2.71	5.68	4.45	0.30	1.82
6	0.16	0.07	35.65	3.95	10.73	8.90	1.37	1.59
7	0.16	0.07	31.07	8.16	18.81	16.38	4.04	1.41
8	0.16	0.07	26.60	11.93	24.76	24.92	7.27	1.23
9	0.16	0.07	22.95	16.30	28.46	33.13	11.32	1.19
10	0.16	0.07	20.05	20.82	30.85	39.54	16.22	1.25
11	0.16	0.07	17.61	25.73	31.77	44.95	21.14	1.44
12	0.16	0.07	15.50	31.05	31.28	49.64	25.29	1.75
13	0.16	0.07	13.68	36.12	30.16	53.44	28.76	2.09
14	0.16	0.07	12.18	40.78	29.16	56.17	31.54	2.40
15	0.16	0.07	10.99	44.82	28.31	58.19	33.61	2.67
16	0.16	0.07	10.04	48.29	27.62	59.78	35.13	2.89
17	0.16	0.07	9.26	51.27	27.12	61.04	36.28	3.05
18	0.16	0.07	8.60	53.79	26.82	62.00	37.19	3.18
19	0.16	0.07	8.03	55.93	26.63	62.78	37.95	3.28
20	0.16	0.07	7.54	57.74	26.45	63.46	38.66	3.36

Note: Since differenced data is used in the estimation of the VAR model of Portugal and level data is used in the estimation of the VEC models of Greece, Ireland and Spain above figures of Portugal cannot be compared directly with the other three countries.

2.6. Discussion

The analysis of the real estate market in Greece, Ireland, Portugal and Spain shows that Spain and Ireland experienced the largest positive bubble formation in the period between the implementation of the single monetary policy under the ECB in 1999 and 2012. Greece and Portugal exhibited only a weak increase in the bubble in the period from 2001 to 2012 and 1999 to 2012 respectively.

The major bubble boom, starting between 2003 and 2005, was followed by the burst at the end of 2008, when interest rates of the ECB reached its second peak in the observed period. The empirical analysis provides evidence that there is a significant long- and short-run relationship between ECB's monetary policy and the formation of real estate bubbles in the Eurozone. The findings show that, in the long-run, the bubble in Greece, Ireland and Spain is positively related to both the Euribor and the lending for house purchase-to GDP ratio. In the short-run, the bubble in Greece responds weakly positive and the bubble in Ireland as well as Spain strongly negative to an increase in the Euribor. The bubble of Greece, Ireland and Spain responds positively to a rise in the lending for house purchase-to GDP ratio. In the case of Portugal, the analysis indicates no long-run cointegration relationship and only a weak positive response to a shock in the two monetary variables in the short-run.

Although all of the four countries have become members of the Eurozone and they are subject to the single monetary policy of the ECB, their real estate market responded differently to monetary policy shifts. These differences can be mainly attributed to the characteristics of the domestic financial system, fiscal- and macroprudential- policies as well as other local structural factors in each country.

First, the monetary policy of the ECB is transmitted differently through the interest rate and credit channel to the countries in the Eurozone (ECB, 2009). Thereby, the interest rate channel describes the process of how key interest rates set by the ECB impact the interest rates at banks at the national level. In this regard, Sorenson and Lichtenberger (2007) point out that although the ECB sets the key interest rate for the entire Eurozone, the interest rates on mortgages are heterogeneous across countries. The credit channel describes the process how monetary policy affects the supply of money on the national level. In this regard, Ciccarelli et al. (2010) shows that a monetary policy shock of the ECB has a significant impact on credit availability. Further, they demonstrate that there are differences between size and timing of the impact across borrowers and economic regions. As a result of the differences in the interest rate and credit channel, the monetary policy of the ECB has a varying impact on domestic deposit and lending conditions of banks. Table 2.9 on the interest rates of housing loans and deposits shows the diverging pattern across Greece, Ireland, Portugal and Spain. Looking at the interest rates for housing loans, it is noteworthy that the two countries with the largest bubble had, most of the time, up to the burst of the bubble in 2008 the lowest interest rate. Further, the interest rate in Greece decreased rapidly from 1999 and its level remained the highest among the four countries up to the mid-2000s.

Table 2.9: Interest Rates on Housing Loans and Deposits

	Average interest rate for housing loans				Average interest rate on deposits*			
	Greece	Ireland	Portugal	Spain	Greece	Ireland	Portugal	Spain
1999	8.51	4.94	5.02	4.79	8.68	0.13	2.4	2.13
2000	7.62	5.19	6.03	5.79	6.12	0.4	3.04	3.36
2001	6.28	5.59	6.04	5.84	3.32	0.4	3.35	3.22
2002	5.01	4.58	5.02	4.85	2.76	0.12	2.96	2.75
2003	4.77	3.73	3.71	3.54	2.41	0.52	1.95	2.01
2004	4.49	3.4	3.49	3.21	2.3	0.45	1.82	1.97
2005	4.11	3.4	3.4	3.23	2.25	0.52	1.88	2.1
2006	4.32	4.14	4.08	4.14	2.96	0.81	2.61	2.83
2007	4.47	5	4.88	5.15	4.09	1.33	3.76	4.01
2008	4.85	5.07	5.34	5.65	4.93	1.41	4.1	4.52
2009	3.79	2.93	2.56	3.03	2.5	0.62	1.82	2.34
2010	3.64	3.16	2.54	2.52	3.36	0.64	1.84	2.51
2011	4.28	3.4	3.86	3.41	4.26	0.64	3.53	2.67
2012	3.2	3.28	3.78	3.21	4.8	0.48	2.88	2.7

Note: Data is sourced from the Eurostat database (Eurostat, 2013) and the European Central Bank (ECB, 2013b). * Deposits with agreed maturity of up to 1 year. In the case of Ireland there is no data on this rate available. Therefore, the interest rate for overnight deposits is shown.

Second, fiscal policies in the Eurozone vary across countries. These policies include, for instance, tax deductibility of interest payments on mortgage loans, capital gains taxes, inheritance tax, wealth tax, real estate property tax and transaction taxes. A structural issues report from the ECB (2009) shows that tax rates in 2008 varied strongly across Eurozone member countries. To give an example, the maximum tax rate applicable on capital gains in Greece is zero if capital gains have been or will be reinvested in another permanent residence within certain time limits. In Portugal, the maximum rate is 42%, in Ireland 20% and in Spain 18%. The divergent tax rates directly impact after-tax returns for investors and thus exert a diverging influence on real estate market developments across countries.

Third, in regard to macroprudential policies as LTV ratios, the report also shows large differences amongst the four countries in 2007. Amongst these countries, Ireland has the highest average loan-to-value ratio of 83% for first-time house buyers, followed by Greece with 73%, Spain with 72.5% and Portugal with 71%.

Fourth, besides financial-, fiscal and macroprudential, other structural factors, such as land availability, local planning system, institutional and contractual features also have an major impact on the functioning of and the transmission of monetary policy to local housing markets. It is also important to note that these factors change continuously over time. Details on structural aspects and major housing market reforms between 1980 and the early 2000s can be found in structural issues report of the ECB (2003) on housing markets in the EU. Details on housing finance in the Euro Area can be found in a more recent structural issues report of the ECB (2009).

The combination of these factors might give an indication why Greece, Ireland, Portugal and Spain exhibited diverging bubble formation and why their real estate market responded differently to monetary policy shifts of the ECB. Further research is needed to assess the the impact of these factors on developments in real estate markets. As this research only covers aggregate data, diverging developments within each country are not captured. Research on property market developments in specific cities or regions within each country would provide valuable insights for policymakers and investors in local real estate markets.

2.7. Conclusion

Overvalued property prices pose a serious risk for economic and financial stability. This essay shows that Ireland and Spain experienced the largest positive bubble formation in the observed period between 1999 and 2012, followed by Greece and Portugal with a relatively small bubble formation. The major boom, starting between 2003 and 2005, was followed by the burst of the bubble at the end of 2008, when the interest rates of the ECB reached its peak. Results of the empirical analysis on the long- and short-run relationship between the monetary policy of the ECB and the bubble indicate a relatively strong relationship in Greece, Ireland and Spain. In the long-run, the bubble is positively related to both an increase in the Euribor and the lending for house purchase-to-GDP. In the short-run, however, the analysis indicates that the relationship between the Euribor and the bubble is very weak in Greece and mean reverting in the case of Ireland and Spain. The response of the three countries bubble to the lending for house purchase-to-GDP is relatively strong and positive. The analysis of the short-run dynamics further shows that the monetary policy of the ECB is transmitted with a lag to the domestic real estate market. The varying extent of the bubble formation and the diverging impact of the monetary policy on the bubble across the four countries can be primarily attributed to differences in the domestic financial-, fiscal- and macroprudential- system as well as other structural factors.

In sum, this essay provides strong evidence that central bank's policies are crucial in triggering the formation of property bubbles by manipulating the interest rate and availability of lending for house purchase. This essay also emphasizes the argument of Confrey and Gerald (2010) that the introduction of the European monetary union brought about a dilemma. Prior to the introduction of the single monetary policy under the ECB, countries within the Eurozone were able to control national housing markets through the use of domestic monetary policy. Under the single monetary policy with its primary goal to stabilize the inflation rate in the Euro Area, national monetary policy has lost this capability. Under the single monetary policy framework, the monetary policies of the ECB are adjusted to cope with aggregate developments in the Eurozone rather than with dynamics in individual member countries. The current single monetary policy framework not only hinders national central banks to cope with precarious developments in domestic housing markets, but potentially induces booms and busts by artificially lowering the cost of capital and providing easy access to finance for investments in property markets. However, each country within the monetary union still have mechanisms, i.e. financial-, fiscal-, macroprudential- as well as structural policies, at their disposal to either soften or strengthen the effects of single monetary policy shifts on the domestic real estate markets.

3. Monetary Policy and Global Commodity Prices

3.1. Introduction

Commodity price movements are important for developing and advanced countries alike. Fluctuations in these prices have an impact on countries' external and internal balance as well as their respective fiscal and monetary policies (Byrne, Fazio, & Fiess, 2013). Hence a lot of academic as well as professional research has focused on the causes and consequences of commodity price booms and busts. Research on the causes of the contemporaneous commodity price boom has basically centered around three lines of argumentation.

The first line of argumentation focuses on demand and supply factors. In this regard many studies argue that the rapid economic growth and industrialization of emerging market economies, particularly China, are pushing up commodity demand and thus prices (J. Hamilton, 2009; He, Wang, & Lai, 2010; Li & Lin, 2011; Radetzki, 2006; Roache, 2012). Amongst these studies, Roache (2012) provides empirical evidence that the economic activity of China is significantly affecting global commodity prices. He applies reduced form VAR models to monthly data spanning from 2000 to 2012 and shows that commodity demand variables of China are Granger causing prices of several commodities. The analysis of the impulse response function further indicates that unexpected shocks to aggregate economic activity of China, i.e. industrial production, have a significant and persistent short-run impact on the price of oil and some base metals.

