TIME VARYING PARAMETER MODELS AND HOUSE PRICES

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Abstract

This study investigates the performance of time varying parameter models on house prices. Three specifications are considered one TVP-AR(1) model one TVP-AR(2) model and one TVP-VAR(1) model. The models are evaluated on five countries during the period 1980-2013 using quarterly data. TVP-models are used to account for the changing expectations the homebuyers' are assumed to have and the non-linearity that follows from their expectations. The TVP-AR models appear to capture the expected mildly explosive behavior during bubbles however the TVP-VAR(1) model does not. The TVP-models all perform better at short- and medium-term forecast for all countries. There is however no evidence that one model specification is better than the others as the result diverge for all countries given the task.

Keywords: Forecasting, House prices, Kalman Filter, Rational Bubbles, Time Varying Parameters

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1 Introduction

During past decades it has become evident that house prices can have a considerably impact on the overall global economic environment. The reason for this can be accounted to the fact that housing has a considerable part of the household wealth and it is usually the most important asset in their portfolio (Case et al. (2005)). In this study the ratio of owner occupied housing to rentals is around 70% for the countries and in Europe mortgage debt accounts for around 70% of homeowners' total liabilities (ECB (2009)). The same figure for the US is slightly higher at just below 75% (The New York FED (2013)).

There are two main channels which house prices can affect the economy. The first channel is through households' consumption. This is a direct effect as households' consumption is affected by changes to the interest rate. Higher interest rates results in lower consumption. The second part of the consumption channel payments rise with higher mortgage rates. Another way consumption is affected through households' ability to use their houses as collateral when house prices decreases. Because the mortgage constitutes a high share of the total liabilities, house prices can have an effect on not only consumption but also the whole economic environment. This channel goes through which house prices can affect the economic environment is through mortgage institutions. This was seen in the last economic crisis where homeowners defaulting shock the whole system. Understanding the channels through which house prices affect the real economy is the first part in the analysis. The second part concerns the detection of unsustainable price developments in the housing market to limit the impact downturns in the housing market have on the real economy. Finding a model which can explain and forecast house prices with precision is thus of importance.

To be able to find a model suitable for the housing market and the potential bubble it could contain one should first define what a bubble is and how prices are determined. In this thesis the bubble behavior is defined as exponentially rising house prices. This is a result of speculation and that the price is a function of future price increase. According to the q-theory of housing the user cost is a function of expected capital gains and depreciation of the property. A more speculative nature on the housing market could result in inflated expectations about future capital gains. This enters into the pricing function through the user cost and will drive the price upward, all else constant.

The market expectation on future price developments is likely to change over time and could result in periods with above unit growth rate. This makes a non-linear model suited. However, in order to detect bubbles in the housing market its beneficial to allow price dynamics to be both linear and non-linear dependent on time. Because of these properties on the housing market, one can utilize Time-Varying-Parameter models (TVP) to explain the price behavior. As the name suggest these types of models allow the parameters to take on different values in each time period.

The benefit of using TVP models is because it solves some issues that are common in time series analysis. First, taking this approach is also to some extent a solution to the Lucas critique (Lucas (1976)), which states that not only the behavior of the economic agents' changes but also their parameter estimates as they revisit their models during policy change. Time Varying Parameter (TVP) models, which estimate parameters in each period, can thus be used even though policy reforms are put into motion.

Drawing from Engle & Watson (1987) there are a few other reasons for using TVP-models. Because of the last financial crisis and the down turn of house prices, estimation of the house price series will now prove more challenging as there is a trend break in the end of the series. However, there are a number of different models that can account for this type of break; the simplest model that comes to mind is the rolling regression method where the sample is split into shorter periods. As this might solve some issues of parameter instability, the required number of data points for estimation will be a problem. In the house prices series, the break point (fourth quarter of 2007) is relatively close to the end together with quarterly observations clearly limits the options to model the break. Another issue with the constant parameter estimation e.g. rolling regression is the underlying assumption that the data generating process (DGP) is stable, which it might not be (Brown 1997). The TVP models' in which the parameter estimate is updated for each observation can both eliminate the parameter instability issue and to some extent the data issue.

The purpose of this thesis is to evaluate how well time varying parameter models explain house prices. The models are evaluated through a comparison with a right tailed ADF-test and through short- and medium-term forecast. The TVP modelling approach is implemented on five countries, four of which already have experienced a boom and a bust and one of which the occurrence of a bubble is unclear. The countries on which the models are applied to are Ireland, Spain, Sweden, United Kingdom and United States. These countries are selected in order to evaluate the models in countries which have experience boom and bust periods. Performing the same analysis for Sweden will provide insight to whether there is a bubble present in the Swedish housing market. The sample the spans from the first quarter of 1980 to the fourth quarter of 2013. The sample period is chosen as to include the latest financial crisis and also be long enough to perform out-of-sample forecast in the run up as well as the bust of house prices. This cumulates into the question:

Are the TVP-Models able to capture the mildly explosive behavior in house prices?

