# House Price Effect on Consumption: an MSTVAR Approach for Three OECD Countries

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# ABSTRACT

House prices and their effect on aggregate economy has always been a matter of interest for economists and policy makers. Especially, in recent years, after U.S. mortgage crisis many researches were conducted to study this effect to evaluate its magnitude and importance. Several theories are supporting the idea that there is a spillover from housing to other parts of economies, like consumer’s expenditure theory.

In this study the effect of changes in house prices on aggregate economy was examined by a nonlinear model, Logistic Smooth Transition Autoregressive model for US, Germany and UK quarterly data from 1970 to 2011.

**Keywords:** House prices, Nonlinearities Time Series, LSTVAR, Consumption.

# ÖZ

Konut fiyatları ve toplam ekonomi üzerindeki etkileri her zaman ekonomistler ve politika yapıcılar için ilgi konusu olmuştur. Özellikle son yıllarda, ABD'de mortgage krizi sonrasında, bunun önemini değerlendirmek için, bir çok araştırma etkisini araştırmak amacıyla yapılmıştır. Çeşitli teoriler konut fiyatları ve tüketim arasında bir bağlantı olduğu fikrini desteklemektedir.

Bu çalışmada ekonomisi üzerindeki ev fiyatlarındaki değişimlerin etkisini doğrusal olmayan bir model tarafından muayene edilmiştir. Üçer aylık veriler üç ülke, Amerika Birleşik Devletleri, Almanya ve Birleşik Krallık için elde edilmiştir.

**Anahtar Kelimeler:** Konut fiyatları, doğrusalsızlığı, zaman serisi, LSTVAR, tüketim

*TO My Dear Husband*

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# Chapter 1

# INTRODUCTION

House prices and their effect on aggregate economy has always been a matter of interest for economists and policy makers. Especially, in recent years, after U.S. mortgage crisis many researches were conducted to study this effect to evaluate its magnitude and importance. Several theories like consumer's expenditure theory, are supporting the idea that there is a spillover from housing to other parts of economies.

Housing as a main household's collateral asset can affect their consumptions. Households try to normalize their consumption throughout their lifetime income and wealth, based on life cycle theory. They prefer to borrow at early stages of life and repay their loan, as they get older, so the value of their houses plays an important role as collateral to effect their consumption. An increase in its price will make it easier for household's to borrow based on its value, and as a result increase their consumptions. And with recent institutional innovations it becomes even easier for households to withdraw money from their home equities to support their consumptions.

Also households prefer to adjust their expenditures with their expected lifetime income. So any unexpected changes in their lifetime income will result in a change in consumption. Based on this hypothesis when house prices increases, household's estimation of their houses future return will increase, and this unexpected change will cause a change in consumption.

It is also must be noted that, housing wealth has influence on consumption via wealth effect. Household's wealth constitutes of different parts, and housing being the main component of it can exert a significant effect on consumption. An increase in housing prices will increase the housing wealth, which in turn will affect the household consumption.

Although these views support the idea that there is a link between house prices and consumption, there are some other theories against this hypothesis. While there are so many studies showing that house prices are affecting aggregate economy, some studies where conducted to show that such relationship does not exist.

Another issue which must be concerned in this topic is the nature of the house prices time series. In most of the studies it was suggested that house prices are linear, and tried to study it's relation with other parts of economies in a linear context. But there are some studies which tested the linearity of house prices and fund some evidences against it.

Based on these theories and the fact that there are evidences against linearity in house prices, in this study a nonlinear structure will be constructed to examine the effect of house prices on economy.

For this purpose Logarithmic Smooth Transition Vector Autoregressive model is going to be used as a nonlinear context to analyze the spillover of housing market to aggregate economy. Three countries, United States, Germany and United Kingdom, are chosen and their quarterly data will be used.

In the following chapter, some previous works in this area will be reviewed. After that in chapter 3 the methodology of constructing the model and estimating impulse response functions will be explained. Parameter estimations will be conducted and results will be examined and reported for three countries in chapter 3. And finally conclusion will be brought to you in chapter 4.

# Chapter 2

# LITERATUE REVIEW

There are numerous studies about the relationship between house prices and aggregate economy. Although there are some theories suggesting that changes in house prices must have some influence on household demand, such relationship is doubtful. Some issues are represented by economists concerning the fact that housing being not only an investment but also a consumption good, will not cause a significant change in household's expenditures as it's value changes, because people only buy housing as they needed. As Sinai, Todd, & Souleles (2005) put it, "Homeownership provides a hedge against fluctuations in future rent payments."

The other issue which is opposing to the idea that house prices and consumption are related is that in aggregate the effect of changes in house prices may be canceled out in economy, since there are both buyers and sellers in the housing market (Skinner J. , 1989).

So many studies addressed these issues and tried to define the relationship between house prices and economic activities and find the magnitude of this relation. In early 1950's Modigliani and Brumberg (1954) introduced a hypothesis that suggest people determine the level of their spending based on the recourses that will be available to them during their entire life. Based on their hypothesis they estimated 4 cents per dollar of marginal propensity to consume for wealth in US. After this result many researches start to study the wealth effect on consumption.

Elliott (1980) in an early study examined the housing wealth effect on consumption. While he found that household's money and financial assets have significant effect on consumption, the effect of non-financial assets, particularly real state was of no value. But his finding was challenged by later studies, which in most of them it was reported that housing can affect aggregate economy through wealth effect.

Skinner (1993) address the issue by asking the question that "Is housing wealth a side show". In the study he argued that in 1970's house prices were increased notably and brought a great amount of wealth to their home owners, and it is expected that by decrease in their prices, households suffer from a potential loss. Despite the changes in housing wealth he examined the changes in household's welfare, to find if changes in house prices have an important effect on consumption and savings or just have "side show" effect on them. What he found was 6 cents increase in US household's consumption in response to 1$ increase in housing wealth.

In another study Green (1997) examined the link between residential investments with GDP. He used granger test to study such relationship for United States using quarterly data from the years 1952-1992. What he found was that residential investments are causing GDP and are leading business cycles while non-residential investments are lagging it.

Case, Quigley, & Shiller (2001) also studied the relation between financial wealth, housing wealth and consumption. They used annual data for panel of 14 developed countries for 25 years and quarterly data for United States from 1980's to 1990's using aggregate consumption and aggregate housing wealth. They found a strong link between variation in housing wealth and consumer expenditures. They also concluded that the effect of the housing wealth on consumption is more important than stock market's effect.

In a more recent study for US Ghent & Owyang, (2010) examined the relationship between house prices and business cycles. They examined 51 cities data and found that house prices are not good leading indicator for business cycles, which was contradictory to other literature that found a link between them.

Iacoviello & Neri, (2010) used a Bayesian method to develop a model and showed that there is a significant spillover from the housing market to consumption for US economy. Andre, Gupta, & kanda (2011) also examined if there is any spillover from housing to consumption using six VAR model. In their study of seven OECD countries they found a positive and significant link between house prices and consumption for Canada, France, Japan and UK.

Most studies more or less are supporting the idea that there is a link between house prices and household consumption; however there are some contradictory evidences among them. But what is common among all these studies is considering house prices following a linear model and trying to examine the relationship between housing market and wider economy using linear methods, while there are some evidences of non-linearity in house prices.

Kim, Sei-Wan, Bhattacharya, & Radha, (2009) questioned the linearity of house prices. They examined US data from 1964 to 2004 in four regions for existing of nonlinearity in a format of smooth transition autoregressive (STRA) model. What they found was nonlinearity in all areas except Midwest region.

Balcilar, Gupta, & Shah, (2011) also examined the nonlinearity in house prices this time for 5 segments in South Africa based on a smooth transition autoregressive model. They find an strong evidence of nonlinearity for all segments. They also support their findings by comparing the out of sample forecasts between the multivariate format of nonlinear and classical and Bayesian model, for each of the five segments and showed that nonlinear model is giving better estimates than linear ones.

In another recent study Guerrieri & Iacoviello, (2012) suggest an asymmetry in house price effect on consumption. They studied the collateral effect of house prices on consumption and find that the positive effect of increasing house prices on consumption is small where the negative effect of declining house price is large.

Based on these evidences of nonlinearity and asymmetry in housing market in this study the effect of changes in house prices on aggregate economy will be examined via a nonlinear model for US, Germany and UK quarterly data from 1970 to 2011. The framework that is going to be used is the multiple equation format of Logistic Smooth Transition Auto Regressive (LSTVAR) model.

# Chapter 3

# METHODOLOGY

## 3.1 STAR Model

One way for modeling nonlinear time series is by defining different regimes for the time series and allowing the parameters of variables to change along different regimes across the time (Priestley, 1980). Different kinds of models were proposed based on this definition of non-linearity with different approaches. One group of these models assume that for each regime time-series follow a linear autoregressive pattern, but parameters of each linear model is unique for each one of them. Among this group two types of models are defined, where in one type it is assumed that there exist an observable variable and the changes between different regimes will be determined by the value of that variable. In the other type it is assumed that the regimes cannot be observed. Smooth Transition Auto Regressive (STAR) model, which is going to be used in this study, belongs to the first type.

STAR model is a generalized format of self existing TAR model, assuming that there exist a smooth transition between different regimes (Chan & Tong, 1986) and this assumption makes it different from models like TAR with discrete jumps between different states of economy. STAR framework with two regimes being involve is represented by (Teräsvirta, 1994):

$$y_t = \left(\emptyset_0 + \sum_{i=1}^{p} \emptyset_i y_{t-i}\right) . \left(1 - f\left(y_{t-d}\right); \gamma, c\right)$$

$$+ \left(\rho_0 + \sum_{i=1}^{p} \rho_i y_{t-i}\right) . f\left(y_{t-d}; \gamma, c\right) \qquad (1)$$

where *f* is a transition function, which is a continuous function and changes smoothly from one regime to another and take values between 0 and 1. This function depends on the past realization of time series under investigation and as it increases throughout time it controls for the transition of the model from one regime to other. Parameter d here is the delay parameter making $y_{t-d}$ threshold variable, a lagged value of the variable under analysis, which in turn along with the value of transition function will determine the occurring regime at time t (Teräsvirta, 1994)

Two different interpretations are existed for STAR models. In one of them, two different regimes will be defined for extreme values of transition function, $f\left(y_{t-d}; \gamma, c\right) = 0$ and $f\left(y_{t-d}; \gamma, c\right) = 1$, and a smooth transition will be allowed between two regimes. In other format a continuum set of regimes will be considered determined by the value of transition function. In this study first interpretation (two regimes) will be considered.

There are different choices for transition function with different behavior. One of the popular forms of them is logistic format, which was defined by Teräsvirta and Anderson (1992) and will be used in this study:

$$f\left(y_{t-d)}; \gamma, c\right) = \frac{1}{1 + \exp\left(-\gamma\left(y_{t-d} - c\right)\right)} \qquad (2)$$

The parameter γ here determines the speed of the transition between two regimes, and c is the threshold between to regimes around which the dynamic of model will change. As $y_{t-d} - c$ increase the function will approach 0 and when it goes down the function will monotonically change to 1. Substituting this function in equation (1) will produce Logistic STAR (LSTAR) model.

LSTAR models are suitable for modeling asymmetries where different two regimes are corresponding to low and high values of transition variable relative to threshold values. Models with expansions and contractions are perfect example of these kinds of asymmetries.

One must notice that when γ becomes very large, the model will change almost instantaneously between two regimes at point c and the model will approximate to SETAR. In other extreme, when γ takes zero, logistic functions become constant and so the model will be no longer nonlinear.

Figure 1 shows some examples of logistic functions with different values of γ where c = 0. It is shown that as γ getting larger the function get steeper and at very large values of γ the function become an indicator function $I\ y_{t-d} - c > 0$ , where $I\ A$ =1 if A is true and otherwise will be zero. This will cause an abrupt jump between different states and STAR model will approaches SETAR. Based on these properties of LSTAR we will be able to define two regimes with different dynamics and allow a smooth transition from one two another as the difference between $y_{t-d}$ and $c$ gets larger.

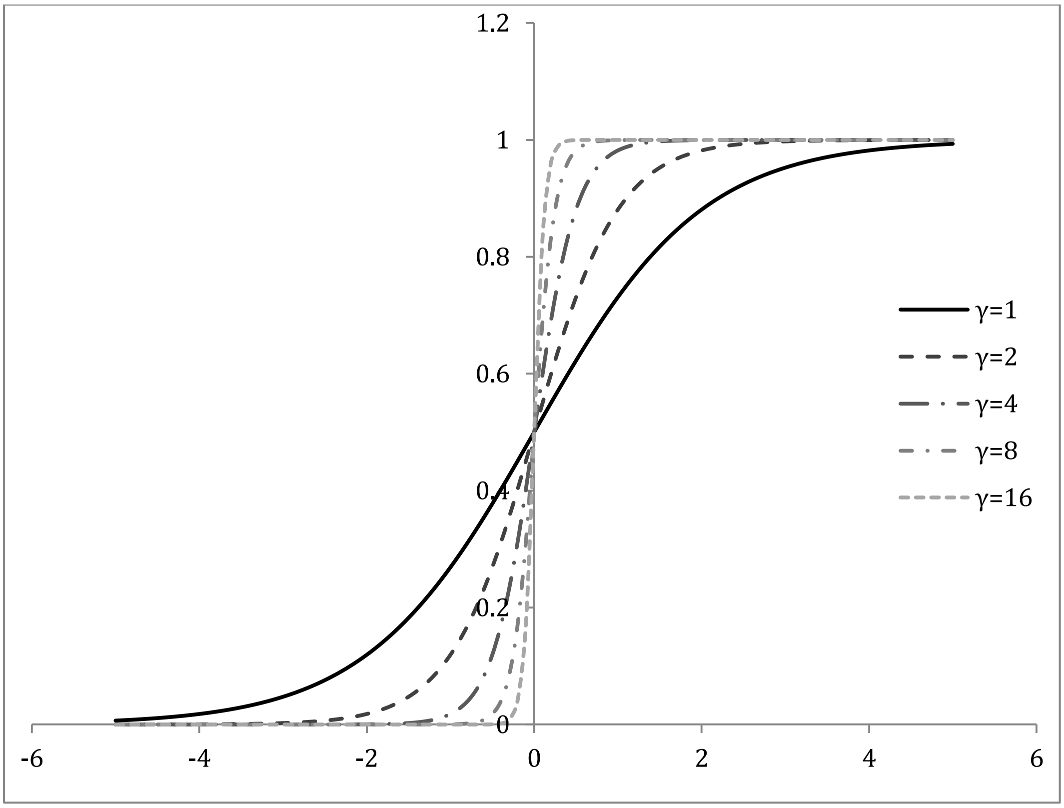



Figure 1: Transition Function, as γ gets larger the transition function gets steeper, when γ=16, transition function is almost instantaneous.

