

**Examining the existence of housing bubbles using fundamental
variables:**

The case of China

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Abstract

The absence or presence of housing bubbles in the Chinese housing market has been an issue recently due to dramatic increases of the housing prices. Using the monthly data from October 1994 to November 2011, this paper investigates a possible existence of a housing bubble in China. Unit root and co-integration tests are employed to check the long-term relationship between the housing price and several crucial fundamental economic variables. This paper indicates that the Chinese housing price index and fundamental variables are unit root variables that are co-integrated, which implies that they are moving toward a stable equilibrium. The vector error correction model is used to test the existence of a housing bubble. This paper confirms the absence of housing bubbles in China, similarly to the findings of the previous studies.

1. Introduction

House prices in mainland China have been rising dramatically since 2000, and have continued to do so even as the worldwide economy nowadays has weakened to a great extent. According to Yu Ren and Yufei Yuan (2010), the average growth rate of housing prices reached as high as 14% per year from 2003 to 2007, and it was even higher for big cities like Beijing and Shanghai. The rapid rise of house prices has received a lot of attention from both the scholars and policy makers, since the fluctuations of house prices not only highly correlate with the living standard of Chinese people, but also play a crucial role at the macroeconomic level. In an emerging market like China, it is important to ensure the stability of the housing market. Before taking appropriate measures to ensure the stability of the housing market, firstly we need to examine whether there is housing bubbles currently in China.

This paper adopts a "fundamental" model, which is used by the majority of the literatures related to testing bubbles in asset markets. A relationship between the housing price index, the unemployment rate, the disposable income, the consumer price index, the market value of stock market and the long-term interest rate is discussed in order to test whether housing prices can be fairly explained by these fundamental variables. Unit root and co-integration tests are used to examine a long-run relationship between these variables, while a vector-error correction model is employed to test the short-run relationship.

The main contribution of this paper, relative to the existing literature, is that the Chinese housing market is analyzed as a whole. Several authors have examined the existence of housing bubbles. However, most of them have focused on the housing prices of several major cities in China. Instead of using the data of several cities, this paper uses the nationwide housing price index in China. Furthermore, this paper uses the recent data (from 1994 to 2011) that captures the

latest features of the relationship between housing prices and fundamental variables to examine the existence of housing bubbles. It is during this period that the Chinese housing prices keep increasing to an extent that draw people's attention. In addition, this paper takes into account a long-term interest rate. The variable should play an important role in determining house prices from a theoretical point of view. However, the interest rates have not included into other studies. The remainder of this paper is organized as follows. Section 2 reviews the relevant studies on housing bubbles. Section 3 and 4 describe the data and methodology in detail. Section 5 reports and analyses the empirical results, and section 6 concludes the findings of this paper.

2. Literature review

Bubbles of financial and housing markets have been an issue for a long time. There are many studies related to the detection of the existence of housing bubbles. Table 3 summarizes the studies reviewed in this paper. The first three subsections of this section focus on the basic theory of housing bubbles, including definitions of housing bubbles and fundamentals, as well as different methods of detecting housing bubbles. The following two subsections review the results of several studies that test housing bubbles in different regions.

2.1 Definitions of the housing bubbles

There is a debate on what a housing bubble really is and how to prove the presence or absence of housing bubbles.

"A sharp rise in price of an asset or a range of assets in a continuous process, with the initial rise generating expectations of further rises and attracting new buyers—generally speculators interested in profits from trading in the asset rather than its use or earning capacity. The rise is usually followed by

a reversal of expectations and a sharp decline in price often resulting in financial crisis."

----Charles Kindleberger (1978, p.281)

"The basic intuition is straightforward: if the reason that the price is high today is *only* because investors believe that the selling price will be high tomorrow-when "fundamental" factors do not seem to justify such a price-then a bubble exists."

---- Stiglitz (1990, p.13)

"A real estate bubble or property bubble...is a type of economic bubble that occurs periodically in local or global real estate markets. It is characterized by rapid increases in the valuations of real property such as housing until they reach unsustainable levels relative to incomes and other economic indicators, followed by decreases that can result in many owners holding negative equity (a mortgage debt higher than the value of the property). "

----Investor's Dictionary (from <http://www.investordictionary.com/>)

Most of the related studies detect the existence of housing bubbles by comparing the fundamental present value of houses with their market value. Thus, the key characteristic of this kind of a housing bubble is that the level of house prices is way higher than what is consistent with underlying fundamentals. Thus, people buy these houses only because of their high expectation of increase of future housing prices. This is similar to the definition given in Stiglitz (1990), which is dominates the literature.

For example, Noguchi (1994) examines the existence of a house bubble in the Japanese housing market. He defines a theoretical housing price first and then uses the deviation of the real price from the theoretical one to detect housing bubbles. However, the definition given by Stiglitz does not refer to a bubble as a whole, but only discusses the fluctuation of prices instead. Meanwhile, it can often be pretty difficult to discount future cash flows, which for houses equal to rental income. The rental income is largely affected by key economic variables, such as GDP and population, which keep changing all the time.

Muellbauer and Murphy (2008) show that a bubble of house prices is a systematic deviation of house price from the levels that are explained by fundamental variables. This is another definition of a housing bubble that is fairly popular in the economic field. According to Himmel et al (2005), the sensitivity of house prices to the changes in fundamentals is high when long-term real interest rates are low and the expected inflation is high. In addition, they argued that the rapid increase of housing prices might not be a good signal of bubble.

In addition, Christopher Mayer (2011) suggests two opposite destinations of housing bubbles. Excessively volatile of housing prices over the business cycle can cause housing bubbles, which indicates a boom when it increases more than fundamentals do and a bust when it declines faster than fundamentals do. In this case, housing bubbles seem to be very common. A second definition given by Mayer is that housing bubbles stand for extreme movement of prices. However, this method heavily depends on the selection of economic fundamentals, and the outcome is very sensitive to which perspective of the fundamentals is chosen.

Blanchard and Watson (1983) indicate that rational expectation bubbles are the only form of bubbles that can exist in efficient markets. More importantly, the characteristics of this kind of bubble are that the prices of the assets may continue to increase for a long time and their returns may exceed the average capital return in the economy. However, Montrucchio and Privileggi (2001) show that rational expectation bubbles were marginal and fragile in general equilibrium. Therefore, solid theoretical support does not exist for applying the equilibrium model to this area.

Wei-Xing Zhou and Didier Scornette (2005) analyze the quarterly data of average sale prices of new houses sold in the United States as a whole to examine whether they have grown at a faster-than-exponential rate which they define as the diagnostic of a bubble.

In this paper, I will define a housing bubble as a situation when the housing price cannot be fairly explained by market fundamental variables. According to Steven P. Clark and T. Daniel

Coggin (2010), a classic financial bubble model, which they refer to as "the co-integrating regression model", evaluates the fundamental value of the asset using economic fundamentals and compares it with the observed market value. Thus, housing bubbles may exist if people pay too much for the present house due to their extremely high expectation of the future value of housing.

2.2 Definition of fundamental housing prices

According to Michael Wickens (2008), stock market bubbles exist when stock prices increase continuously in a way that is inconsistent with the fundamentals and then drop dramatically. He indicates that this situation often implies that asset prices deviate from what fundamentals suggest.

By the same logic, housing bubbles can be examined by testing the relationship between its fundamental values and housing prices. In particular, let P_t defines housing prices:

$$P_t = P_t^f + P_t^b \quad (1)$$

The variable P_t^f denotes the housing prices that fundamentals suggest, while P_t^b describes a possible "bubble" component.

That is the housing prices are made up with the fundamental housing price P_t^f which is attributable to the economic fundamentals and an amount P_t^b that differs from the fundamentals. One can say that if housing prices can be explained by the fundamentals, then there are no housing bubbles and P_t^b here will be zero.

According to Cu Shen and Eddie Chi-man Hui (2005), there are two approaches to define the fundamental value of housing: one is the asset approach, and the other is the "supply and

demand" of the housing market approach. In the asset approach, a "fundamental value" refers to an asset's fundamental value. It is measured by three key determinants: the cash flow received over time, the discount rate used for translating future cash into present value, and the terminal value of an asset.

On the contrary, in the "supply and demand" of the housing market approach, "market fundamentals" are defined as macroeconomic variables which are fundamental to the market. Many studies have suggested a simple "supply and demand" model for housing. However, it can be very problematic to choose market's fundamentals precisely. This approach gives an indirect evidence of bubbles. Considering the difficulty of specifying the intrinsic value by the three determinants due to the absence of data extending infinitely far into the future, the latter method is a better one since the existence of housing bubbles can be measured by the relationship between real estate and macroeconomic fundamental variables. Taking all these factors into consideration, fundamentals used in this paper refer to the market fundamentals.

2.3 Discussion of methods to measure housing bubbles

According to Philip M. Bodman and Mark Crosby (2003), the existing literature regarding different ways of analyzing housing bubbles falls into two classes. Some studies¹ examine the relationship between housing price levels and the real economy, while others try to explain property prices. Two typical approaches can be used to explain property prices.

The first approach, asset pricing approach, treats housing as an asset and assumes that any predictable changes in housing prices need to be arbitrated out of the market. To test the hypothesis of the efficiency of the housing market, housing prices or returns for unit roots are used to make sure that the data is a pure random walk. In this approach, national trends in home

¹ Such as Shimizu, Nishimura and Watanabe (2010) and Bong Han Kim and Hong-Ghi Min (2011)

prices can be measured by some home price series such as the median price of existing and/or homes sold, the constant quality new home price index, or the repeat sales price index. There are a large number of literatures related to this cash flow affordability and simple asset valuation model, such as Jonathan McCarthy and Richard W. Peach (2004).

To solidify the claim of bubbles, ratios like home price to household income and home prices relative to rents can also be employed. A home price-to-household income ratio is frequently used to measure home ownership affordability. If this ratio is high, then a reduction in demand for housing and downward pressure on home prices are expected. A low rent-to-price ratio implies that the return for housing asset is relatively low compared to that of other assets. However, these indicators may not be perfect for measuring bubbles since neither of them takes interest rate explicitly into consideration. By contrast, economic theory suggests that interest rate changes should matter due to their big influence on home ownership affordability into consideration.

