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Monetary policy and housing prices; A case study of Chinese experience in 1999-2010

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Contents

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Abstract

How do monetary policy variables affect housing prices? In this paper we apply a non-linear modelling approach, the Nonlinear AutoRegressive Moving Average with eXogenous inputs (NARMAX), to investigate determinants of housing prices in China over the period 1999:01 to 2010:06. The NARMAX approach has an advantage over prevailing methods in that it automatically selects linear and non-linear forms of variables and the numbers of corresponding lags according to statistical properties. Both linear and non-linear estimation results identify a number of key monetary and price variables, including most notably mortgage rate, producer price, broad money supply and real effective exchange rate. Meanwhile, some key real economic variables such as income are not independently significant. Our findings should be helpful in understanding the formation of housing prices in China and will provide some valuable insights on how to use monetary policies to manage asset prices.

JEL Classification: E47, E52, C32, C67
Keywords: housing prices, monetary policy, NARMAX, China,

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Tiivistelmä

Tutkimuksessa tarkastellaan kiinteistöhintojen määräytymistä Kiinassa vuosina 1999-2010. Tutkimuksessa hyödynnetään epälineaarista NARMAX-mallinnusta, jonka avulla voidaan laajaan tilastolliseen kuukausitason aineistoon perustuen määritellä automaattisesti sekä lineaarisia että epälineaarisia muuttujia ja niiden viiverakenteita. Mallin tulokset viittaavat lukuisten rahataloudellisen muuttujien sekä hintamuuttujien merkitykseen kiinteistöhintojen muutosten selittäjinä. Näitä ovat erityisesti asuntolainojen korko, tuottajahinnat, lavean rahan tarjonta ja kauppapainotettu reaalinen valuuttakurssi. Sen sijaan eräät keskeiset reaalitalouden muuttujat, kuten kotitalouksien tulot, eivät ole tilastollisesti merkittäviä. Tulokset auttavat ymmärtämään kiinteistöhintojen muodostumista Kiinassa ja antavat samalla viitteitä rahapolitiikan tärkeydestä varallisuushintojen muodostumisessa.

JEL: E47, E52, C32, C67

Asiasanat: kiinteistöhinnat, rahapolitiikka, NARMAX, Kiina

1 Introduction

Since the onset of the U.S. subprime crisis, the Federal Reserve (Fed) has been under frequent attack for its unusually loose monetary policies during the years preceding the crisis. Abundant liquidity and low interest rates were probably the most important macroeconomic factors in the formation of the super bubble in the U.S. housing market. A decline in housing prices beginning in 2007 eventually led to the world's worst financial crisis and economic recession in almost eight decades[1].

Underscoring this popular discussion is the more delicate academic question of the relationship between monetary policy and asset price. Maintaining price stability is widely regarded as the most important objective for monetary policy. In this context, price stability is often defined as stability of the consumer price index (CPI). During the years before the global crisis, the U.S. experienced a period of rapid GDP growth with modest CPI inflation. Therefore, there was no reason for the Fed to hike interest rates or tighten liquidity conditions, according to conventional monetary policy doctrine.

Since the crisis, there has been increasing recognition among economists and policymakers that central banks should monitor asset prices as well as goods prices (Blanchard et al, 2010). But it remains unclear whether it is possible to formally incorporate asset prices into the monetary policy objective function. Even if this could be done, controlling asset prices is much more difficult than regulating goods prices. Perhaps we need to answer a more basic but also more fundamental question before we can consider the policy framework: how do monetary policy variables affect asset prices?

The Chinese experience of the past decade probably provides a good case study of the relationship between monetary policy and housing prices. Housing prices in major cities such as Beijing and Shanghai more than tripled between 1999 and 2010. The total value of China's residential housing market reached 91.5 trillion Yuan at the end of 2009, nearly three times nominal GDP in the same year.[2]

In recent years, economists and policymakers have become increasingly worried about China's housing bubble and are now highly cognizant of the huge risk associated with a potential

[1]Reuters. February 29, 2009. Three top economists agree 2009 worst financial crisis since great depression; risks increase if right steps are not taken.
[2] China Securities Journal, July 15, 2009.

bubble-burst of such magnitude.[3] Hou (2008) compared housing prices with the rational expectations price, mortgage loans, ratio of price to income, and rental yields. He concluded that housing prices in Beijing and Shanghai were already beyond what could be accounted for rationally. Some observers even argued that China's housing bubble problem was actually much bigger than those in the U.S. and U.K. before the global financial crisis.[4]

Concerns about potential risks of a bubble-burst in the housing market prompted the policymakers to take a number of actions to contain the housing bubble[5]. In recent years the government has adopted several policy packages for this purpose. The most dramatic tightening measures were introduced in April 2010 and were focused mainly on administrative matters. One of these is the restriction on purchases of second and third apartments by a single household. Such controls, it seems, have not been highly effective. Whenever there were signs of government relaxing of controls, housing prices began to rebound rapidly.

The Chinese government's proactive policy intervention indicates its concern about the negative consequences of housing bubbles. But is it applying the right policy instruments? Having observed the experiences of loose monetary policy leading to a housing bubble in the U.S., we find it odd that none of the recently adopted policy packages aimed at the housing market has focused on monetary policy tools.

In this paper, we attempt to investigate the determinants of China's housing prices, with a special focus on monetary variables. This study is motivated by three major concerns. First, we want to explore the general relationship between monetary policy and housing prices, although the Chinese experience may not be typical. Secondly, we feel it useful to apply the non-linear modelling approach, NARMAX, which automatically selects forms and lag structures for individual explanatory variables. And finally, we hope to draw some important policy implications for the management of housing prices or housing bubbles in China.

Although there is a large literature that focuses on interactions between asset prices and monetary policy, the relevant literature on the specific impacts of monetary policy on house prices is fairly limited (Negro and Otrok, 2007). Our paper complements the literature by identifying important determinants of housing prices in China over the period 1999:01 to 2010:06. We focus on

[3] Forbes has recently ranked China's real estate market bubble second in the top seven looming financial bubbles in the world, see Randal D. K. and Hawkins A. (2010) Seven Looming Financial Bubbles, Forbes, December 15 2009; Gao, Shanwen, the chief economist at Anxin Securities, claimed the house market bubbles in some big cities will burst in the next 3 to 5 years; see 'The housing market bubble will burst in the next 3 to 5 years' (fangchan paomo jiang zai 3 dao 5 nian nei pomie), Shenzhen Special Zone Daily (Shen Zhen Tequbao), April 12, 2010.

4 Vega R. (2010), China's housing market worse than US before subprime collapse, Daily Reckoning, June 2, 2010.

5 About half of a middle class household's income is locked up in mortgage payments and other housing related spending, and a moderate housing market decline could wipe out a huge amount household wealth. See Zhou S. (2010), Housing market: China's own 'too big to fail', China Stakes, April 14, 2010.

price and monetary variables, as well as economic fundamentals; all together an extensive monthly data set of 17 macroeconomic variables including income, broad money, interest rates, stock index, industrial production, land and goods prices, international trade and foreign reserves.

Summarising our results, the most significant variables identified in this study as drivers of house price dynamics are monetary policy and price variables, including mortgage rate, producer price and real effective exchange rate. Remarkably, key real economic variables such as personal disposable income, GDP, value-added industrial output, and international trade exhibit only weak independent explanatory power for house price dynamics, and some of them have to be combined with monetary or price variables to exhibit nonlinear-effects. These findings should be helpful in understanding the formation of housing prices in China, and should also provide valuable insights on how to use monetary policies to manage asset prices.