This set up also allows one to give input to the question, "*is there a bubble present in the Swedish housing market?*" which has been discussed extensively in Sweden and abroad. The TVP-models are expected to capture the non-linearity in the house price series with mildly explosive behavior if the bubble is driven solely by speculations. This is tested by the hypothesis H_0: parameter=1, No bubble and the alternative H_1: parameter>1, Bubble. Parameter values above one are thus expected in the run up to the fourth quarter of 2007 for Ireland, Spain, UK and US. For Sweden the parameter series is expected to vary around one with some periods possibly experiencing mildly explosive value. The period where this is expected is the beginning of 1980s before the Swedish house prices collapse. The result is in accordance with the expectations for the TVP-ARs and show that the approach can detect periods of mildly explosive behavior, however TVP-VAR(1) model does not seem to detect this behavior. In general the more parsimonious TVP-AR representation is preferred over the TVP-VAR specification.

The reminding part of this paper is organized in the following way. In the next section a brief introduction to the existing literature concerning this paper is presented. In section 2, the underlying theory to the models is presented. In section 3, the models are presented as well as the data used in the empirical research. In the 4th section the results from the estimation of the models are found. The forecast performance is presented in section 5 followed by a discussion of the results from the estimation and forecasts in section 6. In the last section the concluding remarks are found.

2 Literature Review

The housing market has been studied extensively during the last years. The literature concerning this thesis is twofold and concerns model section and properties of housing markets with mildly explosive behavior. The first part of the literature review deals with the housing market and is followed by empirical studies of the housing market. Much of the research done on rational bubbles with non-linear models have focused on the US and UK housing market and most often these models have been either some state space model or Markov-switching model (among others Hall et al. (1997), Guirgius et. at. (2005)).

A recent study by case et al. (2012) on the expectations of homebuyers was conducted in US focusing on the expectations before and after the outbreak of the latest financial crisis. The authors use the results from a questionnaire about homebuyers' expectations and decision making conducted in 1988 and annually during 2003-2012. The survey in this context is used to seek out the reason of the homebuyers' behavior during the years leading up to the sub-prime crisis and after its outbreak. The paper studies the expectations homebuyers had on both short-term and long-term and find that buyers are generally well-informed. Moreover the short-term expectations underreacted to the change between years and that the long-term expectations were much higher than the mortgage rate suggested it should have been. The authors argue that the over and under predictions from the buyers is the root cause of the crisis.

The expectations the homebuyers had the years leading up to the latest financial crisis could be explained in the framework of rational bubbles. This is the start point of a paper by Phillips and Yu (2011) which seeks out to date the boom and bust of the housing bubble in US. They modify the methodology developed in Phillips et al. (2011) to date the origin and burst of speculative bubbles. They apply the methodology to a house price series, crude oil price and the spread between Aaa and Baa bond in US. The results show that a bubble started forming in 2002 for the house price series and after the sub-prime crisis in 2007, booms and busts were detected in the bond market and commodity market all of which had burst by the end of 2008. The authors find that the modified methodology works well for dating bubbles as it follows the dateline relatively closely. The test developed in the paper will be used in this thesis to evaluate the how well suited the TVP-models are to explain house prices; more on the ADF-test and how it relates to the TVP-models are found in section 3.

Blanchard and Watson (1983) argue that an asset where the fundamental value is difficult to assess is more likely to be affected by a bubble. For a buyer it can be hard to root out what effect a change in fundamentals will result in for the future value of a dwelling. The authors argue that the buyer might instead base their choice of whether or not the buy or sell the asset on what have happened in the past, thus making the choice of an autoregressive structure appropriate.

In response the linear models often used on the UK housing market Brown et al. (1997) study quarterly house prices in UK from 1968Q2 to 1992Q2 with time varying parameters. They assume that the parameter of nominal user cost follow a random walk with changes in income as drift and the coefficient of expected gains on housing is modeled as a random walk with mortgage rate changes as drift. They conclude that the TVP-regression out-perform all of the comparison models. These baseline models include an error correction model, vector autoregressive model and an autoregressive model.

Also studying the UK housing market with a non-linear model is Hall et al. (1997). They take a different approach to detect bubble behavior in UK house price using a Markov-switching error-correction model. They find that the house prices have experienced periods of regime change which points to bubbles. They also conclude that the probability of staying in an unstable regime decreases as prices get further away from the equilibrium.

When studying the US market Guirgius et. at. (2005) considers a number of different models in which the parameters are allowed to vary over time. They show that sub samples sufferers from considerable parameter instability. The authors evaluate the performance of the models used by out of sample forecast which spans from 1985Q3 to 1998Q2. They find that two of the models perform particularly well; the two models are a rolling GARCH model and TVP-AR model.