The second approach uses macroeconomic fundamentals to explain property prices. To apply this approach, macroeconomic variables that affect demand and supply of housing markets need to be chosen first. Then econometric tests such as unit root and co-integration tests need to be done to make sure a supply and demand model has been correctly specified. Examples of this approach include Philip M. Bodman and Mark Crosby (2003), Tsai and Peng (2010), T. Thanh-Binh Nguyen and Kuan-Min Wang (2010), Clark and Coggin (2010) and Chang and Nguyen (2011).

Take Vyacheslav Mikhed (2009) for instance. He firstly implement the unit root and co-integration tests for cross sectional panel data to examine the relationship between the United States housing prices and house related earnings and find that error correction model was inappropriate because of the lack of co-integration in this case, which indicated the presence of

housing bubbles. In addition, he also develops a bubble indicator using price-rent ratios and the panel data tests. Based on the results of Granger causality tests, they suggest that the fluctuations of housing prices did well in predicting changes in rents.

Clark and Coggin (2010) is another paper that uses unit root and co-integration tests to investigate the existence of housing bubbles in the United States. Due to the absence of the co-integration, the error correction model is still inappropriate in this situation.

Since housing markets usually have large transactions costs and heterogeneous products in comparison with other asset markets, models with fundamentals may be more appropriate for testing housing bubbles. Therefore, this paper examines the existence of housing bubbles using fundamental variables. In particular, I use the economic approach given in Diba and Grossman (1988) in their study of stock prices. A stationary linear combination of unit root time series variables may exist if they are co-integrated, which indicates that these variables converge to a stationary equilibrium relationship. On the contrary, unit root time series variables will continue on their non-stationary time path of divergence if they are not co-integrated. In this manner, the absence of an equilibrium relationship implies the existence of housing bubble.

2.4 Testing housing bubbles for the regions other than China

There are many studies related to testing housing bubbles in different countries and regions. Table 3 summarizes some studies related to housing bubbles in different countries and regions.

Motivated by a high level and rapid growth rate of housing prices in many Australian capital cities since 2001, Philip M. Bodman and Mark Crosby (2003) examine the existence of housing bubbles in Australian housing market from 1980 to 2002. Using both time series and "fundamentals" approaches, they find that there were no housing bubbles in Australia as a whole. However, their study shows that housing prices in some major cities such as Sydney, Brisbane,

Perth and Adelaide seemed to be overvalued to some different extent.

Weixing Zhou and Didier Sornette (2005) and Steven P. Clark and T. Daniel Coggin (2010) detect the existence of a housing bubble in the United States. The former one analyze the quarterly panel data of new houses sold in the United States as a whole, as well as in the Midwest, Northeast, West and South of the United States. This study is based on a general theory of stock market instabilities and financial crashes. They find that 22 states exhibit a fast-growing bubble. Meanwhile, Clark and Coggin focus on the time series statistical relationship between the United States house prices and some fundamental variables using panel data, and they confirm the existence of housing bubble as well.

With respect to housing market in UK, Gavin and John (2006) examine the systematic deviation of British housing prices from fundamentals, which they regard as housing bubble, during the period 1972 to 2003. The model in their paper consists of a system of inverted housing demand equations, including interactions and lags and relevant parameter heterogeneity. They conclude that there is no evidence for a housing bubble.

Qin Xiao and Gee Kwang (2007) analyze housing maker in Hong Kong from 1980 to 2002 using the Kalman filter, and find that a periodically collapsing speculative bubble could explain the large price swings in the housing market in Hong Kong.

A Kalman filter was also used in Bong Han Kim and Hong-Ghi Min (2011). Using a regime-switching model, a Kalman filter technique, generalized impulse response function analysis and variance decompositions, they investigate whether interest rate and household lending could explain the housing price bubble in Korea from 1986 to 2003. They indicate that housing price bubbles might be positively correlated with household lending and industrial production, but negatively correlated with interest rate. They argue that preemptive intervention on household lending might be a good policy to deal with housing bubbles whereas interest rate

seems to be a less effective method.

T. I-Chun Tsai and Chien-Wen Peng (2011) test whether there were bubbles in the Taiwan housing market using housing prices from 1980 to 2006 in four Taiwanese cities. In their paper, the bubble indicator for the housing market is constructed, and the unit root test on the asset price and fundamentals are also implemented. They show that bubbles in the Taiwan housing market are highly related to expansionary monetary policy and they suggest that the government could not merely interfere with low house prices while overlooking housing bubbles.

In Thanh-Binh Nguyen and Kuan-Min Wang (2010), they investigate the housing-macroeconomic nexus with endogenous structural breaks during the period 1991 to 2006 in Taiwan housing market. Taking the time trend into account, they show that inflation affect housing returns negatively, whereas housing returns had a positive influence on inflation. Their findings suggest the inefficiency of inflation hedging of the housing market and the opportunistic characteristics of those investors.

Instead of studying housing bubbles of a specific country, Qin Xiao (2009) analyzes the world housing market as a whole. In addition, he summarizes the causes of housing cashes in selected countries. The theory of market crashes they introduce suggest that the bursting of a fully fledged speculative bubble lead to market crashes directly and a market crash is highly correlated with a speculative bubble which is periodically collapsed. Furthermore, he points out that most literature related to housing bubbles are based on a set of assumptions, which indicate that when a hypothesis of no housing bubbles is accepted, it is not one hundred percent sure to determine whether the hypothesis is indeed correct or falsely maintained assumptions resulted in this outcome.

2.5 Testing housing bubbles in mainland China

With respect to studies related to the Chinese mainland housing market, several authors examine whether there is a housing bubble in specific cities.

Yue Shen, Eddie Chi-man Hui, and Hongyu Liu (2005) use Granger causality tests, generalized impulse response analysis and the reduced form of housing price determinants to examine the housing price bubble in Beijing and Shanghai in 2003. Using monthly data for these two cities, they indicate that there was a housing bubble in Shanghai in 2003, whereas there was no sign of a bubble in Beijing. Their conclusion is based on their finding that housing prices have interacted abnormally with market fundamentals such as local GDP in Shanghai.

Meanwhile, Jianying Hu, Liangjun Su, Sainan Jin and Wanjun Jiang (2006) decompose Chinese housing prices into fundamental and non-fundamental components. Taking a potential nonlinear feedback from historical growth rate of prices on the present housing prices into consideration, they indicated that the non-linear fundamentals played a very small role in the housing price increase.

Eddie and Ivan (2009) investigate the relationships between housing prices and fundamental variables for Shenzhen and Hong Kong. In addition, they test whether a housing price bubble existed in these two cities in 2006. They suggest that the housing prices in Shenzhen have interacted abnormally with market fundamentals, such as GDP and personal income. In addition, they point out that while Shenzhen's housing prices are mainly explained by personal income and previous housing prices, housing prices in Hong Kong can be explained by most economic indicators.

Yu Ren, Yufei Yuan and Cong Xiong (2010) confirm the absence of bubbles in the housing market based on the data of 29 cities in China by applying the theory of rational

expectation bubbles to the housing market. Their findings imply that house returns in Chinese cities do not necessarily cause housing bubbles and the GDP growth rate cannot affect the local expected returns.

Feng Guo and Ying Sophie Huang (2010) investigate the extent of the impact from speculative capital inflow on the fluctuations of China's housing market and stock market. Their study indicates that those speculative capital inflows have driven up asset prices and contributed to the accelerating volatilities in both housing market and stock market. In addition, They point out that speculative capital inflow ranks as the second largest contribution in the fluctuations of Chinese housing market.

By analyzing the price-to-rent ratios and price-to-income ratios of some major cities in China during period 2003 to 2010, Wu, Gyourko and Deng (2012) suggest the potential for substantial mispricing in Beijing and other Chinese housing markets.

Although several papers examine the existence of a housing bubble in the Chinese cities and regions, studies related to the analysis of Chinese housing market as a whole seem to be rare. This paper analyzes the Chinese housing market using fundamental model methods to examine whether there are housing bubbles in the mainland China from 1994 to 2011.

3. Data

The data come from several sources: the National Bureau of Statistics of China (NBSC), the Institute of Economics Chinese Academy of Social Sciences, China Statistical Database and China statistical yearbook. The main focus of the paper is the housing price index, and the valuation of macroeconomic fundamentals. This section first describes the housing price index,

and then discusses how the housing reforms may affect this index. Afterword, it describes all other economic series used in the analysis. All data are listed with their sources in Table 1. Basic descriptive statistics about the growth rates of the series can also be found in Table 1 continued.

3.1 Chinese housing price index

A House Price Index (HPI) measures the price of residential housing. Such an index is commonly used by studies examining housing bubbles. The housing price index data used in this paper is from the National Bureau of Statistics of China. The summary statement can also be found in the database offered by Economic Forum of People's University of China. The Chinese government statistical system is made up with the institution of statistical agencies and development of statisticians of the government. The NBSC is established under the State Council while independent statistical agencies are set up by people's governments.

The house price index is monthly. This series spans from October 1994 to November 2011, and are converted to natural logarithms for the statistical analysis. Figure 1 shows the time path of the housing price index. This figure is based on the data of house price index from October 1994 to November 2011, in logarithms. There is a big fluctuation in this period while the housing prices keep increasing until 2011. This paper examines the relationship between housing price index and other macroeconomic variables during this period.

Figure 2 spots the housing price index deflated by the CPI. Since the CPI series spans from January 1999 to July 2011, we can only get the real housing price index during this period. As it is shown in Figure 2, the real housing price index keeps increasing from 1999 to 2011.

3.2 Brief introduction of housing reform and land system in China

Since this paper examines housing prices in mainland China, it is helpful to know some housing policies in China in order to better deal with housing bubbles if there are some. This information is from the Bureau of Land Resources and Housing, and China Real Estate Market-Laws and Regulations concerning Land and Real Estate written by Xiannian Ye.