## 3.2 Vector STAR Models:

Vector Auto Regressive (VAR) model is a common way to model vector time series. VAR models are dynamic system of equations which allow every variable to be defined with past realizations of it and other variables in the system:

$$y_t = \theta_0 + \theta_1 y_{t-1} + \theta_2 y_{t-2} + \cdots + \theta_p y_{t-p} + \epsilon_t$$

Where $y_t$ is a vector of endogenous variables, $\theta_i \; for \; (i = 1, \dots, p)$ are coefficient vectors and $p$ is the number of the lag in the system.

We can extend the univariate context to multivariate format and use it to study regime-switching type of nonlinearity in VAR models. Consider a VAR model with k different time series, the resulting STVAR model will be:

$$y_t = \emptyset_0 + \emptyset\ l\ y_{t-1} + \ \theta_0 + \theta\ l\ y_{t-1}\ F\ z_t\ + u_t \quad (3)$$

where $y_t$ is a vector of (k×1) elements, $y_t = \ y_{1t}, \dots, y_{kt}$ , $\emptyset_0$ and $\theta_0$ are $(k \times 1)$ vectors, and $\emptyset(l)$ and $\theta(l)$ are infinite order polynomials in lag operator.

One thing that must be considered in equation (3) is that all the variables are facing the same regime, because the same transition function is controlling for changing from one state to another.

### 3.3 Modeling Procedure:

Following the approach of (Teräsvirta, 1994) for describing the specifications of nonlinear models six steps need to be considered:

1) Specifying an appropriate baseline linear VAR model for the time series under investigation.
2) Test null hypothesis of linearity against LSTVAR type of nonlinearity and if null get rejected choosing the best transition variable that suits the data the best.
3) Estimate the parameter of the model.
4) Using diagnostic tests for final approval of the model and finding inadequacy in the model.
5) Making necessary adjustment for the model
6) Use model for descriptive or forecasting purposes.

In the following, each step will be explained briefly, for more detail see (van Dijk, Franses, & Lucas, 1999a)

First step includes finding the appropriate lag order p for the linear VAR(p) model:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots + \alpha_p y_{t-p} + \varepsilon_t$$

There are different approaches that can be used to determine the appropriate lag order for VAR model, some methods like Akaike Information criterion (AIC) or the Schwarz Information criterion (SC).

**3.3.1 Nonlinearity Test:**

Next step is testing for nonlinearity of the model. In this step other than testing linearity against LSTVAR model, one can also run several portmanteau tests. BDS test is one model of these kinds of tests but rejecting nonlinearity using these tests will not necessarily mean existing of LSTVAR kind of nonlinearity, so other tests must be done to reject linearity in favor of LSTVAR.

As was explained earlier, when $\gamma=0$ star model will collapse to linear format. So it seems natural to test for the null hypothesis of $\gamma=0$ against $\gamma>0$ as a test of nonlinearity. Also there is another alternative test, where null hypothesis will be equating parameters of the different regimes to each other against the alternative hypothesis that they are not equal.

$$H_0\colon \emptyset_0 = \theta_0, \emptyset = \theta, \qquad H_1\colon \emptyset_0 \neq \theta_0 \; or \; \emptyset \neq \theta$$

For each of these tests there exists an identification problem, because there are nuisance parameters in each of them that are only identified under alternative hypothesis and are not restricted under null hypothesis. As a consequence of nuisance parameters classical statistical approaches cannot be used anymore. In order to solve this problem Luukkonen, Saikkonen, & Teräsvirta (1988) suggested using a Lagrange multiplier test with asymptotic $\chi 2$ distribution. In this test there is no need to estimate the model under the alternative hypothesis. In order to derive the test the model (3) is rewritten in the form of:

$$y_t = \emptyset_0 + \emptyset \ l \ y_{t-d} + (\theta_0 + \theta \ l \ y_{t-d} F^* \ z_t \ + u_t$$

where:

$$f^* = (1 + exp \ -\gamma \ z_t - c \ \ )^{-1} - \frac{1}{2}$$

and the first order Taylor approximation around γ=0 of the new transition function will be substituted in the model, which after some parameterizations and arrangements will yield the auxiliary model which will be used in a 3 steps procedure to produce the LM test. The steps here are followed from Granger & Teräsvirta (1993) and modified to multivariable format. Assume that we have a VAR model of order p with k variables. Define:

$$x_t = y_{1,t-1}, y_{1,t-2}, \dots, y_{1,t-p,} \dots, y_{k,t-1}, \dots, y_{k,t-p}$$

Now conduct the linearity test for each equation as below following Luukkonen et al. (1988):

1) Estimate the linear model (restricted model) by regressing $y_{it}$ on $x_t$ and collect residual $\varepsilon_{it}$ and compute the sum of squared residuals SSR0= $\varepsilon_{it}^2$
2) Estimate the auxiliary regression of $\varepsilon_{it}$ on $x_t$ and $z_t x_t$, collect residuals $u_{it}$ and compute the sum of squared residuals, SSR1= $u_{it}^2$

3) Compute LM statistic as:

$$LM = n\frac{SSR_0 - SSR_1}{SSR_1}$$

where n is number of observations.

The distribution of the test will follow $\chi^2 \; pk$ , which will be approximately distributed by F statistic as: $\frac{(SSR_0 - SSR_1)/pk}{SSR_0/(n-2 \; pk+1 \;)}$

It must be noticed that a joint test is also needed to test the linearity of the system as a whole. Because it is assumed that linearity must be rejected in all of the equations simultaneously. The joint test will be log-likelihood test of $\gamma_j$=0 for j= 1, ⋯, k.

### 3.3.2 Choosing Transition Variable:

After running the LM linearity tests, the results can be used to choose the best transition variable. Comparing different statistics of different variables, the one with lowest p-values will be selected as transition variable of the LSTVAR model the reason is that if the transition variable is chosen correctly the power of the test will be maximum (Teräsvirta, 1994)

### 3.3.3 Estimating Parameters of the Model:

In this step the Nonlinear Least Square (NLS) method will be used in order to estimate parameters of the LSVAR model. In order to find the optimum values of NLS estimators (γ, c and coefficient parameters) we must find a suitable starting point for γ and c, because there is a chance of a slow convergence to optimum and selection of a local minimum. In order to find such values grid research will be conducted.

The estimated values can be selected for NLS estimation to find the optimum value. Basic idea of this method is searching in the space of γ and c, and calculating the model parameters based on each value that was found for them, following the fact that for fixed γ and c the model will become linear. The starting point will be the pair of them that produces the smallest residuals some of squares. After this step, selected values can be used to estimate parameters using NLS.

### 3.4 Impulse Response Functions:

One method for evaluating time series model is impulse response functions. This method is examining the effect of shock at time t on the time series. The main concept of IRF's is to study the response of $y_{t+h}$ to the impulse δ at time t. The traditional IRF method is defined for linear models and defined as the deference between two different realizations of $y_{t+h}$. The history of both realizations till time *t-1* is the same, but one of them will be hit by a shock with the size δ at time t while there will be no shock for the other one. Shocks For other periods between $y_t$ and $y_{t+h}$ must be set equal to zero:

$$I_y\ h, \delta, \omega_{t-1}\ = E\ y_{t+h}\ \vartheta_t = \delta, \vartheta_{t+1} = 0, \dots, \vartheta_{t+h} = 0$$

$$-E\ y_{t+h}\ \vartheta_t = 0, \vartheta_{t+1} = 0, \dots, \vartheta_{t+h} = 0$$

This definition of IRF has some characteristic that makes it suitable for linear model. For example being symmetric is one of them, it does not matter if the $\delta$ is positive or negative, in either case the results will be the same. Or the fact that response in this method will be proportionate to the shock. Also the resulted responses are independent of history of the time series. These characteristics will not hold in nonlinear model.

For nonlinear time series history of the variables play an important role and different histories will cause different responses to the shock. Also responses are not symmetric, positive shocks can have different effect than negative ones. In nonlinear time series we can not set intermediate shocks equal to zero because it may cause false inferences.

Koop, Pesaran and potter (1996) address these issues and propose Generalized Impulse Response Function (GI) to solve them. In GI the response function will be an average of what the history could be by averaging out the intermediate shocks. So it will be an expectation function which is conditioned only on history.

$$GI_y\left(h,\delta,\omega_{t-1}\right)=E\left[y_{t+h}\mid\vartheta_t=\delta,\omega_{t-1}\right]-E\left[y_{t+h}\mid\omega_{t-1}\right]$$

As you can see the function is only conditioned on $\vartheta_t$ and $\omega_{t-1}$. A natural benchmark for the function is conditioning $y_{t+h}$ on initial values, in this case $\vartheta_t$ will also be averaged out.

In order to compute the impulse response functions following steps must be taken:

1) Select initial values of endogenous variables as history, $\omega_{t-1}$ from favored subsample.
2) Draw residuals from the LSTVAR model for h time with replacement. $\vartheta_{t+n}, n = 0, \dots, h$.
3) Simulate $y_{t+n}$ for h+1 periods based on the history and residuals from last two parts to create the benchmark.
4) Substitute the first element of residuals for ith variable. Leave residuals for other

variables unchanged. Again simulate expected value of $y_{t+n}$ conditioned on history and residuals to compare it with benchmark.

5) Repeat step 2 to 4 for desirable times.
6) Repeat above steps for several times and take the average to compute average IRF functions.

# Chapter 4

# EMPERICAL RESULTS

## 4.1 Data

In order to study the effect of house prices on aggregate economy three countries were chosen, namely United States, Germany and United Kingdom. Quarterly data are gathered from OECD data base and going to be used. Seven different variables have been selected to be included in the model: consumer prices (p), private consumption (c), house prices (hpr), interest rate (i), share prices (s), price to rent ratios (pr) and price to income ratios (pi).

Consumer prices, private consumption, house prices and share prices are in logarithmic form. Private consumption, house prices and share prices are reported in real terms. For US, Nominal house prices were originated from Federal Housing Finance Agency (FHFA) of United States. For Germany data source for house prices is Deutsche Bundesbank, and for UK they were gathered form Department for Communities and Local Government.

Nominal house prices were deflated by private consumption deflator in order to generate real house prices. Price to income ratio was calculated by dividing nominal house prices by nominal disposable income per head. And Price to rent ratio is nominal house prices divided by rent prices. Share prices are from the OECD main economic indicators database.

## 4.2 Specification of LSTVAR model:

Following (Waise, 1999) the LSTVAR model will be estimated in the form of:

$$Y_t = \emptyset_0 + \emptyset\,(L)Y_{t-1} + (\theta_0 + \theta(L)Y_{t-1})F(z_t) + u_t$$

Where $Y_t$ is $m\times 1$ vector of endogenous variables at time $t$, here containing $p, c, hpr, i, s, ir, pr$ :

$$Y_t = [\,p, c, hpr, i, s, ir, pr]';\ \ (2)$$

$\emptyset_0$ and $\theta_0$ are $m\times 1$ vector of constants for two regimes, $\emptyset\,(L)$ and $\theta(L)$ are infinite-order polynomials in the lag operator. And $F(z_t)$ is the transition function which controls the smooth transition between different regimes. In this case logistic transition function will be used as a form of:

$$F\ z_t\ = (1 + \exp\ -\gamma\ z_t - c\ \ )^{-1} - 1/2, \gamma > 0.\ (3)$$

### 4.2.1 Estimating VAR Model:

As we discussed earlier first step in estimating LSTVAR model is defining appropriate VAR model of order p as the baseline of the model.

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots + \alpha_p y_{t-p} + \varepsilon_t$$

Schwartz information criterion (SIC) was used to determine the appropriate lag for the model, and one lag was selected for all the three countries. After running Augmented Dicky-Fuller test it became clear that none of the variables (except interest rate) were stationary for United States, for United Kingdom none of the time series were stationary and for Germany only house prices and consumer prices were stationary. The problem was taken care of by taking first differences of the variables.

### 4.2.2 Linearity Test:

The next step is testing linearity of the model. BDS test of Brock, Dechert, Scheinkman, & LeBaron, (1996) is applied to the residuals of VAR model as a portmanteau test for nonlinearity. The results for US are reported in table 1 (look appendices E and F to find the tables of the results for Germany and United Kingdom.) For most of the combinations, the null hypothesis is rejected which means the possibility of existence of LSTVAR type of nonlinearity structure in the data.

Table 1. BDS Test

| Variables | Dimension 2 | Dimension 4 | Dimension 6 | Variables | Dimension 2 | Dimension 4 | Dimension 6 |
|---|---|---|---|---|---|---|---|
| P | 4.708545 | 5.410033 | 6.293064 | C | 1.093719 | 3.149677 | 4.957648 |
| | (0.007078) | (0.013556) | (0.013793) | | (0.006371) | (0.012108) | (0.012222) |
| HPR | 4.708545 | 5.410033 | 6.293064 | PR | 5.59202 | 6.515014 | 8.073207 |
| | (0.007078) | (0.013556) | (0.013793) | | (0.008936) | (0.017114) | (0.017429) |
| I | 2.042238 | 2.370148 | 2.751374 | S | -0.77736 | 1.176127 | 1.794592 |
| | (0.006206) | (0.011821) | (0.011957) | | (0.006373) | (0.012158) | (0.012318) |
| IR | 1.782902 | 1.385627 | 2.574349 | | | | |
| | (0.005746) | (0.010863) | (0.010903) | | | | |

But BDS test just show the misspecification in linear format, so another test must be conducted to compare two models and reject the linearity in favor of LSTVAR model. In order to be able to run such a comparison, parameters of LSTVAR must be estimated based on the specification of the linear model.

As mentioned before, when *γ=0,* model will become nonlinear, so the nonlinearity test will be testing null hypothesis of $H_0$*: γ=0* against the alternative hypothesis of $H_1$*:γ>0* in equation (1). But this will cause an identification problem where more than one restriction can be used as $H_0$ hypothesis. In order to solve this problem Luukkonen et.al. (1988) suggest to use the suitable order of Taylor extension of transition function around γ=0.