The second line of explanation argues that the commodity price boom is fuelled by the financialisation of commodity markets. As shown in Table 3.1, global commodity trading volumes, in both the over-the-counter (OTC) and regulated exchange market have been increasing dramatically since 2004. Over the ten year period from 2002 to 2012, the total notional amount outstanding OTC traded contracts increased from 0.92 to 2.59 trillion USD. Over the same period, the notional turnover of exchange traded contracts increased from 3.15 to 118.33 trillion USD. Trade volumes of commodity derivatives have become so large that they reached multiples of the production in the physical market.

Table 3.1: Global Commodity Derivatives Trading Volume

Year	OTC traded contracts (in Trillion USD of Notional Amount Outstanding)	Exchange traded contracts (in Trillion USD of Notional Turnover)
2002	0.92	3.15
2003	1.41	5.85
2004	1.44	4.10
2005	5.43	16.47
2006	7.12	23.28
2007	8.46	2.30
2008	4.43	20.67
2009	2.94	642.06
2010	2.92	764.27
2011	3.09	122.72
2012	2.59	118.33

Note: Data on exchange traded contracts and over-the-counter (OTC) traded contracts is sourced from the World Federation of Exchanges Database (WFE, 2013) and the Bank for International Settlements (BIS, 2013a) respectively. Exchange traded contracts refer to the total notional turnover of commodity futures and option contracts traded at WFE member and non-member exchanges. Data on OTC contracts refer to the total amount outstanding of forwards and swaps as well as options. OTC figures are as of December of each year. Units reported are in trillion USD.

As pointed out by Domanski and Heath (2007), not only the trade volume but also the number of financial investors has been growing rapidly, resulting in commodity markets that are more like financial markets. A report of the United Nations Conference on Trade and Development (2011) examined commodity markets and conducted a survey amongst market participants. This study confirms that the process of financialisation has strongly affected the functioning of commodity markets. Thereby, rather than basing trading decision solely on supply and demand fundamentals, market participants increasingly consider factors which are related to portfolio diversification or other markets. Tang and Xiong (2010) point out that financialisation of commodity markets has led to market conditions strongly affected by a set of financial factors. The UNCTAD report (2011) further shows that while markets are acknowledged to be determined by supply and demand fundamentals in the medium- and long-run, financial investors could move commodity prices in the short-run. Looking at the oil market, Lombardi and Robays (2011) confirms that financial activity in derivatives markets can destabilize spot prices in the short-run.

The third strand of argumentation suggests that the current commodity price boom is driven by expansionary monetary policy. Most of these studies focus on the role of US monetary policy. For instance, Frankel (2008) uses annual data of US real interest rates, different commodity indices and a set of commodity prices of the period between 1950 to 2005 and applies bivariate regression models to test his model. The empirical analysis shows that real commodity prices overshoot their long-run equilibrium in response to a drop in real interest rates. Akram (2009) applies structural VAR models and uses quarterly data over the period from 1990 to 2007. His results also indicate a significant overshooting of crude oil, food, metals and industrial raw materials prices in response to a fall in US real interest rates. Within a factor augmented VAR framework, Byrne et. al. (2013) provide empirical evidence for an inverse relationship between real interest rates and real commodity prices.

China is now the world’s most populous nation, world’s second largest economy and largest holder of foreign reserves. After decades of strong economic growth, industrialization and rising living standards, China has also become a dominant player in commodity markets. On the physical side, the country is a key producer as well as a consumer of a wide range of commodities including agricultural, energy and metal markets. According to a report of the United States International Trade Commission (2011), China is considered the largest agricultural economy in the world. As shown in Table 3.2, and as of 2010, China was the world's largest producer in 11 out of 17 agricultural aggregates used in the Food and Agriculture Organization of the United Nations (FAO, 2013) statistical yearbook. Amongst these categories, China's share of global production accounted for 20.11% in cereals, 28.31% in rice, 17.63% in wheat, 21.73% in root and tuber, 51.70% in vegetable, 22.54% in treenut, 20.09% in fruit, 19.50% in citrus fruit, 27.33% in meat, 30.13% in egg, milk and processed milk and 35.91% in fish.

Table 3.2: Agriculture Production in 2010

Commodity	China (in 1,000 Tonnes)	World Total (in 1,000 Tonnes)	China % of Total	Rank
Cereals	497,943	2,476,416	20.11%	1
Coarse grain	185,550	1,121,933	16.54%	2
Rice	197,212	701,128	28.13%	1
Wheat	115,181	653,355	17.63%	1
Oilcrop	16,491	170,274	9.68%	4
Pulse	3,891	68,829	5.65%	4
Root and tuber	162,457	747,740	21.73%	1
Vegetable	539,993	1,044,380	51.70%	1
Sugar	9,296	228,748	4.06%	8
Treenut	3,142	13,940	22.54%	1
Fruit	122,350	608,926	20.09%	1
Citrus fruit	23,977	122,976	19.50%	1
Fibre crop	6,329	28,143	22.49%	2
Jute and jute-like	69	3,072	2.25%	3
Meat*	80,926	296,107	27.33%	1
Egg, milk, and processed milk**	32,361	107,413	30.13%	1
Fish***	53,315	148,477	35.91%	1

Note: Data is sourced from the Food and Agriculture Organization of the United Nations (FAO) statistical yearbook (2013). The aggregate agriculture production figures included are those reported in the FAO statistical yearbook. *Figure includes beef & buffalo, pig, sheep & goat and poultry. **Figure includes eggs, milk, butter & ghee, cheese, evaporat & condensed milk and skim milk & buttermilk. ***Figure includes inland and marine capture as well as aquaculture fish production.

Although China is largely self-sufficient, it is the world's second largest importer of agricultural commodities after the US in 2009 (USITC, 2011). In the energy sector, China has replaced the US as the world's largest primary energy[10] consumer in the year 2011 (BP, 2013). As of 2012, as shown in Table 3.3, China consumed 21.92% of global primary energy, followed by the US with 17.70%. The country is the largest coal and second largest oil consumer after the US, accounting for 50.22% of the world's coal and for 11.71% of global oil consumption.

Table 3.3: Energy Consumption in 2012

Energy	China	US	World Total	China % of Total	US % of Total
Oil	484	820	4,131	11.71%	19.85%
Natural Gas	130	654	2,987	4.34%	21.89%
Coal	1,873	438	3,730	50.22%	11.74%
Nuclear Energy	22	183	560	3.93%	32.69%
Hydro electric	195	63	831	23.44%	7.60%
Other Renewables	32	51	237	13.44%	21.36%
Total	2,735	2,209	12,477	21.92%	17.70%

Note: Data is sourced from British Petroleum (BP) Statistical Review of World Energy (2013). Figures are in million tonnes of oil equivalent.

While the lion's share of China's coal consumption is satisfied by its own production, only a small portion of its oil consumption is covered by domestic production, making it the second largest net oil importer after the US in 2009 (EIA, 2012). Table 3.4 summarizes production figures of the three largest primary energy sources in 2012, emphasizing the China's dominant position as a producer in the global coal market.

Table 3.4: Energy Production in 2012

Energy	China	US	World Total	China % of Total	US % of Total
Oil	208	395	4119	5.04%	9.59%
Natural Gas	97	619	3034	3.18%	20.41%
Coal	1825	516	3845	47.46%	13.42%

Note: Data is sourced from British Petroleum (BP) Statistical Review of World Energy (2013). Production figures on nuclear energy, hydroelectric and other renewables are not available in the report. Figures are in million tonnes of oil equivalent.

[10] Primary energy comprises commercially traded fuels including oil, natural gas, coal, nuclear energy, hydro-electricity and renewables according to the definition used in the BP Statistical Review of World Energy 2013 (BP, 2013).

China is also an important player in the global metals sector. As of 2012, the country was the dominant producer of 22 out of 41 elements and element groups that are of economic value (BGS, 2012). Table 3.5 gives an overview on China's production of selected strategic metals relative to global production as of 2011. Amongst these metals, China was world's dominant producer of the industrial metals aluminum (39.96%), lead (50.18%), tin (42.47%), zinc (33.66%) and the precious metal gold (13.88%).

Table 3.5: Metals Production in 2011

Commodity	China	World Total	China % of Total	Rank	Unit
Aluminium	18,061,700	45,200,000	39.96%	1	Metric T
Copper	1,299,300	16,200,000	8.02%	2	T MC
Lead	2,358,300	4,700,000	50.18%	1	T MC
Nickel	89,800	1,826,000	4.92%	7	T MC
Tin	127,400	300,000	42.47%	1	T MC
Zinc	4,308,300	12,800,000	33.66%	1	T MC
Gold	360,960	2,600,000	13.88%	1	KG
Silver	3,231,626	23,294,000	13.87%	3	KG MC

Note: Data is sourced from British Geological Survey (BGS) report on world mineral production (2013). Metals included in the list are those traded on the London Metal Exchange (LME). T denotes tonnes; Kg denotes kilogrammes and MC metal content. Figures on aluminium are for primary aluminium only. Copper, lead, nickel, tin, zinc, gold and silver only include mine production and do not include smelter and refinery production.

Also in the sphere of metals, China is not only the largest producer but also world's largest consumer of a many metals and minerals (Pitfield, Brown, & Idoine, 2010).

Having emerged to a major player on the physical side, China also developed its commodity futures markets substantially. After the merger of 50 Chinese commodity exchanges into 14 in 1995 and subsequent consolidation into three in 1999, the trading volumes at these three exchanges have grown at an astonishing rate. According to data of the World Federation of Exchanges (WFE, 2013), and as shown in the upper panel of Table 3.6, the aggregate number of commodity contracts traded at the three commodity exchanges Dalian Commodity Exchange (DCE), Shanghai

Futures Exchange (SFE) and Zhengzhou Commodity Exchange (ZCE) increased from 0.15 billion traded contracts in 2004 to 1.87 billion contracts in 2013, accounting for 57.25% of globally traded commodity contracts. The lower panel of Table 3.6 shows the notional turnover of commodity derivatives traded in China, indicating a strong surge from 0.71 trillion USD in 2004 to 20.89 trillion USD in 2013. Also in terms of notional turnover, China accounts for a substantial share of the global commodity derivatives trading volume.

Table 3.6: Commodity Derivatives Trading Volume in China

Year	DCE	SFE	ZCE	China Total	World Total	China % of Total
Contracts Traded (in Million)						
2004	88.03	40.58	24.24	152.85	497.67	30.71%
2005	99.17	33.79	28.47	161.44	603.78	26.74%
2006	120.35	58.11	46.30	224.75	799.13	28.12%
2007	185.61	85.56	93.05	364.23	892.72	40.80%
2008	319.16	140.26	222.56	681.98	1,908.23	35.74%
2009	416.78	434.86	227.11	1,078.76	2,373.43	45.45%
2010	403.17	621.90	495.90	1,520.97	3,034.04	50.13%
2011	287.94	308.24	406.44	1,002.61	2,908.92	34.47%
2012	633.04	365.33	347.09	1,345.46	3,140.71	42.84%
2013	700.50	642.47	525.28	1,868.25	3,263.26	57.25%
Notional Turnover (in Trillion USD)						
2004	0.31	0.40	0.01	0.71	4.10	17.35%
2005	0.29	0.52	0.02	0.83	16.47	5.06%
2006	0.33	N/A	N/A	N/A	23.28	N/A
2007	0.82	N/A	N/A	N/A	2.30	N/A
2008	2.01	2.12	1.14	5.27	20.67	25.50%
2009	2.76	5.40	1.40	9.56	642.06	1.49%
2010	3.16	9.37	N/A	N/A	764.27	N/A
2011	4.74	6.90	5.31	16.95	122.72	13.81%
2012	5.35	7.16	2.79	15.29	118.33	12.93%
2013	7.79	9.98	3.12	20.89	125.71	16.62%

Note: Data is sourced from the World Federation of Exchanges Database (WFE, 2013). China Total is the sum of the respective figure on derivatives traded at the three commodity exchanges in China. World Total is the sum of the respective figure on commodity futures and option contracts traded at WFE member and non-member exchanges. Only future contracts are traded at commodity exchanges in China. DCE is the Dalian Commodity Exchange, SFE is the Shanghai Futures Exchange and ZCE is the Zhengzhou Commodity Exchange.