The legal system of China is a combination of common law and continental legal systems. Under the Constitution, the central government owns the urban land and collectives own the rural land since the founding of the People's Republic of China in 1949. During this period, the state, which was the monopoly supplier of housing, determined the national economic plans and allocated housing to individuals at a very low rent. The private housing market did not exist until the late 1970s.

A series of economic reforms took place in 1979. These reforms included the housing market reform. Commodity housing started to appear to people's eyes in some coastal cities at first, and was quickly expanded to the entire country. However, the development of housing market grew at a very slow pace. It was also limited in scope because the target customers were only foreigners or employees of foreign funded companies.

With the passage of the 1988 Constitutional Amendment and a series of housing reform policies, real estate sales in China started to take place in the form of transfer of rights to use land for urban residential purposes for a maximum of 70 years. To obtain land-use rights, people must sign a land-grant contract and pay a land-grant fee in advance to the local land authority. The grantee can enjoy a fixed land-grant term but have to utilize the land for the special purpose stated in the land-grant contract. Depending on the type and purposes of land use, the maximum term of a land grant varies from 40 years for commercial purpose to 70 years for residential usage. According to Jing Wu, Joseph Gyourko and Yongsheng Deng (2011), the amount of

private housing built as a share of the total annual flow supply more than doubled from 13 percent in 1986 to 33 percent in 1993 and further increased to 72 percent by 2006.

Since the Chinese housing market is quite new, housing prices may be expected to change in a very unusual way. It is very crucial for government to ensure the stability of housing prices in an emerging market like China.

3.3 Other fundamental variables

The market fundamental variables used in this paper are the consumer price index, the unemployment rate, the disposable income, the interest rate and the market value of the stock market. Although the variable choice is due to the limitation of available data, these variables are believed to affect the supply and demand of the housing. The summary and notation of these variables can be found in table 2.

Consumer Price Index: The CPI, which is short for consumer price index, measures changes in the price level of consumer goods and services purchased by households. Figure 4 describes the time path of CPI. This figure is based on the monthly data of CPI from January 1999 to November 2011. The CPI series is taken from Institute of Economics Chinese Academy of Social Sciences. The predecessor of The Institute of Economics of the Chinese Academy of Social Sciences (CASS) is the Institute of Social Survey of the Chinese Education and Culture Foundation, which was established in 1929. Based on the source from National Bureau of Statistics in China, Food is the single biggest contributor to China's CPI, followed by Entertainment and Rental. It is worth noting that the housing price is not included in the CPI. The component of CPI in China is illustrated in figure 5.

Income: The income variable represents the aggregate *after-tax* income of urban household, and it spans from October 1994 to November 2011. Since commodity houses are

mostly built in urban area, and it is the housing prices in urban area that increase dramatically, income and unemployment rate of urban citizens are believed to be enough to explain changes of housing prices. To be consistent with the housing price index, this variable is monthly data as well. Figure 6 describes the time path for income. Further information can be found in the China Statistical Yearbook. The summary statement can also be found from the database offered by Economic Forum of People's University of China at <http://bbs.pinggu.org/>.

Unemployment Rate: The unemployment rate is calculated by dividing the number of unemployed by the number of all individuals currently in the labor force. It measures the prevalence of unemployment. This variable here represents the unemployment rate of urban citizens. It is a monthly series ranges from October 1994 to June 2011. Figure 7 represents the time path for this variable.

Market Value of Stock Market: The market value is the current quoted price at which investors buy or sell a share of common stock or a bond at a given time. The stock market represents the public entity for the trading of company stock and derivatives. The market capitalization of stock market represents the total market value of the Shanghai composite index and Shenzhen composite index. It is a monthly series which spans from October 1994 to July 2011. The time path of this variable can be seen in Figure 8. The unit of this variable is 0.1 billion Yuan.

Long-Term Interest Rate: The interest rate here is the 5-year saving rate that is offered by the Bank of China. The interest rate in China is decided by the People's Bank of China Monetary Policy Committee. This variable is also a monthly data, and ranges from October 1994 to July 2011. Figure 9 represents the time path for this variable based on the data in logarithms.

4. Methodology

This section describes the theoretical model and econometric methods used in this paper to examine the existence of housing bubbles in China.

4.1 Model

According to Mikhed and Zemcik (2007), the relationship between housing prices and market fundamental variables that are believed to affect the demand and supply of housing market can be explained by the structural model of housing supply and demand. Demand shifters can include variables such as income, population, inflation, mortgage rate, while supply shifters can include stock market wealth, user cost, etc.

The demand equation can be given as follows:

$$H_t^d = \beta_0 + \beta_1 P_t^d + \beta_2 D_t \quad (2)$$

where, H_t^d is quantity of housing demanded, P_t^d is the housing price consumers are willing to pay, and D_t represents a vector of demand shifters. Theoretically, there is a negative relationship between the demand for housing and the housing prices. Therefore, the sign of the coefficient of housing prices may be negative.

The supply equation can be given as follows:

$$H_t^s = \alpha_0 + \alpha_1 P_t^s + \alpha_2 S_t \quad (3)$$

where H_t^s is the quantity of housing supplied, P_t^s is the price suppliers are willing to trade and S_t represents a vector of supply shifters. The sign of the coefficient of housing prices may be positive.

A housing market should be in an equilibrium in which the quantity demanded must be equal to the quantity supplied, and the price demanded must be equal to the price supplied. Thus:

$$H_t^d = H_t^s = H_t \quad (4)$$

$$P_t^d = P_t^s = P_t^f \quad (5)$$

These two conditions imply that housing prices should be a function of demand shifters and supply shifters. The equilibrium price can be defined as:

$$P_t^f = \gamma_0 + \gamma_1 D_t + \gamma_2 S_t \quad (6)$$

Thus, this model here describes how the fundamental price P_t^f from the equation (1) on page 11 is determined.

In the absence of housing bubbles, the housing price is equal to its fundamental value, which corresponds to the theoretical market equation:

$$P_t^f = \gamma_0 + \gamma_1 D_t + \gamma_2 S_t \quad (7)$$

Empirically, the observed housing prices can deviate from this implicit fundamental value due to adjustment costs, data measurement problems or even people's speculative motivations. Thus, let ε_t represents such deviation. Then

$$P_t = P_t^f + \varepsilon_t$$

$$P_t = \gamma_0 + \gamma_1 D_t + \gamma_2 S_t + \varepsilon_t \quad (8)$$

This specification serves as a housing prices empirical estimation. If the error term ε_t is stationary, then the housing price deviates from its fundamental value only temporarily. By contrast, if ε_t is not stationary, then there are persistent deviation of the housing price from its fundamental value. These persistent deviations can be given an interpretation of a housing bubble. In this case, $\varepsilon_t = P_t^b$. Thus, a test of housing bubble in this paper is a test of stationarity of the error term ε_t .

To construct the fundamental price P_t^f , this paper uses several macroeconomic variables that are believed to be important in affecting either the demand or supply of housing. These variables are listed in the data section, and further discussed below.

Following the description of the "supply and demand" model used in Mikhed and Zemcik (2007) and Steven P. Clark and Daniel (2010), the demand and supply of the housing market in this paper is a function of several major macroeconomic variables. These variables areas disposable income (INCOME), the CPI (CPI), the unemployment rates (UNEMP), the market value of the stock market (STOCK), and the long-term interest rate (R). Theoretically, demand for housing can be largely affected by income, CPI, unemployment rate and long-term interest rate; while supply of housing is assumed to be mainly affected by housing prices and market value of stock market.

In addition, it is rational to expect a positive relationship between the housing price and people's income, and, and negative relations of the housing price with the unemployment rate, the market value of stock market and the interest rate. This is because people here are assumed to be rational and houses are normal goods, which implies that people will demand more houses when

population and/or income increase. Meanwhile, if market value of stock market or interest rate is high, consumers may have alternative investments, such as buying stock or simply save money in banks, which can yield higher return than buying houses. In this case, speculative motive of people for buying houses has been taken into consideration. This paper uses the Chinese nationwide housing price index (HPI) to represent housing prices. The housing index and all market fundamental variables are included into the equation (8) in logarithms.

The econometric approach to test a housing bubble includes three steps. First, we need to implement unit root tests for the housing price index and the macroeconomic fundamentals to see whether these variables are stationary. Second, we need to do co-integration tests between the housing price index and fundamental variables in order to test if there is long-run relationship. Third, we need to use a vector-error correction model to test the short-run relationship.

If the variables are found integrated order one and co-integrated, then the empirical error term ε_t should be stationary. Thus, the housing bubbles could be rejected. The error term captures the long term relationship between the variables of the VECm and plays the central role in the model. The error term is found to be stationary, which confirms the correctness of the co-integration. In addition, the long-run property can be captured by the error correction coefficient.

According to Clark and Coggin (2011), no single set of variables used to examine housing bubbles has been generally agreed, and it is meaningless to comprehensively examine such a list. However, the variables used in this paper are enough to explain housing prices in China. It is discussed further in the results section.

4.2 Econometric methods

4.2.1 Unit root tests

Many macroeconomic variables are not stationary in levels, but stationary in differences. Such variables are defined as integrated order one process, or I (1) variables². A time series is nonstationary and unpredictable using only past values if it contains a unit root³. Estimates from non-stationary variables may generate a spurious regression unless they are co-integrated. Thus, it is necessary to do unit root test to check whether or not key variables in the model are stationary or non-stationary.

This paper uses the Augmented Dickey–Fuller test⁴, which is the default preference in Eviews and mostly used in large samples.

$$\Delta y_t = \mu + \beta t + \gamma^* y_{t-1} + \sum_{j=1}^p \phi_j \Delta y_{t-j} + \varepsilon_t \quad (9)$$

$$\text{where } \phi_j = -\sum_{k=j+1}^p \gamma_k \quad \text{and} \quad \gamma^* = \left(\sum_{i=1}^p \gamma_i \right) - 1 \quad (10)$$

The unit root test is carried out by testing the null hypothesis $\gamma^* = 0$ against $\gamma^* < 0$. The t-test DF_τ may be used to do this test.