The methodology, the Nonlinear Auto Regressive Moving Average with eXogenous inputs (NARMAX) model, which is widely used in the natural sciences and engineering but rarely in economic and financial analysis, distinguishes our analysis from previous studies. To our knowledge, this is the first use of NARMAX to analyse housing price dynamics. Most of the previous studies apply the vector autoregressive/cointegration model (VAR/VECM), and are deficient in terms of selection of explanatory variables (Gupta et al, 2010) and may suffer from the over-fitting problem (Zhang et al, 2011). Our empirical exercise shows that the estimated linear and nonlinear NARMAX models are both powerful tools for predicting future housing prices, with the nonlinear one performing best in-sample and the linear one performing best out-of-sample. This provides evidence that the NARMAX method, combined with the algorithms of term selection and parameter estimation, provides a reasonably accurate representation of house price dynamics and helps to capture the complicated dynamics between China's property market and its underlying fundamental factors.

As one of initial applications of the NARMAX to economic analysis, this study anticipates some criticism. Foremost among these is that the trend needs to be removed prior to NARMRX modelling, which may be too costly in that it removes long-run co-movements between macroeconomic variables. To overcome this pitfall, we develop an empirical modelling strategy to combine cointegration and the error-correction model with the NARMAX model. To see whether cointegration relationships can improve forecasting performance, we employ cointegration tests to first uncover the long-run relationships, and then incorporate these long-run cointegration equations into the NARMAX model. Our results show that taking the current cointegration restrictions or error correction terms directly into our NARMAX specification evidently does not greatly improve either the in-sample or out-of-sample forecasting performance.

Our research also has limitations that are not addressed in this study. For instance, although our data set contains many macroeconomic variables, we are still not able to incorporate all the potentially important variables for the housing market, due to data limitations. One such aggregate variable is the (non-measurable) government influence on land supply. Other aggregate data such as demographic structure and rural-urban migration numbers are only available at annual frequency and hence adding them into our monthly analyses would not have not much economic meaning, even if we split them into monthly frequency. Some of these outstanding questions should be addressed in future studies. It should also be noted that whether the results of this initial try at combining the NARMAX and VECM approaches have real economic meaning or are merely econometric or statistical inferences remains to be tackled in future research.

The remainder of this paper is organized into four sections. Section 2 summarizes the existing evidence in the literature. Section 3 discusses the facts and explanations for the Chinese housing boom. Section 4 describes data and methodology, namely the NARMAX model's polynomial representation, term selection and parameter estimation. In Section 5, we report the empirical and forecasting results and Section 6 concludes with the main findings.

2 Literature review

Numerous papers have explored the determinants of house prices across a number of countries, one strand being based on national or regional macroeconomic factors and the second on regional or micro data. This paper, in the first strand, tries to identify those macroeconomic variables that are potential predictors of house price growth in China. Many macroeconomic variables have been found to influence house prices: GDP growth or the business cycle, demographic structure, bank credit or money supply, personal income, user costs of housing, interest rates, inflation, speculative capital flows, taxation, stock market wealth, and others (Tsatsaronis and Zhu, 2004; Shiller, 2005; Mikhed and Zemcik, 2009; Rapach and Strauss, 2009).

Many studies have sought after the main forces driving aggregate house prices within individual countries. Holly and Jones (1997) find that the single most important determinant of real house prices in the UK from 1939 to 1994 was real income. Tsatsaronis and Zhu (2004) argue that inflation is dominate in the determination of real house prices in 17 industrialized countries and that a declining interest rate environment typically boosts the demand for residential real estate. Jacobsen and Naug (2005) find that interest rates, housing construction, unemployment and household income are the most important explanatory factors for house prices in Norway. Wheaton and Nechayev (2008) investigate whether the 1998-2005 house price inflation in the US can be explained by increases in demand fundamentals such as population, income growth, and the decline in interest rates. They find that the magnitude of house price variation in 2005 is also associated with an increase in house buying for second homes and investment, and with greater use of the sub-prime mortgage market and looser loan underwriting. Gupta et al (2010) find that house price inflation responds negatively to monetary policy shocks in South Africa. Yang et al (2010) measures the heterogeneous effects of monetary policy on regional house prices in Sweden 1991–2002. They find significant regional effects of monetary policy on housing markets and that interest rate effects dominate the influence of local price innovations in the core economic regions in Sweden. Gimeno and Martinez-Carrascal (2010) analyzed the relationship between mortgage loans and housing prices in Spain and show that the significant increase observed in house prices and house purchase loans in the past years has raised their levels above those implied by the fundamentals.

Cross-country research has been conducted as well. For instance, Beltratti and Morana (2010) investigate linkages between linkages between general macroeconomic conditions and the housing market for the G-7 area over the period 1980:1–2007:2 and consider eleven variables including the growth rates of real GDP, private consumption, investment, the rate of CPI inflation, the levels of the long-term and short-term nominal interest rates, the nominal money growth rate, the rates of change of the real house price, the real effective exchange rate, the real stock price, and the real price of oil. They find that global supply-side shocks are an important determinant of house prices fluctuations.

Interactions between monetary policy and asset prices have also been the subject of a large number of studies. It is widely accepted that monetary variables affect not only goods prices but also asset prices (Rigobon and Sack, 2004). Monetarists believe that the quantity of money is the single most important factor determining price levels in an economy. Credit expansion is often an important source of funds for fuelling stock market and real estate bubbles. Even if prices are not fully flexible in the short run, the central bank can temporarily influence the real interest rate, which, in turn, should impact real output as well as nominal prices (Bjørnland and Leitemo, 2009).

Nevertheless, despite the popularity of the topic, studies focusing on specific impacts of monetary on housing prices are relatively scarce (Negro and Otrok, 2007) and the results rather mixed. Iacoviello and Minetti (2003) assessed the credit channel of monetary policy, especially the bank-lending channel, in four housing markets: Finland, Germany, Norway and the UK. They find that the response of house prices to interest rate surprises is bigger and more persistent in periods characterised by more liberalised financial markets. Fratantoni and Schuh (2003) study the effects of monetary policy on regions in the U.S. from 1966 to 1998 and find that the response of housing investment to monetary policy varies by region. Iacoviello (2005) estimates a VAR in interest rates, inflation, and detrended output and house prices using quarterly data from 1974 to 2003, and finds that monetary policy shocks have a significant effect on house prices. Negro and Otrok (2007) adopt a similar approach in using quarterly U.S. state-level data from 1986 to 2005, but find the impact of policy shocks on house prices to be small in comparison with the magnitudes of recent fluctuations. Mora (2008) finds that bank credit fuelled the real estate boom in Japan during the 1980s. Vargas-Silva (2008) examines the impact of monetary policy shocks on the US housing market, and the results indicate that housing starts and residential investment respond negatively to contractionary monetary policy shocks.

When it comes to China's housing market, only a small stream of literature has explored the determinants of the recent house price boom, such as Zhang and Fung (2006), Hou (2008), Guo and Huang (2010), Wang et al (2010), Du et al (2010), and Chen et al (2011), albeit there are abundant explanations available in the media. In next section, we discuss and categorize these studies and media explanations.

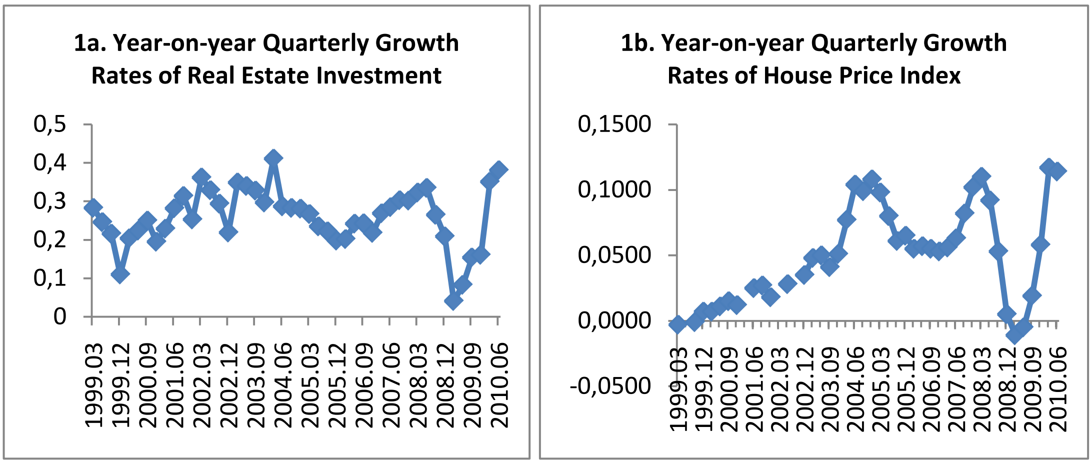
3 Facts and explanations for the Chinese house market boom

3.1 A brief history of Chinese house market boom

In the planned-economy era of China before 1978, urban housing was basically owned by work units or housing management departments of local governments. Since the initiation of economic reforms in 1978, various new policies have been designed to privatize and reform the public-sector-dominated housing system in China (Chen et al, 2011). In July 1994, the State Council in China issued a directive that provided the basic framework for housing reform in the 1990s, which aimed to abolish the work unit-based, welfare-oriented housing system gradually through housing privatization reform as well as rent reform. The second stage of housing reform started in July 1998, when the State Council announced the termination of in-kind distribution of public-owned housing (Sato, 2006). The free market was made the main channel for providing residential housing, and housing privatization has become the mainstream of housing policy.