Undeniably, China has become a dominant player in both physical and financial commodity markets. With this development, global commodity markets have become increasingly exposed to macroeconomic developments in China (J. Hamilton, 2009; He et al., 2010; Li & Lin, 2011; Radetzki, 2006; Roache, 2012). China's weight in financial commodity markets also plays a remarkable and increasingly important role in the pricing of globally traded commodities (Liu & An, 2011). Given the pivotal role of China in international commodity markets, it is surprising that to the best knowledge of the author, no previous study has attempted to examine the role of the People's Bank of China (PBC) monetary policy on global commodity prices.

The objective of this study is to shed light on the relevance of China in international commodity price dynamics. By focusing on both China's economic activity and monetary policy, this study adds to the literature on the role of China in global commodity price dynamics from a macroeconomic perspective on the nexus between monetary policy and commodity prices in general.

The rest of this paper is organized as follows. The next section briefly reviews the theoretical framework. Section three presents the data and methodology used to investigate long- and short-run dynamics in the empirical analysis. Section four leads through the empirical results, followed by the conclusion in section five.

3.2. Framework

In order to investigate the impact of China's monetary policy on commodity prices, this study mainly builds on the theoretical model of commodity price overshooting developed by Frankel (1986, 2008).

Drawing on Dornbusch's (1976) exchange rate overshooting hypothesis, Frankel (1986, 2008) developed the commodity overshooting model that provides an theoretical explanation why commodity prices overshoot their long-run equilibrium in response to an expansionary monetary policy shift. The theory assumes that the goods market is broadly divided into a sticky fix-price manufacturer and services sector and a flexible sector with commodities that are traded on fast-moving auction markets that are able to respond instantaneously to macroeconomic shocks. In order to compensate for the slow adjustment of fix price sector, commodities in the flexible sector change more than proportionally to changes in the monetary policy stance. In response to an expansionary (restrictive) monetary policy shock, real commodity prices overshoot (undershoot) their new long-run equilibrium. It is necessary that real commodity prices are overvalued (undervalued) so that there will be an expected future rate of decrease (increase) in the price sufficient to offset the lower (higher) real interest rate.

Building on the work of Dornbusch (1976) and Frankel (1986), Saghaian et. al. (2002) further extended the commodity price overshooting theory to an open economy. In addition to the fix price manufactured goods and services sector and the flexible commodity sector, their model[11] considers the exchange rate as a second flexible sector.

This extended model however is not applicable in the case of China because its exchange rate regime has not been fully liberalized[12] over the observed period, implying that only the commodity sector can be flexible. Therefore this essay considers Frankel's (1986, 2008) commodity price overshooting model as the theoretical framework. In order to account for China's shift from a fixed- to a managed floating exchange rate system, this study further considers a dummy variable in the empirical model.

[11] For a detailed description of the model see (Saghaian et. al., 2002b).

[12] After the Asian financial crisis in 1997, China pegged its currency, i.e. RMB, at a fixed exchange rate to the USD. On 21 July 2005 China lifted the peg and officially moved to a managed floating exchange rate system. In fall 2008, the PBC re-pegged the RMB to the USD before it started to float again in the mid of 2010.

3.3. Data and Methodology

The following section presents the data and methodology for the empirical analysis. The data section gives an overview of the variables and includes commodity-group price indices, economic activity and the real interest rate of China. The methodology section explains the methods used to analyze the long- and short-run dynamics between the variables in the model.

3.3.1. Data

For the empirical analysis, the analysis applies monthly data from 1998M01 to 2012M12. The time period starts at the point when China accelerated banking sector reforms and officially replaced its credit quota system by a target system and interest rates started to be increasingly determined by market forces. The analysis considers five distinct commodity group indices as well as economic activity and real interest rate of China. Data is sourced via Bloomberg.

The empirical analysis uses commodity group indices rather than prices of individual commodities because of the advantage that idiosyncratic factors affecting individual commodities have far less influence on an index capturing a basket of different commodities (Belke, Bordon, & Volz, 2013). In particular, the analysis uses the DJ-UBS Commodity Group Spot Price Indices on agriculture, energy, industrial metals, livestock and precious metals sector which are deflated by the CPI of China sourced from OECD. These indices provide general estimates of trends in commodity prices across these sectors. The relative quantity of the commodities included are based on liquidity as well as production figures and subject to weighting restrictions applied annually. The indices are dynamically adjusted and capture the economic significance and market liquidity of the included commodities. Table 3.7 summarizes the components of each commodity group index.

Table 3.7: Components of DJ-UBS Commodity Group Spot Price Indices

Group	Commodity	Designated Contract	Exchange	Weight
Energy	Crude (WTI)	Light, Sweet Crude Oil	NYMEX	28.35%
	Crude (Brent)	Brent Crude Oil	ICE	17.01%
	Heating Oil	Heating Oil	NYMEX	10.30%
	Natural Gas	Henry Hub Natural Gas	NYMEX	34.72%
	Unleaded Gasoline	RBOB	NYMEX	9.62%
Agriculture	Corn	Corn	CBOT	17.09%
	Soybean Meal	Soybean Meal	CBOT	9.81%
	Soybean Oil	Soybean Oil	CBOT	8.87%
	Soybeans	Soybeans	CBOT	19.44%
	Wheat (Chicago)	Soft Wheat	CBOT	11.83%
	Wheat (Kansas)	Hard Red Winter Wheat	KCBOT	4.70%
	Coffee	Coffee "C"	NYBOT	6.64%
	Cotton	Cotton	NYBOT	6.98%
	Sugar	World Sugar No. 11	NYBOT	14.64%
Industrial Metals	Aluminium	High Grade Primary Aluminium	LME	28.89%
	Copper	Copper	COMEX	42.70%
	Nickel	Primary Nickel	LME	12.46%
	Zinc	Special High Grade Zinc	LME	15.95%
Precious Metals	Gold	Gold	COMEX	75.43%
	Silver	Silver	COMEX	24.57%
Livestock	Lean Hogs	Lean Hogs	CME	37.47%
	Live Cattle	Live Cattle	CME	62.53%

Note: Weight refers to the weight of each commodity contract in the respective commodity-group index as of 2013. CBOT is the Chicago Board of Trade, CME is the Chicago Mercantile Exchange, COMEX is the Commodity Exchange a division of the NYMEX, ICE is the Intercontinental Exchange, KCBOT the Kansas City Board of Trade, LME is the London Metal Exchange, NYBOT is the New York Board of Trade and NYMEX is the New York Mercantile Exchange.

Figure 3.1 shows the movement of the log transformed commodity group indices of the agriculture, energy, industrial metals, livestock and precious metals group since 1998. It is interesting to note that the prices of most commodity groups move very closely. One explanation for this co-movement is that different commodities amongst different groups are impacted by common macroeconomic factors such as the real interest rate (Byrne et al., 2013).

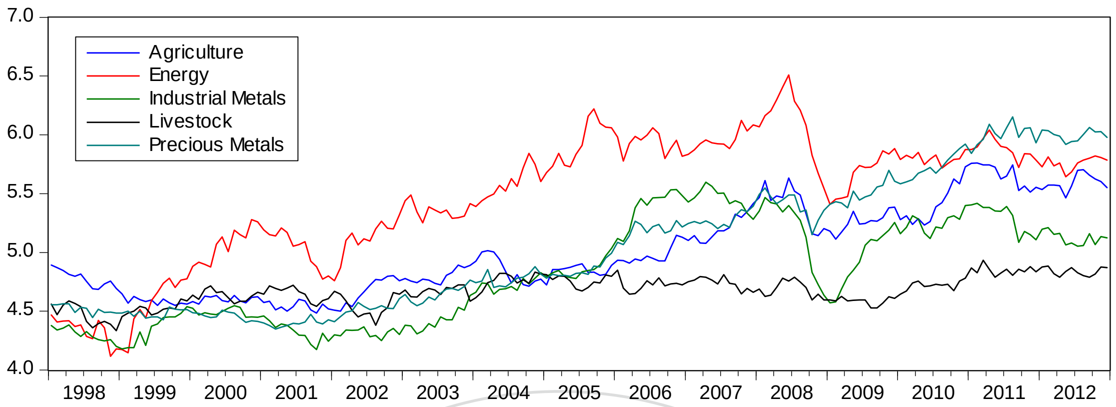

Figure 3.1: Commodity Group Spot Price Indices

Similar to Akram (2009) and in order to account for the interaction between economic activity, monetary policy and global commodity prices, this study considers industrial production in the empirical model. Although alternatives have been developed (Kilian, 2009), it is common to use industrial production as a measure of economic activity (Akram, 2009; Reinhart & Borensztein, 1994; Roache, 2012). Since there is no index available, the National Bureau of Statistics of China's Y-o-Y industrial production percentage change of China[13] is used as a measure for economic activity.

The following figure shows the Y-o-Y industrial production of China. With values around 10%, growth in industrial production was relatively low up to the end of 2001. After that and up to the financial crisis in 2008 industrial production growth hovered at a level above 15%. Following the financial crisis, industrial production dropped heavily followed by a recovery to values back to around 15% between the end of 2009 and 2011. In 2012, industrial production growth levels fell back to levels before 2001.

[13] Starting in 2007, in order to remove the impact of the different date of "Spring Festival" of each year, the National Statistics Bureau of China jointly releases January and February data on industrial production. In order to align the data up to 2007, we compute the average of the January and February figure and use this average figure for both January and February.