² A note on notations: The unit root process is called an integrated of order 1 or for short I(1) process, while a stationary process is called an I(0) process. Thus, we can define I(d) process, where d indicates the number of differencing used in order to make the series stationary.

³ Refer to chapter 6, Xiao tong Zhang (2007): data analysis and Eviews application. For any random process $\{y, t = 1, 2, \dots\}$, if $y_t = \rho y_{t-1} + \varepsilon_t$, where $\rho = 1$, and $E(\varepsilon_t) = 0, COV(\varepsilon_t, \varepsilon_{t-1}) = \mu, < \infty$, then this process is called a unit root process.

⁴ Refer to Chapter 21, William H. Greene (2010): Econometric analysis.

$$DF_{\tau} = \frac{\hat{\gamma}}{Est.Std.Error(\hat{\gamma})} \quad (11)$$

If the test statistic is less than the critical value, then the null hypothesis of $\gamma^* = 0$ is rejected and no unit root is present. If the series is integrated, then only the one obtained in the lagged changes (Δy_{t-k}) can be used to predict the changes in y_t . In this case, null hypothesis is not rejected.

4.2.2 Co-integration test

Two or more Series are said to be co-integrated if they are individually integrated, while some linear combination between them has a lower order of integration. It is crucial to take the presence of co-integration into consideration.

Any arbitrary linear combination of I (1) variables is typically spurious. However, if there is a long-run relationship, regression errors have tendency to disappear and return to zero. If there exists a relationship between two or more non-stationary I(1) series, such that the residuals of the regression

$$Y = \beta_0 + \beta_1 X_t + u_t \quad (12)$$

are stationary, then the variables in question are said to be co-integrated and there is a long run relationship toward which they always come back. If a long run relationship exists then errors should be a stationary series and have a zero mean.

The Johansen Maximum likelihood (LM) test is a procedure for testing co-integration between several I (1) time series. It is more generally applicable than the Engle-Granger method since more than one co-integrating relationship is allowed in this test. In addition, all the variables

are assumed to be endogenous even though there may be a possibility that exogenous variables are included. Unlike Engle-Granger method which is based on ordinary least square (OLS), the multivariate test is based on a vector auto regression (VAR), not a single Ordinary Least Square (OLS) estimation, and this test relies on the relationship between the rank and eigenvalues or characteristic roots of a matrix.

$$x_t = A_1 x_{t-1} + u_t \quad (13)$$

$$\Delta x_t = (A_1 - I)x_{t-1} + u_t = \pi x_{t-1} + u_t \quad (14)$$

$$\pi = (A_1 - I) \quad (15)$$

where x_t and u_t here are $g \times 1$ vectors, A_1 is an $g \times g$ matrix of parameters and I is an $g \times g$ identity matrix. The rank of π equals the number of co-integrating vectors and if as with the ADF test, then rank of the matrix equals zero, all of the x are unit root processes, which indicates that the variables are co-integrated.

There are two types of the Johansen test, trace tests and maximum eigenvalue. Both of them can be employed to examine the number of co-integration relation even if they do not always indicate the same number. The null hypothesis for trace test, which is a joint test, is that the number of co-integrating vectors is less than or equal to r , whereas that for maximum eigenvalue is that there are r co-integrations. The distribution of both test statistics is nonstandard. There are five assumptions in Johansen test. In this paper I use the assumption c^5 , which includes a constant in the cointegrating vector.

⁵ Allow for linear deterministic trend in data: intercept (no trend) in CE and test VAR

4.2.3 Vector autoregression

Since the Johansen test is based on a vector autoregression (VAR), there is a necessity to discuss VAR a little bit further. A VAR is a statistical model, which examines a linear relation among multiple time series. In a VAR, there is an assumption that all the variables are treated symmetrically and each one can be explained by its evolution based on its own lags and that of all the other variables in the model.

A p -th order VAR, which is denoted VAR (p) is

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \dots + A_p y_{t-p} + e_t \quad (16)$$

where c is a $k \times 1$ vector of constants, A_i is a $k \times k$ matrix and e_t is a $k \times 1$ vector of error terms satisfying the following assumptions:

1. $E(e_t) = 0$ which indicates that every error term has a mean zero;
2. $E(e_t, e_t') = \Omega$, which implies that the contemporaneous covariance matrix of error terms is a $k \times k$ positive-definite matrix;
3. $E(e_t, e_{t-k}') = 0$, which requires that there is no correlation across time for any non-zero k . Particularly, there is no serial correlation in individual error terms.

If all the variables are $I(1)$, there will be two different cases. The first one is that all variables are co-integrated. In this case the model becomes a restricted VAR, known as a VECM model, and the error correction term has to be included in the VAR. Another case is that those variables are not co-integrated. Then the variables have to be differenced one time and then specification must be estimated.

4.2.4 Vector error correction model

Using a vector error correction model (VECM), we can better understand the relationship between different non-stationary series, and forecast longer term relationship over an unconstrained model. The VECM is the basic VAR with taking error correction term into account. It can be formed with the condition that multivariate co-integration exist.

The basic form of a VECM is

$$\Delta y_t = \delta + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Phi_i \Delta y_{t-i} + e_t \quad (17)$$

where Δ is the differencing operator, such that $\Delta y_t = y_t - y_{t-1}$. Once get a VECM is estimated, a unit root test can be applied to the error term.

To summarize, the procedure to test the housing bubble using econometric methods is to test all economic variables for stationarity using the usual (Augmented) Dick-Fuller test first and then apply the Johansen LM tests for co-integration. The Akaike Info Criterion (AIC) can be used to indicate the proper number of lags in the co-integration test. If a co-integration is found, a VECM for all the endogenous variables can be estimated to get the magnitude of the error correction term.

5. Empirical results

This section describes the findings of this paper. The results of unit root and cointegration tests are discussed in detail, as well as the long-run and short-run relationship between housing price index and fundamental variables.

5.1 House price-to-income ratio

The price-to-income ratio is the basic affordability measure for housing in a given area. It is generally the ratio of mean market price of a standardised housing unit to average household incomes, expressed as a percentage or as years of income.

According to I-Chun Tsai and Chien-Wen Peng (2011), household income and housing prices should be closely related because the effective demand for housing depends on income. However, a stable equilibrium relationship between housing prices and household income can be changed by other factors from the side of housing prices, such as shortage of housing supply or increase in demand for housing. In addition, the rising house price-to-income ratio may cause serious issues. For example, an increasing house prices-to-incomes ratio means that it is increasingly difficult for first time buyers to get their own houses. In areas of high housing prices, the lack of affordability may lead to a shortage of key public sector workers. Furthermore, it is argued that increases in house price to income ratios are unsustainable and could lead to a future crash in house prices.

The ratio of house prices to income remains an important guide for a long term affordability of housing. However, it does not make it a perfect guide to estimate house prices. Just because the ratio of house prices to incomes have increased doesn't necessarily mean a house price crash will occur. Nevertheless, the rising ratio of house price to income does raise some serious concerns.

Figure 3 plots the ratio of house price index-to-household income of China from 1994 to 2011. As it is shown in Figure 3, although the housing prices index to income ratio decreases from 1994 to 2000, it sharply increases from 0.45 in 2002 to 0.51 in 2005. That can be caused either by the higher demand for housing or the lower supply of housing. Considering the fact that

more housing is built in China nowadays, we may infer that the housing prices increase could be mostly due to the larger amount of people demanding for housing.

In summary, we can conclude from the housing prices-to-income ratio that the increasing in housing prices cannot be explained by changes in the household income. Thus, we need to further examine the relationship between housing prices and some other fundamental variables.

5.2 Results of unit root tests

This paper uses the augmented Dickey-Fuller (ADF) test to examine the null hypothesis that a time trend series contains a unit root. A formal ADF test is conducted using Eviews 7.0 with an intercept but no trend for the variables CPI, R, and UNEMP, but with both an intercept and trend for the variables, INCOME and STOCK. The choice of intercept depends whether the mean value of a variable equals 0, and the choice of trend depends on whether a variable fluctuates or not. If mean value is not zero, intercept is included, and if there is an increasing or decreasing trend, trend is included. Table 2 shows the results of unit root tests. Take a variable HPI as an example. The unit root test of the HPI shows this variable is non-stationary and contains a unit root, since the probability value is larger than 0.05. By contrast, the unit root test of the first difference of the HPI indicates that the first difference is stationary. Thus, we know that HPI is $I(1)$.

The maximum number of lags allowed in this analysis is 14, which is chosen by the Schwarz Info Criterion. The ADF test is a t-test on the coefficient for the lag of the variable. A significant ADF t-test suggests the variable is stationary.

From table 2, we can see that all six macroeconomic variables contain unit roots and are integrated of order one. In this case, we may infer that these variables are non-stationary at the significance level of 5%. Their variances and other moments depend on time and diverge to infinity.

5.3 Results of co-integration tests

Since all variables used in this analysis contain unit roots, results for co-integration test need to be considered⁶. These results are shown in Table 4. We can see that the trace test indicates 2 co-integration equations at the 0.05 level, and the max-eigenvalue test indicates there are 2 co-integration equations at the same level as well. According to Helmut and Pentti (2000), the Monte Carlo comparison implies that the distorted sizes of trace tests is more than that of maximum eigenvalue tests and their power is superior to eigenvalue tests in some situations. Due to this reason, the number of co-integration equations chosen in this paper is 2. The normalized co-integrating coefficients are (standard error in parentheses):

$$\ln HPI = 0.541 \ln INCOME + 0.191 \ln R - 0.473 \ln STOCK - 0.464 \ln UNEMP \quad (18)$$

(0.39536) (0.29735) (0.13483) (0.89955)

$$\ln CPI = -0.387 \ln INCOME - 0.287 \ln R + 0.168 \ln STOCK + 0.188 \ln UNEMP \quad (19)$$

(0.11507) (0.08654) (0.03294) (0.26181)

Since this paper is mainly discussing the relationship between housing prices and fundamental variables, I will only discuss the first equation, which represents the long-run relationship.