Crawford and Fratantoni (2003) considered a Markov-switching model to explain house prices in the US. They find that the Markov-switching compares worse than the ARIMA model which, is used as a comparison model, at out-of-sample forecasting. As a response after replicating the same model, Miles (2008) considers different non-linear models. The author find that the Generalized AR (GAR) performs better than ARMA and GARCH models especially in markets with historically higher volatility.

In a comparative study between the US and UK market, Meen (2001) adopt a common methodology to explain both countries house price movements. The author finds that given the common methodology the same theory can explain the dynamics of house prices in both countries which at first sight do not appear to be that similar.

Although there have been numerous studies done on house prices in the other countries there is to my knowledge none published with time varying parameters. A study conducted by Hort (1998) uses an error-correction model for studying the determinants of house prices in Sweden and if the market possibly contains speculative bubbles. The author uses panel data from 20 urban areas in Sweden between 1968 and 1994. The main findings include significant long-run coefficients for income, user cost, construction and the support of strong autoregressive structure of house prices. Although the results support the notion of speculative behavior, the price changes are well explained by the changes in fundamental demand.

A more recent study on the Swedish housing market is conducted Englund (2011) as part of the The Riksbank’s inquiry into the risks in the Swedish housing market. Englund argues that the house prices in Sweden have largely been driven by fundamentals which indicate that the Swedish housing market is not over evaluated. Concern is however raised that an over valuation is present in Sweden based on the speculations whether or not the US was in a bubble pre-subprime crisis.

This thesis will complement previous research with a different way of modelling house prices with non-linear models as well as providing estimates for countries where the non-linear approach have not been used to the same extent as in the US.

3 Theoretical Framework

This section presents the underlying theory on which this thesis is based. This section builds on the theory of rational speculative bubbles and is chosen as it gives a theoretical motivation why to choose a time varying approach for modeling house prices. Before turning to the properties of the times series data which may contain a bubble, a short introduction to the transversality condition is given in order to motivate the presentence of a bubble.

The transversality condition states that if the price of an asset increases at a rate less than the discount rate, its terminal value will eventually not be of any particular value. This would result in asset prices being equal to the discounted value of all future cash flows and thus no bubble could exist. However, if there are investors that do not intend to hold the asset for an infinite time period, this does not necessary hold and bubble can occur. (Stiglitz, (1990), p 14).

Through the transversality condition one can conclude that an asset growing with the rate of the discount factor or greater would be explosive and thus move towards infinity as $t \to \infty$. This can be illustrated from the arbitrage condition. The price today is determined by the expected price tomorrow and tomorrow's cash flow.

$$P_t = \frac{1}{1+r} E_t \left(P_{t+1} + D_{t+1} \right) \quad (1)$$

through recursive substitution this can be written as

$$P_t = \sum_{i=1}^{\infty} (1+r)^{-i} E_t \left(D_{t+i} \right) + B_t \quad (2)$$

Where P_t is the asset price, r is the interest rate; D_{t+1} is the dividend; and $E_t\left(.\right)$ denotes the expectation given all information available at t. For convenience the fundamental component is denoted by F_t:

$$F_t = \sum_{i=1}^{\infty} (1+r)^{-i} E_t \left(D_{t+i} \right) \quad (3)$$

$$P_t = F_t + B_t \quad (4)$$

To assure mildly explosive behavior, component B_t, is modelled as:

$$E_t (B_{t+1}) = (1+r) B_t \quad (5)$$

The bubble component (5) is the homogenous part of the solution to the difference equation (2). Even though the bubble component does not have a defined value we can still say that it is growing explosively as $(1+r) > 1$ (Flood and Hodrick (1990)). The equations 4-5 The bubble term (5) is what drive the house prices up and is usually the expected capital gains in case of a housing bubble.

The relationship between house prices and fundamental variables is easiest explained by the simple q-theory of housing demand. The q-theory states that there is a relationship between disposable income, housing demand, and user cost. Assuming time invariant depreciation rate one is left with a relationship between the price and expected capital gains, disposable income and housing demand (Sörensen & Whitta-Jacobsen (2010)). Not controlling for these variables could give an indication of explosive behavior, when in fact the price behavior is motivated by for example rising income.

The price drop after a bubble burst can partly be explained as follows. During a bubble the higher price result in higher returns on new produced dwellings and thus a larger housing stock. The bubble component is assumed to grow at an exponential rate and thus driving the prices upward. Keeping demand constant, this implies lower rents in the future and thus a lower fundamental value. The price will then drop to a lower level than before the as a result of the now larger housing stock (Blanchard & Watson (1983)).