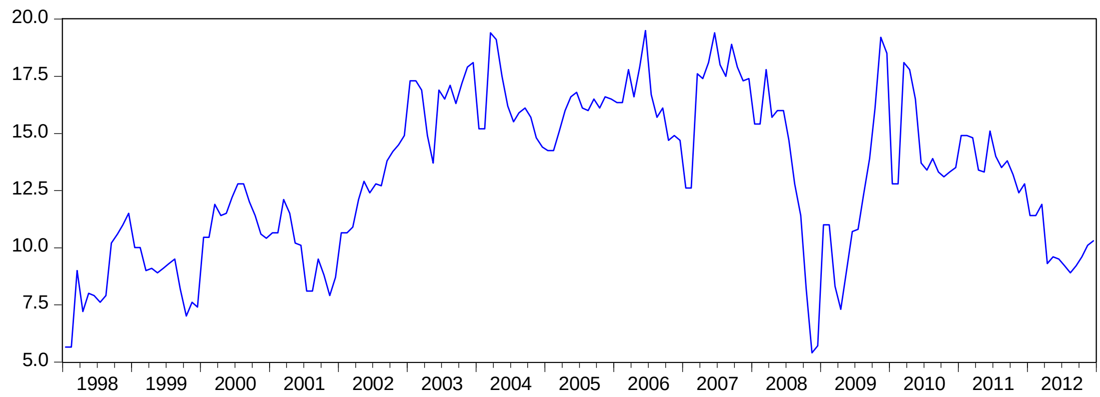

Figure 3.2: Industrial Production of China

The real interest rate is calculated by subtracting the one-year inflation rate observed over the preceding year from the one-year interest rate. Thereby the annualized weighted average interbank lending rate from the PBC and Y-o-Y inflation rate from the National Bureau of Statistics of China is used. Figure 3.3 shows the interest rate, inflation rate and the real interest rate of China. As the fluctuations of the inflation rate are large relative to the fluctuations of the interest rate, most of the movement in the real interest rate can be attributed to movements in inflation. Furthermore, changes in interest rates and inflation can be primarily attributed to monetary policy shifts. For instance, an expansionary monetary policy will likely decrease the real interest rate by decreasing interest rates and increasing inflation and a contractionary monetary policy will likely result in high real interest rates by increasing interest rates and decreasing inflation.

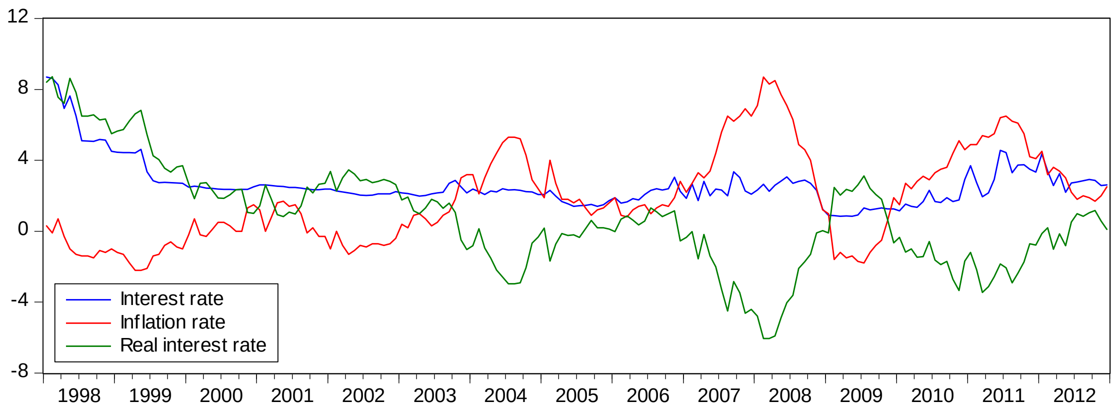

Figure 3.3: Real Interest Rate of China

In order to account for the exchange rate regime change in China, the analysis further considers a dummy variable capturing the shift of China from a fixed exchange rate regime to a managed floating exchange rate regime in 2005M07. The following graph clearly illustrates the peg of the RMB to the USD up to the mid of 2005 and the adoption of the managed floating exchange rate system afterwards.

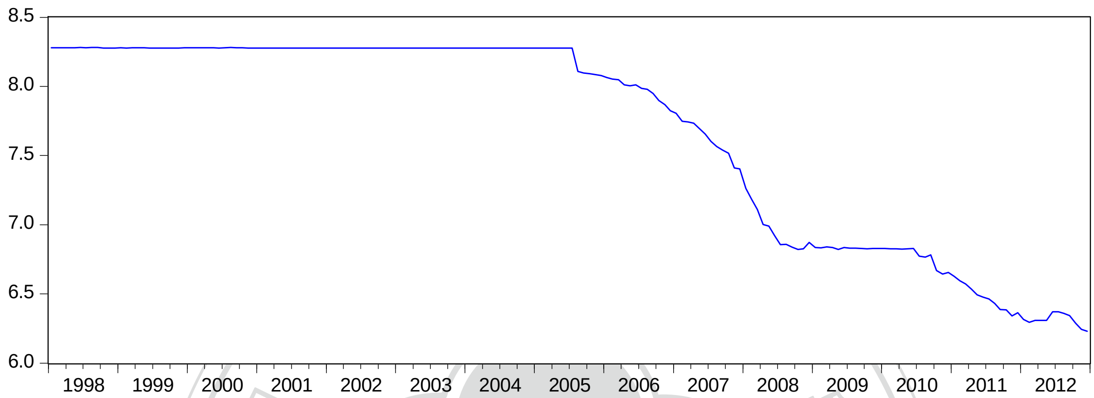

Figure 3.4: RMB/USD Exchange Rate

As also apparent in the Figure 3.4, the PBC, in fact, temporarily re-pegged the RMB to the USD in the period around the financial crisis from 2008M10 to 2010M06. The dummy variable considers the period of the fixed exchange rate regime as well as the stabilization of the RMB/USD exchange rate in the period surrounding the financial crisis, taking on a value of zero in the period from 1998M01 to 2005M07 as well as 2008M10 to 2010M06 and a value of one otherwise.

Table 3.8 summarizes the descriptive statistics of the variables considered in the following analysis. All variables have been transformed to log form. The coefficient of variation, indicating the standard deviation relative to the mean, shows that the real interest rate of China (*RIR*) has the highest volatility. The high volatility of the real interest rate largely reflects the strong fluctuations in inflation. The livestock commodity group price (*CP_LI*) exhibits the lowest volatility amongst the considered variables.

Table 3.8: Descriptive Statistics

	CP_AG	*CP_EN*	*CP_IN*	*CP_LI*	*CP_PR*	*EA*	*RIR*
Mean	5.013	5.472	4.828	4.676	5.049	2.536	1.968
Standard deviation	0.379	0.541	0.438	0.122	0.560	0.288	0.460
Coefficient of variance	0.076	0.099	0.091	0.026	0.111	0.114	0.234
Skewness	0.444	-0.736	0.124	-0.434	0.450	-0.669	-1.468
Kurtosis	1.897	2.695	1.523	2.766	1.803	2.830	6.946
Observations	180	180	180	180	180	180	180

Note: All variables have been log transformed. Commodity group indices have been deflated by the CPI of China. *CP_AG* represents the real agricultural group price, *CP_EN* the real energy group price, *CP_IN* the real industrial metals group price, *CP_LI* the real livestock group price, *CP_PR* the real precious metals group price, *EA* the economic activity of China and *RIR* the real interest rate of China.

Table 3.9 summarizes the correlation coefficients between the variables. As expected, the coefficients show positive correlation between China's economic activity (*EA*) and all of the commodity group prices. Energy (*CP_EN*) shows the strongest correlation followed by industrial metals (*CP_IN*), livestock (*CP_LI*), agricultural (*CP_AG*) and precious metals (*CP_PR*). Also as expected, the correlation coefficients indicate an inverse relationship between the real interest rate (*RIR*) and all of the commodity group prices. In sum, the analysis of the correlation coefficients shows relatively strong linear relationships between the economic activity (*EA*) as well as real interest rates (*RIR*) and commodity group prices.

Table 3.9: Contemporaneous Correlation Coefficients

	CP_AG	*CP_EN*	*CP_IN*	*CP_LI*	*CP_PR*	*EA*	*RIR*
CP_AG	1.000						
CP_EN	0.683***	1.000					
CP_IN	0.794***	0.849***	1.000				
CP_LI	0.561***	0.719***	0.645***	1.000			
CP_PR	0.960***	0.705***	0.822***	0.605***	1.000		
EA	0.209***	0.620***	0.488***	0.417***	0.205***	1.000	
RIR	-0.590***	-0.739***	-0.667***	-0.533***	-0.522***	-0.533***	1.000

Note: Superscripts ***, ** and * represent significance levels at 1%, 5%, and 10%, respectively.

It is important to note that these coefficients only reflect the contemporaneous correlation between the variables. The following empirical analysis sheds light on the relationship between these variables over time.

3.3.2. Methodology

The following empirical analysis broadly follows the methodology applied by Soytas et. al. (2009) and Nazlioglu and Soytas (2011) to assess long- and short-run dynamics between the variables in the empirical model.

In order to account for the long-run dynamics, the analysis applies the methodology (T&Y hereafter) proposed by Toda and Yamamoto (1995). The T&Y procedure allows running a VAR) model formulated in its levels, regardless of the order of integration of the variables. The advantage of this procedure is that there is no need to test for cointegration, which prevents a likely pretest bias. Another advantage of the T&Y procedure is that by using data in its level, loss of information resulting from differencing data can be avoided. The T&Y methodology starts with determining the maximum order of integration d_{max} of the variables included in the system. In this case, a VAR(*p*) model of the following specification, where x_t is the *n×1* vector of the variables in its levels, A_0 the *n×1* vector of intercept terms, A_i the *n×n* matrix of coefficients, ψ and D_t the *n×1* vector of coefficients and *n×1* vector of dummy variables respectively, and ε_t the *n×1* vector of error terms, is set up.

$$x_t = A_0 + A_1 x_{t-1} + \cdots + A_p x_{t-p} + \psi D_t + \varepsilon_t \tag{1}$$

More specific, the VAR(*p*) model can be written as (2)

$$\begin{bmatrix} CP\_AG_t \\ CP\_EN_t \\ CP\_IN_t \\ CP\_LI_t \\ CP\_PR_t \\ EA_t \\ RIR_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \end{bmatrix} + \begin{bmatrix} A_{11,1} & A_{12,1} & A_{13,1} & A_{14,1} & A_{15,1} & A_{16,1} & A_{17,1} \\ A_{21,1} & A_{22,1} & A_{23,1} & A_{24,1} & A_{25,1} & A_{26,1} & A_{27,1} \\ A_{31,1} & A_{32,1} & A_{33,1} & A_{34,1} & A_{35,1} & A_{36,1} & A_{37,1} \\ A_{41,1} & A_{42,1} & A_{43,1} & A_{44,1} & A_{45,1} & A_{46,1} & A_{47,1} \\ A_{51,1} & A_{52,1} & A_{53,1} & A_{54,1} & A_{55,1} & A_{56,1} & A_{57,1} \\ A_{61,1} & A_{62,1} & A_{63,1} & A_{64,1} & A_{65,1} & A_{66,1} & A_{67,1} \\ A_{71,1} & A_{72,1} & A_{73,1} & A_{74,1} & A_{75,1} & A_{76,1} & A_{77,1} \end{bmatrix} \begin{bmatrix} CP\_AG_{t-1} \\ CP\_EN_{t-1} \\ CP\_IN_{t-1} \\ CP\_LI_{t-1} \\ CP\_PR_{t-1} \\ EA_{t-1} \\ RIR_{t-1} \end{bmatrix} + \cdots$$

$$+ \begin{bmatrix} A_{11,p} & A_{12,p} & A_{13,p} & A_{14,p} & A_{15,p} & A_{16,p} & A_{17,p} \\ A_{21,p} & A_{22,p} & A_{23,p} & A_{24,p} & A_{25,p} & A_{26,p} & A_{27,p} \\ A_{31,p} & A_{32,p} & A_{33,p} & A_{34,p} & A_{35,p} & A_{36,p} & A_{37,p} \\ A_{41,p} & A_{42,p} & A_{43,p} & A_{44,p} & A_{45,p} & A_{46,p} & A_{47,p} \\ A_{51,p} & A_{52,p} & A_{53,p} & A_{54,p} & A_{55,p} & A_{56,p} & A_{57,p} \\ A_{61,p} & A_{62,p} & A_{63,p} & A_{64,p} & A_{65,p} & A_{66,p} & A_{67,p} \\ A_{71,p} & A_{72,p} & A_{73,p} & A_{74,p} & A_{75,p} & A_{76,p} & A_{77,p} \end{bmatrix} \begin{bmatrix} CP\_AG_{t-p} \\ CP\_EN_{t-p} \\ CP\_IN_{t-p} \\ CP\_LI_{t-p} \\ CP\_PR_{t-p} \\ EA_{t-p} \\ RIR_{t-p} \end{bmatrix} + \begin{bmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \\ \psi_5 \\ \psi_6 \\ \psi_7 \end{bmatrix} \begin{bmatrix} D_t \\ D_t \\ D_t \\ D_t \\ D_t \\ D_t \\ D_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \\ \varepsilon_{7t} \end{bmatrix}$$