Table 2. Lagrange Multiplier Test

| | *p* | *c* | *Hpr* | *i* | *s* | *ir* | *pr* | *LR* |
|---|---|---|---|---|---|---|---|---|
| $p_{t-1}$ | 26.6713<br>(0.0005) | 29.8302<br>(0.0000) | 19.5915<br>(0.0130) | 164.9844<br>(0.0000) | 161.4017<br>(0.0530) | 164.9887<br>(0.0000) | 164.9822<br>(0.0000) | 115.8254<br>(0.0000) |
| $c_{t-1}$ | 9.5083<br>(0.2470) | 20.3244<br>(0.0055) | 13.9444<br>(0.0680) | 164.9838<br>(0.0000) | 161.2620<br>(0.0655) | 164.9883<br>(0.0000) | 164.9815<br>(0.0000) | 98.0661<br>(0.0000) |
| $hpr_{t-1}$ | 30.1141<br>(0.0015) | 13.9730<br>(0.0620) | 29.3679<br>(0.0000) | 164.9855<br>(0.0000) | 161.6436<br>(0.0200) | 164.9895<br>(0.0000) | 164.9834<br>(0.0000) | 102.4799<br>(0.0000) |
| $i_{t-1}$ | 19.3485<br>(0.0105) | 28.1760<br>(0.0005) | 21.6896<br>(0.0040) | 164.9846<br>(0.0000) | 161.4536<br>(0.0425) | 164.9889<br>(0.0000) | 164.9825<br>(0.0000) | 139.0318<br>(0.0000) |
| $s_{t-1}$ | 27.3068<br>(0.0010) | 5.6069<br>(0.6340) | 12.7083<br>(0.0930) | 164.9837<br>(0.0000) | 161.2314<br>(0.0730) | 164.9882<br>(0.0000) | 164.9814<br>(0.0000) | 94.4956<br>(0.0000) |
| $ir_{t-1}$ | 24.6766<br>(0.0060) | 33.1799<br>(0.0000) | 20.1408<br>(0.0065) | 164.9845<br>(0.0000) | 161.4153<br>(0.0445) | 164.9888<br>(0.0000) | 164.9823<br>(0.0000) | 123.4012<br>(0.0000) |
| $pr_{t-1}$ | 28.9477<br>(0.0025) | 17.6476<br>(0.0150) | 29.2291<br>(0.0005) | 164.9854<br>(0.0000) | 161.6402<br>(0.0185) | 164.9895<br>(0.0000) | 164.9834<br>(0.0000) | 115.5797<br>(0.0000) |

The 3step procedure of an F version of Lagrange-multiplier test is conducted as was described earlier.

In table 2 the results of linearity tests are reported for US (look appendices A and B for the reported results for Germany and United Kingdom). Bootstrapped P-values are reported in parentheses. The test was run for all first lags values of variables as switching variables and as you can see for almost all cases linearity is rejected so the test provide an strong evidence against linearity in VAR model in favor of the

LSTVAR.

Based on the calculated p-values for each switch variable and LR statistics price to rent ratios and income to rent ratios are selected as switch variables. As you can see when ir and pr are switch variables linearity is rejected for all the equations, suggesting that they all have LSTVAR kind of nonlinearity. In the next section model 1 will be corresponding to the model where pr is switch variable and model 2 is a model with ir as switch variable.

### 4.2.3 Parameters Estimation

Following the procedure in chapter 3, two LSTVAR models are going to be estimated using two different switching variables.

The combination of parameters, which corresponds to the lowest value for the log of the determinant of the variance-covariance matrix are reported in table (4) for two different models with different switch variables. In the first column estimated values of k are reported.  As you can see for US corresponding slope for the model with *ir* as switch variables is -105.8976 which is high and suggest that TAR model can also be used as a good approximation instead of STAR model for estimating the system, but when *pr* is switch variable smoothness parameter is -1.3017 which means there exist an smooth transition between two regimes.

For the United Kingdom and Germany also there is smooth transition between different regimes,  since the value of k is reasonably low for both models.

Table 3. Optimal Values of Smoothness and Threshold Parameters

| Countries | Switching Variable | Value of K | Value of C | SCHWARZ Criterion |
|---|---|---|---|---|
| US | Pr | -1.3017 | 4.9380 | -20.1500 |
| | Ir | -105.8976 | 2.2200 | 2.0434 |
| UK | Pr | -0.4622 | 19.9900 | -16.8263 |
| | Ir | -2.1364 | 2.9800 | -16.7466 |
| GER | Pr | 1.2526 | 1.1100 | -18.7945 |
| | Ir | -2.1116 | 11.8500 | -18.8474 |

After estimating the parameters of the model, another linearity test was conducted. This time an F test was constructed with the null hypothesis of equating the coefficients of transition function equal to zero against the alternative hypothesis that at least one of them is not zero. The results for US are reported in table (4). (look appendices C and D to see other two countries results). Asymptotic P values are reported in parentheses. As it is shown for most of the equations null hypothesis are rejected for 5%, when pr is switch variable the null hypothesis is rejected for 10% for price equation and for share prices we cannot reject the null hypothesis but when we look at the joint test, the null hypothesis is rejected for 1% which is evidence against linearity in favor of LSTVAR. When income to rent ratio is switch variable we can see that we cannot reject the null only for share prices and price to rent ratios equations, in this case also the joint test is rejected for 1% and it is an evidence against nonlinearity in favor of LSTVAR model.

Results for UK are also show strong evidence against linearity (to see the corresponding table go to appendix c). In model 1 the linearity is rejected for 5% except for s, ir and pr equations. In model 2 it is only interest rate equation that can not be rejected even at 10% level. In both models joint test is rejected for 1% level. And the results for third country are reported in appendix D. As you can see also for Germany the test is great evidence against linearity and like those other two countries joint test is rejected for 1%

Table 4. Optimal Values of Smoothness and Threshold Parameters

| | Switch variables | |
|---|---|---|
| | pr | Ir |
| Price eq. | 3.0645<br>(0.0019) | 5.3494<br>(0.0000) |
| Consumption eq. | 1.8535<br>(0.0626) | 6.5930<br>(0.0000) |
| House price eq. | 6.4748<br>(0.0000) | 4.8605<br>(0.0000) |
| Interest rate eq. | 6.4748<br>(0.0399) | 2.4128<br>(0.0133) |
| Share prices eq. | 1.6021<br>(0.1183) | 0.7649<br>(0.6339) |
| Price to rent ratio eq. | 3.1183<br>(0.0016) | 1.4938<br>(0.1534) |
| Income to rent ratio eq. | 2.6076<br>(0.0075) | 4.0166<br>(0.0001) |
| All equations | 17.9941<br>(0.0000) | 12.7957<br>(0.0000) |

## 4.3 Impulse Response Functions

In this section Generalized Response Function was used to study the effect of one standard deviation house price shock to the system. The responses were generated for 10 quarters after the shock. Figure two reports the variables responses to 1sd hpr shock for US model 1. Also linear responses are included in order to compare them to the results from LSTVAR model. In appendices, results for model 2 of the US and also for two other countries are reported. The responses are showing that in almost all cases LSTVAR results are substantially different from linear ones.

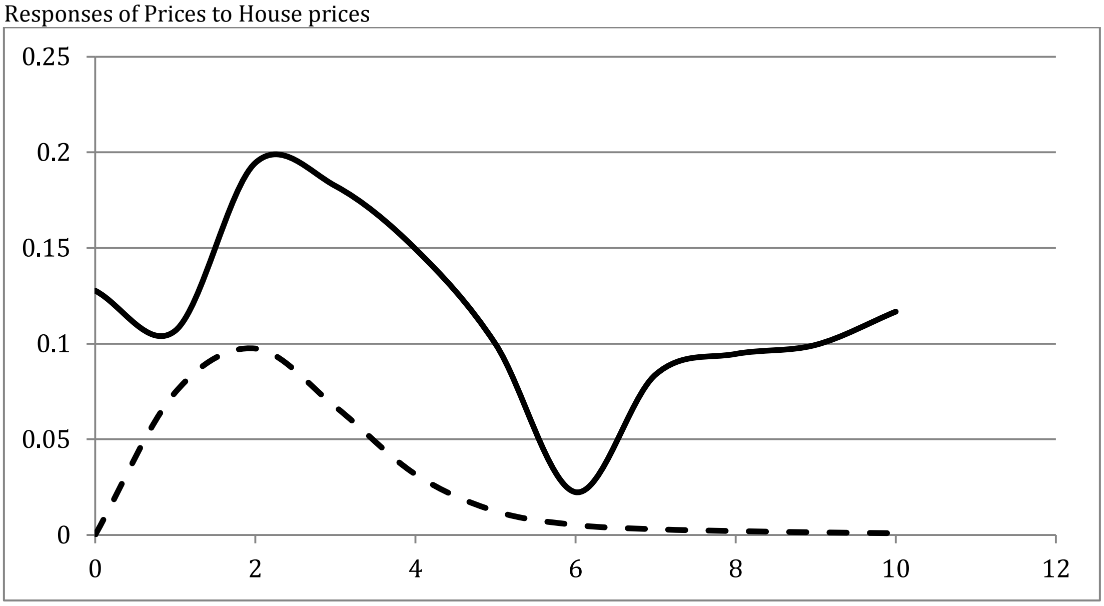
As you can see in figure 2, for most of the variables responses are as what was expected. All the variables have shown proper respond to an increase in house price. Prices responded positively to the hpr shock and linear model show stronger link between these two rather than LSTVAR model for US model 1 and model 2. Also the UK house prices linear model show stronger respond to house price shock, LSTVAR predicts a positive reaction of prices for four quarters. For Germany also results for Impulse responses of prices to house price changes in linear model are stronger than LSTVAR model responses.

Consumption responses show that house prices have positive effect on household's consumption in first three years. For the US predicted linear responses are greater than LSTVAR model's. There is a high response in first quarters and the response got decreased in following periods, which is similar to linear response.

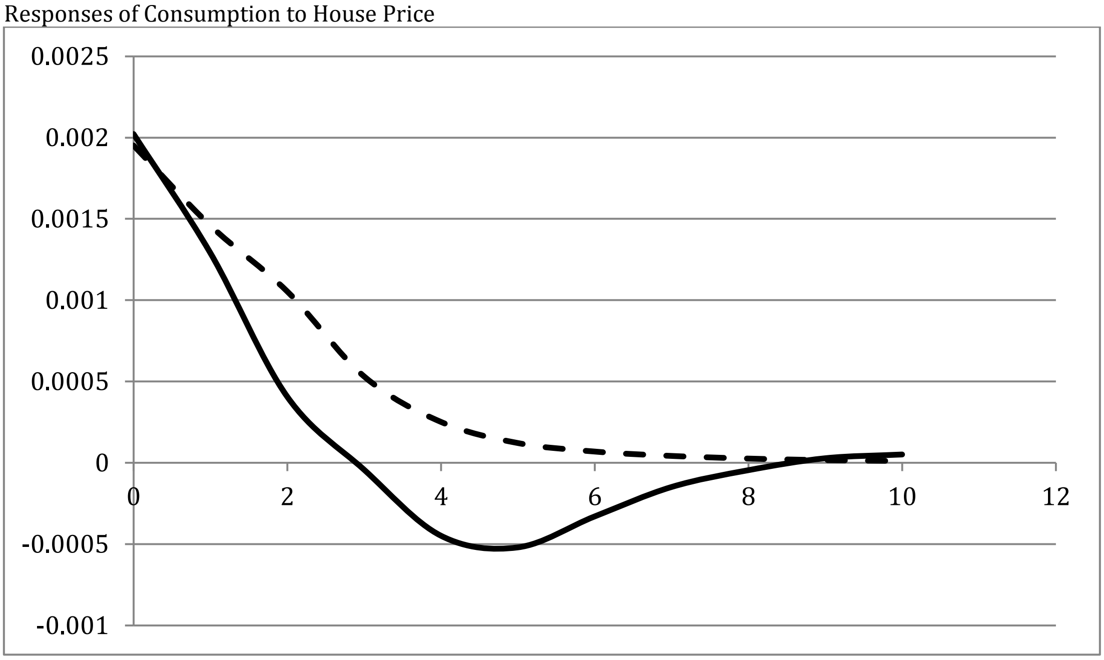
Nominal interest rate shows a delay positive response, which could be due to a new monetary policy against the inflation, since price level has been raised.

Share prices show stronger response to house price shock in first quarters compare to linear model, but after some periods linear responses get stronger. Price to rent ratios and Income to rent ratios show similar responses to house price shock, Strong positive response in early periods and decrease in responses in following periods.