It should be noted that the discount rate might be time dependent and this could potentially affect the fundamental price. However, the analysis in this thesis is carried out with the assumption that the discount rate is constant over time. This is supported by the result in Phillips and Yu (2011) where the authors show that for the most part the discount rate does not affect the fundamental price. They show that under a certain time profile where investors start to value the present increasingly higher the fundamental part will show explosive behavior (Phillips and Yu (2011)). As this can be considered a special case and will not likely be the case in the housing markets studied in this paper this will not be accounted for.

Although used numerous times the theoretical framework for speculative bubbles can be questioned both from a theoretical and empirical perspective. From a theoretical perspective it can be shown that the solution including bubble components can violate partial and general equilibrium. As some of the criticism is specific to the housing market only the criticism which can be related to the housing market is presented.

The first issue with the theory stems from partial equilibrium and concerns negative bubbles and limited liabilities. One implication of a negative bubble is that it would result in a negative asset price in the future. In market with limited liabilities this is clearly an undesirable property from which it follows that it is not possible for a bubble to start within an asset model. Thus, the bubble must have its origin from the moment the asset started trading since if the bubble ever had a zero value its expected value will also be zero (Campbell et al. (1997)). Since the bubble cannot take on zero values, it would have to take on the value zero with certainty in the future for it to have expected value zero (Diba & Grossman (1988)).

Continuing with the general equilibrium, the criticism of the theory concerning house prices is that a bubble cannot be present in an asset price if the interest rate exceeds the growth rate. In the context of an overlapping generation economy this would result in the bubble being infinitely large compared to the overall wealth of the economy and thus violate some agents' budget constraints. Thus, a bubble can only be present in dynamically inefficient economies which over accumulate capital driving the interest rate down (Campbell et al. (1997)).

Using time varying models the bubble term (B_t) can be captured in periods where standard OLS-models would not. This because the OLS-models will smooth the parameter estimate when in fact some sub-samples the parameter should be indicating exponential growth e.g. a bubble. The TVP-models used in this thesis is estimated through the Kalman filter and presented in the next section. The use of the Kalman filter and time varying parameter could thus be seen modeling approach to rational expectations. When moving in the sample from one point in time to another the filtering accounts for both the forecast and the past information of the parameter estimate. The coefficient accounts for the new expectations the market have on future price movements in each data point given what has happened so far (Engle & Watson (1987, pp245-249)). More on the technical aspect of this is found in section 4.3 The Kalman Filter.

The expected mildly explosive behavior of the series will be tested by a Right Tailed Augmented Dickey Fuller (RTADF) test in order to determine the presence of explosive behavior in the house price series. The test result can then be used to compare the results by the TVP-AR and TVP-VAR models to see if the models correctly capture the presence of bubble behavior in the series. Thus, the RTADF test is expected to identify periods of mildly explosive behavior by rejecting the null hypothesis. Rejection of the null hypothesis in the RTADF corresponds to a parameter value significantly higher than one in the time varying models.

4 Method

To be able to evaluate if the housing market is subject to a bubble a time varying parameter model is applied to the data. The idea behind this approach is that if the market is subject to excessively high prices the series should be mildly explosive during the period up until the burst. To evaluate this, a TVP modelling approach is implemented on five countries, four of which already have experienced a boom and a bust and one of which the occurrence of a bubble is unclear. Also presented in this section is the descriptive statistics of the data used.

4.1 Empirical Model

When the bubble burst equation (4) reduces to just $P_t = F_t$ this should manifest in the TVP framework as parameter values at unity or below. Engle & Watson (1987) argue that strong autocorrelation in house prices motivate the assumption that the parameter of lagged house prices on house prices show be close to unit. As the bubble component is unobserved, using a time varying model can help find periods with rapidly increasing prices. When using a TVP-model to investigate the presence of a bubble the growth rate of the bubble will show up in the parameter of lagged house prices.

As a mildly explosive series is expected during the years leading up the burst of a bubble specifying the parameter as a random walk is suited. This because it self is non-stationary and should thus capture the expected increase in the parameter values during the run up. The random walk specification of the parameter is widely used and has shown to perform well and is suited for permanent and temporal shifts in the series (see Engle and Watson (1987) Primiceri (2005)).

Compared to other TVP-models the specifications used in this thesis is more general and offers an alternative to more complex models as those used in for example Brown et al. (1997). The random walk modelling is chosen over Markov-switching models largely base on the fact that Markov-switching models not being particularly good when evaluated through out-of-sample forecast result. A negative implication of the random walk property is that it will hit an upper or lower limit with certainty. However, this will not be an issue in this study as the time period is finite.