The lag length p is determined by applying the usual lag selection criteria and the respective VAR model is then augmented by the maximal order of integration d_{max} identified in the unit root tests. The model of the form VAR$(p + d_{max})$ is then estimated with the d_{max} coefficients defined as exogenous variables. In this case, the lag augmented VAR model, including the dummy variable, is specified as following where *k* represents the order of $(p + d_{max})$.

$$x_t = A_0 + A_1 x_{t-1} + \cdots + A_p x_{t-p} + \cdots + A_k x_{t-k} + \psi D_t + \varepsilon_t \tag{3}$$

The lag augmented VAR$(p + d_{max})$ model including the dummy variable can be written as (4)

$$\begin{bmatrix} CP\_AG_t \\ CP\_EN_t \\ CP\_IN_t \\ CP\_LI_t \\ CP\_PR_t \\ EA_t \\ RIR_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \end{bmatrix} + \begin{bmatrix} A_{11,1} & A_{12,1} & A_{13,1} & A_{14,1} & A_{15,1} & A_{16,1} & A_{17,1} \\ A_{21,1} & A_{22,1} & A_{23,1} & A_{24,1} & A_{25,1} & A_{26,1} & A_{27,1} \\ A_{31,1} & A_{32,1} & A_{33,1} & A_{34,1} & A_{35,1} & A_{36,1} & A_{37,1} \\ A_{41,1} & A_{42,1} & A_{43,1} & A_{44,1} & A_{45,1} & A_{46,1} & A_{47,1} \\ A_{51,1} & A_{52,1} & A_{53,1} & A_{54,1} & A_{55,1} & A_{56,1} & A_{57,1} \\ A_{61,1} & A_{62,1} & A_{63,1} & A_{64,1} & A_{65,1} & A_{66,1} & A_{67,1} \\ A_{71,1} & A_{72,1} & A_{73,1} & A_{74,1} & A_{75,1} & A_{76,1} & A_{77,1} \end{bmatrix} \begin{bmatrix} CP\_AG_{t-1} \\ CP\_EN_{t-1} \\ CP\_IN_{t-1} \\ CP\_LI_{t-1} \\ CP\_PR_{t-1} \\ EA_{t-1} \\ RIR_{t-1} \end{bmatrix} + \cdots$$

$$+ \begin{bmatrix} A_{11,p} & A_{12,p} & A_{13,p} & A_{14,p} & A_{15,p} & A_{16,p} & A_{17,p} \\ A_{21,p} & A_{22,p} & A_{23,p} & A_{24,p} & A_{25,p} & A_{26,p} & A_{27,p} \\ A_{31,p} & A_{32,p} & A_{33,p} & A_{34,p} & A_{35,p} & A_{36,p} & A_{37,p} \\ A_{41,p} & A_{42,p} & A_{43,p} & A_{44,p} & A_{45,p} & A_{46,p} & A_{47,p} \\ A_{51,p} & A_{52,p} & A_{53,p} & A_{54,p} & A_{55,p} & A_{56,p} & A_{57,p} \\ A_{61,p} & A_{62,p} & A_{63,p} & A_{64,p} & A_{65,p} & A_{66,p} & A_{67,p} \\ A_{71,p} & A_{72,p} & A_{73,p} & A_{74,p} & A_{75,p} & A_{76,p} & A_{77,p} \end{bmatrix} \begin{bmatrix} CP_{AG_{t-p}} \\ CP_{EN_{t-p}} \\ CP_{IN_{t-p}} \\ CP_{LI_{t-p}} \\ CP_{PR_{t-p}} \\ EA_{t-p} \\ RIR_{t-p} \end{bmatrix} + \cdots$$

$$+ \begin{bmatrix} A_{11,k} & A_{12,k} & A_{13,k} & A_{14,k} & A_{15,k} & A_{16,k} & A_{17,k} \\ A_{21,k} & A_{22,k} & A_{23,k} & A_{24,k} & A_{25,k} & A_{26,k} & A_{27,k} \\ A_{31,k} & A_{32,k} & A_{33,k} & A_{34,k} & A_{35,k} & A_{36,k} & A_{37,k} \\ A_{41,k} & A_{42,k} & A_{43,k} & A_{44,k} & A_{45,k} & A_{46,k} & A_{47,k} \\ A_{51,k} & A_{52,k} & A_{53,k} & A_{54,k} & A_{55,k} & A_{56,k} & A_{57,k} \\ A_{61,k} & A_{62,k} & A_{63,k} & A_{64,k} & A_{65,k} & A_{66,k} & A_{67,k} \\ A_{71,k} & A_{72,k} & A_{73,k} & A_{74,k} & A_{75,k} & A_{76,k} & A_{77,k} \end{bmatrix} \begin{bmatrix} CP\_AG_{t-k} \\ CP\_EN_{t-k} \\ CP\_IN_{t-k} \\ CP\_LI_{t-k} \\ CP\_PR_{t-k} \\ EA_{t-k} \\ RIR_{t-k} \end{bmatrix} + \begin{bmatrix} \psi_1 \\ \psi_2 \\ \psi_3 \\ \psi_4 \\ \psi_5 \\ \psi_6 \\ \psi_7 \end{bmatrix} \begin{bmatrix} D_t \\ D_t \\ D_t \\ D_t \\ D_t \\ D_t \\ D_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \\ \varepsilon_{7t} \end{bmatrix}$$

The long-run Granger causality can be tested by applying Wald tests on the joint significance on the parameters of the coefficients of the first *p* coefficient matrix. As long as the order of integration of the variables does not exceed the true lag length of the model, the Wald Test statistic, with an asymptotic Chi-square distribution and *p* degrees of freedom, can be applied to test for restriction on the parameters of the first

p coefficient matrix of the lag augmented VAR($p + d_{max}$) model. For instance, to test for long-run Granger causality running from the economic activity *EA* and real interest rate *RIR* to the agricultural commodity price *CP_AG*, it is possible to test for the joint significance of the coefficients $A_{16,1}, \dots, A_{16,p}$ and $A_{17,1}, \dots, A_{17,p}$ respectively. The respective hypotheses can be written as

$$H_{0,1}\colon\ A_{16,1} = \cdots = A_{16,p} = 0,\ \text{No Granger causality running from } EA \text{ to } CP\_AG \qquad (5)$$
$$H_{0,2}\colon\ A_{17,1} = \cdots = A_{17,p} = 0,\ \text{No Granger causality running from } RIR \text{ to } CP\_AG$$

The null of no Granger causality is rejected if the Wald test statistic is significant. The augmented Granger causality test provides information whether there is a long-run equilibrium relationship between the variables. However, it does not show how each variable reacts to innovations in other variables and whether the effect is time persistent or not.

In order to investigate this relationship, the empirical analysis applies the generalized impulse response function (GIRF) developed by Koop et al. (1996) and Pesaran and Shin (1998) to the VAR(p) model in levels defined in (1). Using a VAR model in levels still allows obtaining consistent estimates of parameters describing the system's dynamics (C. A. Sims, Stock, & Watson, 1990). Comparing impulse response estimators based on VAR model specifications determined by pre-tests for unit roots and cointegration as well as unrestricted VAR specifications in levels, Gospodinov et. al. (2013) point out that the impulse response estimators obtained from VAR model specification in levels tend to be the most robust for applied empirical work. Therefore the following analysis considers VAR models in levels as specified in (1). Considering the model in (1), the GIRF can be defined as

$$x_{t+n} = (S_n \sum e_j)\,(\sigma_{ij})^{-1} \qquad (6)$$

where the term $(S_n \sum e_j)(\sigma_{ij})^{-1}$ represents the generalized impulse response of x_{t+n} with respect to a unit shock to the *j*th variable at time *t*. Note that $S_n = A_1 S_{n-1} + \cdots + A_p S_{n-p}, n = 1,2,\ldots, S_0 = I, S_n = 0$ for $n < 0$ and e_j is the *n×1* selection vector with unity as its *j*th element and zero elsewhere and covariance $\sum = \sigma_{ij}$. Similar to Soytas et. al. (2009) and Nazlioglu and Soytas (2011), the GIRF is used because, unlike the standard approach, this approach does not require orthogonalization of shocks. As the results of the GIRF approach are invariant to the ordering of the variables in the VAR model, it overcomes the orthogonalization problem of the traditional approach.

In addition to the above presented base model, another specification, taking the effect of US monetary policy variable into account, has been estimated. In addition to the seven variables of the base model, the alternative specification considered the US real interest rate as endogenous variable in the VAR model. As this specification did not change the outcome of the analysis on both long- and short-run dynamics between economic activity as well as real interest rate and global commodity prices, results are not reported here.

3.4. Empirical Analysis

The first section of the empirical analysis covers unit root and optimal lag length tests followed by an estimation of the lag augmented VAR models and diagnostic tests in section two. Section three and four presents the results on the long- and short-run dynamics of global commodity prices in relation to economic activity and monetary policy of China.

3.4.1. Unit Root Tests and Lag Length Selection

In the first step, the maximum order of integration d_{max} of the variables is determined. Thereby a variable is said to be integrated of order n when it achieves stationarity after taking its n-th difference. In order to determine the order of integration of the variables, the augmented Dickey and Fuller (1979) (ADF) test is applied. Table 3.10 summarizes the results. All of the unit root tests indicate at the 1% level of significance that d_{max} is one.

Table 3.10: ADF Unit Root Tests

		Level			Difference		
	Variable	t-value	p-value	Lags	t-value	p-value	Lags
Intercept	*CP_AG*	-0.629	0.860	0	-13.836	0.000	0
	CP_EN	-1.833	0.364	0	-12.462	0.000	0
	CP_IN	-1.166	0.689	0	-12.249	0.000	0
	CP_LI	-2.660	0.083	0	-14.565	0.000	0
	CP_PR	0.408	0.983	1	-16.302	0.000	0
	EA	-2.610	0.093	2	-12.415	0.000	1
	RIR_CN	-2.485	0.121	0	-11.953	0.000	0
Trend and Intercept	*CP_AG*	-3.488	0.044	0	-13.855	0.000	0
	CP_EN	-1.803	0.699	0	-12.503	0.000	0
	CP_IN	-1.586	0.795	0	-12.223	0.000	0
	CP_LI	-3.817	0.018	0	-14.521	0.000	0
	CP_PR	-3.093	0.111	0	-16.380	0.000	0
	EA	-2.447	0.354	2	-12.424	0.000	1
	RIR_CN	-2.553	0.303	0	-11.950	0.000	0

Note: The number of lags included in the ADF test is decided by the automatic lag length selection criteria based on SIC with maximum lag length of 13.