Since then, China's house market has been developing rapidly. By the end of 2009, the total value of China's residential housing market reached 91.5 trillion Yuan, nearly three times GDP in the same year. Based on official statistics, real estate investment has grown at an average rate of 25.82% per year in China from 1999:01 to 2010:06, while residential property prices in China have continued to increase at 5.09% per year (Figure 1).

Figure 1 Year-on-year quarterly growth rates of real estate investment and national house price index in China, 1999-2010



Data source: Wind Data Base

In connection with intensified expectations of RMB appreciation in 2004-2007, residential property prices in China had soared and prompted fear that a property price bubble. The government implemented measures to deflate the bubble. Tighter housing policies included new property taxes and tighter lending conditions. For instance, although the Chinese government had allowed foreigners to freely own properties in 2001, in 2007 it restricted ownership to resident foreigners who have worked, studied or lived in China for at least a year. These measures led to a slowdown of house price rises in the first half of 2008 and, combined with the global financial crisis, caused house prices to fall in the second half of 2008. GDP growth decreased sharply from 11.3% year-on-year during the first quarter of 2008 to 6.5% in the first quarter of 2009, while the national house price index moderated sharply as well, from 11% to -1.1%.

In response to the global financial crisis, the government largely reversed its previous tight macroeconomic policies. At first, to help exporters weather a slump in external demand, the government has slowed the rise of the Yuan since July 2008 and effectively pegged the Yuan at about 6.83 per dollar. Secondly, the government announced a CNY4 trillion (US$585 billion) stimulus package in November 2008, with allocations for housing and infrastructure projects, manufacturing, education, and industry. Local governments were allowed to issue CNY200 (US$27.6) billion in bonds, through the Ministry of Finance. Thirdly, the tight housing policies were also generally loosened. The property deed tax rate for first-time home buyers was reduced to 1% from 1.5% for the period January 2009 to December 2009, provided the purchased residential property covered less than 90 square meters. The stamp duty and land value-added tax were waived for individuals purchasing residential properties from January 2009 to December 2009. Moreover, if residential property is held for more than two years, the seller is exempted from the 5.5% business tax.

Boosted by a massive economic stimulus package as well as direct government intervention in the housing markets, both real GDP and house prices in China rose again in the second quarter of 2009, in a quick recovery from declining growth rate in late 2008 and early 2009. GDP growth picked up to 7.4% in the second quarter and accelerated to 9.10% in the fourth quarter. House prices recovered quickly too, and their year-on-year growth rates increased to 5.8% in the fourth quarter of 2009 and to 11.7% and 11.4% in the first and second quarters of 2010, respectively (see Figure 1).

Surging house prices had led to increasingly open discontent from middle-class families in major cities and prompted Chinese policymakers to take policy action to contain housing bubbles. After months of indecision, Beijing in mid-April announced a package of policies intended to blow the froth out of the market by restricting speculative purchases. But it focused mainly on administrative measures, such as raising the down payment rate from 20% to 30% for first home buyers, reducing the mortgage rate discount from 30% to 15% of the benchmark interest rate, prohibiting the same family from purchasing second or third etc properties, suspending mortgage loans to non-residents of a city unless they can prove that they have paid taxes in that city for at least one year. A proposal for extending the property tax to investment properties has been offered by some local governments, which may dramatically raise the costs of second properties. Such controls, however, may have cooled the house market in the short term, but whether they are effective in the long run is still questionable.

3.2 Existing explanations and hypotheses

So far many explanations and hypotheses have been offered for China's housing market boom in 1999-2010, in the literature and in the media, covering structural shocks to both the demand and supply sides of the Chinese housing market. These may be summarized as follows.

(E1) Income and demand push

This is one of the favourite explanations for China's house market boom. Accordingly, a huge demand for residential housing has been unleashed by the housing reform in 1998, which can be fully justified by increasing household income or personal disposable income due to 30 years of rapid economic growth, as well as a high household saving rate and scale in China. Therefore, some argue that the property boom in China is not a big deal, since it is not a bubble because it is supported by a 'solid' demand for residential housing[6].

(E2) Monetary policy push

Since the boom in Chinese house prices is a national phenomenon, monetary policy may well provide a good explanation. Based on Bernanke and Gertler's (1995) discussion, there are two channels for monetary policy to impact the housing market. The first is by causing changes in house investors or speculators' balance sheets and income statements, including variables such as net wealth, cash flow and liquid assets. The second is the bank lending channel, which makes financial institutions more willing to supply loans and potential buyers willing to obtain the mortgages. Liang and Cao (2007) investigates the relationship between property prices and bank lending for the case of China over the period 1999–2006, and find that there is unidirectional causality running from bank lending to property prices. Some media articles saw the sharp increase in property prices in 2009 as a consequence of the extremely loose monetary policy adopted by the Chinese government to counter the global financial crisis, including easily-attainable bank loans and discounts in interest rates.

(E3) Inflation or user cost push

Loose monetary policy may produce positive shocks to both output and inflation, which result in rising inflation or user costs such as house rents[7]. To hedge against inflation and rising user costs, buying property is particularly appealing in China because the limited financial sector offers few other investment options. Some argue that the current growing demand in the housing market is due to certain companies' and investors' fear of inflation[8].

[6] Childs M. and Keene T., 2010. China's housing market isn't overheating, Roach says, *Bloomberg*, June 15, 2010.

[7] House rents may be defined as the user or opportunity cost of occupying a house; and if house rents increase, demand for buying house is likely to increase. The rent index published by Chinese authority may also be seen as complementary to inflation measures used by Chinese government, as the proportion of house rents in Chinese consumer price index (CPI) is much lower than those of many other countries, and hence the effects of house rents on inflation or inflation expectations has been greatly underestimated on the basis of CPI figures.

[8] People's Daily Online, July 14, 2009. Is inflation expectation pushing housing prices up?

(E4) Land price push

Many see the house price boom in China as being a result of local governments' dependence on land financing, namely local governments have strong incentive and capability to generate significant revenue from the sale of 'land use rights'. The soaring land price pushes up the house price. For instance, Du et al (2010) reviews the evolution of Chinese land policy over the past two decades and examines its impact on the dynamic relationship between housing and land prices in the Chinese real estate market. Using panel datasets from Beijing, Shanghai, Tianjin, and Chongqing, they find that there exists a long-run equilibrium between Chinese urban housing and land markets.

(E5) Exports or international trade momentum

Following the role models of Japan, Singapore and Hong Kong, China has relied on exports or international trade for driving its economic growth since it opened up its economy in 1978. Rapid growth of international trade volume has contributed much to the Chinese economic boom in the last thirty years and hence may provide momentum for house price changes. Wang et al (2010) examined the linkage between trade openness, the ratio of trade volume as a percentage of GDP, and urban real estate prices. They found that urban economic openness alone accounted for about 15.90% of the appreciation of Chinese real estate prices during the sample period.