The state space representation of the TVP-model is given by (6) and (7)

$$P_t = \beta_t F_t + \varepsilon_t, \qquad \varepsilon_t \sim NID\left(0, \sigma_\varepsilon^2\right) \tag{6}$$

$$\beta_t = \beta_{t-1} + \eta_t, \qquad \eta_t \sim NID\left(0, \sigma_\eta^2\right) \tag{7}$$

Where, P_t is the house price index F_t is the house price index lagged one period and t=2, 3, …, 136 and the corresponding assumptions:

$$E(y_t, \varepsilon_t) = 0,\ E(\beta_t, \varepsilon_t) = 0,\ E(\beta_t, y_t) = 0,\ \forall t = 2, \ldots, 136$$

The error terms in (1) and (2) are assumed to normal and independently distributed with constant variance. The system (6)-(7) is the state space model representation of the AR process assumed for house prices[1].

The VAR representation of the TVP model is straight forward from (6) and (7) where P and F are row vectors and β is a 3x3 matrix with time varying coefficients in the top row. The TVP-VAR model is model in this way to ease the computing power needed to estimating the model. Like Doan et al. (1984) the VAR system was estimated separately to ease the stress of the iteration algorithm, although some efficiency might be lost by

[1] Estimation of the TVP-model was done in Eviews using the Kalman filter

estimating the system separately, convergence was achieved were it previously was not.

$$P_t = \begin{bmatrix} hp_t \\ inc_t \\ r_t \end{bmatrix}, \; F_t = \begin{bmatrix} hp_{t-1} \\ inc_{t-1} \\ r_{t-1} \end{bmatrix}, \varepsilon_t = \begin{bmatrix} \varepsilon_{hp,t} \\ \varepsilon_{inc,t} \\ \varepsilon_{r,t} \end{bmatrix}, \; \beta_t = \begin{bmatrix} \beta_{1,t} & \beta_{2,t} & \beta_{3,t} \\ \beta_4 & \beta_5 & \beta_6 \\ \beta_7 & \beta_8 & \beta_9 \end{bmatrix},$$

$\beta_{i,t} = \beta_{i,t-1} + \eta_{i,t}$, for i=1, 2, 3

Where hp_t is house price index, inc_t is real disposable income and r_t is real interest rate.

4.2 Kalman Filter

In section 2. Theoretical Framework it is argued that the parameter estimation can be a way to cope with changing expectations that homebuyers' are assumed to have. This section will give a presentation of the Kalman filter and how the changing expectations are accounted for in the state space representation.

The Kalman filter is based on two components, one that deals with the optimal forecast given all information available up until time t, the other component consist of the part that cannot be forecasted i.e. the forecast error. Just as in the concept of rational expectations the forecast errors are independent of each other making each forecast the optimal forecast given the information available in that period (Beck (1983)).

The Kalman filter estimation in this case can be presented as follows. Denote the conditional probability of the state parameter as

$$\beta_{t|t} = E[\beta_t \mid Y_t] \qquad (3)$$

where $Y_t = [y_t, y_{t-1}, \ldots, y_1]$

Let $\beta_{t|t}$ denote the mean of (3) and $\Sigma_{t|t}$ denote the variance of (3) then the Kalman filter recursion is given by the following system:

$$\beta_{t+1|t} = \beta_{t|t}$$

$\Sigma_{t+1|t} = \Sigma_{t|t} + Q$, Q is the variance matrix of η_t from (2)

$\beta_{t+1|t+1} = \beta_{t+1|t} + k_{t+1}\left[y_{t+1} - y_t\beta_{t+1|t}\right]$

$\Sigma_{t+1|t+1} = \Sigma_{t+1|t} - k_{t+1}y_t\Sigma_{t+1|t}$

and $k_{t+1} = \left[y_t\Sigma_{t+1|t}y_t + R\right]^{-1} \times \Sigma_{t+1|t}y_t$,

k is known as the Kalman gain and determines the importance or weight put on new information. R is the variance matrix of ε_t from (1).[2]

The Kalman filter is initialized with diffuse priors, a benefit of initializing the Kalman filter with diffuse priors is that the assumption of stationarity most not be fulfilled. The fact that assumption of stationarity can be dropped is important to this thesis as it is based on the assumption that house prices' is an unstable process. In short diffuse priors mean that large initial values are assigned in the covariance matrix and the initial parameter values are chosen arbitrarily (Brown et al. (1997)).

4.3 The Forward Recursive ADF-test

To begin with right tailed unit root tests are performed to root out periods where the series experienced mildly explosive behavior. This is done to better evaluate the TVP-models ability to capture the non-linearity in the house price series.[3] This is done by applying the recursive test procedure developed in Phillips et al. (2011). The test procedure has shown to be able to detect bubbles both in the stock market (Phillips et al. (2011)) and the housing market (Phillips & Yu (2011)). Ideally the results from the time

[2] For a more extensive view of the Kalman filter representation see Abraham & Ledolter (1983), Andersson & Moore (1979).