From Table 5, we may infer that there is a long-run negative relationship between HPI and market value of stock market, unemployment rate while a long-run positive relationship between HPI and income, long-run interest rate. This is consistent with what I expected at the very beginning. With the economic development of China, people's income is getting higher as well, this results to an increase in housing prices. A one percent increase in household income will increase housing prices by 0.54 percent. However, taking the situation in China into

⁶ The Johansen LM test is based on a VAR. I run a VAR first, but the result of the VAR have been omitted.

consideration, the demand for housing can also be affected by people's speculative motivation. This causes the special situation which some people own more than two or three houses while some cannot afford to buy one.

If the interest rate increases by one percent, housing prices will increase by 0.191 percent. Theoretically, higher interest rate will motivate people to save more money in banks rather than investing in housing market.

The negative relationship between housing prices index and market value of stock market is reasonable, since real estate market and stock market can be seen as two substitute markets. A one percent increase in the market value of stock market decreases housing prices by 0.473 percent. If there are more opportunities in the stock market, people, which are assumed to be rational, may shift their money from the housing market to the stock market.

The relationship between HPI and unemployment rate is also reasonable. If the unemployment rate is high, then more people could not be able to afford to buy any houses. Decreasing demand for houses will lead to a reduction in the housing prices.

In summary, although most of these variables are not significant, the hypothesis that there is no co-integration between housing price index and fundamental variables is rejected. In this case, there is a long-run relationship between those macroeconomic variables and housing prices and no housing bubbles in the Chinese housing market. The housing price can be explained by the market fundamentals. However, the co-integrating regression only takes long-run property into consideration and neglects the short-run dynamics of the model. Therefore, a VECM is estimated and analyzed next.

5.4 Vector error correction model

Table 6 represents the outcome of the VECM. From the results of the VECM, we may infer that the error correction terms are negative, which implies that there is a reverse revision mechanism. The coefficient of the error correction term is -0.004 and -0.036, which means the non-equilibrium error of last unit modifies Δ HPI of this year adversely at a 0.04% rate and 3.6% respectively. Meanwhile, the Akaike Information Criterion and Schwarz Criterion are -30.81 and -28.74 respectively. Both of these indicators are small enough to imply that the choice of lag is appropriate.

The short-run relationship between the Housing Price Index and the fundamentals follows (standard errors in parentheses)

$$\begin{aligned}
 D(\text{HPI}) = & -0.004*\text{ECM1} - 0.036*\text{ECM2} + 0.625*D(\text{HPI}(-1)) + 0.102*D(\text{HPI}(-2)) + \\
 & (0.00539) \quad (0.01735) \quad (0.08488) \quad (0.08565) \\
 & 0.009*D(\text{CPI}(-1)) - 0.045*D(\text{CPI}(-2)) + 0.0007*D(\text{INCOME}(-1)) - 0.011*D(\text{INCOME}(-2)) + \\
 & (0.06207) \quad (0.06234) \quad (0.01122) \quad (0.01111) \\
 & 0.005*D(\text{R}(-1)) + 0.008*D(\text{R}(-2)) + 0.008*D(\text{STOCK}(-1)) + 0.009*D(\text{STOCK}(-2)) + \\
 & (0.00938) \quad (0.00925) \quad (0.00453) \quad (0.00448) \\
 & 0.008*D(\text{UNEMP}(-1)) + 0.037*D(\text{UNEMP}(-2)) - 0.002 \quad (20) \\
 & (0.03439) \quad (0.03439)
 \end{aligned}$$

From the VECM, we may infer that in the short run, lag(1) and lag(2) of the HPI, the interest rate, the stock value and the unemployment rate seem to have a positive influence on Δ HPI. Specifically, one unit of change in ln HPI, ln income, ln R, ln stock of last year will change HPI this year by 0.625, 0.0007, 0.004, 0.005, and 0.008 units respectively.

Tables 7 and 8 report two diagnostic statistics for the model. These statistics are the results of Residual Portmanteau Tests for Autocorrelations and the Residual Heteroskedasticity test. We may infer from the tables that the residual autocorrelation and homoscedasticity are rejected. This result further confirms the robustness of the model specification in this paper.

6. Conclusion

Housing bubbles have been an issue for a long time. Using the monthly data from October 1994 to November 2011, this paper investigates whether there is a housing bubble in China. Unit root and co-integration tests are employed to test the long-run relationship between housing prices and some specific fundamental variables. The existence of co-integration indicates the absence of housing bubbles in China, which confirms the results of the earlier studies. In addition, vector error correction model is used to analyze both the short and long run relationship.

This paper firstly tests all economic variables for stationarity using the usual (Augmented) Dick-Fuller test, and then applies the Johansen LM tests for co-integration. The Akaike Info Criterion (AIC) is used to indicate the proper number of lags in the co-integration test. After finding the co-integration, a VECM for all the endogenous variables is estimated to detect the magnitude of the error correction term.

Since there is no precise model that can describe the relationship between fundamental variables and housing prices, people may get different conclusions depending on the variable they choose. Fortunately, based on the results of this paper, we can infer that the variables chosen in this paper are enough to explain Chinese housing prices. If cointegration between HPI and fundamental variables was rejected, the variables chosen in this model may not be enough to explain the housing price index. However, cointegration is accepted in this paper, which implies that the variables used in this paper are enough to explain HPI. Based on the model in this paper, further studies can use panel data of all cities in China to analyze the housing prices.

Figures

Figure 1 Housing price index

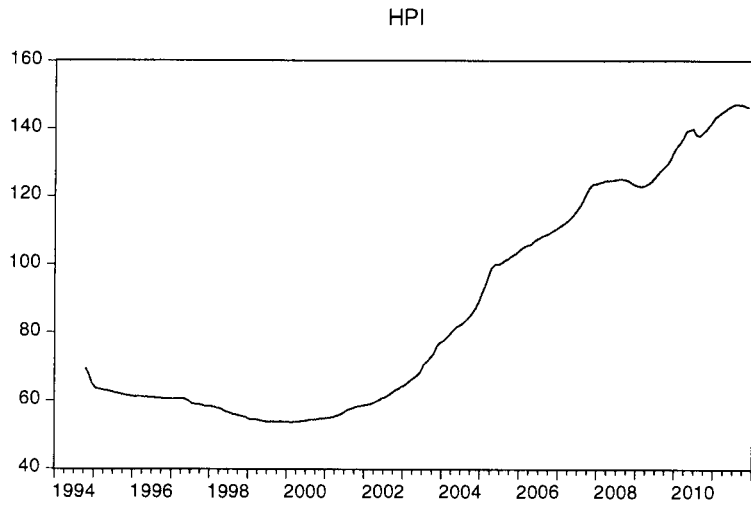


Figure 2 Housing price index (deflated by CPI)