(E6) Exchange rate fluctuation push

Many have argued that China's exchange rate policy played a critical role in its international trade and Foreign Direct Investment (FDI) booms and improved China's competitiveness in attracting FDI flows to China as well as creating favourable conditions for maximizing exports; see e.g. Xing (2006). Such arguments suggest that exchange rate fluctuations may influence house price changes.

(E7) Hot money push

Some argue that the speculative capital flow or 'hot money' due to RMB appreciation expectations is one of the main factors in accelerating the bubble. Zhang and Fung (2006) point out the speculative capital flow is one of main factors helped accelerate the bubble. Guo and Huang (2010) find supportive evidence for their research as well: hot money ranks as the second largest contributor to fluctuations of China's real estate prices.

(E8) Foreign reserve accumulation push

China's relative stabilization policy of the RMB exchange rate against the dollar as well as the corresponding huge amount of foreign exchange reserve and hence a large credit expansion as well as a relatively low (negative) interest rate, which helps to produce an increase in the house demand and hence greatly impact house price changes.

(E9) Stock market wealth push

China's stock market is relatively new. Its two official stock exchanges, the Shanghai Exchange and the Shenzhen Exchange, were established in December 1990 and July 1991, respectively. Accompanying the fast growing Chinese economy, the two exchanges have expanded swiftly since their establishment. According to statistics published by the World Federation of Exchanges (WFE), in January 2008 and July 2009, China had overtaken Japan to become the world's second-biggest stock market in terms of capitalization. By end-2009, the Shanghai and Shenzhen stock exchanges listed around 1,700 companies and had a market capitalization of US$3.57 trillion. This naturally leads one to conjecture that China's stock market wealth plays a significant role in pushing up house prices.

(E10) Rural-urban migration and urbanization

Compared with other countries, China differs in migration and urbanization patterns due to its unique Household Registration System (Hukou) and huge population base. Chen et al (2011) explore the possible effects of rural-urban migration and urbanization on China's urban housing prices and find that the different processes of provincial urbanization and the migration situation have significant effects on urban house prices in China. Coastal provinces receive a large number of migrants from inland provinces due to their rapid economic growth and employment opportunities and hence face greater pressure in the urban housing supply.

(E11) Other momentum factors

There are other factors for momentum in the house price boom as well, such as inefficient housing supply, market structure and urban economic openness. Inefficient housing supply means that in attempting to achieve rapid GDP growth, the Chinese government encouraged commercial housing construction and investment (Liu et al., 2002) and hence had no motivation to supply enough economic affordable housing. The inefficiency in housing supply results in higher house prices. The market structure factor emphasises the participation of large State-owned enterprises (SOEs) in the real estate market. Large SOEs can mobilize their own cash flows and loans from state banks to participate in the house market. They can afford to hold the market because they can privatize the benefits and socialize the risk. In such a case, house price continue to soar.

4 Data and methodology

4.1 Data

The aim of this paper is to gauge the impact of major macroeconomic factors on the housing pricing in China. We use national-level monthly time series from January 1999 to June 2010. For the dependent variable, we use a national house price index (H), and we test 16 potential determinants or predictors of housing price growth. Ideally, an aggregate house pricing model should consider factors from both the demand and supply sides and include as many variables in existing explanations and hypotheses as possible to examine which are quantitatively important. However, due to a lack of reliable aggregate data at monthly or quarterly frequency, such as rural-urban migration, economic and commercial house supply, and market structure, this study only examines the first nine explanations mentioned above, which are represented by E1, E2, E3, E4, E5, E6, E7, E8, and E9, respectively, and leave the other explanations for future research.

The first three are income variables used to study income effects in E1, including personal disposable income (PY), real GDP output (Y), and value-added industrial output (VAI). Real GDP is only published quarterly whereas we need monthly observations. To overcome this problem, we use the method of Cubic Spline Interpolation to split the data. Two measures of monetary policy, namely an average of medium and long-term Mortgage rates (MR) and a broad monetary aggregate (M2), are used for testing E2.

Popular measures of inflation in China include two goods price indices (consumer price index (CPI) and producer price index (PPI)) and a national rent index (R), which are used to test inflation push in E3. A national land price index (L) is used to investigate the effects of land prices in E4. The national rent and land price indices are also only available at quarterly frequency and hence are also split by the method of Cubic Spline Interpolation. To test E5, we make direct use of growth rates for both exports (EX) and imports (IM) rather than calculating trade openness by total value of exports plus imports divided by GDP. The reason is that using split real GDP at monthly frequency will introduce some inaccuracy to the definition of trade openness. To assess E6, we use the real effective exchange rate index (REER). To test E7, following Guo and Huang (2010), we define a new variable, hot money (HM), which is calculated by (change in foreign exchange reserves) minus (trade and service balance) minus (foreign direct investment). The 12-Month RMB/dollar Non-deliverable Forward contracts (NDF) is also collected in order to measure the effects of RMB expectations. To test E9, we use foreign exchange reserves (FR), and for testing E9 a stock price index (Shanghai Stock Exchange Composite Index, SP). During the entire sample period, Chinese authorities only published year-on-year growth rates for some time series such as VAI, CPI and PPI. Hence we also use year-on-year growth rates (percentage changes) of other variables, except hot money and mortgage rates.

All together, 17 monthly series are used, each series including 138 observations. The data are collected from the Wind Database, China Economic Information Network Statistic Database (CEI), and the Bloomberg database. Table 1 provides some summary statistics for these variables as well as their first differences. It shows that over the sample period most of the series display significant skewness and kurtosis. The Jarque–Bera test statistic suggests rejection of the null hypothesis of normal distribution for most variables except PY, PPI and REER. As recorded in the literature, the housing market growth rate always moves in a predictable cycle with positive serial price correlation, and much of empirical evidence has shown that house prices are far from a random walk and move in smooth and predictable patterns (DiPasquale and Wheaton, 1994). We have also found that there is significant autocorrelation in the house price growth rate and some other economic variables, the latter indicating volatility clustering, as is revealed by the Ljung-Box–Pierce and ARCH effects test statistics.