In the next step, the optimal lag length of the VAR model specified in (1) is determined. As specified by T&Y (1995), the usual lag selection criteria can be applied to the VAR model. Table 3.11 summarizes the results of the optimal lag selection tests for the model. All of the lag order selection criteria indicate a maximum optimal lag length of one. Thus a lag length of one is applied in the following analysis.

Table 3.11: Lag Selection Tests

	AIC	FPE	HQ	SIC
VAR lag order selection criteria	1	1	1	1

Note: AIC is the Akaike information criterion, FPE is the Final Prediction Error, HQ is the Hannan-Quinn Information Criterion and SIC the Schwarz Information Criterion. 13 lags were included in the lag specification.

3.4.2. VAR Estimation and Model Robustness

On the basis of the optimal lag length, a VAR(1) model as specified in (1) is estimated. The 7×1 vector of our model jointly considers the prices of the agriculture, energy, industrial metal, livestock and precious metals group as well as economic activity and real interest rate of China, such that $x_t = (CP\_AG_t, CP\_EN_t, CP\_IN_t, CP\_LI_t, CP\_PR_t, EA_t, RIR_t)'$. The model further considers a dummy variable capturing the effect of the managed floating- against the fixed exchange rate regime of China. The variable has a value of zero in the periods of fixed exchange rate system and a value of one otherwise. The estimated VAR(1) model satisfies the stability condition so that no roots lie outside the unit circle.

Next, the $VAR(p)$ model is augmented to $VAR(p + d_{max})$ as specified in (3). The unit root tests indicate that d_{max} is one. Therefore the VAR(1) model is augmented to VAR(1+1). As specified in (3), the additional d_{max} lags are defined as exogenous variable in the lag augmented VAR model. As the VAR system must satisfy the common regression assumptions to be valid, the residuals of each equation in the model are tested for autocorrelation and heteroskedasticity. Table 3.12 summarizes the results of the diagnostic tests for the augmented VAR model.

Table 3.12: Diagnostic Tests

Equation	BG	BPG	WHITE	ARCH
CP_AG	1.53	2.00**	2.08**	0.69
CP_EN	2.44*	0.56	0.50	0.15
CP_IN	0.52	0.98	1.06	0.57
CP_LI	1.45	1.01	1.00	0.13
CP_PR	4.20**	2.80***	2.86***	2.75*
EA	3.31**	3.64***	3.28***	1.58
RIR	0.30	2.91***	3.03***	0.90

Note: Superscripts ***, ** and * represent significance levels at 1%, 5%, and 10%, respectively. BG is the Breusch-Godfrey test with H0 of no serial correlation up to lag 2. BPG is the Breusch-Pagan-Godfrey test for H0 of homoskedasticity. WHITE is the White test for the null of homoskedasticity. ARCH is the Engle test for H0 of no autoregressive conditional heteroskedasticity up to lag 1.

The test statistics of the Breusch-Godfrey test (BG) indicate problems with autocorrelation in the *CP_EN*, *CP_PR* and *EA* equation. The other diagnostic tests further indicate problems with heteroscedasticity in the *CP_AG*, *CP_PR*, *EA* and *RIR* equation. In order to yield valid test results in the subsequent hypotheses testing, the Newey-West Heteroskedasticity and Autocorrelation Consistent (HAC) corrected standard errors are applied to the computations of the respective equations.

3.4.3. Long-Run Dynamics

In the next step, the analysis applies Wald tests on the first lag coefficient matrix of the lag augmented VAR(1+1) model while ignoring the coefficients in the augmented lag matrix. From the Chi-squared statistic of the Wald test, it is possible to infer Granger causality. The results of this test, with the null of no Granger causality, are shown in Table 3.13.

Table 3.13: Granger Causality Tests

	CP_AG	*CP_EN*	*CP_IN*	*CP_LI*	*CP_PR*	*EA*	*RIR*
CP_AG	-	0.425	0.799	1.417	2.107	0.000	0.252
CP_EN	0.256	-	1.424	0.085	0.826	7.437***	1.720
CP_IN	0.865	1.585	-	0.000	0.001	4.000**	0.001
CP_LI	0.086	2.709*	0.224	-	4.439**	0.006	0.296
CP_PR	1.009	2.672	0.475	0.027	-	0.062	0.001
EA	3.360*	1.272	3.828*	0.021	1.232	-	0.181
RIR	3.600*	0.017	2.138	0.070	1.556	0.100	-

Note: Superscripts ***, ** and * represent significance levels at 1%, 5%, and 10%, respectively. Significance means that the column variable Granger causes the row variable.

The T&Y Granger causality tests indicate that energy (*CP_EN*) as well as industrial metals (*CP_IN*) prices are Granger caused by China's economic activity (*EA*) at the 1% and 5% level of significance respectively. These findings are in line with the findings of Roache (2012) who reports significant Granger causality running from the industrial production of China to global oil and lead prices over the period from 2000M01 to 2011M09. This finding provides significant evidence that the economic activity of China is a determinant of global commodity prices, at least in the group of energy and industrial metals. At the 10% level of significance, the test statistics shows that agricultural (*CP_AG*) and industrial metals (*CP_IN*) prices are Granger causing economic activity (*EA*). This relationship might be due to commodity producers in these sectors who have benefited from increasing prices and thus stimulate economic activity.

As for the monetary policy variable of China, the analysis provides no empirical evidence that the real interest rate of China is Granger causing commodity prices. On the reverse side however, test results indicate that agricultural commodity prices (*CP_AG*) are Granger causing the real interest rate. This relationship is in line with Awokuse and Yang (2003) who report Granger causality running from commodity price to nominal interest rate and inflation. One explanation for this relationship is that fluctuations in commodity prices may provide signals to policy makers to adjust monetary policy variables such as the interest rate. Another explanation that seems to be more plausible in the case of China with a relatively flat interest rate is that changes in commodity prices affect inflation and thus real interest rates. This is because commodities are raw materials that are used as input factor, in the production of higher order goods. A change in the cost of the input factor has an impact on the higher order goods and thus on inflation and real interest rates.

The test results further indicate spillover effects from precious metals (*CP_PR*) and energy (*CP*_EN) to livestock prices (*CP_LI*). While the effect of precious metals is surprising, the impact of energy prices on livestock prices might be explained by an energy cost spillover that is incorporated in the price of livestock.

The estimated coefficients of the dummy variable included in the lag augmented VAR model are presented in Table 3.14. The coefficients of the dummy variable, capturing the effect of the managed floating- against the fixed exchange rate regime, indicates that industrial metals (*CP_IN*) prices are significantly higher when the managed floating exchange rate system is in place. One possible explanation for this relationship might be that the value of the RMB versus the USD tends to increase during the time of a managed floating exchange rate system. As the USD is the predominant invoicing currency in international commodity transactions, an appreciation of the RMB relative to the USD implies that purchasing power of Chinese commodity consumers and thus commodity demand and prices are pushed up.

Table 3.14: Exchange Rate Regime Dummy Estimates

	CP_AG	CP_EN	CP_IN	CP_LI	CP_PR	EA	RIR
Coefficient	0.026	0.018	0.045**	0.012	0.010	-0.017	0.022
Standard Error	0.016	0.025	0.018	0.013	0.015	0.032	0.038
t-statistic	1.601	0.718	2.552	0.942	0.667	-0.538	0.581

Note: Superscripts ***, ** and * represent significance levels at 1%, 5%, and 10%. The respective critical value for the t-test is 2.576(1%), 1.96(5%) and 1.645(10%). Estimates are based on the lag augmented VAR model.

3.4.4. Short-Run Dynamics

The augmented Granger causality test provides information whether there is a long-run relationship between the variables. However, it does not show how each variable reacts to innovations in other variables and whether the effect is time persistent or not. The analysis of the GIRF provides an approach to investigate this relationship. In the following, the GIRF analysis is applied to the aforementioned VAR(1) model.

The following figure shows the response of the variables included in the VAR(1) model to a generalized one standard deviation innovation in the economic activity (*EA*) and real interest rate of China (*RIR*). Monte Carlo simulation procedure with 1000 replications is used to generate error bands. The dashed line shows the ±2 standard deviation error band, representing the 5% level of significance.

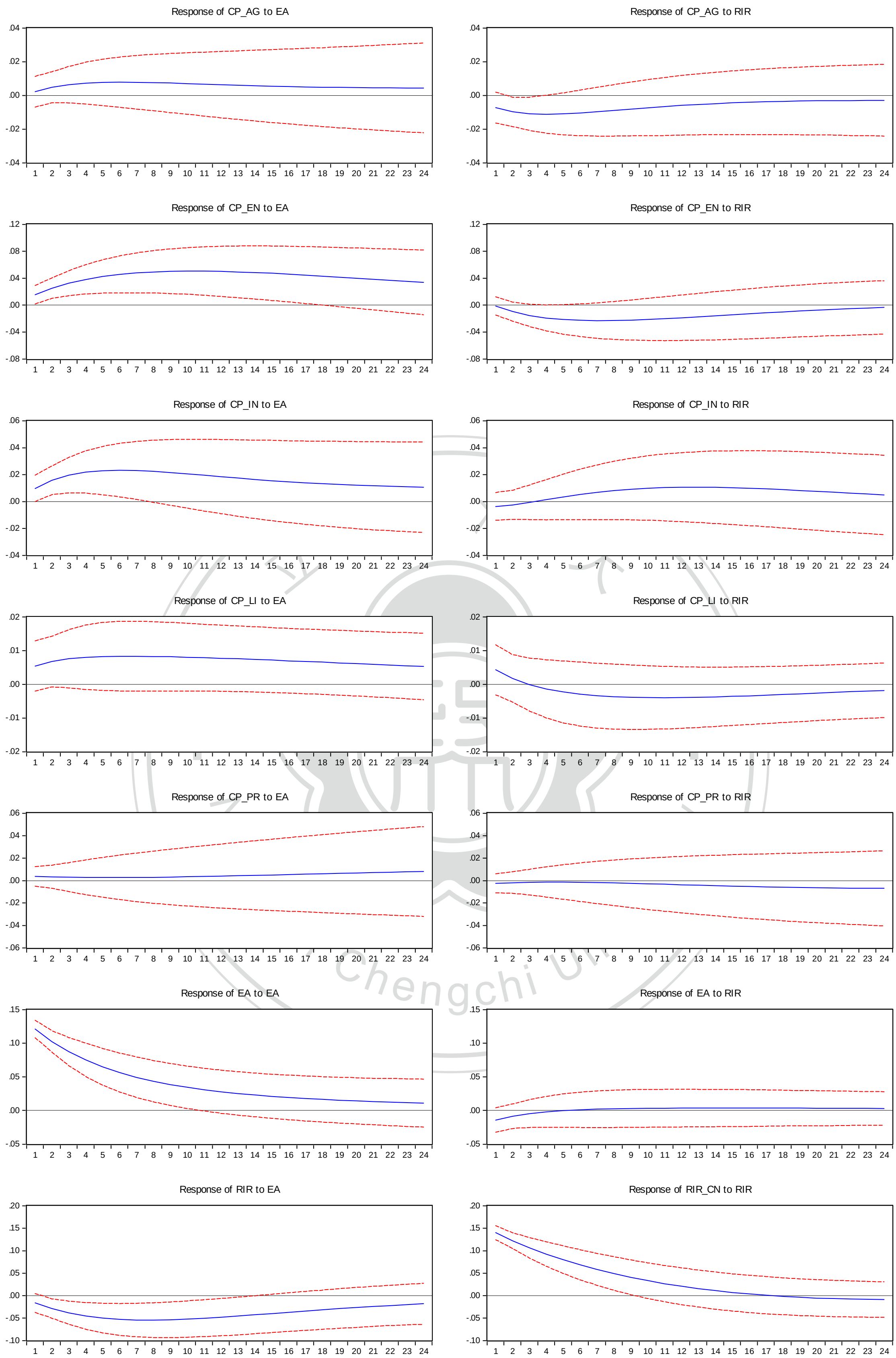

Figure 3.5: Commodity Price Responses to Generalized One S.D. Innovations

The first column of the GIRF shows the response of the variables to a shock in the economic activity of China (*EA*). As for the commodity group prices the analysis indicates that energy (*CP_EN*) and industrial metals (*CP_IN*) prices respond positively to a positive shock in the economic activity of China (*EA*). While the response of the energy price (*CP_EN*) continues to be significant for around 16 months, the feedback of industrial metal prices (*CP_IN*) is less persistent, already becoming insignificant after around six months.