[3] RTADF test is available through the rtadf add-in for eviews.

varying regression will detect the same periods as the recursive test. Under the null hypothesis the recursive test statistic is given by[4]:

$$ADF_r \Rightarrow \frac{\int_0^r \tilde{W}\, dW}{\left(\int_0^r \tilde{W}^2\right)^{1/2}} \quad \text{and} \quad \sup_{r\in[r_o,1]} ADF_r \Rightarrow \sup_{r\in[r_o,1]} \frac{\int_0^r \tilde{W}\, dW}{\left(\int_0^r \tilde{W}^2\right)^{1/2}}$$

Where W is a standard Brownian motion and $\tilde{W}$ is the demeaned Brownian motion $\tilde{W}(r) = W(r) - \frac{1}{r}\int_0^1 W$.

The recursive test statistic series can then be compared to the right tailed critical values to determine where the series have mildly explosive behavior (Phillips & Yu (2011).

4.4 Forecasting

In order to evaluate the performance of the models, forecasts are performed. Focus lies on one-step-ahead and four-step-ahead to capture the short- and medium-term forecasting performance. This is done through pseudo out-of-sample forecast with 64-period estimation window (from 1980Q1 to 1996Q4) with a rolling window spanning over 68 periods (from 1997Q1 to 2013Q4). To evaluate the forecast an AR(1) models is used as a baseline model to compare the TVP-models against. The measures used to evaluate the forecast is average forecast error (BIAS), Forecast error variance (FEV), MAFE mean absolute forecast and error RMSFE root mean square forecast error.

Testing is also performed using two different tests to test the hypothesis if the TVP-models perform equally to the baseline model or better. The

[4] See Phillips et. al. (2011) for a complete derivation of the test statistic and a discussion on the properties of the recursive test.

models are clearly nested as posing a restriction of time invariant parameters reduces the model to a standard AR(1) process. Given that the models are nested it can be argued that the test does not give reliable inference. For instance the Clarke and McCracken (2001) showed that the Diebold-Mariano (DM) test do not have a t-distribution when the models are nested. The reason behind this is that under the null hypothesis that the restricted model is the true model the forecast error would be the same. This null concerns the population level, in this thesis the interest is instead the performance of the forecast in a finite sub-sample of the population and the critique can be overlooked.[5]

The fact that the DM-test performs worse in small samples can be helped with the Harvey, Leybourne and Newbold small sample modification (Harvey et. al (1997)). Furthermore, the Morgan-Granger-Newbold (MGN) test, Theil U-statistic will also help guide the conclusion of which model performs best.

4.5 Data

In order to evaluate the performance of the model five countries are considered. The countries are Ireland, Spain, Sweden, United Kingdom and United States. These countries were selected to see how well the model could explain the behavior of house prices. Ireland, Spain and US all experienced a severe downturn in the third quarter of 2008. The house prices in UK dropped initially but have later recovered some from the initial price drop. Sweden is chosen because the prices have not experience the same bust period and is thus of interest to see if the model work better when it does not have to deal with the clear break point.

The sample used covers the period 1980Q1to 2013Q4, 136 quarters. This period was selected based on available data on house prices and to

[5] See Giacomini & White (2006) for a more in depth discussion.

have a large enough period before the sub-prime crisis to be able to conduct out-of-sample forecast. It is worth noting that Sweden experience a boom and a bust in the late 80's. This is a bit of an issue, as the coefficients given the estimation method will take this into account and could possibly affect the results. However, this issue is easily accounted for in a robustness check.

The variables used in the empirical model are a House price index and real disposable income per capita both from oxford economics through Datastream and a long-term interest rate from OECD. The two control variables (real disposable income per capita and interest rate) are common when analyzing house prices and included to see if the coefficients on lagged house prices change. This will also help determine if the bubble experienced in the countries affected was driven largely by speculation or if fundamentals explained the price increase.

The descriptive statistics are presented in table 1 below as well as the sources that the house prices are collected from. All variables are seasonally adjusted with the x-12 method and in real terms. A few things are worth noting from the descriptive statistics. The average growth of house prices during the period is all around 1.5% with the exception of US which is below 1%. During the period it is also clear that Ireland and England have experience higher volatility in the real disposable income series than the other countries. Sweden have experience the lowest mean income growth during and the statistics for interest rate are quite uniform with the exception of Ireland which have had the high min and max values.