Table 1 Summary statistics for economic variables and their first differences

Variable	*Mean*	*Std. Dev.*	*Skewness*	*Kurtosis*	*Min*	*Max*	*Jarque-bera*	*Ljung-Box-Pierce*	*ARCH test*
H	0.034	0.027	-1.038	4.611	-0.053	0.091	39.71*	550.757	109.35*
ΔH	0.00001	0.008	1.764	12.778	-0.020	0.047	616.79*	73.615*	0.020
L	0.067	0.055	0.572	3.392	-0.065	0.227	8.42**	515.51*	129.63*
ΔL	0.00209	0.012	1.159	6.759	-0.026	0.058	111.33*	163.895	73.889*
R	0.014	0.019	-0.792	6.522	-0.059	0.064	85.74*	364.82*	82.60*
ΔR	0.00000	0.008	-4.234	35.274	-0.068	0.019	6355.1*	111.00*	118.28*
MR	0.054	0.005	1.154	3.405	0.049	0.066	31.55*	757.46*	129.70*
ΔMR	-	0.001	-4.123	26.605	-0.009	0.003	3568.8*	32.6**	9.182*
PY	0.135	0.052	-0.345	2.897	0.004	0.220	2.806	1335.93	135.26*
ΔPY	0.00081	0.006	-0.804	5.476	-0.021	0.013	49.76*	197.48*	80.272*
Y	0.102	0.020	0.532	2.555	0.064	0.146	7.64**	974.69*	132.25*
ΔY	0.00000	0.004	-0.801	5.200	-0.012	0.010	42.27*	112.45*	60.828*
VAI	0.136	0.046	-0.751	3.962	-0.034	0.251	18.28*	224.42*	29.83*
ΔVAI	-	0.048	-0.201	7.930	-0.185	0.167	139.65*	51.74*	17.381*
CPI	0.016	0.025	0.876	3.291	-0.022	0.087	18.15*	657.07*	125.92*
ΔCPI	0.00029	0.007	-0.351	4.325	-0.026	0.020	12.835*	78.3*	0.433
PPI	0.017	0.042	-0.380	2.517	-0.082	0.101	4.658	469.91*	117.40*
ΔPPI	0.00082	0.010	-0.263	7.546	-0.046	0.038	119.53*	219.09*	53.041*
M2	0.176	0.038	1.495	5.083	0.129	0.297	76.39*	628.18*	126.64*
ΔM2	0.00029	0.011	0.903	6.204	-0.030	0.050	77.219*	80.129*	0.011
REER	0.087	0.069	0.309	2.357	-0.039	0.261	4.571	1111.85	118.60*
ΔREER	0.00083	0.021	0.262	2.646	-0.040	0.052	2.285	50.60*	0.876
NDF	-0.0237	0.0386	-0.0308	4.2405	-0.132	0.0971	8.87**	376.8*	101.3*
ΔNDF	-	0.0169	-0.3006	3.5504	-0.0502	0.042	3.793	54.31*	31.5*
SP	0.181	0.554	1.649	6.044	-0.710	2.240	115.83*	661.52*	110.91*
ΔSP	-	0.170	-0.783	9.313	-0.919	0.521	241.52*	58.76*	1.759
EX	0.207	0.176	-0.908	3.314	-0.265	0.518	19.516*	352.5*	23.69*
ΔEX	0.00401	0.116	-0.117	5.776	-0.447	0.455	44.29*	74.55*	9.566*
IM	0.227	0.202	-0.290	4.222	-0.431	0.859	10.53**	303.47*	25.76*
ΔIM	0.00148	0.158	0.515	5.344	-0.410	0.618	37.4*	94.58*	18.392*
FR	0.286	0.143	-0.277	1.966	0.033	0.531	7.904**	1178.87	127.9*
ΔFR	0.00086	0.027	0.130	11.609	-0.123	0.147	423.47*	63.3*	0.080
HM	24.122	182.490	-1.090	9.745	-	611.980	288.93*	74.842*	4.223**
ΔHM	-	209.339	-1.534	12.567	-	671.982	576.15*	58.879*	21.015*

Notes: 1. * and ** denote the rejection of normal distribution, no serial correlation or ARCH effects hypothesis at 1% and 5% significant levels, respectively.

Table 2 presents the results of unit root tests for stationarity of both level values and first differences of the individual time series. As seen, 6 of 17 variables are stationary at the 5% significant level (R, VAI, PPI, NDF, IM and HM) and the remaining 11 variables are integrated of order one (I(1)).

Table 2 Tests for unit root

Variable	*Augmented Dickey-Fuller*		*Phillips-Perron*	
	Levels	**Differences**	**Levels**	**Differences**
H	-2.40	-8.00*	-2.54	-8.26*
L	-2.80	-4.03*	-1.91	-5.69*
R	-4.71*	-1.56	-4.06*	-9.48*
MR	-2.14	-7.86*	-1.99	-7.88*
PY	-2.16	-3.58*	-1.99	-4.28*
Y	-1.64	-3.80*	-1.82	-2.97**
VAI	-3.195**	-11.19*	-8.49*	-37.19*
CPI	-1.79	-5.73*	-2.24	-10.35*
PPI	-3.66*	-5.06*	-2.80	-5.15*
M2	-0.93	-6.05*	-2.44	-11.79*
REER	-1.54	-12.49*	-1.44	-12.59*
NDF	-3.91*	-6.55*	-4.07*	-8.39*
SP	-2.35	-8.81*	-2.37	-8.90*
EX	-2.59	-19.84*	-4.06*	-19.95*
IM	-3.04**	-19.45*	-5.19*	-19.62*
FR	-1.59	-3.57*	-1.82	-9.04*
HM	-8.07*	-12.30*	-8.24*	-23.32*

Notes: 1. The table presents the results of unit root tests for stationarity of the individual time series. 2. * and ** denote the rejection of the unit root hypothesis at the 1% level and 5% level of significance, respectively.

4.2 The NARAMX model, term selection and parameter estimation

The impacts of various macroeconomic variables on aggregate house price movements have been difficult to establish. There are frequent interactions between the various factors, and these determinants necessarily impact house price changes not only in direct or clear-cut ways but also in more subtle ways. For instance, tremendous pressure for RMB appreciation over the last ten years has left little space for the central bank in China to independently adopt interest rate policies. Decision making has to be done in international policy coordination: if the spreads between China's or other main countries' interest rates widen, then greater volumes of speculative money will seek entry into China. Exchange rate changes may also affect inflation expectations. Just as is the case for many other real world systems, the mechanisms behind house price movement are usually unknown and may be time-variant or nonlinear. Determining the structure of the house pricing model is the most difficult part of the identification process.

To cope with the complexities in house price dynamics, we adopt a NARMAX method with linear terms, and a NARMAX with nonlinear terms to investigate the extent to which economic variables are responsible for house price fluctuations, namely to select the structure of the house price model. As a generalization of the ARMAX model, the NARMAX model has successfully modelled many real world nonlinear systems, including chaotic electronic circuits, water management systems, turbocharged diesel engines (Billings and Coca, 2001) and more recently the visual system of fruit flies and other complex biological systems. It is also extremely useful in the linear case when there are many candidate variables or terms. The structure of the model can be formatted by selecting the terms with ERR above a chosen cutoff value. The final selected model will consist only of most significant terms. Zhang et al (2011) compare the out-of-sample predictive ability of three different modelling approaches, namely a cointegrated vector autoregressive and error correction (VECM) model, a Nonlinear Auto Regressive Moving Average with an eXogenous inputs (NARMAX) model with linear terms, and a NARMAX with nonlinear terms. They find that both NARMAX models outperform the VECM model.

The NARMAX representation with linear terms for the house price dynamics test all linear combinations of various variables and can be written as

$$\Delta H_t = \sum_{i=1}^{n} \alpha_i \Delta H_{t-i} + \sum_{i=0}^{n} \beta_i \Delta X_{t-i} + C + \varepsilon_t \tag{4.1}$$

where H is the dependent variable, house price, α, β are model parameters, t is the time variable, n denotes lag term and X is a data vector of 16 explanatory variables, i.e. $X = [H, L, R, MR, PY, Y, VAI, CPI, PPI, M2, REER, NDF, SP, EX, IM, FR, HM]$. C is the constant term, ε the error term, and Δ denotes the first differences operation.

The polynomial NARMAX representation of house price dynamics can be written as

$$\Delta H_t = \sum_{i=1}^{n} \theta_i p_i \left(\Delta H_{t-i}, \Delta X_t, \Delta X_{t-i}\right) + C + \varepsilon_t \tag{4.2}$$

where the $p_i(\;)$ are model terms that are a linear or nonlinear combination of variables, and the θ_i are unknown related parameters.

Model (4.2) includes all possible combinations of the variables, and the parameters for those terms can number in the hundreds or more when the order of nonlinearity is high. In this research, we set $n = 12$, and in general the second degree nonlinear terms of the nonlinear house price model produces over 20000 potential model terms. In practice, many of the terms will be insignificant or redundant and thus can be removed.

However, the most commonly used parameter estimation method Least Square (LS) is not capable of determining the significance from all the possible terms of a NARMAX model, and the information criteria usually employed to select parsimonious models based on the same data set may involve computational burdens because of the large number of candidate variables and the prohibitively large computational requirements of standard method when applied to large nonlinear models. Accordingly, the Orthogonal Least Square (OLS) algorithm was developed by Korenberg, Billings and Liu (1988) to overcome these difficulties. OLS allows the significance of the model terms to be determined based on the value of the Error Reduction Ratio (ERR) of each term. However, the original OLS algorithm has one major drawback, which is the choice of the initial orthogonalized position. The values of ERRs may change depending on the order in which the terms are entered into the model. The Orthogonal Forward Regression (OFR) was proposed to solve this problem by Billings et al. (1988). To save space here, we do not give the mathematical details of the Orthogonal Least Squares algorithm and the Orthogonal Forward Regression method here. The reader is referred to Billings et al. (1988, 1989), Korenberg et al. (1988), Chen et al. (1989), Billings and Zhu (1994), Wei, Billings and Liu (2004) for more information.