The positive response of these commodity prices to an unexpected shock in the economic activity of China is consistent with the findings of Roache (2012), where global oil and copper prices displayed positive and persistent responses to innovations in the industrial production of China in the time interval from 2000M01 to 2011M09.

The GIRF analysis further indicates that the real interest rate of China (*RIR*) responds negatively to an innovation in the economic activity of China (*EA*). One possible explanation for the negative response to an innovation in the economic activity is that the boost of the economic activity is followed by an increase in the general price level or a cut in interest rates of the monetary authority in an attempt to stimulate the economy.

The second column of figure Figure 3.5 indicates that agricultural commodity prices (*CP_AG*) respond negatively to a positive shock in the real interest rate of China (*RIR*) and vice versa. The overshooting behavior of commodity prices in response to a drop in the real interest rate is in line with Frankel's (1986, 2008) commodity overshooting model as well as with empirical evidence on the relationship between real interest rate of the US and different individual- as well as commodity- group prices (Akram, 2009; Frankel, 2008).

3.5. Conclusion

This essay examined the long- and short-run dynamics between commodity prices of the agriculture, energy, industrial metals, livestock and precious metals group, economic activity and real interest rate of China over the period from 1998M01 to 2012M12. The time period starts at the point when China accelerated banking sector reforms and officially replaced its credit quota system by a target system and interest rates started to be increasingly determined by market forces.

Results from the T&Y (1995) type Granger causality tests provide significant evidence for a long-run relationship between China's economic activity and global commodity prices. In particular, energy as well as industrial metals prices are Granger caused by China's economic activity at the 1% and 5% level of significance respectively. As for the monetary policy of China, the analysis finds no significant evidence of a long-run relationship between the real interest rate and international commodity prices. The coefficient estimates of the exchange rate regime dummy variable, however, indicate at the 5% level of significance that industrial metals prices tend to be higher when the fixed exchange system of China is relaxed.

As for the short-run dynamics, the GIRF analysis indicates at the 5% level of significance that both energy and industrial metals prices respond positively to an innovation in the economic activity of China. As for China's monetary policy, the GIRF indicates, at the 5% level of significance, that the agricultural commodity prices overshoot in response to a drop in the real interest rate of China.

These results confirm that global commodity markets have become increasingly interrelated with macroeconomic developments in China. The most apparent reason for this is that China, as illustrated in the introduction, has become a dominant player in both financial and physical commodity markets. Shifts in economic and monetary policies have an impact on China’s domestic supply and demand patterns which in turn have a spillover effect on global commodity prices. Macroeconomic variables, in particular economic activity as well as real interest rate, may be useful predictors of future commodity price movements. This finding supports not only investors in commodity markets to better determine the extent to which they are exposed to changes in macroeconomic conditions of China, but also policy makers to assess the possible effects of economic and monetary policies on commodity prices. Policymakers should be aware that abrupt policy interventions might lead to disruptive fluctuations of commodity prices. These sharp movements can have a severe impact on commodity consumers and producers of commodities as well as a destabilizing effect on the economy as a whole.

When formulating economic and monetary policies, decision makers should not only consider the effects on commodity markets in general but also the possible up- and down side effects of commodity price changes on market participants. It is important to note that while commodity producer’s generally benefit from an increase in prices consumers lose. The negative effect of high commodity prices can be particularly strong for consumers in developing countries. In these countries, a large proportion of households typically spend a relatively large share of their income on primary, especially agricultural and energy, commodities. Policies that bolster commodity prices have a disproportionately severe effect on available income and living standards of a large proportion of the population in these countries.

Further research is needed to examine the impact of China’s policies on specific commodities. From the domestic perspective for China, it would be also interesting to examine the effect of economic and monetary policy shifts on domestic commodity prices.

4. Conclusion

The recent global financial and Eurozone crisis has attracted new attention to the occurrence of asset price booms and busts. Monetary policy has often been identified as a major driver of asset price cycles as well as an instrument to mitigate the possibly severe consequences on economic and financial stability.

This dissertation consists of two essays that examine the dynamics between monetary policy and asset prices in two specific markets. The first essay presented in chapter two looks at the role of the ECB in the formation of real estate bubbles in Greece, Ireland, Portugal and Spain. The reason for looking at this market and region is that these four countries stand in the epicenter of the ongoing financial crisis in Europe and that all of them relied strongly, above EU average, on the construction sector. The essay first examines the extent to which the four countries experienced property bubbles and then investigates the role of the monetary policy of the ECB in the formation of these real estate price bubbles. The findings on the extent of bubble formation indicate that Spain and Ireland experienced the largest positive bubble formation, followed by Portugal and Greece with a slightly increasing bubble. The results of the cointegration tests and impulse response analysis applied to the VAR and VEC models provide evidence for a weak short-run relationship between monetary policy and bubble formation in Portugal, but evidence for both, long- and short-run relationship in the case of Ireland, Greece and Spain. The qualitative analysis in the discussion part points out that the varying extent of the bubble formation and the differing impact of the monetary policy on the bubble across the four countries can be mainly attributed to characteristics in the domestic financial-, fiscal- and macroprudential system as well as to other structural factors. This essay also emphasizes the argument of Confrey and Gerald (2010) that the introduction of the European monetary union brought about a dilemma. The single monetary policy framework not only hinders national central banks to cope with precarious developments in domestic housing markets, but also potentially induces booms and busts by artificially lowering the cost of capital and providing access to finance for investments in property markets. However, individual countries within the monetary union still have mechanisms, i.e. financial-, fiscal- and macroprudential as well as structural policies, at their disposal to either soften or strengthen the effects of single monetary policy shifts on domestic real estate markets.

The second essay presented in the third chapter focuses on the relationship between monetary policy and global commodity prices. In light of China's emergence as world's second largest economy and dominant player in commodity markets, the study attempts to shed light on the role of China's policies in global commodity price dynamics. Specifically, the essay looks at the long- and short-run dynamics between global commodity prices of the agriculture, energy, industrial metals, livestock and precious metals sector, economic activity and monetary policy of China. In regard to monetary policy, T&Y (1995) type Granger causality tests provide no significant evidence for a long-run relationship between the real interest rate of China and international commodity prices. The coefficient estimates of the exchange rate regime dummy variable, however, indicate that industrial metals prices tend to be significantly higher when the fixed exchange system of China is relaxed. As for the short-run dynamics, the GIRF analysis indicates that agricultural commodity prices overshoot in response to a drop in the real interest rate of China.

In sum, the two essays show that monetary policy has an impact on asset prices across different regions and markets. The first paper shows that monetary policy can significantly affect domestic real estate markets, whereas central bank's policies are crucial to trigger the boom and burst of property bubbles by manipulating the interest rate and availability of lending for house purchase. The second essay looking at global commodity markets shows that the effect of monetary policy has the potential to affect asset prices that go beyond the domestic market. Specifically, the analysis shows that agricultural commodity prices overshoot in response to a fall in real interest rate of China.

The empirical findings are in line with both the monetarist and Austrian view to the extent that they acknowledge loose monetary policy as a driver of asset prices. It is important to emphasize that fluctuations in asset prices alone can have severe direct effects on market participants. As for real estate markets, a strong upsurge in prices squeeze individual's purchasing power for housing for consumption purpose in favor of investors betting on higher returns, further fuelling the housing boom. Changes in commodity price can have both up- and down side effects on participants across the market. While commodity producer's generally benefit from an increase in prices, consumers lose. The negative effect of high commodity prices can be particularly strong for consumers in developing countries. In these countries a large proportion of households typically spend a relatively large share of their income on primary, especially agricultural and energy, commodities. Thus, increasing commodity prices have a disproportionately severe effect on available income and living standards of a large proportion of the population in these countries.

However, as emphasized by the Austrian view, asset price not only have a direct effect on market participants, they are also an inherent element of economic cycles that pose a risk for the economy as a whole. Monetary policy that leads to a credit-financed investment and asset price booms might turn into financial instability and serious economic recession. Unless monetary policy or other mechanisms hinder credit-financed investment and asset price booms, a crash with its negative consequences might be inevitable. Central banks and policymakers should take into account the negative side-effects of loose monetary policy and should not sacrifice financial and economic stability for unsustainable and artificial economic growth.

5. References

Adams, Z., & Füss, R. (2010). Macroeconomic Determinants of International Housing Markets. *Journal of Housing Economics, 19*, 38-50.

Agnello, L., & Schuknecht, L. (2011). Booms and Busts in Housing Markets: Determinants and Implications. *Journal of Housing Economics, 20*, 171-190.

Ahearne, A. G., Ammer, J., Doyle, B. M., Kole, L. S., & Martin, R. F. (2005). Monetary Policy and House Prices: A Cross-Country Study. *Board of Governors of the Federal Reserve System International Finance Discussion Papers, No. 841*.

Akram, Q. F. (2009). Commodity Prices, Interest rates and the Dollar. *Energy Economics, 31*, 838-851.

Alessandri, P. (2006). Bubbles and Fads in the Stock Market: Another Look at the Experience of the US. *International Journal of Finance and Economics, 11*, 195-203.

Asmussen, J. (2012). The Irish Case from an ECB Perspective, from http://www.ecb.int

Awokuse, T. O., & Yang, J. (2003). The Informational Role of Commodity Prices in Formulating Monetary Policy: A Reexamination. *Economic Letters, 79*, 219-224.

Belke, A., Bordon, I. G., & Volz, U. (2013). Effects of Global Liquidity on Commodity and Food Prices. *World Development, 44*, 31-43.