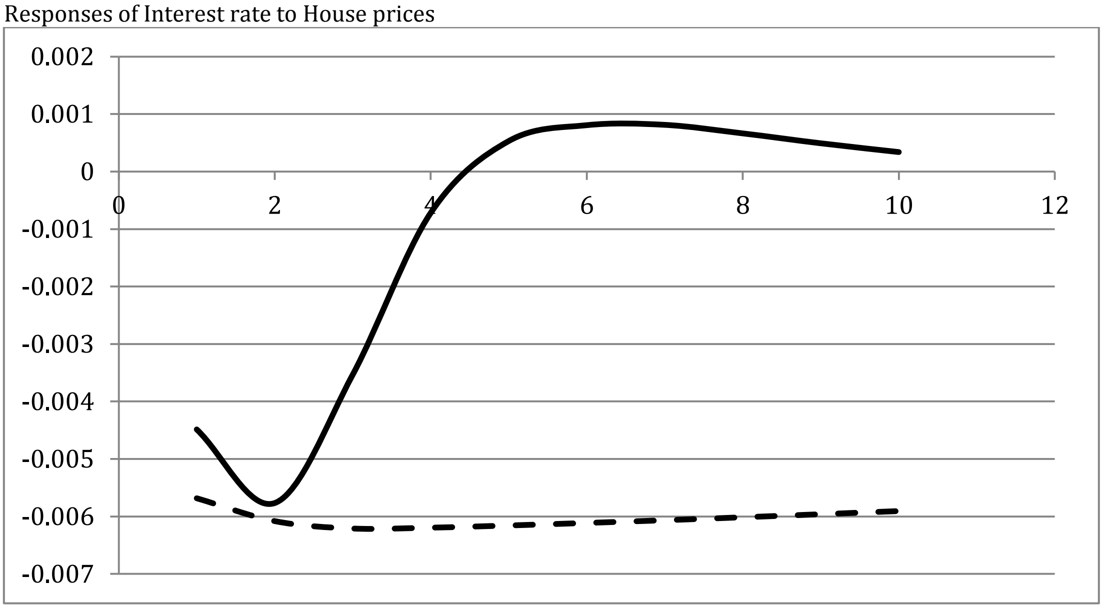
Responses of Prices to House prices



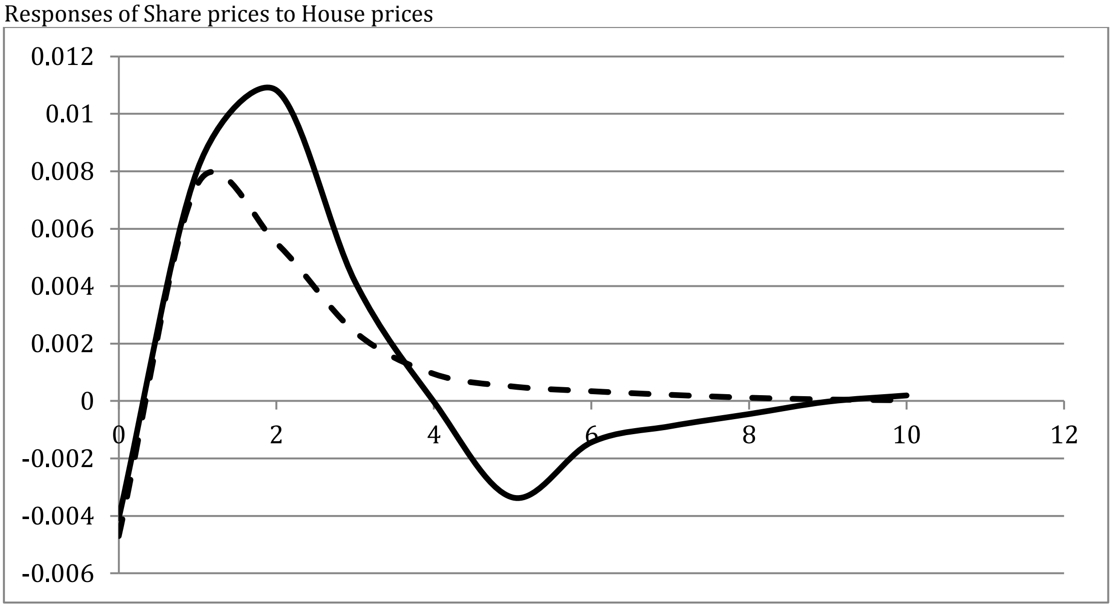

Responses of Consumption to House Price



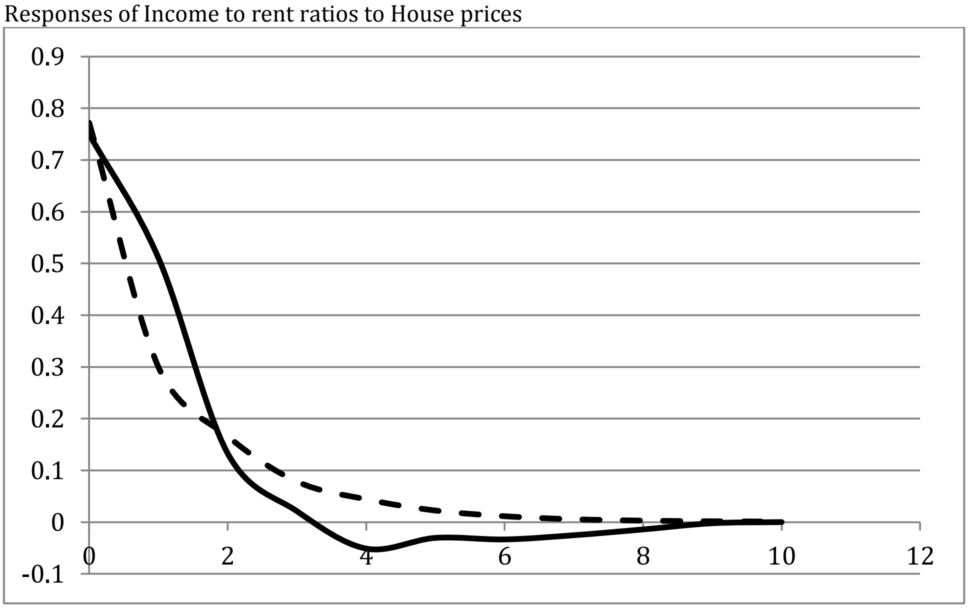
Responses of Interest rate to House prices




Responses of Share prices to House prices



Responses of Income to rent ratios to House prices




Responses of Price to rent ratios to House prices

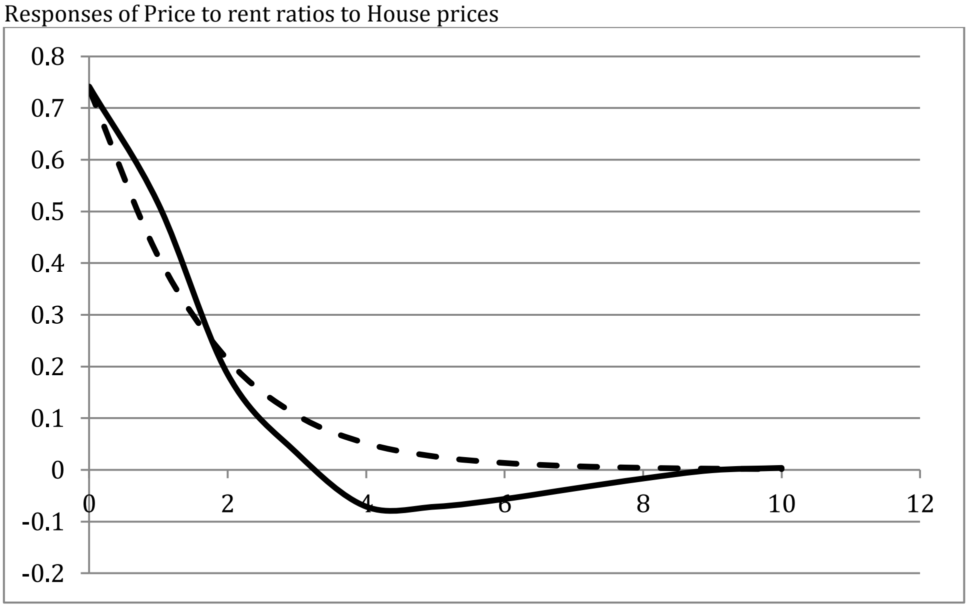



Figure 2 (Difference between responses for LSTVAR model and Linear model)

——— LSTVAR Positive shock

-------Linear model

# Chapter 5

# CONCLUSION

Logistic Smooth Transition Autoregressive framework for 7 variables, consumer prices, private consumption, house prices, interest rate, share prices, price to rent ratios and price to income ratios provided a good depiction of the effect of changes of house prices on economy for three countries, the Unites States, Germany and the United of Kingdom.

This study provides evidence of positive relationship between house prices and private consumption for all three countries, and it was shown that the LSTVAR results are substantially different than linear results.

Also by rejecting linearity in house prices in favor of the nonlinear LSTVAR model, this study provides another evidence of nonlinearity in house price time series.

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# APPENDICES

# Appendix A: Lagrange Multiplier Test for UK

LAGRANGE MULTIPLIER TESTS FOR LINEARITY

| Switch variables | F statistics | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | p | c | hpr | i | s | ir | pr | LR |
| $p_{t-1}$ | 15.6014 | 10.1822 | 10.2461 | 164.9504 | 156.7261 | 164.9803 | 164.9724 | 120.7395 |
| | (0.0305) | (0.2005) | (0.1975) | (0.0000) | (0.2665) | (0.0000) | (0.0000) | (0.0000) |
| $c_{t-1}$ | 22.7483 | 36.8518 | 9.0187 | 164.9500 | 156.6605 | 164.9801 | 164.9721 | 113.5282 |
| | (0.0030) | (0.0000) | (0.2765) | (0.0000) | (0.3125) | (0.0000) | (0.0000) | (0.0000) |
| $hpr_{t-1}$ | 13.5316 | 30.9777 | 16.8377 | 164.9855 | 157.0785 | 164.9811 | 164.9735 | 147.2211 |
| | (0.0655) | (0.0000) | (0.0130) | (0.0000) | (0.2065) | (0.0000) | (0.0000) | (0.0000) |
| $i_{t-1}$ | 8.1360 | 13.0535 | 15.6589 | 164.9521 | 157.0155 | 164.9810 | 164.9733 | 99.7928 |
| | (0.3615) | (0.0935) | (0.0340) | (0.0000) | (0.2315) | (0.0000) | (0.0000) | (0.0000) |
| $s_{t-1}$ | 11.6606 | 17.5093 | 8.0488 | 164.9497 | 156.6086 | 164.9800 | 164.9720 | 102.7381 |
| | (0.1270) | (0.0250) | (0.3820) | (0.0000) | (0.3045) | (0.0000) | (0.0000) | (0.0000) |
| $ir_{t-1}$ | 10.8606 | 25.8196 | 9.4446 | 164.9502 | 156.6832 | 164.9802 | 164.9722 | 99.2474 |
| | (0.1560) | (0.0025) | (0.2395) | (0.0000) | (0.2795) | (0.0000) | (0.0000) | (0.0000) |
| $pr_{t-1}$ | 8.9245 | 20.8753 | 10.3028 | 164.9504 | 156.7291 | 164.9803 | 164.9724 | 126.2646 |
| | (0.2930) | (0.0080) | (0.1935) | (0.0000) | (0.2845) | (0.0000) | (0.0000) | (0.0000) |

## Appendix B: Lagrange Multiplier Tests for GER

| LAGRANGE MULTIPLIER TESTS FOR LINEARITY | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Switch Variables | F statistics | | | | | | | |
| | p | c | Hpr | i | s | ir | pr | LR |
| $p_{t-1}$ | 29.8302 | 19.0806 | 14.9026 | 164.9865 | 161.4017 | 163.8284 | 164.9952 | 134.4910 |
| | (0.000) | (0.0070) | (0.1265) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| $c_{t-1}$ | 20.3244 | 18.3507 | 9.1419 | 164.9860 | 161.2620 | 163.7834 | 164.9950 | 124.1725 |
| | (0.025) | (0.0100) | (0.3045) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0005) |
| $hpr_{t-1}$ | 13.9730 | 14.2290 | 6.9132 | 164.9858 | 161.6436 | 163.7660 | 164.9949 | 77.4298 |
| | (0.001) | (0.0570) | (0.4950) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0245) |
| $i_{t-1}$ | 28.1760 | 11.7452 | 5.3715 | 164.9846 | 164.9857 | 163.7540 | 164.9949 | 66.1576 |
| | (0.1125) | (0.1315) | (0.6285) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0800) |
| $s_{t-1}$ | 5.6069 | 10.2404 | 14.3847 | 164.9837 | 164.9865 | 163.8243 | 164.9952 | 60.3699 |
| | (0.1770) | (0.2110) | (0.0540) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.1420) |
| $ir_{t-1}$ | 33.1799 | 10.0671 | 7.0220 | 164.9845 | 164.9858 | 163.7669 | 164.9949 | 136.1393 |
| | (0.0620) | (0.1940) | (0.4630) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| $pr_{t-1}$ | 17.6476 | 10.6299 | 29.2884 | 164.9854 | 164.9878 | 163.9407 | 164.9956 | 115.2716 |
| | (0.2425) | )0.1745) | (0.0005) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |

## Appendix C: Coefficient Test for UK

| Optimal Values of Smoothness and Threshold Parameters | | |
|---|---|---|
| Null Hypothesis: coefficients equal to 0 | Switch Variable | |
| | PR | IR |
| Price eq. | 1.9960 | 7.0604 |
| | (0.04) | (0.0000) |
| Consumption eq. | 1.8957 | 3.4888 |
| | (0.05) | (0.0005) |
| House Price eq. | 1.8735 | 2.3944 |
| | (0.05) | (0.0141) |
| Interest rate eq. | 3.1290 | 1.9208 |
| | (0.00) | (0.0524) |
| Share price eq. | 1.4748 | 3.3867 |
| | (0.16) | (0.0007) |
| Income to rent ration eq. | 0.6843 | 0.2992 |
| | (0.70) | (0.9665) |
| Price to rent ratio eq. | 0.9111 | 1.8946 |
| | (0.50) | (0.0562) |
| All equations | 5.9167 | 7.3234 |
| | (0.00) | (0.0000) |

# Appendix D: Coefficient Test for GER

| Optimal Values of Smoothness and Threshold Parameters | | |
|---|---|---|
| Null Hypothesis: coefficients equal to 0 | Pr | IR |
| price eq. | 1.7320 | 2.0843 |
| | 0.0856 | 0.0337 |
| consumption eq. | 0.6618 | 3.2677 |
| | 0.7257 | 0.0010 |
| House price eq. | 9.7930 | 5.1713 |
| | 0.0000 | 0.0000 |
| Interest rate eq. | 3.9528 | 9.8382 |
| | 0.0001 | 0.0000 |
| Share prices eq. | 0.3899 | 1.1356 |
| | 0.9267 | 0.3352 |
| Income to rent ratio eq. | 4.7284 | 5.6289 |
| | 0.0000 | 0.0000 |
| Price to rent ratio eq. | 10.4572 | 1.3945 |
| | 0.0000 | 0.1930 |
| All equations | 17.3006 | 33.8331 |
| | 0.0000 | 0.0000 |