4.3 An new modelling strategy based on both NARMAX and cointegration and error-correction models

One of most popular econometric frameworks for dealing with multiple time series is the vector-autoregressive/error-correction model (VAR/VECM). VAR/VECM is a reduced-form linear dynamic simultaneous equation model in which all variables are treated as endogenous. A reduced form representation can be consistently estimated by regressing each variable on a number of lags of all endogenous variables. VAR/VECM is commonly used to measure the impact of monetary policy innovations in the literature and in general, and has proved to be a convenient method of summarizing the dynamic relationships among macroeconomic variables, and many have used it to include various combinations of variables, such as Bernanke and Gertler (1995) and Iacoviello (2005).

Nevertheless, the VAR/VECM has some limitations. Firstly, the candidate variables or terms to be selected here are too numerous for such models, because they can only handle up to 8 or 12 variables (Gupta et al, 2010). Secondly, this strand of models has an important deficiency in selecting explanatory variables and may face an over-fitting problem. Zhang et al (2011) demonstrate the accuracy of NARMAX models in predicting out-of-sample stock market returns over the popular VAR /VECM approach. Thirdly, when interpretation of VAR/VECM results are given, more studies focus on impulse response functions, whereas estimated parameters of VAR models contain little information. Finally, the use of different identification schemes in a VAR/VECM can alter the results significantly (Vargas-Silva, 2008).

NARMAX modelling can also be applied in the linear case when the number of candidate variables or terms is high and one is able to overcome the limitations of VAR/VECM. However, one shortcoming of NARMAR modelling is that the trends must first be removed, for which reason first differences of variables are used in NARMAX modelling and forecasting. As seen in Table 2, many economic variables used in this study are non-stationary and integrated of order one, I(1). If a linear combination of two or more nonstationary, I(1), time series is stationary, I(0), then the variables are cointegrated. Ever since Engle and Granger (1987) introduced the concept, cointegration has been widely investigated, because many time series in economics and business are I(1), and many I(1) series are indeed cointegrated. Although it is argued that cointegration is a purely statistical concept and the cointegration relationship need not carry economic interpretation (Maddala and Kim, 1998), cointegration still has important implications for long-run relationships such as predictability, causality, and market efficiency among the time series in question. The direct use of first differences in the NARMAX model may be too costly because it removes long-term co-movements.

To overcome the problem, we observe the empirical modelling strategy of combining the co-integration/error-correction model with the NARMAX model. To see whether cointegration relationships may improve forecasting performance, we use cointegration tests to uncover the long-run relationshipst, and then add these long-run cointegtation equations to the NARMAX model. This new modelling strategy is very easy to use in long term time series forecasting, which is an important practical problem with a variety of applications in business and economic planning.

5 Empirical results

5.1 Modelling with NARMAX techniques

5.1.1 Linear house pricing model

In the NARMAX model with linear terms we include all the variables above and their lagged terms up to 12. There are 208 terms in model (4.1). Table 3 shows the terms generated by the NARMAX term selection algorithm.

Table 3 Selected terms for linear house price model

Term	*ERR*	*Parameter*
$\Delta MR(t-11)$	16.6633	-1.9313
$\Delta PPI(t)$	9.6065	0.1997
$\Delta M2(t-5)$	7.6137	0.2091
$\Delta REER(t-11)$	6.5512	0.1111
$\Delta R(t-4)$	4.4612	0.4565

As listed in the Table 3 according to ERR ranking, the eleventh lag of mortgage rate is the most significant term for describing house price changes, and it accounts for 16.7% of the total variance in output. It enters the model with a negative parameter, which indicates that it has negative effects on house price dynamics. The other four terms which are also significant in affecting the changes in house price growth rate include growth rates in changes in PPI at current sampling point[9], 5-month lagged broad money supply, 11-month lagged real effective exchange rate and 4-month lagged house rents. All together, they account for around 28.23% of house price variance. The autocorrelation of the modelling residuals indicates that the estimated model in Table 3 has not been rejected, as there is no outlier outside of the 95% confidence bounds.

To summarise, the results for the linear formulation show that the most significant explanatory factors for house price dynamics are mortgage rate, PPI, broad money supply, real exchange rate and house rental; and obviously they are all associated with monetary variables. Real economic activity variables such as GDP, personal disposable income, value-added in industrial output, exports, and imports, and such other variables as land price, CPI, stock index, hot money and foreign reserves, have rather weak explanatory power from a statistical point of view.

[9] The value of changes in PPI at current sample point is unknown when the model is used to predict the future house price. Therefore, a model is also needed to predict the PPI process. It is listed in Appendix A.

5.1.2 Non-linear house pricing model

The non-linear effects of various economic variables on house price are then investigated by the NARMAX approach as well. In general the second degree of the nonlinear house price reference model has over 20000 terms if all combinations are included. Based on the term selection algorithm, the ultimately selected nonlinear house price model is displayed in Table 4.

Table 4 Selected terms for non-linear house price model

Term	*ERR*	*Estimated Parameter*
$\Delta MR(t-11)\Delta VAI(t-11)$	30.4119	58.5591
$\Delta PPI(t-1)\Delta Y(t-10)$	12.4339	-42.5545
$\Delta REER(t-9)\Delta SP(t-2)$	12.8443	0.9004
$\Delta EX(t-8)\Delta HM(t-4)$	7.2845	-0.0001
$\Delta H(t-6)\Delta PPI(t-9)$	5.1456	27.3582

As seen in Table 4, the product of 11-month lagged mortgage rates and value-added industrial outputs best explains the variance in the house price growth rate, and its ERR is as high as 30.4119. Other nonlinear terms, including the product of 1-month lagged producer price index and 10-month lagged GDP growth, the product of 9-month lagged real effective exchange rate and 2-month lagged stock index, the product of 8-month lagged export growth and 4-month lagged hot money, and the product of 6-month lagged house price index and 9-month lagged producer price index, are able in combination to account for 37.71% of house price variance.

The empirical exercise reveals significant nonlinearity in the house price determination process. The results for the nonlinear modelling generally show that nine macroeconomic variables - mortgage rates, value-added industrial output, PPI, GDP, exchange rate, stock index, exports, hot money and past house price - have mostly significant nonlinear effects on house price dynamics. Among them, the mortgage rate in combination with industrial output has the most explanatory power, while the products of PPI and output, exchange rate and stock index, hot money and exports, and inflation and past house prices also have significant effects on house prices. Other macroeconomic variables such as changes in personal disposable income, land price, house rental, CPI, foreign reserves, RMB appreciation expectations, and imports do not have significant nonlinear impacts.

5.1.3 Linear NARMAX modelling with co-integration relationships

For 11 non-stationary variables, we conduct both trace and Max-eigenvalue tests for cointegration, and both indicate 4 cointegration equations at the 5% level. From an economic view, it is difficult to interpret the results of cointegration analysis when there is more than one cointegration relationship (Maddala and Kim, 1998).

Because our aim here is to investigate the determinants of China's housing prices, with a special focus on monetary policy variables, we choose to normalize four variables, Y, PY, M2 and MR. The corresponding four cointegrating equations (standard error in parentheses and t-statistics in brackets) are reported in Table 5. The results show that house price enters every cointegration equation with a significant coefficient.