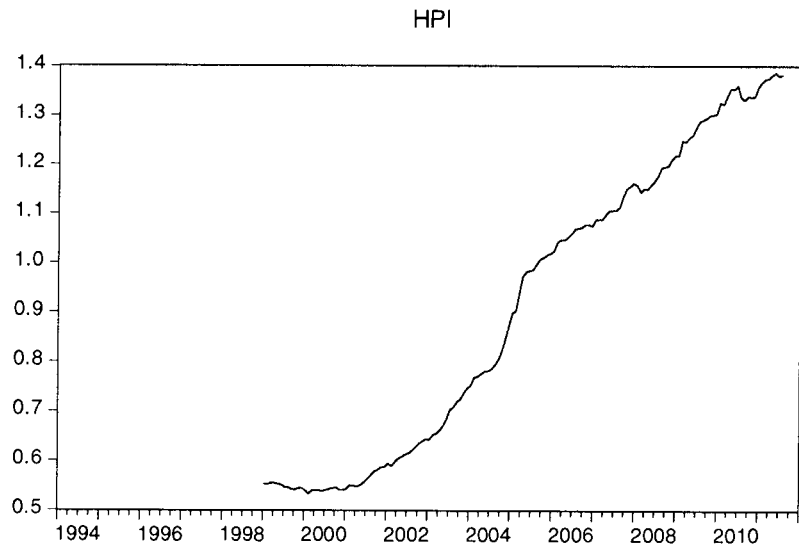


Figure 3 The housing price index to income ratio

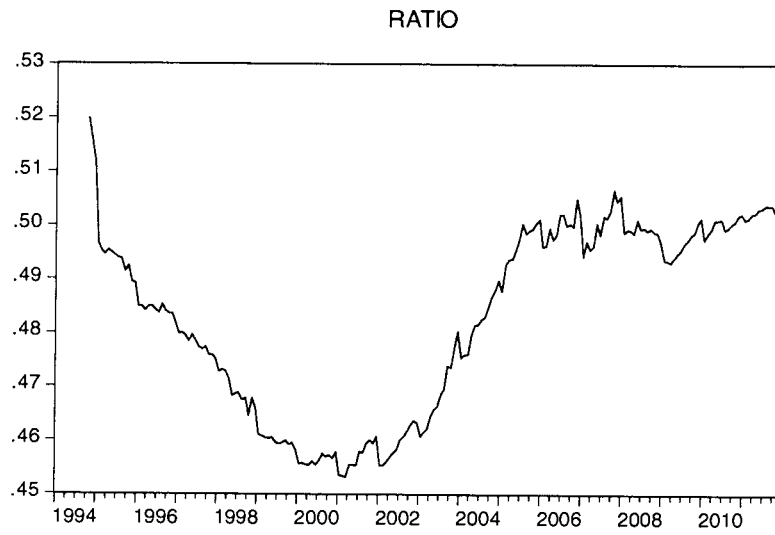


Figure 4 Consumer price index

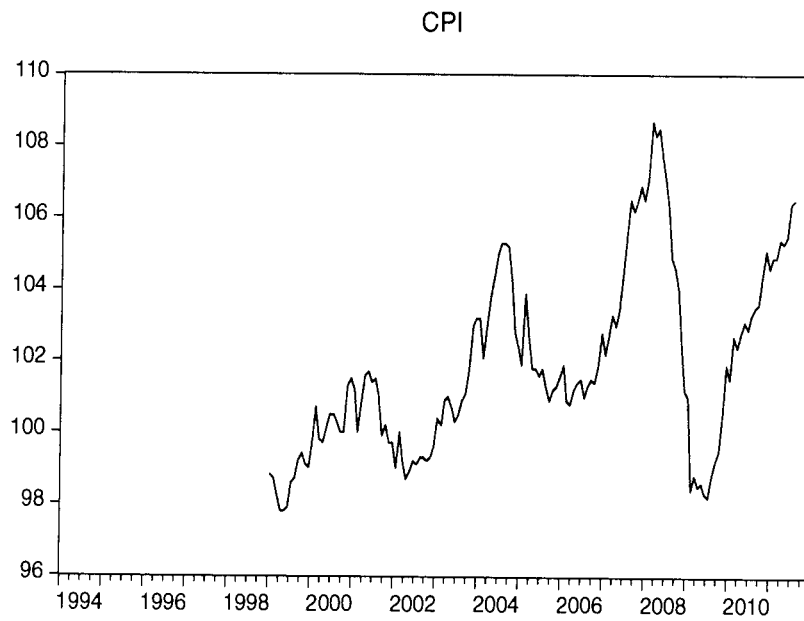


Figure 5 Consumer price index components (2008)

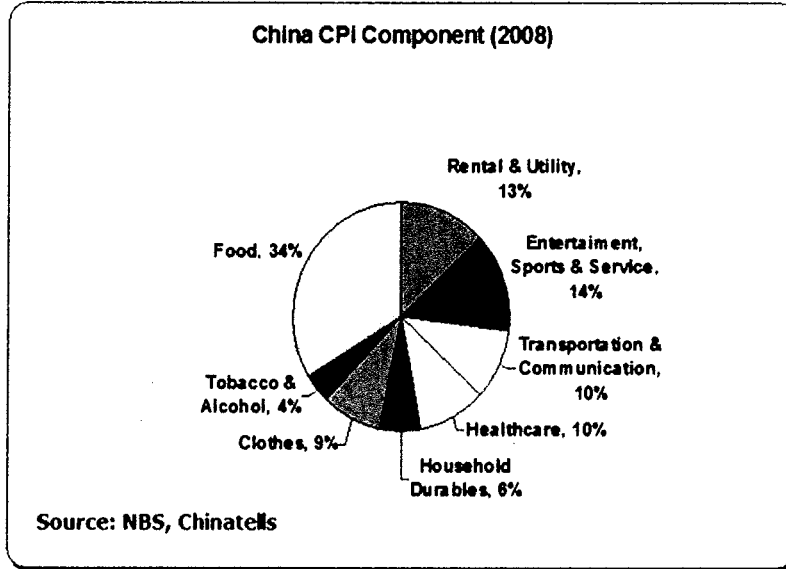


Figure 6 Income

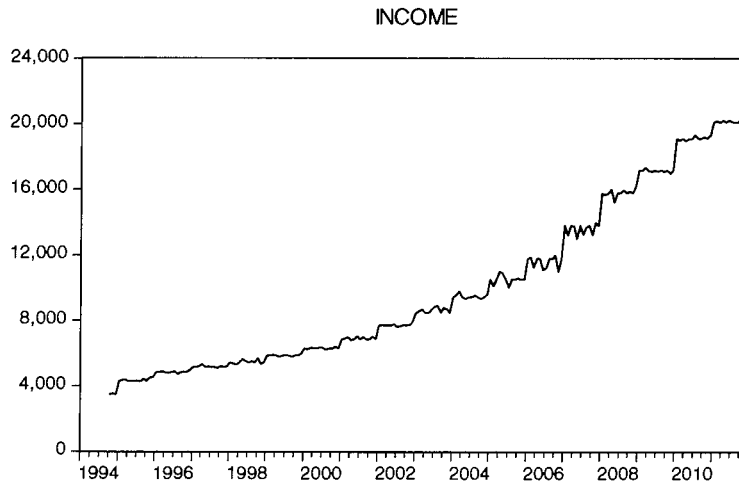


Figure 7 Unemployment rate

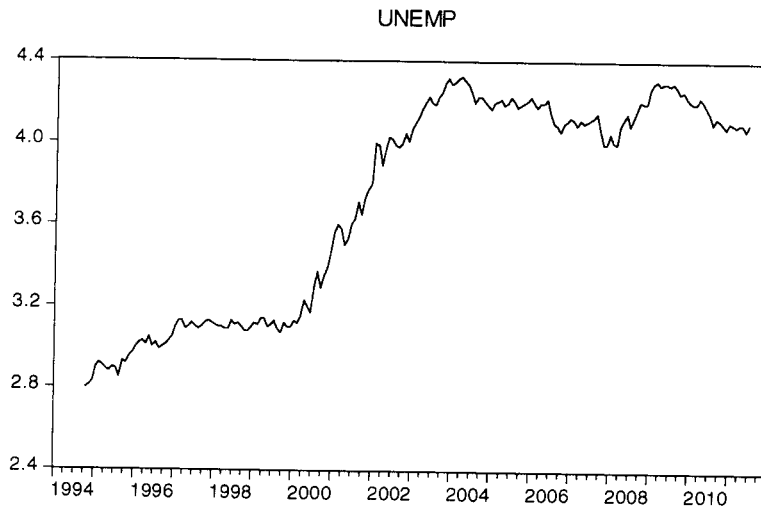


Figure 8 Market value of the stock market

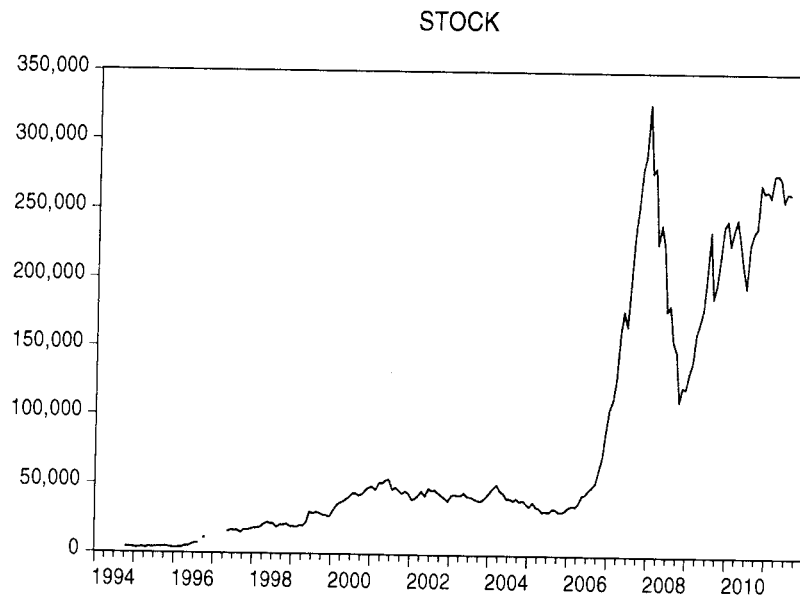
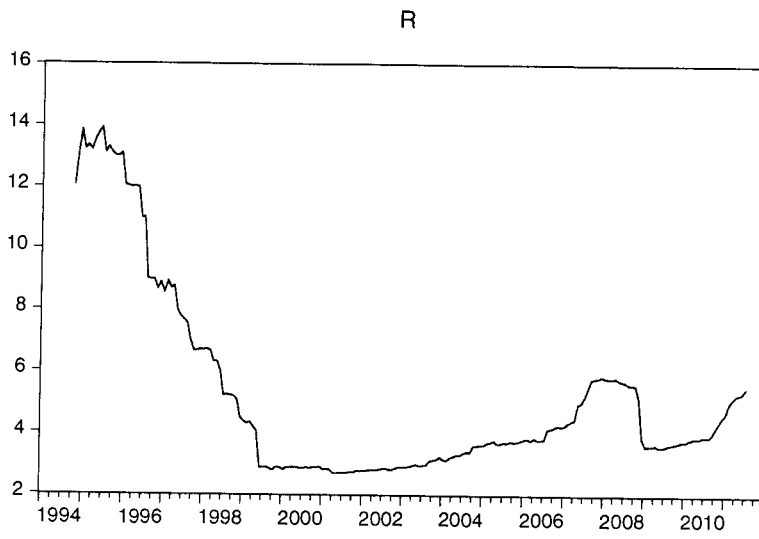


Figure 9 Long-term interest rate



Tables

Table 1 Data description summary

| Variables | Notation | Period | Sources |
|------------------------------------|----------|-----------------------------------|--|
| House Price Index | HPI | October 1994- November 2011 | National Bureau of Statistics of China, Table "Monthly Data and Graph of Chinese housing price Index" http://bbs.pinggu.org/forum.php |
| Income | INCOME | October 1994- November 2011 | "China statistical Yearbook"(1994, 2011), "Per Capita Annual Income and Engle Coefficient of Urban and Rural Households" |
| Consumer Price Index (1978=100) | CPI | January 1999- November 2011 | Chinese Academy of Social Sciences, table 17, "Monthly Consumer Price Indices by Category" http://ifb.cass.cn/jrtj/datagrids.asp?si d=1 |
| Unemployment Rate | UNEMP | October 1994- January 2011 | "China statistical Yearbook"(1994, 2011), "Monthly Data of Total Unemployment and Unemployment Rate of Urban Households" |
| Market Value of Stock Market | STOCK | October 1994- November 2011 | Chinese Academy of Social Sciences, table 06, "Monthly Data of Market Capitalization of Stock Market" http://ifb.cass.cn/jrtj/datagrids.asp?si d=0 |
| Long-Term Interest Rate | R | October 1994- November 2011 | Bank of China, "Table of RMB Saving Rate" http://www.boc.cn/finadata/lilv/ |