# Appendix E: BDS Test for UK

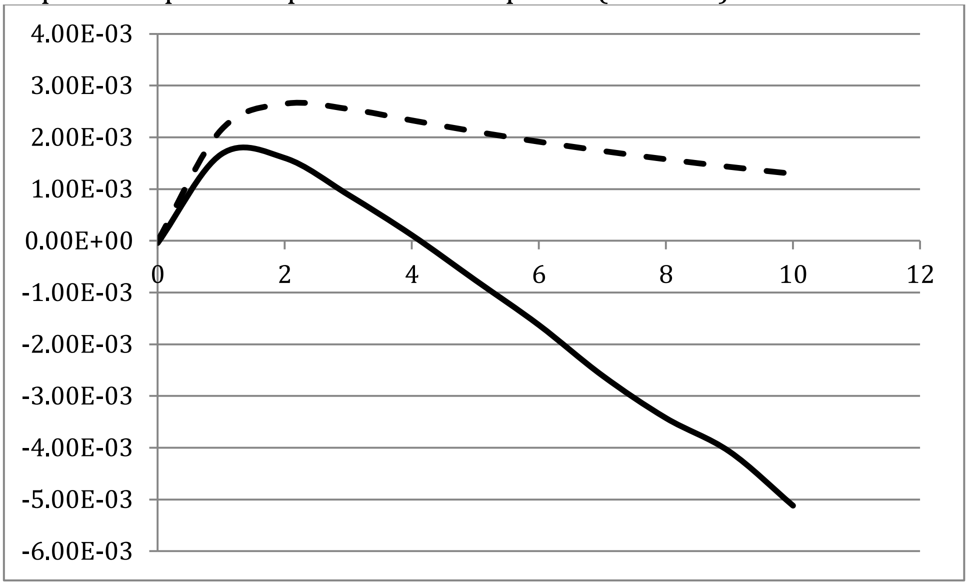
| BDS Test | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Dimension | | | Variables | Dimension | | |
| Variables | 2 | 4 | 6 | | 2 | 4 | 6 |
| C | 3.659094 | 3.659094 | 3.659094 | P | 0.805446 | 0.805446 | 0.805446 |
| | ( 0.005827) | (0.005827) | ( 0.005827) | | (2.704532) | ( 2.704532) | (2.704532) |
| HPR | 2.552493 | 2.552493 | 2.552493 | PR | 5.59202 | 6.515014 | 8.073207 |
| | (0.005677) | (0.005677) | (0.005677) | | (0.006455) | (0.006455) | (0.006455) |
| I | 3.439109 | 3.439109 | 3.439109 | S | 4.018409 | 4.018409 | 4.018409 |
| | ( 0.007917) | (0.007917) | (0.007917) | | (0.006881) | (0.006881) | (0.006881) |
| IR | 1.140234 | 1.140234 | 1.140234 | | | | |
| | (0.005941) | (0.005941) | (0.005941) | | | | |

# Appendix F: BDS Test for GER

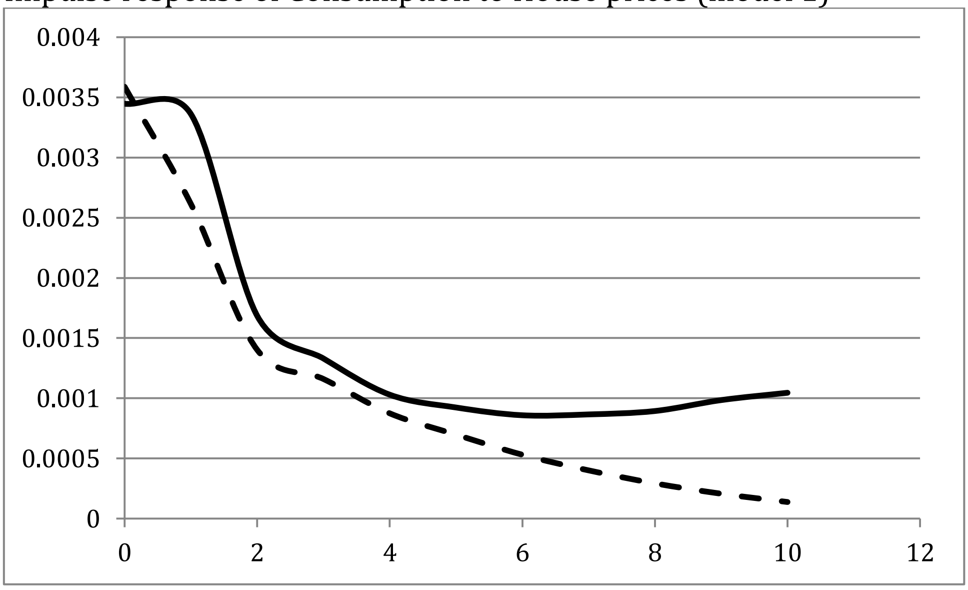
| BDS Test | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Dimension | | | | Dimension | | |
| Variables | 2 | 4 | 6 | Variables | 2 | 4 | 6 |
| C | 3.659094 | 3.659094 | 3.659094 | P | 5.831650 | 5.831650 | 5.831650 |
| | (0.007127) | (0.007127) | (0.007127) | | (0.005494) | (0.005494) | (0.005494) |
| HPR | 3.571226 | 3.571226 | 3.571226 | PR | 3.299711 | 3.299711 | 3.299711 |
| | (0.007364) | (0.007364) | (0.007364) | | (0.008762) | (0.008762) | (0.008762) |
| I | 3.532213 | 3.532213 | 3.532213 | S | -1.458416 | -1.458416 | -1.458416 |
| | (0.009715) | (0.009715) | (0.009715) | | (0.007016) | (0.007016) | (0.007016) |
| IR | 1.842251 | 1.842251 | 1.842251 | | | | |
| | (0.006610) | (0.006610) | (0.006610) | | | | |

## Appendix G: Impulse Response Results for Germany

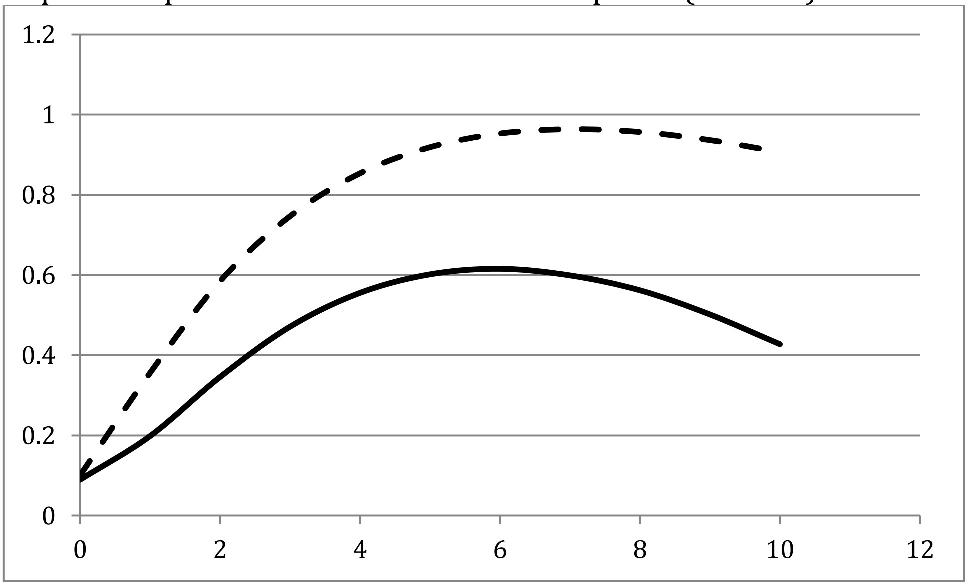
Impulse response of prices to House prices (model 1)



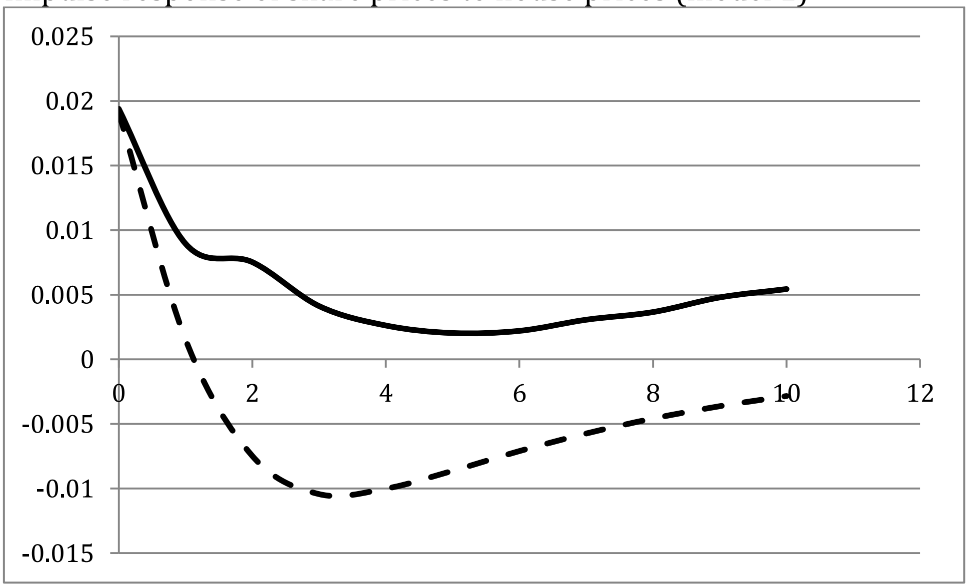

Impulse response of Consumption to House prices (model 1)



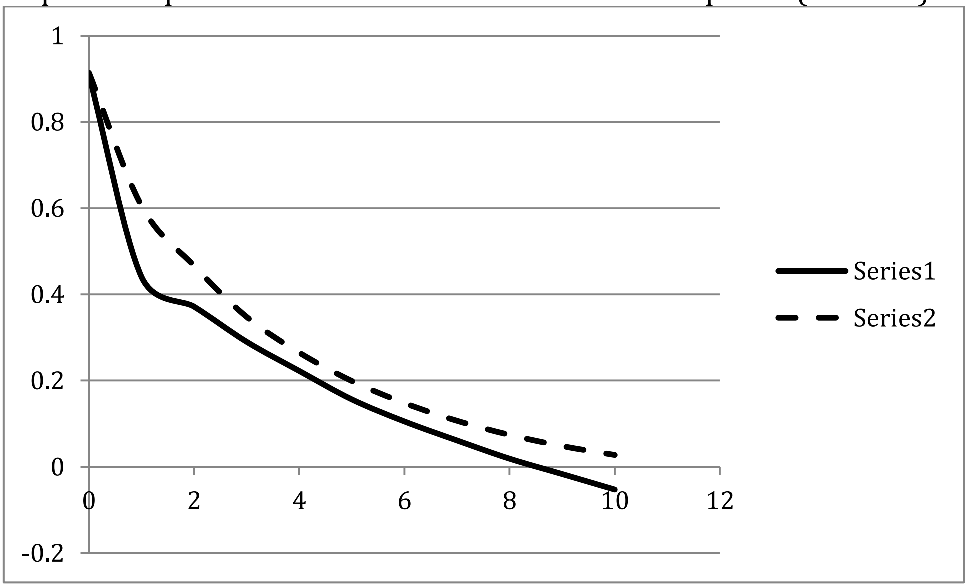
Impulse response of Interest rate to House prices (model 1)



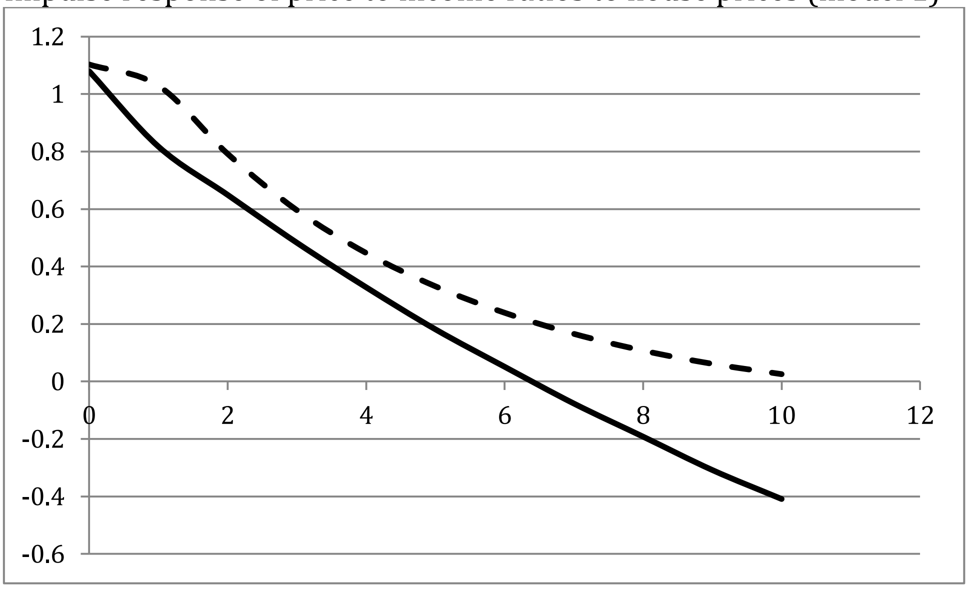

Impulse response of share prices to house prices (model 1)



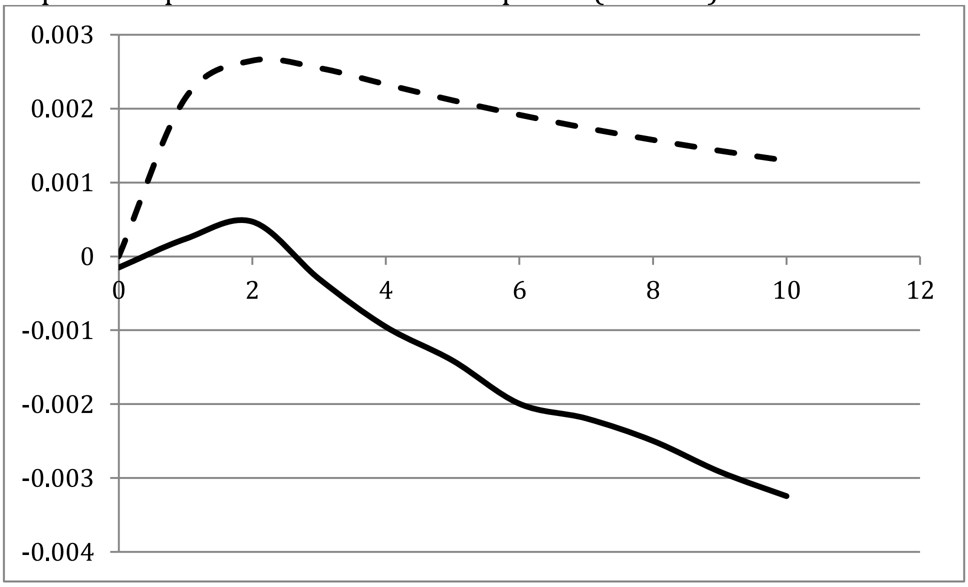
Impulse response of Income to rent ratios to house prices (model 1)