Table 5 Coefficients of four cointegrating equations

	Y_{-1}	PY_{-1}	$M2_{-1}$	MR_{-1}	H_{-1}	CPI_{-1}	L_{-1}	EX_{-1}	$REER_{-1}$	FR_{-1}	SP_{-1}	C_{-1}
CE01	1	0	0	0	-2.004	-0.489	-0.809	0.242	0.683	0.360	-0.049	-0.175
					(-0.328)	(-0.448)	(-0.251)	(-0.067)	(-0.179)	(-0.095)	(-0.016)	
					[-6.115]	[-1.093]	[-3.218]	[3.634]	[3.814]	[3.789]	[-3.083]	
CE02	0	1	0	0	-5.950	-3.114	-2.054	0.757	1.602	1.041	-0.101	-0.319
					(-1.074)	(-1.467)	(-0.823)	(-0.218)	(-0.587)	(-0.311)	(-0.053)	
					[-5.542]	[-2.123]	[-2.495]	[3.469]	[2.729]	[3.345]	[-1.932]	
CE03	0	0	1	0	-1.082	-0.966	-0.708	0.383	0.584	0.301	0.012	-0.293
					(-0.260)	(-0.355)	(-0.200)	(-0.053)	(-0.142)	(-0.075)	(-0.013)	
					[-4.157]	[-2.719]	[-3.551]	[7.245]	[4.103]	[3.987]	[0.930]	
CE04	0	0	0	1	-1.510	-0.448	-0.510	0.235	0.458	0.281	-0.020	-0.126
					(-0.228)	(-0.312)	(-0.175)	(-0.046)	(-0.125)	(-0.066)	(-0.011)	
					[-6.618]	[-1.437]	[-2.912]	[5.067]	[3.670]	[4.245]	[-1.780]	

We then add all four cointegration equations without lagged terms to our NARMAX specification, and the selected model is the same as for the linear NARMAX, which is shown in Table 3. The suggests that adding current cointegration restrictions does not greatly improve the estimation efficiency.

To check whether there may be a lagged partial adjustment mechanism, we add lagged cointegration relationships to the linear house pricing model. The new selected linear model is displayed in Table 6.

Table 6 Selected terms for linear house price model with cointegration equations

Term	*ERR*	*Parameter*
$CE01(t-8)$	25.9201	0.0427
$\Delta REER(t-11)$	7.8611	0.1093
$\Delta PPI(t)$	6.0474	0.2119
$\Delta MR(t-11)$	3.7874	-1.5186
$\Delta PPI(t-10)$	3.0194	0.1742

The results of linear modelling with lagged cointegration equations indcate that adding the long-run cointegration relationship at the eighth lag, defined in the first cointegration equation, is the most significant term in the estimation, and other significant variables include 11-month lagged exchange rate, PPI at current sampling points, 11-month lagged mortgage rate, and 10-month lagged PPI. This indicates that the long-run relationship between GDP, house price, CPI, land price, exports, REER, foreign reserves and stock price index may have a lagged impact on house price dynamics. Since the cointegration relationship does not necessary permit economic interpretation, we are unable to conclude from this result that individual variables of GDP growth, CPI or other variables included in this cointegration relationship have significant effects on house price dynamics. However, other significant terms, such as REER, PPI, and MR, do indicate significant effects on house price dynamics.

To summarise the results of all three linear and nonlinear formulations, three variables including mortgage rate, PPI, and REER exhibit both linear and nonlinear impacts on house prices, while broad money is identified to have only a linear impact. Five factors, VAI, GDP, exports, hot money and stock market index do not exhibit independent significant linear effects, but their combinations with monetary or price variables have significant nonlinear effects. The empirical exercise lends most support to the explanations of E2, E3 and E6, and provides some evidence for E1, E5, E7 and E9. Other variables such as personal disposal income, CPI and land price have no explanatory power for house price dynamics.

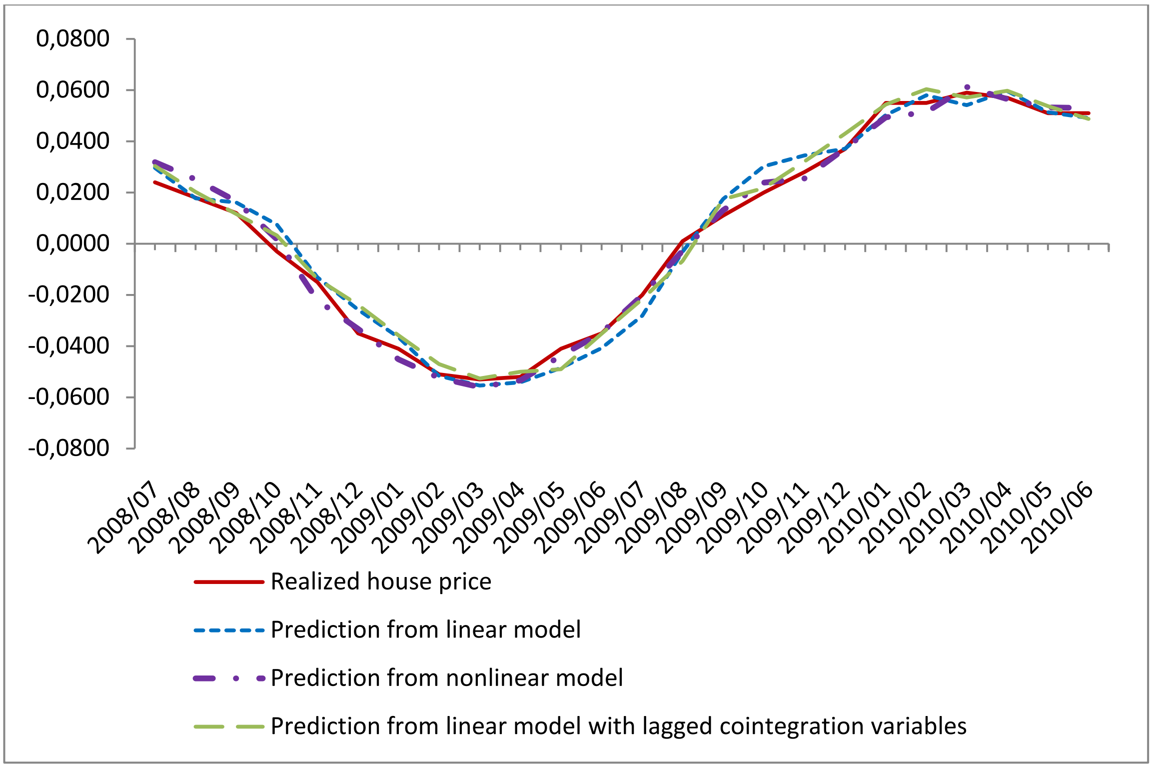
5.1.4 Forecasting and back testing

Forecasting ability is a key criterion for evaluating model performance. Once the house pricing models in Table 3, 4, and 6 are estimated, their prediction ability needs to be assessed. We produce in-sample one-step-ahead forecasting at first and then use back test results to test their out-of-sample predictive ability.

5.1.5 In-sample forecasting and errors

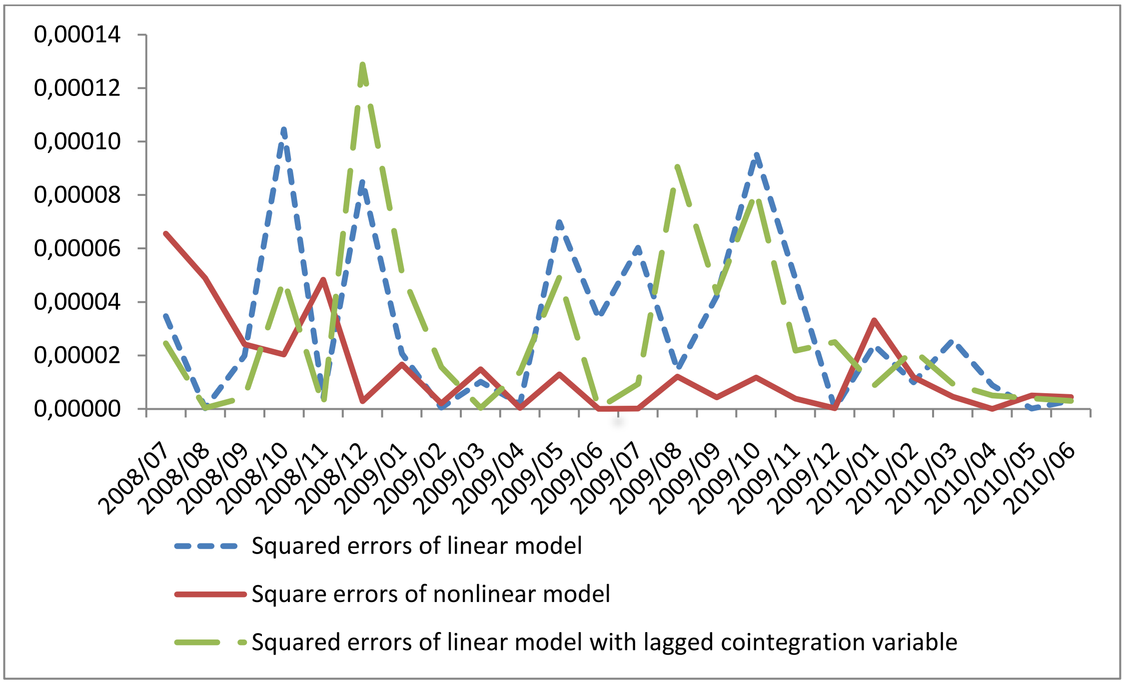
Due to the limited numbers of sample size, only predicted growth rates in the final two-year period of the entire sample, namely 2008:07 to 2010:06, are produced using NARMAX models. The predicted house prices and realized house prices are shown in Figure 2. As seen, the NARMAX method is generally very powerful in predicting the house price growth rate over this two-year period. The movements in predicted house price grow rate by both linear and nonlinear models are very consistent with those in the realized one.