Table 2 Data description summary (continued)

| Variables | Mean | Standard deviation | Max | Min |
|------------------------------------|----------|--------------------|----------|----------|
| D(HPI) | 0.013226 | 0.004355 | 0.018826 | 0.006815 |
| D(INCOME) | 0.000127 | 5.92e-05 | 0.000286 | 4.87e-05 |
| D(CPI) | 0.009869 | 0.000246 | 0.010278 | 0.009242 |
| D(Unemployment Rate) | 0.322418 | 0.058321 | 0.441833 | 0.262595 |
| D(Market Value of Stock Market) | 5.03e-05 | 7.79e-05 | 0.000362 | 5.03e-05 |
| D(Long-Term Interest Rate) | 0.281361 | 0.119386 | 0.462624 | 0.074495 |

Note: $D(X) = \log(X) - \log(X\{-1\})$

Table 2 Results of unit root tests

| | Augmented Dickey-Fuller test statistic | 5% level | Prob.* |
|-----------|--|-----------|---------|
| HPI | -2.179311 | -3.432005 | 0.4981 |
| D(HPI) | -5.130164 | -3.432005 | 0.0002 |
| CPI | -1.630371 | -2.882433 | 0.4644 |
| D(CPI) | -5.387834 | -2.882433 | 0.0000 |
| INCOME | -2.560241 | -3.433525 | 0.2992 |
| D(INCOME) | -4.196601 | -3.433525 | 0.0055 |
| R | -2.360768 | -2.875825 | 0.1543 |
| D(R) | -11.52994 | -2.875825 | 0.0000 |
| STOCK | -2.080921 | -3.433906 | 0.5526 |
| D(STOCK) | -7.245111 | -3.433906 | 0.00000 |
| UNEMP | -1.988444 | -2.875825 | 0.2918 |
| D(UNEMP) | -11.42509 | -2.875972 | 0.0000 |

Note : Null Hypothesis: variable has a unit root

Exogenous: Constant for CPI, R, UNEMP

Exogenous: Constant and linear trend for HPI, INCOME, STOCK

Lag Length: 1 (Automatic - based on SIC, maxlag=14)

*MacKinnon (1996) one-sided p-values.

Table 3 Summary of studies

| Authors | Country/region | Period | Definition of housing bubbles | Approach/ method | Conclusion |
|---------------------------------------|-------------------|-------------|--|--|--|
| Bodman and Crosby (2003) | Australia | 1980 - 2002 | Housing price cannot be explained by fundamental variables | Time series and "fundamental" approaches | Only Brisbane and Sydney have housing bubbles |
| McCarthy and Peach (2005) | The United States | 1976 - 2004 | Housing price cannot be explained by fundamental variables | Analyzing rent-price ratio, price-income ratio, "fundamental" approaches with interest rates | No housing bubbles |
| Mkhd and Zemcik (2009) | The United States | 1975 - 2006 | Housing price cannot be explained by fundamental variables | Cross-sectionally robust panel data tests for unit roots and co-integration | There is a bubble |
| Zhou and Sornette (2005) | The United States | 1993 - 2006 | Housing prices grow at a faster-than-exponential rate | Document another important instance of herding | They expected the turning point of the bubble will occur around mid-2006 |
| Kim and Min (2011) | Korea | 1986 - 2003 | Whether housing prices can be explained by the stochastic bubble model | Regime-switching regression model, Kalman filter technique, Generalized impulse response function analysis | Housing price bubbles increased with household lending and industrial production |
| Cameron, Muellbauer and Murphy (2006) | U.K. | 1972 - 2003 | Housing price cannot be explained by fundamental variables | Inverted demand function approach | No housing bubbles |

Table 3 Summary of studies (continued)

| | | | | | |
|-----------------------------|-------------------|-------------|--|---|---|
| Tsai and Peng (2011) | Taiwan | 1980 - 2007 | Housing price cannot be explained by fundamental variables, and whether the movement of house prices diverges from income and rent | Analyzing house price-to-income ratio and price-to-rent ratio, and panel unit root test and panel co-integration test | No housing bubbles, but the bubble-like behaviour of house prices is related to mortgage rate |
| Xiao and Liu (2010) | Hong Kong | 1980 - 2004 | Housing price cannot be explained by fundamental variables | Kalman filter | No housing bubbles |
| Xiao, Kwang Tan and (2006) | Hong Kong | 1980 - 2002 | Housing price cannot be explained by fundamental variables | Kalman filter asset pricing present value model | No housing bubbles |
| Wu, Gyourko and Deng (2012) | China | 2000 - 2010 | Housing price cannot be explained by fundamental variables | Housing affordability metrics (price-to-rent ratio, price-to-income ratio) | There is no housing bubbles |
| Ren, Fei and Xiong (2010) | China (29 cities) | 1998 - 2008 | Adopted the definition of rational expectation bubbles proposed by Blanchard and Watson (1983) | Theory of rational expectation bubbles | No housing bubbles |

Table 4 Co-integration test for non-stationary variables

Unrestricted Cointegration Rank Test (Trace)

| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** |
|------------------------------|------------|--------------------|------------------------|---------|
| None * | 0.333865 | 142.7963 | 95.75366 | 0.0000 |
| At most 1 * | 0.228044 | 83.88809 | 69.81889 | 0.0025 |
| At most 2 | 0.117730 | 46.35807 | 47.85613 | 0.0687 |
| At most 3 | 0.107518 | 28.19573 | 29.79707 | 0.0756 |
| At most 4 | 0.048004 | 11.70208 | 15.49471 | 0.1718 |
| At most 5 | 0.031018 | 4.568853 | 3.841466 | 0.0325 |

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

| Hypothesized No. of CE(s) | Eigenvalue | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
|------------------------------|------------|------------------------|------------------------|---------|
| None * | 0.333865 | 58.90821 | 40.07757 | 0.0001 |
| At most 1 * | 0.228044 | 37.53003 | 33.87687 | 0.0175 |
| At most 2 | 0.117730 | 18.16234 | 27.58434 | 0.4817 |
| At most 3 | 0.107518 | 16.49365 | 21.13162 | 0.1973 |
| At most 4 | 0.048004 | 7.133232 | 14.26460 | 0.4735 |
| At most 5 | 0.031018 | 4.568853 | 3.841466 | 0.0325 |

Note: Sample (adjusted): 1999M06 2011M06

Included observations: 145 after adjustments

Trend assumption: Linear deterministic trend

Series: HPI CPI INCOME R STOCK UNEMP

Lags interval (in first differences): 1 to 4

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Table 5 Long-term relationships between HPI and fundamental variables.

| | | | | | | |
|---|------------------------|------------------------|------------------------|------------------------|------------------------|--|
| 2 Cointegrating Equation(s): | | Log likelihood | 2384.147 | | | |
| Normalized cointegrating coefficients (standard error in parentheses) | | | | | | |
| HPI | CPI | INCOME | R | STOCK | UNEMP | |
| 1.000000 | 0.000000 | 0.541464 (0.39536) | 0.190800 (0.29735) | -0.472586 (0.13483) | -0.464151 (0.89955) | |
| 0.000000 | 1.000000 | -0.386728 (0.11507) | -0.286922 (0.08654) | 0.167691 (0.03924) | 0.187984 (0.26181) | |
| Adjustment coefficients (standard error in parentheses) | | | | | | |
| D(HPI) | 0.003622 (0.00639) | 0.020098 (0.02251) | | | | |
| D(CPI) | -0.015914 (0.00887) | -0.045916 (0.03125) | | | | |
| D(INCOME) | 0.073364 (0.04893) | 0.249288 (0.17240) | | | | |
| D(R) | 0.328355 (0.05111) | 1.172297 (0.18009) | | | | |
| D(STOCK) | -0.169483 (0.11807) | -0.810576 (0.41599) | | | | |
| D(UNEMP) | -0.016047 (0.01450) | 0.001351 (0.05109) | | | | |

Table 6 Vector-error correction model outcome

Vector Error Correction Estimates

Date: 03/31/12 Time: 15:02

Sample (adjusted): 1999M04 2011M06

Included observations: 147 after adjustments

Standard errors in () & t-statistics in []

| Cointegrating Eq: | CointEq1 | CointEq2 | | | | |
|-------------------|---------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| HPI(-1) | 1.000000 | 0.000000 | | | | |
| CPI(-1) | 0.000000 | 1.000000 | | | | |
| INCOME(-1) | -1.242409 (0.12660) [-9.81347] | 0.110640 (0.03984) [2.77689] | | | | |
| R(-1) | -0.506218 (0.09468) [-5.34651] | -0.087827 (0.02980) [-2.94746] | | | | |
| STOCK(-1) | 0.269772 (0.04243) [6.35876] | -0.040849 (0.01335) [-3.05944] | | | | |
| UNEMP(-1) | 0.090385 (0.28934) [0.31238] | 0.050318 (0.09106) [0.55258] | | | | |
| C | 4.548900 | -5.148229 | | | | |
| Error Correction: | D(HPI) | D(CPI) | D(INCOME) | D(R) | D(STOCK) | D(UNEMP) |
| CointEq1 | -0.004083 (0.00559) [-0.72978] | 0.005612 (0.00782) [0.71803] | 0.107570 (0.04436) [2.42489] | 0.198172 (0.04679) [4.23562] | -0.259521 (0.10705) [-2.42422] | 0.025327 (0.01352) [1.87264] |
| CointEq2 | -0.035666 (0.01735) [-2.05515] | -0.042642 (0.02424) [-1.75880] | 0.155819 (0.13761) [1.13236] | 0.711897 (0.14513) [4.90518] | -0.517480 (0.33208) [-1.55832] | -0.050530 (0.04195) [-1.20445] |
| D(HPI(-1)) | 0.625120 (0.08488) [7.36489] | 0.106715 (0.11858) [0.89996] | 0.350196 (0.67301) [0.52034] | 0.114824 (0.70981) [0.16177] | -0.596080 (1.62413) [-0.36702] | -0.054451 (0.20518) [-0.26538] |
| D(HPI(-2)) | 0.102120 (0.08565) [1.19236] | -0.025446 (0.11965) [-0.21267] | -0.266102 (0.67909) [-0.39185] | -0.083249 (0.71623) [-0.11623] | -0.743925 (1.63881) [-0.45394] | -0.110035 (0.20704) [-0.53147] |
| D(CPI(-1)) | 0.009809 (0.06207) [0.15803] | 0.090306 (0.08671) [1.04146] | -0.261934 (0.49214) [-0.53223] | 0.396804 (0.51906) [0.76447] | 1.719793 (1.18766) [1.44805] | -0.048723 (0.15004) [-0.32473] |