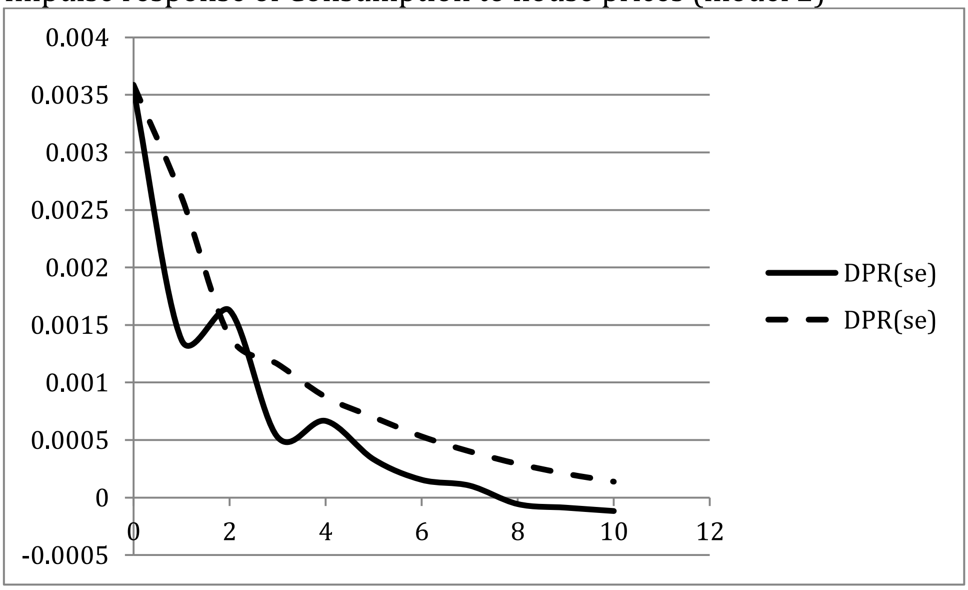

Impulse response of price to income ratios to house prices (model 1)



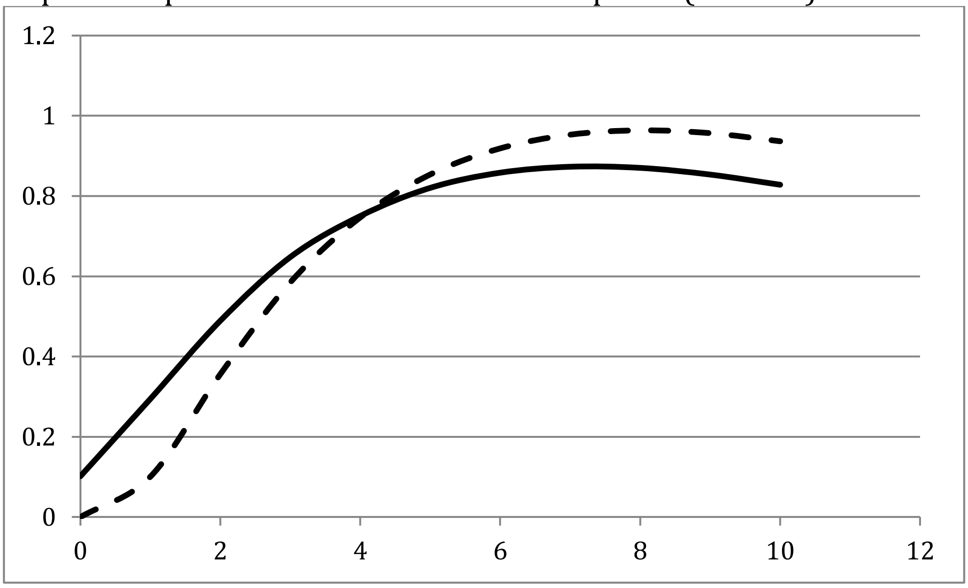
Impulse response of Prices to house prices (model2)



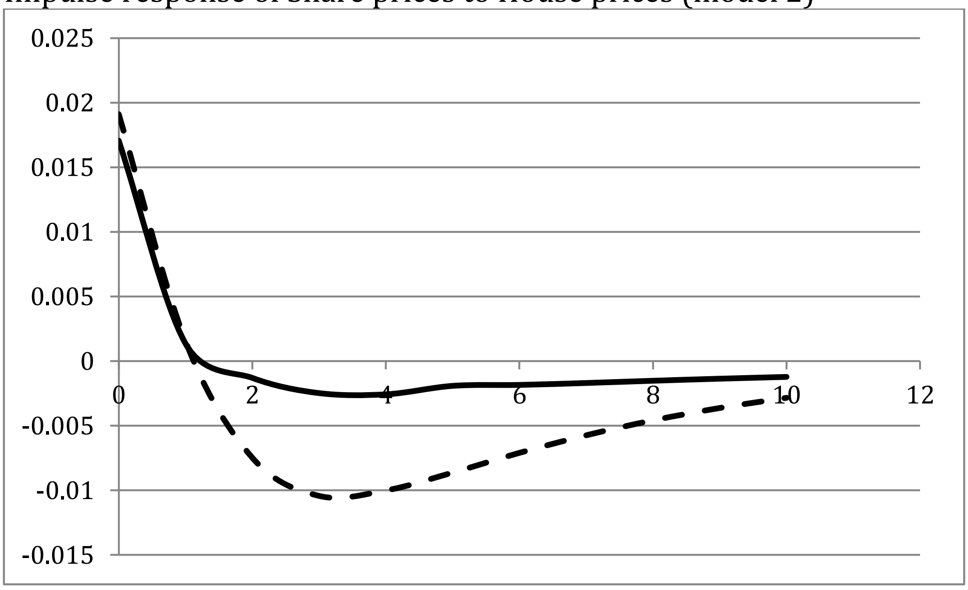

Impulse response of Consumption to house prices (model 2)



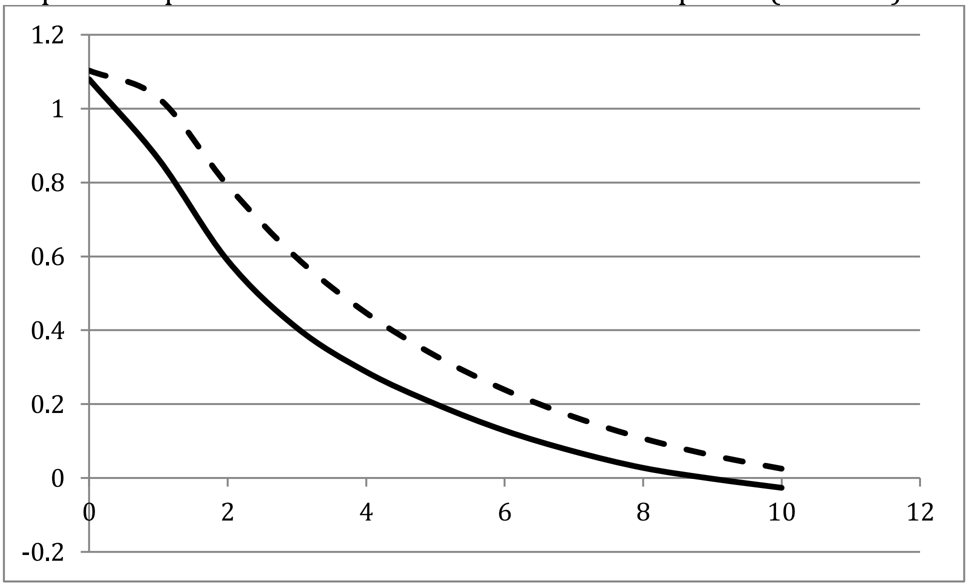
Impulse response of Interest rate to House prices (model 2)



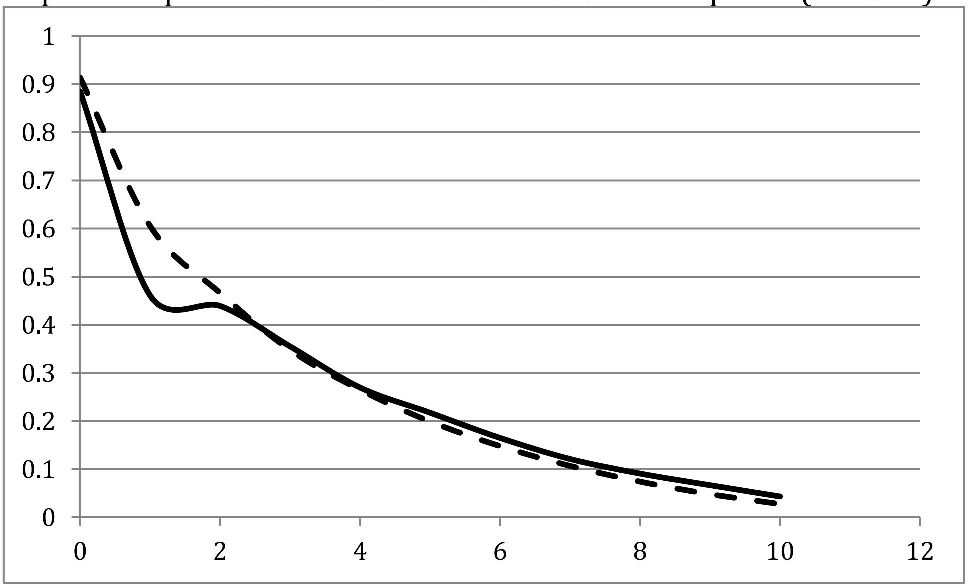

Impulse response of Share prices to House prices (model 2)



Impulse response of Price to rent ratios to House prices (model 2)




Impulse response of Income to rent ratios to House prices (model 2)

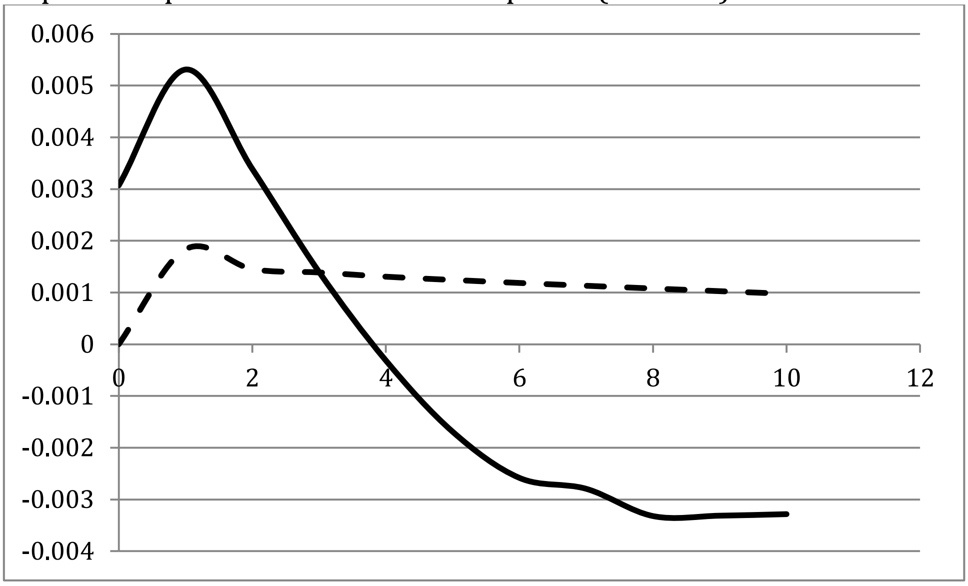



_______ LSTVAR model

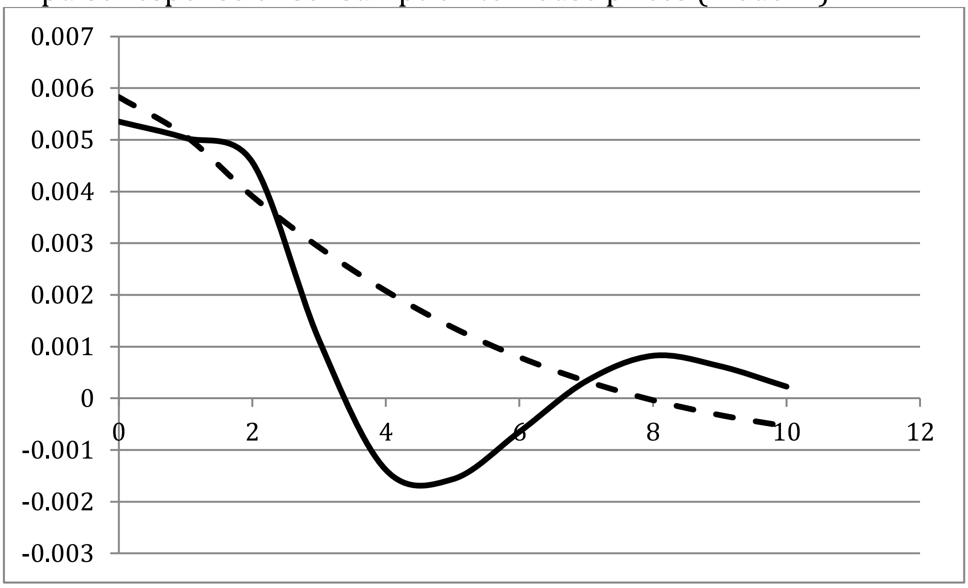
------- Linea model

## Appendix H: Impulse Responses for the United Kingdom

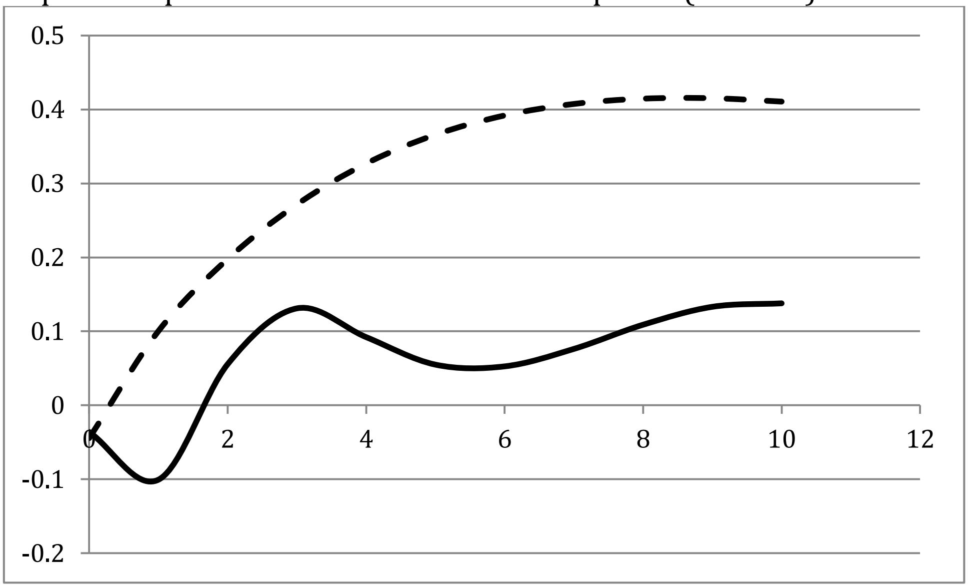
Impulse response of Prices to House prices (model 1)