Figure 2 A comparison of predicted and realized house price growth rates



The in-sample forecasting errors of the linear and nonlinear house price models are drawn together in Figure 3. The mean of the squared errors for predictions from the linear NARMAX, the nonlinear NARMAX, and the linear NARMAX with lagged cointegration variables are 0.00299%, 0.00145%, and 0.00276%, respectively. To summarise, the in-sample errors of the nonlinear model are smaller than those of the other two models and hence have the best one step ahead prediction ability. This is evidence of significant non-linear effects.

Figure 3 In-sample squared forecasting errors of house price models

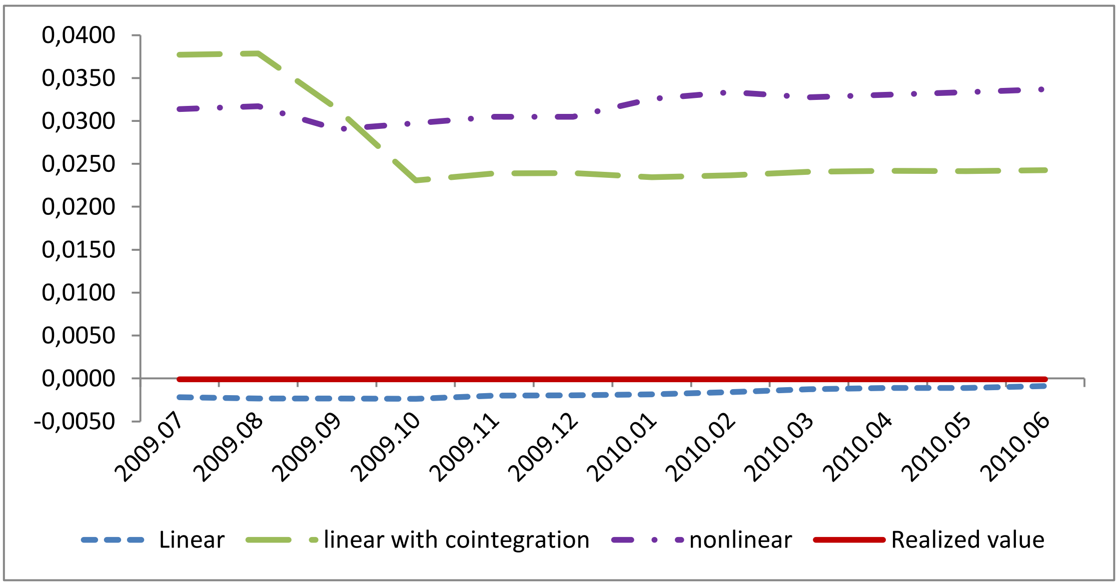


5.1.6 Back testing for robustness of out-of-sample forecasting

Back testing can indicate whether the underlying model produces good out-of-sample predictions (Dowd et al., 2008). Therefore, in this part the back testing method is employed to check the ex post forecast performance of the fitted NARMAX type house pricing models. Since all three models involve external variables the prediction of these variables may impact the back testing results. Therefore, the values of these variables are assumed to be known and back-testing is used solely to compare the house price models.

A rolling window prediction of the most recent value, which is the difference between house prices at 2010/05 and 2010/06, is used with a window length of 126. The rolling window begins at the differences of house price between 2009/06 and 2009/07 and ends at the most recent value. The parameters of terms in each model are separately estimated in each rolling window and the parameters are then used to predict the most recent value. The rolling window predictions of these three models are then drawn together in Figure 4 for comparative purposes.

Figure 4 Rolling window predictions of most recent house price differences at 2010/05-06



It is clear from Figure 4 that predictions from the linear model are converging to the realized values and predictions from the nonlinear model display a nearly constant departure from realized values. Predictions from linear model with lagged cointegration variables converge a little around 2009/08-09 and then display a constant departure from realized values. This also indicates that the nonlinear house price model is sensitive with parameter estimation, as the prediction errors are much bigger than those for the linear model. The linear model with lagged cointegration variables suffers a problem similar to that of the nonlinear model.

To summarise, our back testing results show that the linear NARMAX model is more robust to parameter change and hence has the best out-of-sample predictive ability. Nonlinear NARMAX modelling, i.e. adding the long-run relationship restrictions to the linear NARMAX specification, is more sensitive to parameter estimations.

6 Conclusions and policy implications

The aim of the paper is to analyze the likely effects of various macroeconomic variables on house price movements in China during 1999:01-2010:06. We adopt three NARMAX approaches to investigate whether recently surging China's house prices have been justified quantitatively by changes in fundamental factors such as land price and personal disposable income or are simply a monetary phenomenon.

Several interesting findings are obtained. First, both linear and non-linear estimation results identified a number of monetary variables as the most important explanatory factors for Chinese house prices, including most notably mortgage rate, producer price, and real effective exchange rate. Secondly, other factors - VAI, GDP, exports, and stock market index - have significant nonlinear effects on house price dynamics, but only if linked to monetary or price variables. Most remarkably, a key income variable, personal disposable income, has no explanatory power on Chinese house prices at all. Thirdly, the nonlinear formulation reveals that there is significant nonlinearity in house price dynamics conditioned on economic factors. This reveals the significant roles played by the product of mortgage rates and value-added industrial output, the product of producer prices and GDP growth, and the product of real effective exchange rate and stock index are dominant in the determination of house prices.

We also test both in-sample and out-of-sample forecasting performance of all three NARMAX models. Both linear and nonlinear models estimated using the NARMAX approach proved to be very powerful tools for predicting future housing prices. In comparison, the linear model is more robust to out-of-sample parameter changes while nonlinear model has the best in-sample one-step-ahead prediction ability. Adding the long-run cointegration relationship restrictions to our NARMAX specification generally does not greatly improve either the in-sample or out-of-sample predictions.

This study is of both academic and policy importance. There is a continual debate about the relationship between the house price boom and monetary policies in China or other countries. This case study of China's experiences shows that monetary policies and price variables may be key factors influencing house prices in China, while other aggregate economic variables have relatively less significant impacts or have to be linked to monetary or price variables to exhibit nonlinear effects. Our findings also have some important implications for policymakers regarding the real estate market in China. The government should probably begin to adjust the monetary policies, such as interest rates, exchange rates and money supply, in order to effectively contain the housing bubble.

Appendix A

Table A. 1 NARMAX selected terms for PPI model

Term	*ERR*	*Parameter*
$\Delta PPI(t-1)$	46.0740	0.6094
$\Delta PPI(t-12)$	11.3720	-0.4107

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