Table 1. Descriptive statistics

	Mean	Mean Growth	Max	Min	Std. Dev
House Price Index					
Ireland	49.07	1.5%	130.72	9.44	37.37
Spain	55.94	1.5%	124.70	11.61	36.21
Sweden	74.32	1.3%	155.21	27.34	41.78
United Kingdom	55.38	1.6%	120.45	11.78	33.72
United States	65.52	0.93%	111.60	28.86	25.53
Real Dispsable Income Per Capita (euros)					
Ireland	3182.07	0.5%	4897.63	1767.56	1069.77
Spain	2676.13	0.3%	3518.71	1842.5	550.44
Sweden	4384.81	0.13%	5845.02	3440.87	482.99
United Kingdom	4255.65	0.47%	6069.31	2499.89	1084.45
United States	2465.72	0.62%	3747.9	1189.2	529.18
Real Interest Rate (%)					
Ireland	7.14		16.65	1.94	3.36
Spain	7.63		15.63	1.06	3.97
Sweden	6.79		13.21	0.98	3.35
United Kingdom	6.50		13.65	0.58	3.04
United States	5.85		13.59	0.95	2.86

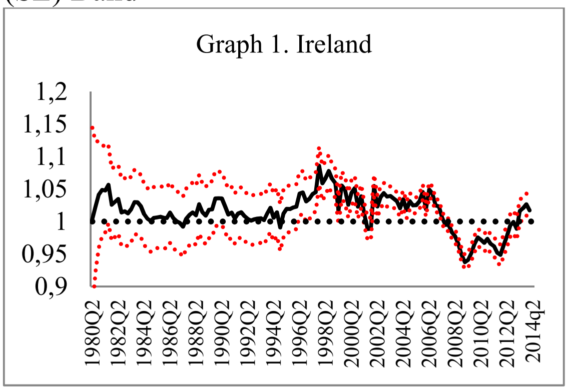
House Prices for Ireland are Central Statics Office Ireland, for Spain: Ministerio de Vivenda, for Sweden: Statistics Sweden, for UK: Department for communities and Local Government and for US: Federal Housing Finance Agency

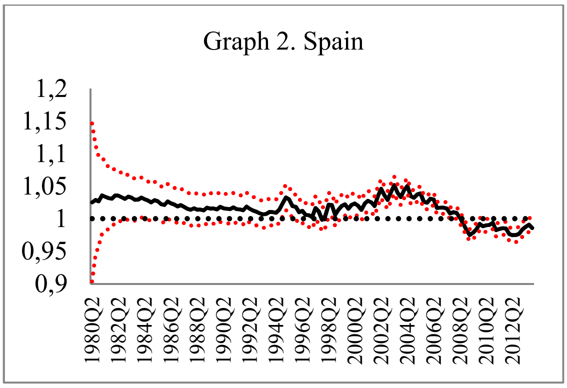
5 Results

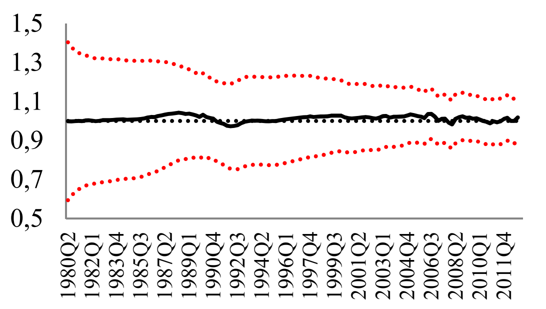
In this section, results from the estimation of the TVP-models are found as well as a discussion of the robustness of the results and a comparison of the TVP-Models with the results from the right tailed adf-test.

Presented in graph 1-24 are the results from TVP-models. The first graphs (1-5) depicts the estimation results from the TVP-AR(1) model together with 1.96*standard error (SE) band. These results indicate, as expected, that the coefficients are above one during the run up to the last financial crisis at 95%-significance level. The specification works well for Ireland, Spain and US where the pattern is evident. For Sweden the series' is more or less stable throughout the sample and fluctuate around unit which could be expected. However, the burst in the 1980's is not captured; this could be a result from the estimation which improves as more data is used later in the later part of the series. The state parameter for UK also fluctuates around unit but is more volatile and has periods where it is significantly higher than one and lower than one. The model also seems to capture the downturn for UK as well as the recovery.

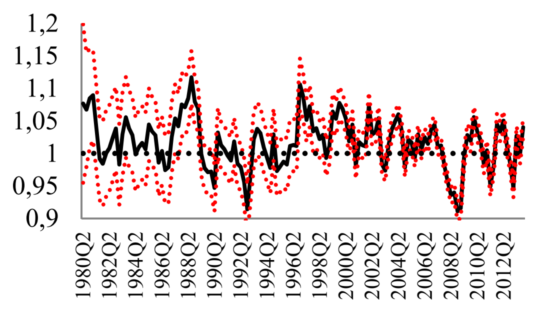
Graph 1-5. Filtered State Variable Estimates For TVP-AR(1) With 1.96*Standard Error (SE) Band