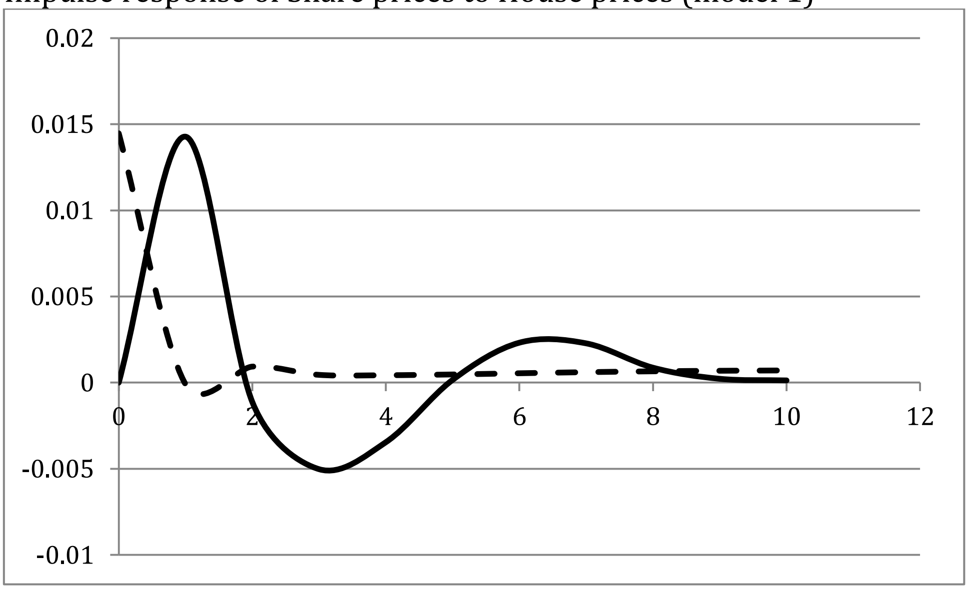

Impulse response of Consumption to House prices (model 1)



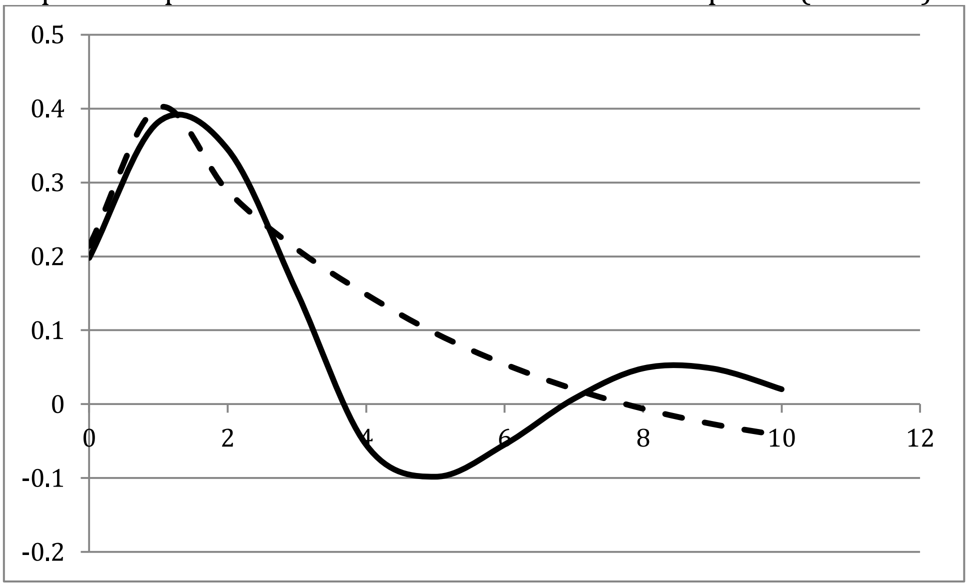
Impulse response of Interest rate to House prices (model 1)



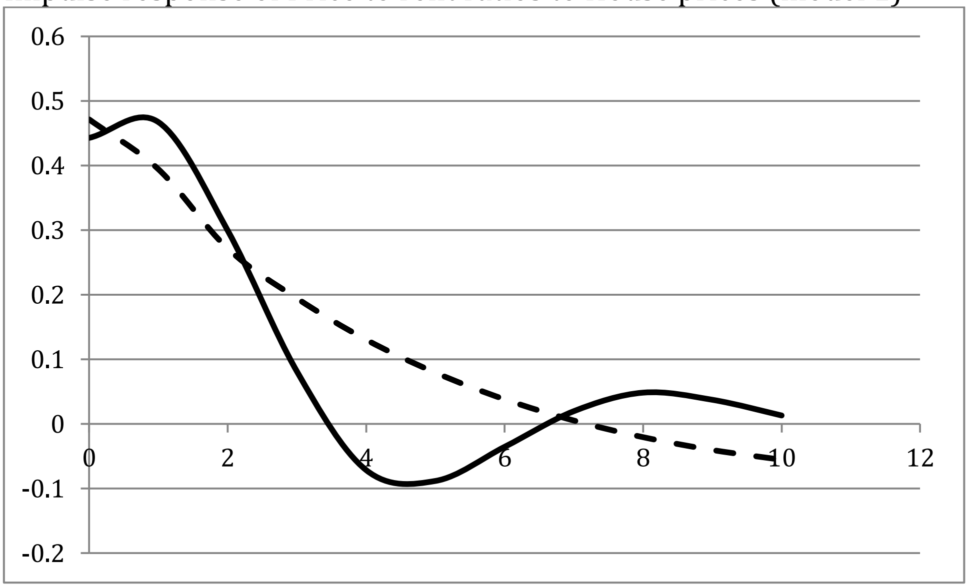

Impulse response of Share prices to House prices (model 1)



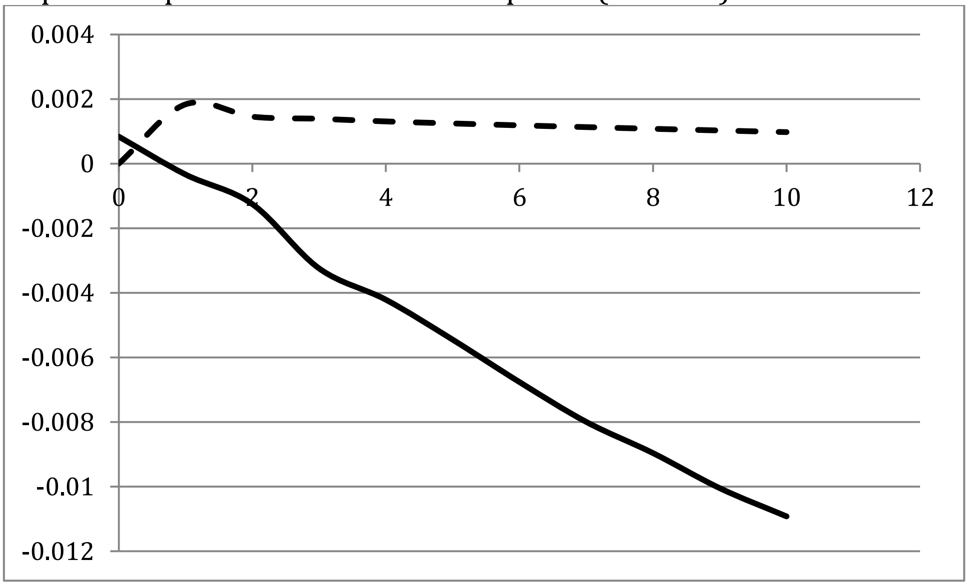
Impulse response of income to rent ratios to House prices (model 1)



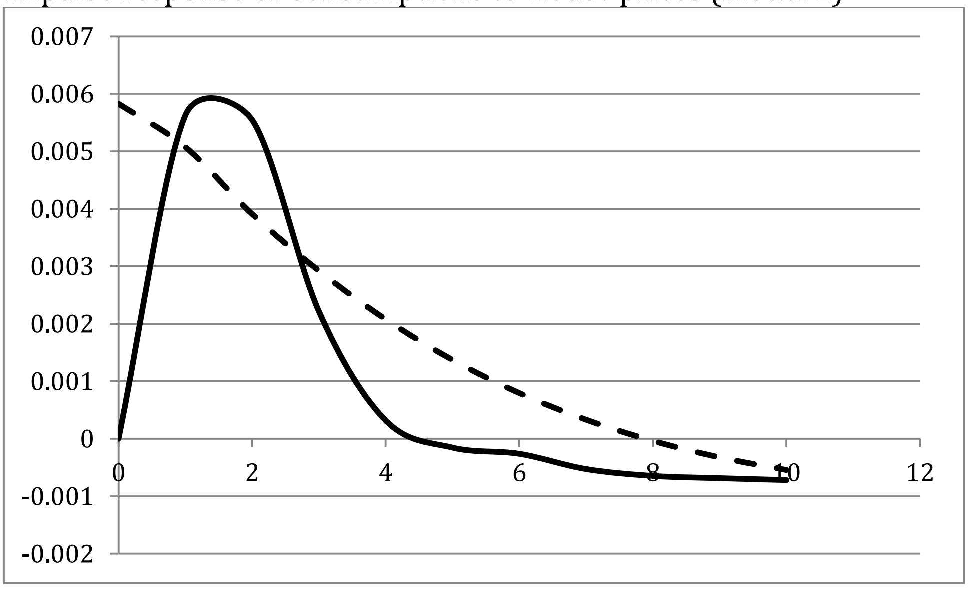

Impulse response of Price to rent ratios to House prices (model 1)



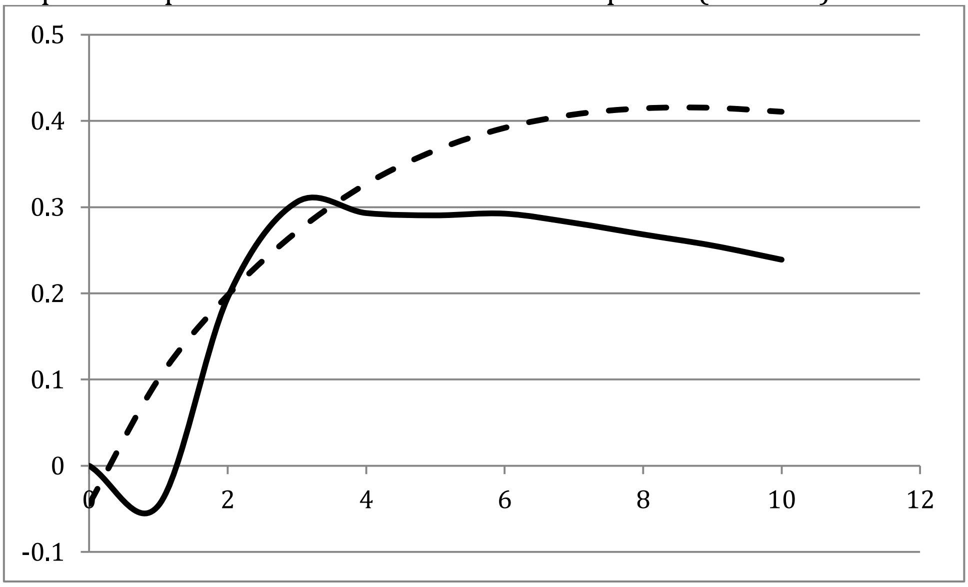
Impulse response of Prices to House prices (model 2)



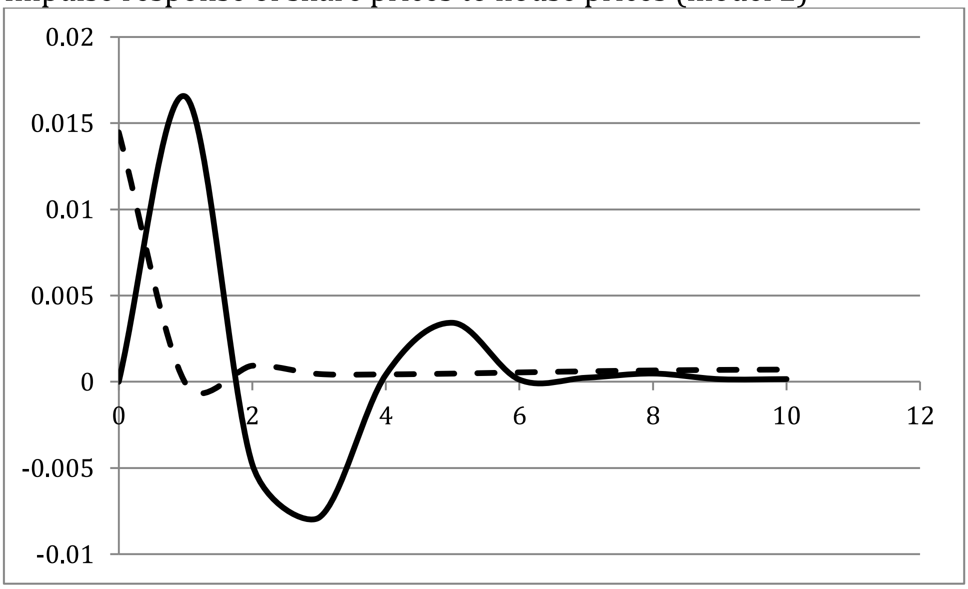

Impulse response of Consumptions to House prices (model 2)