BGS. (2012). Risk list 2012, from http://www.bgs.ac.uk

BGS. (2013). World Mineral Production 2007-2011, from http://www.bgs.ac.uk

BIS. (2013a). Derivatives Statistics, from http://www.bis.org

BIS. (2013b). Property Price Statistics, from http://www.bis.org

Bjoerklund, K., & Soederberg, B. (1999). Property Cycles, Speculative Bubbles and the Gross Income Multiplier. *Journal of Real Estate Research, 18*, 151-174.

Black, A., Fraser, P., & Hoesli, M. (2006). House Prices, Fundamentals and Bubbles. *Journal of Business and Accounting, 33*, 1535-1555.

Bordo, M. D., & Landon-Lane, J. (2013). Does Expansionary Monetary Policy Cause Asset Price Booms; Some Historical and Empirical Evidence. *NBER Working Paper Series, No. 19585*.

Bordo, M. D., & Wheelock, D. C. (2004). Monetary Policy and Asset Prices: A Look at Past U.S. Stock Market Booms. *Federal Reserve Bank of St. Louis Review, 86*, 19-44.

Borio, C. (2012). The Financial Cycle and Macroeconomics: What Have We Learnt? *BIS Working Papers, No. 395*.

Borio, C., English, W., & Filardo, A. (2003). A Tale of Two Perspectives: Old or New Challenges for Monetary Policy? *BIS Working Papers, No. 127*.

Borio, C., & Lowe, P. (2002). Asset Prices, Financial and Monetary Stability: Exploring the Nexus. *BIS Working Papers, No. 114*.

BP. (2013). BP Statistical Review of World Energy 2013, from http://www.bp.com

Byrne, J. P., Fazio, G., & Fiess, N. (2013). Primary Commodity Prices: Co-movements, Common Factors and Fundamentals. *Journal of Development Economics, 101*, 16-26.

Chan, H. L., Lee, S. K., & Woo, K. Y. (2001). Detecting Rational Bubbles in the Residential Housing Markets of Hong Kong. *Economic Modelling, 18*, 61-73.

Ciccarelli, M., Maddaloni, A., & Peydro, J.-L. (2010). Trusting the Bankers: A New Look at the Credit Channel of Monetary Policy. *ECB Working Paper Series, No. 1228*.

Conefrey, T., & Gerald, J. F. (2010). Managing Housing Bubbles in Regional Economies Under EMU: Ireland and Spain. *National Institute Economic Review, No. 211*.

Detken, C., & Smets, F. (2004). Asset Price Booms and Monetary Policy. *ECB Working Paper Series, No. 364*.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series With a Unit Root. *Journal of the American Statistical Society, 75*, 427-431.

Dol, K., & Haffner, M. (2010). Housing Statistics in the European Union 2010, from http://www.housingeurope.eu

Domanski, D., & Heath, A. (2007). Financial Investors and Commodity Markets. *BIS Quarterly Review, March 2007*, 53-67.

Dornbusch, R. (1976). Expectations and Exchange Rate Dynamics. *The Journal of Political Economy*, *84*, 1161-1176.

ECB. (2003). Structural Factors in the EU Housing Markets. *European Central Bank Structural Issues Report*.

ECB. (2009). Housing Finance in the Euro Area. *European Central Bank Structural Issues Report*.

ECB. (2010). Asset Price Bubbles and Monetary Policy Revisted. *ECB Monthly Bulletin*, *November 2010*, 71-83.

ECB. (2013a). Monetary Policy, from http://www.ecb.europa.eu

ECB. (2013b). Statistical Data Warehouse, from http://sdw.ecb.europa.eu

EIA. (2012). China Country Analysis, from http://www.eia.gov

EMF. (2012). Hypostat 2011: A Review of Europe's Mortgage and Housing Markets, from http://www.hypo.org

Enders, W. (2010). *Applied Econometric Time Series*: John Wiley & Sons.

Engle, R. F., & Granger, C. W. J. (1987). Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica, 55*, 251-276.

Eurostat. (2013). Eurostat Statistical Database, from http://www.epp.eurostat.ec.europa.eu

FAO. (2013). FAO Statistical Yearbook 2013- World Food and Agriculture, from http://www.fao.org

Frankel, J. (1986). Expectations and Commodity Price Dynamics: The Overshooting Model. *American Journal of Agricultural Economics, 68*(2), 344-348.

Frankel, J. (2008). The Effect of Monetary Policy on Real Commodity Prices. In J. Y. Campbell (Ed.), *Asset Prices and Monetary Policy* (pp. 291-327): University of Chicago Press.

Friedman, M. (1970). The Counter-Revolution in Monetary Theory. *Institute of Economic Affairs Occasional Paper, No. 33*.

Friedman, M., & Schwartz, A. J. (1965). Money and Business Cycles. *The Review of Economics and Statistics, 45*, 32-64.

Gospodinov, N., Herrera, A. M., & Pesavento, E. (2013). Unit Roots, Cointegration, and Pretesting in Var Models. In T. B. Fomby, L. Kilian & A. Murphy (Eds.), *VAR Models in Macroeconomics - New Developments and Applications:*

Essays in Honor of Christopher A. Sims (Advances in Econometrics, Volume 32) (pp. 81-115): Emerald Group Publishing.

Hamilton, J. (2009). Causes and Consequences of the Oil Shock of 2007-2008. *Brookings Papers on Economic Activity, Spring 2009*, 215-261.

Hamilton, J. D. (1985). Uncovering Financial Market Expectations. *Journal of Political Economy, 93*, 1224-1241.

Hatzvi, E., & Otto, G. (2008). Prices, Rents and Rational Speculative Bubbles in the Sydney Housing Market. *The Economic Record, 84*, 405-420.

Hayek, F. A. (1935). *Prices and Production* (Second ed.). New York: Augustus M. Kelly, Publishers.

He, Y., Wang, S., & Lai, K. K. (2010). Global Economic Activity and Crude Oil Prices: A Cointegration Analysis. *Energy Economics, 32*, 868-876.

Hofmann, B. (2004). The Determinants of Private Sector Credit in Industrialized Countries: Do Property Prices Matter? *International Finance, 7*, 203-234.

Hui, E. C. M., & Yue, S. (2006). Housing Price Bubbles in Hong Kong, Beijing and Shanghai: A Comparative Study. *Journal of Real Estate Finance and Economics, 33*, 299-327.

Igan, D., & Loungani, P. (2012). Global House Prices Still Showing Down Trend. *IMF Survey Magazine: IMF Research*, from http://www.imf.org

Johansen, S. (1995). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*: Oxford University Press.

Kilian, L. (2009). Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market. *American Economic Review, 99*, 1053-1069.

Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse Response Analysis in Nonlinear Multivariate Models. *Journal of Econometrics*, *74*, 119-147.

Li, H., & Lin, S. X. (2011). Do Emerging Markets Matter in the World Oil Pricing System? Evidence of Imported Crude by China and India. *Energy Policy, 39*, 4624-4630.

Liu, Q., & An, Y. (2011). Information Transmission in Informationally Linked Markets: Evidence from US and Chinese Commodity Futures Markets. *Journal of International Money and Finance, 30*, 778-795.

Lombardi, M. J., & Robays, I. V. (2011). Do Financial Investors Destabilize the Oil Price. *ECB Working Paper Series, No. 1346*.

Mikhed, V., & Zemcik, P. (2009). Testing for Bubbles in Housing Markets: A Panel Data Approach. *Journal of Real Estate Finance and Economics*, *38*, 366-386.

Mises, L. v. (1912). *Theorie des Geldes und der Umlaufsmittel*. Muenchen und Leipzig: Verlag von Duncker & Humblot.

Nazlioglu, S., & Soytas, U. (2011). World Oil Prices and Agricultural Commodity Prices: Evidence From an Emerging Market. *Energy Economics, 33*, 488-496.

Oikarinen, E. (2009). Interaction Between Housing Prices and Household Borrowing: The Finnish Case. *Journal of Banking & Finance, 33*, 747-756.

Pesaran, H. H., & Shin, Y. (1998). Generalized Impulse Response Analysis in Linear Multivariate Models. *Econometric Letters*, *58*, 17-29.

Pitfield, P. E. J., Brown, T. J., & Idoine, N. E. (2010). Mineral Information and Statistics for the BRIC countries 1999-2008, from http://www.bgs.ac.uk

Poterba, J. M. (1984). Tax Subsidies to Owner-Occupied Housing: An Asset-Market Approach. *The Quarterly Journal of Economics*, *99*, 729-752.

Praet, P. (2011). Housing Cycles and Financial Stability - The Role of the Policymaker, from http://www.ecb.europa.eu

Radetzki, M. (2006). The Anatomy of Three Commodity Booms. *Resources Policy, 31*, 56-64.

Reinhart, C., & Borensztein, E. (1994). The Macroeconomic Determinants of Commodity Prices. *IMF Staff Papers, 41*, 236-261.

Roache, S. K. (2012). China's Impact on World Commodity Markets. *IMF Working Paper WP/12/115*.

Saghaian, S. H., Reed, M. R., & Marchant, M. A. (2002). Monetary Impacts and Overshooting of Agricultural Prices in an Open Economy. *American Journal of Agricultural Economics, 84*, 90-103.

Sims, C. (1980). Macroeconomics and Reality. *Econometrica, 48*, 1-48.

Sims, C. A., Stock, J. H., & Watson, M. W. (1990). Inference in Linear Time Series Models With Some Unit Roots. *Econometrica, 58*, 113-144.

Smith, M. H., & Smith, G. (2006). Bubble, Bubble, Where's the Housing Bubble? *Brookings Papers on Economic Activity, 1:2006*.

Soytas, U., Sari, R., Hammoudeh, S., & Hacihasanoglu, E. (2009). World Oil Prices, Precious Metal Prices and Macroeconomy in Turkey. *Energy Policy, 37*, 5557-5566.

Stiglitz, J. E. (1990). Symposium on Bubbles. *The Journal of Economic Perspectives, 4*, 13-18.

Tang, K., & Xiong, W. (2010). Index Investment and Financialisation of Commodites. *NBER Working Paper, No. 16385*.

Teng, H.-J., Chang, C.-O., & Chau, K. W. (2013). Housing Bubbles: A Tale of Two Cities. *Habitat International*, *39*, 8-15.

Tobin, J. (1969). A General Equilibrium Approach To Monetary Theory. *Journal of Money, Credit and Banking*, *1*, 15-29.

Toda, H. Y., & Yamamoto, T. (1995). Statistical Inference in Vector Autoregressions with Possibly Integrated Processes. *Journal of Econometrics, 66*, 225-250.

Tsai, I. C., & Peng, C.-W. (2011). Bubbles in the Taiwan Housing Market: The Determinants and Effects. *Habitat International*, *35*, 379-390.

UNCTAD. (2011). Price Formation in Financialized Commodity Markets: The Role of Information. *United Nations Publication UNCTAD/GDS/2011/1*.

USITC. (2011). China's Agricultural Trade: Competitive Conditions and Effects on U.S. Exports. *USITC Publication, No. 4219*.

WFE. (2013). World Federation of Exchanges Statistics Database, from http://www.world-exchanges.org

Xiao, Q., & Tan, G. K. R. (2007). Signal Extraction with Kalman Filter: A Study of the Hong Kong Property Price Bubbles. *Urban Studies*, *44*, 865-888.