| | | | | | | |
|---|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| D(CPI(-2)) | -0.045351 (0.06234) [-0.72752] | -0.014419 (0.08709) [-0.16557] | -0.194330 (0.49427) [-0.39317] | -0.074612 (0.52130) [-0.14313] | 1.061403 (1.19278) [0.88986] | -0.011738 (0.15069) [-0.07790] |
| D(INCOME(-1)) | 0.000731 (0.01122) [0.06512] | 0.017612 (0.01567) [1.12368] | -0.205370 (0.08896) [-2.30860] | 0.162069 (0.09382) [1.72738] | 0.207449 (0.21468) [0.96633] | 0.012661 (0.02712) [0.46683] |
| D(INCOME(-2)) | -0.011341 (0.01111) [-1.02110] | 0.027129 (0.01552) [1.74836] | -0.117156 (0.08807) [-1.33031] | 0.095497 (0.09288) [1.02814] | -0.296410 (0.21253) [-1.39470] | 0.051143 (0.02685) [1.90481] |
| D(R(-1)) | 0.005669 (0.00938) [0.60437] | 0.004446 (0.01310) [0.33932] | -0.035378 (0.07437) [-0.47569] | 0.158057 (0.07844) [2.01506] | 0.038036 (0.17947) [0.21193] | -0.025109 (0.02267) [-1.10739] |
| D(R(-2)) | 0.007507 (0.00925) [0.81115] | 0.034240 (0.01293) [2.64829] | -0.004645 (0.07338) [-0.06329] | 0.071072 (0.07739) [0.91833] | 0.077573 (0.17708) [0.43806] | 0.020580 (0.02237) [0.91993] |
| D(STOCK(-1)) | 0.007897 (0.00453) [1.74316] | -0.005960 (0.00633) [-0.94164] | -0.007999 (0.03592) [-0.22268] | -0.008489 (0.03789) [-0.22407] | 0.128028 (0.08669) [1.47689] | -0.022311 (0.01095) [-2.03725] |
| D(STOCK(-2)) | 0.009920 (0.00448) [2.21429] | 0.012367 (0.00626) [1.97581] | 0.021184 (0.03552) [0.59634] | 0.109537 (0.03747) [2.92362] | 0.239962 (0.08573) [2.79915] | -0.020097 (0.01083) [-1.85561] |
| D(UNEMP(-1)) | 0.008162 (0.03439) [0.23734] | 0.002767 (0.04805) [0.05759] | 0.053434 (0.27270) [0.19595] | 0.439207 (0.28761) [1.52709] | -0.850115 (0.65808) [-1.29181] | 0.003749 (0.08314) [0.04510] |
| D(UNEMP(-2)) | 0.036834 (0.03449) [1.06791] | -0.102556 (0.04819) [-2.12837] | -0.113851 (0.27348) [-0.41630] | 0.063317 (0.28844) [0.21952] | 0.215603 (0.65998) [0.32668] | -0.281253 (0.08338) [-3.37325] |
| C | -0.001546 (0.00060) [-2.55945] | -0.000393 (0.00084) [-0.46526] | 0.010652 (0.00479) [2.22423] | -0.004172 (0.00505) [-0.82605] | 0.020389 (0.01156) [1.76428] | 0.003690 (0.00146) [2.52745] |
| R-squared | 0.632414 | 0.185310 | 0.126742 | 0.349532 | 0.179736 | 0.170207 |
| Adj. R-squared | 0.593427 | 0.098904 | 0.034124 | 0.280543 | 0.092739 | 0.082199 |
| Sum sq. resids | 0.002566 | 0.005007 | 0.161306 | 0.179432 | 0.939401 | 0.014993 |
| S.E. equation | 0.004409 | 0.006159 | 0.034957 | 0.036869 | 0.084360 | 0.010658 |
| F-statistic | 16.22139 | 2.144631 | 1.368438 | 5.066484 | 2.065989 | 1.933990 |
| Log likelihood | 596.6788 | 547.5292 | 292.3099 | 284.4829 | 162.8076 | 466.9251 |
| Akaike AIC | -7.913998 | -7.245296 | -3.772924 | -3.666434 | -2.010987 | -6.148641 |
| Schwarz SC | -7.608852 | -6.940149 | -3.467777 | -3.361288 | -1.705841 | -5.843495 |
| Mean dependent | 0.006747 | 0.000546 | 0.008386 | 0.001408 | 0.017497 | 0.001815 |
| S.D. dependent | 0.006914 | 0.006488 | 0.035570 | 0.043467 | 0.088567 | 0.011125 |
| Determinant resid covariance (dof adj.) | | 7.98E-22 | | | | |
| Determinant resid covariance | | 4.18E-22 | | | | |
| Log likelihood | | 2366.564 | | | | |
| Akaike information criterion | | -30.81039 | | | | |
| Schwarz criterion | | -28.73540 | | | | |

Table 7 VEC residual portmanteau tests for autocorrelations

| Lags | Q-Stat | Prob. | Adj Q-Stat | Prob. | df |
|------|----------|--------|------------|--------|-----|
| 1 | 3.098609 | NA* | 3.119832 | NA* | NA* |
| 2 | 13.31647 | NA* | 13.47863 | NA* | NA* |
| 3 | 33.50984 | 0.9978 | 34.09270 | 0.9972 | 60 |
| 4 | 72.45722 | 0.9651 | 74.12951 | 0.9524 | 96 |
| 5 | 104.6462 | 0.9620 | 107.4519 | 0.9423 | 132 |
| 6 | 143.7223 | 0.9127 | 148.1909 | 0.8621 | 168 |
| 7 | 173.4743 | 0.9407 | 179.4304 | 0.8917 | 204 |
| 8 | 201.2179 | 0.9675 | 208.7707 | 0.9281 | 240 |
| 9 | 240.0223 | 0.9423 | 250.1059 | 0.8665 | 276 |
| 10 | 258.9607 | 0.9871 | 270.4266 | 0.9571 | 312 |
| 11 | 303.3622 | 0.9595 | 318.4194 | 0.8706 | 348 |
| 12 | 395.9734 | 0.3258 | 419.2628 | 0.1040 | 384 |

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution
Null Hypothesis: no residual autocorrelations up to lag h
Sample: 1994M01 2011M12
Included observations: 147

Table 8 VEC residual heteroskedasticity tests

| Joint test: | | | | | |
|-------------|-----|--------|--|--|--|
| Chi-sq | df | Prob. | | | |
| 699.1568 | 588 | 0.0010 | | | |

| Individual components: | | | | | |
|------------------------|-----------|-----------|--------|------------|--------|
| Dependent | R-squared | F(28,118) | Prob. | Chi-sq(28) | Prob. |
| res1*res1 | 0.190240 | 0.990077 | 0.4889 | 27.96526 | 0.4663 |
| res2*res2 | 0.332195 | 2.096371 | 0.0033 | 48.83272 | 0.0087 |
| res3*res3 | 0.296622 | 1.777210 | 0.0180 | 43.60345 | 0.0304 |
| res4*res4 | 0.400570 | 2.816202 | 0.0001 | 58.88377 | 0.0006 |
| res5*res5 | 0.186382 | 0.965398 | 0.5224 | 27.39810 | 0.4967 |
| res6*res6 | 0.240762 | 1.336390 | 0.1443 | 35.39197 | 0.1587 |
| res2*res1 | 0.150881 | 0.748839 | 0.8102 | 22.17944 | 0.7729 |
| res3*res1 | 0.286445 | 1.691754 | 0.0278 | 42.10737 | 0.0424 |
| res3*res2 | 0.211211 | 1.128444 | 0.3188 | 31.04804 | 0.3150 |
| res4*res1 | 0.335409 | 2.126882 | 0.0028 | 49.30505 | 0.0077 |
| res4*res2 | 0.269973 | 1.558496 | 0.0533 | 39.68605 | 0.0705 |
| res4*res3 | 0.295633 | 1.768800 | 0.0188 | 43.45812 | 0.0314 |
| res5*res1 | 0.098895 | 0.462512 | 0.9898 | 14.53756 | 0.9829 |
| res5*res2 | 0.279601 | 1.635647 | 0.0367 | 41.10134 | 0.0526 |
| res5*res3 | 0.160898 | 0.808089 | 0.7379 | 23.65198 | 0.6998 |
| res5*res4 | 0.405543 | 2.875012 | 0.0000 | 59.61476 | 0.0005 |
| res6*res1 | 0.102003 | 0.478697 | 0.9868 | 14.99440 | 0.9785 |
| res6*res2 | 0.208583 | 1.110704 | 0.3385 | 30.66174 | 0.3323 |
| res6*res3 | 0.071440 | 0.324230 | 0.9995 | 10.50162 | 0.9989 |
| res6*res4 | 0.333283 | 2.106663 | 0.0031 | 48.99256 | 0.0084 |
| res6*res5 | 0.164692 | 0.830902 | 0.7079 | 24.20971 | 0.6704 |

No Cross Terms (only levels and squares)
Sample: 1994M01 2011M12
Included observations: 147

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