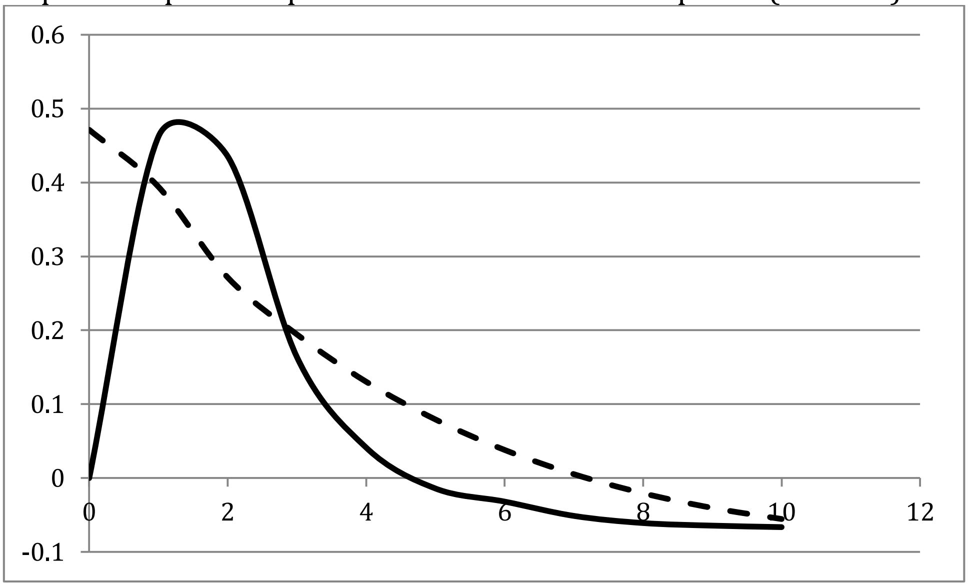
Impulse response of Interest rates to House prices (model 2)



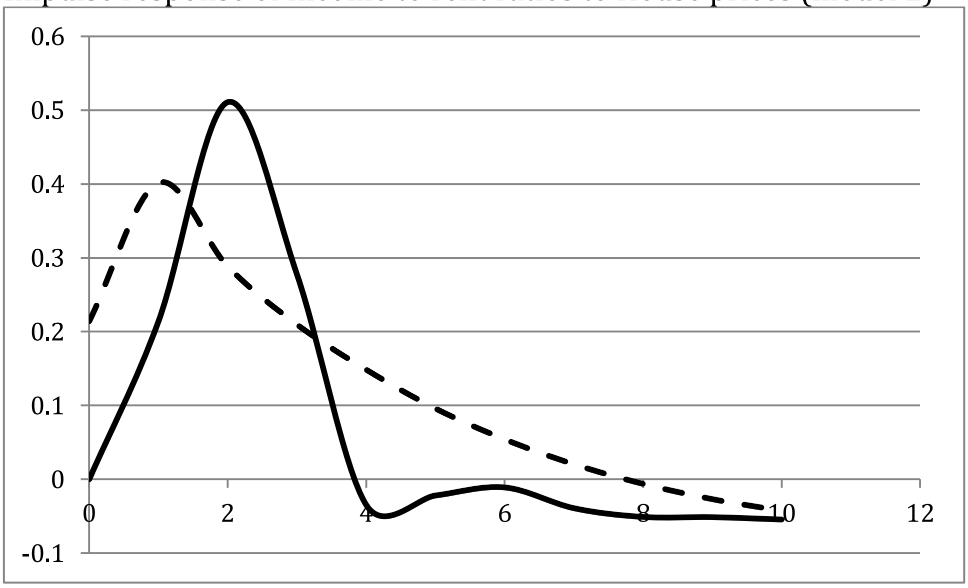

Impulse response of share prices to house prices (model 2)



Impulse response of price to rent ratios to House prices (model 2)




Impulse response of Income to rent ratios to House prices (model 2)

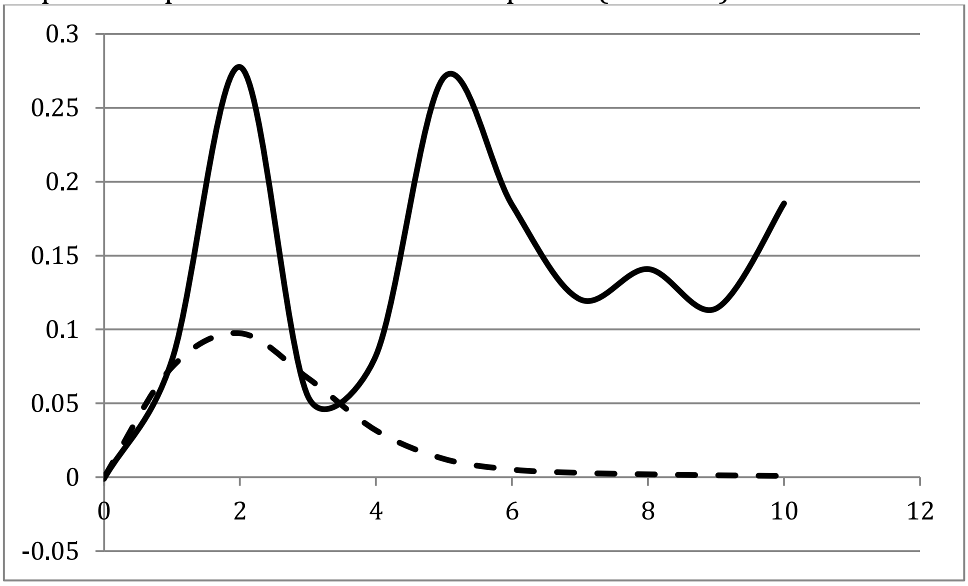



_______ LSTVAR model

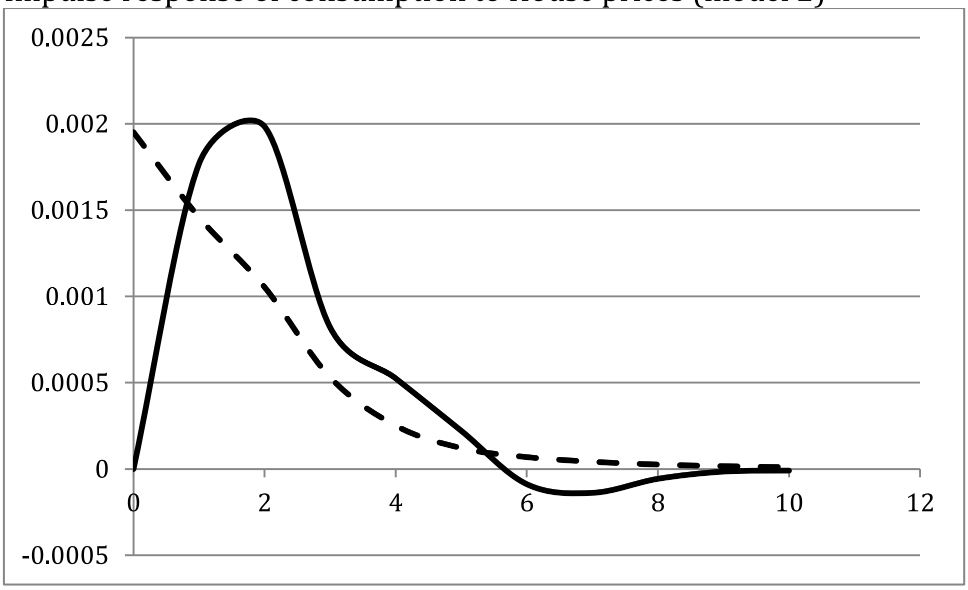
------ Linea model

# Appendix I: Impulse Responses for US (model 2)

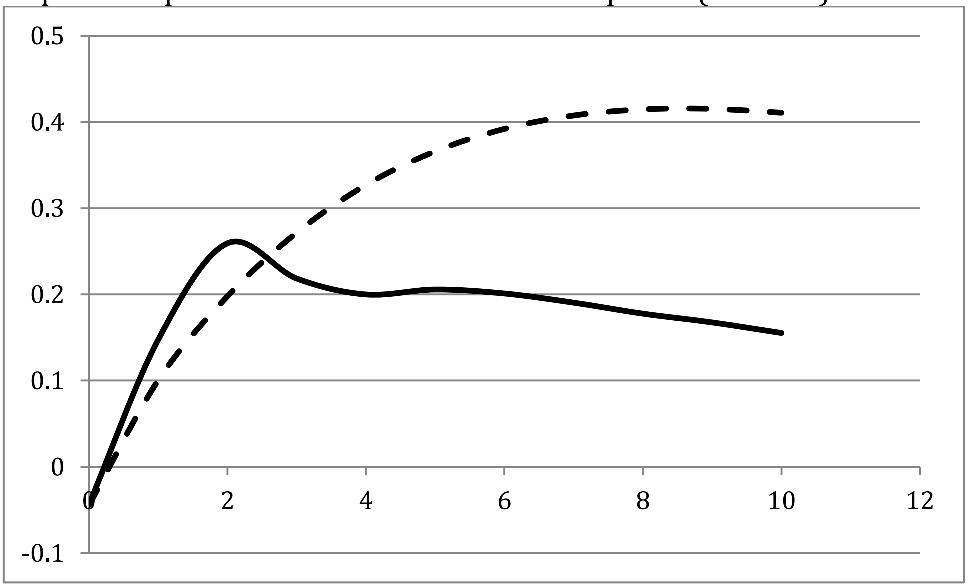
Impulse response of Prices to House prices (model 2)



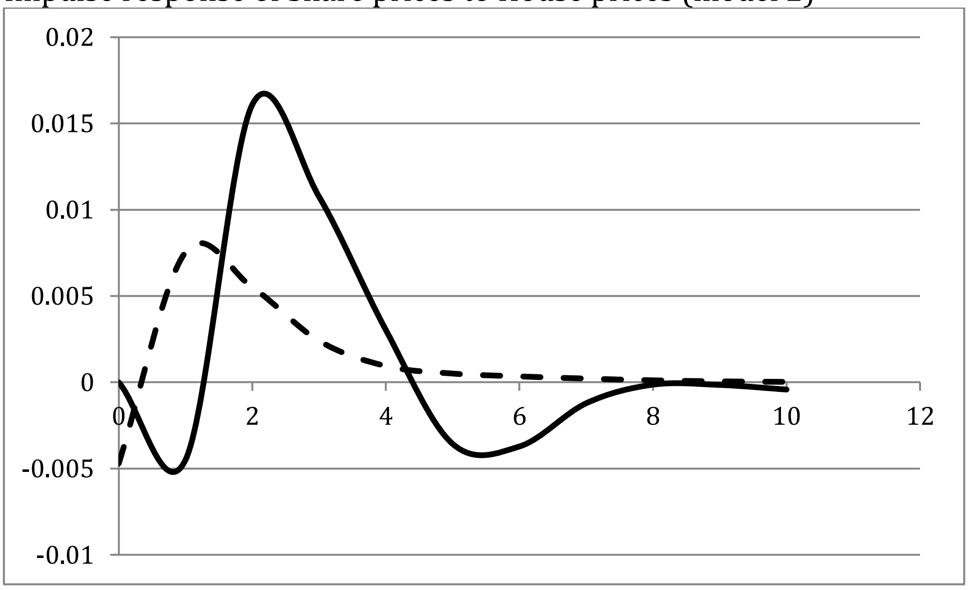

Impulse response of consumption to House prices (model 2)



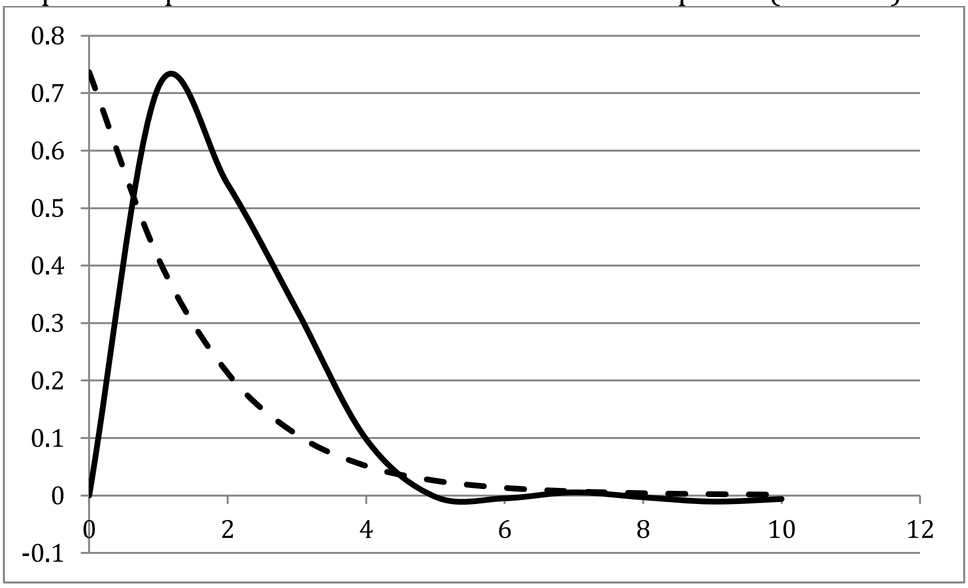
Impulse response of Interest rates to House prices (model 2)



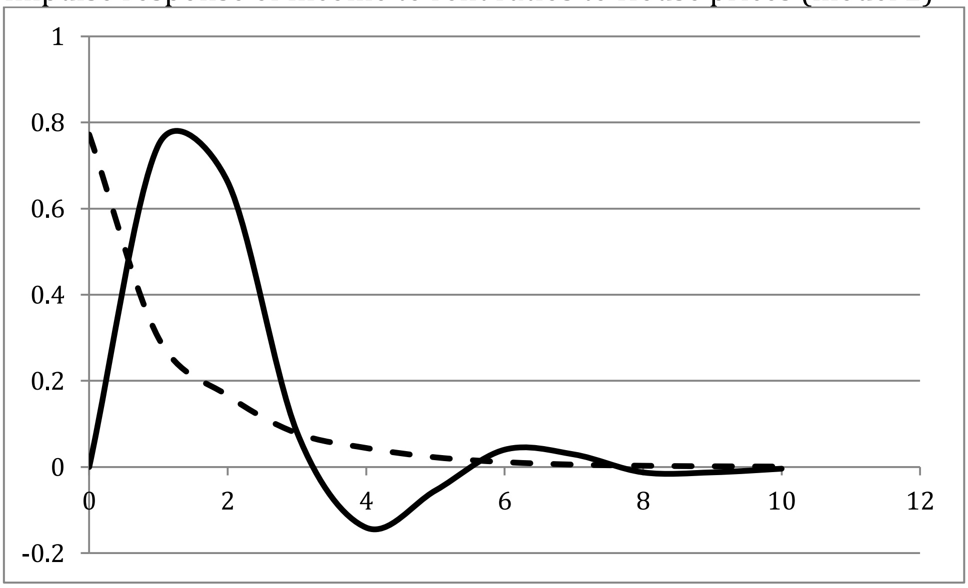

Impulse response of Share prices to House prices (model 2)



Impulse response of Price to rent ratios to House prices (model 2)




Impulse response of Income to rent ratios to House prices (model 2)




______LSTVAR model

-------- Linea model