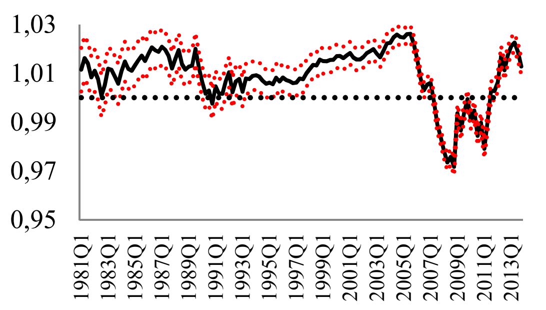




Graph 3. Sweden



Graph 4. United Kingdom



Graph 5. United States

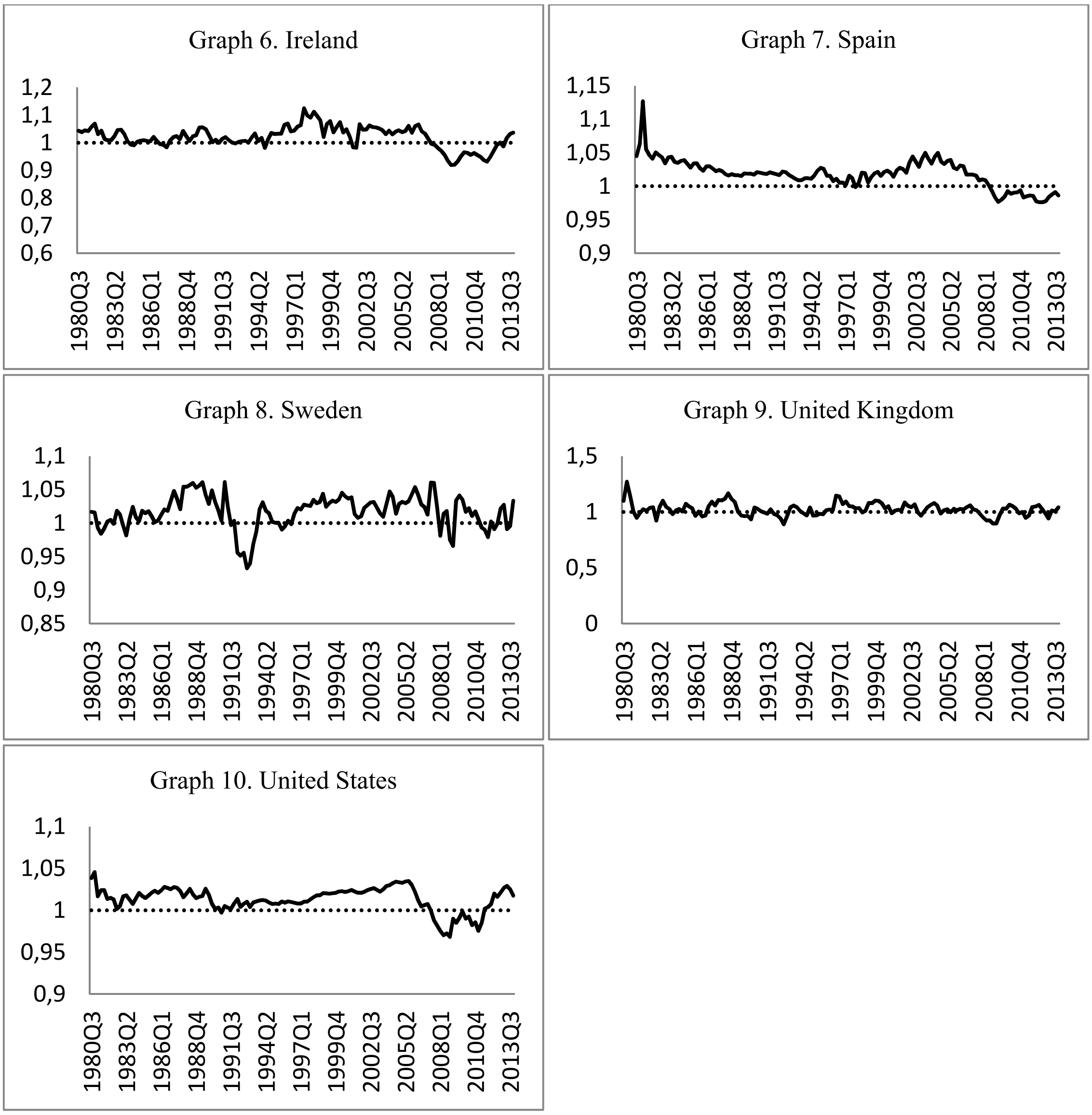
To determine if the TVP-AR(2) parameters exhibit mildly explosive behavior, The Stralkowski triangular condition is used. The triangular condition was presented in Stralkowski (1970) and states three conditions for an AR(2) model to be stable.

The conditions are;

$$\begin{cases} \beta_{1,t} + \beta_{2,t} < 1 \\ \beta_{2,t} - \beta_{1,t} < 1, \\ |\beta_{2,t}| < 1 \end{cases}$$

The results from the TVP-AR(2) estimation is depicted in Appendix A together with 1.96*SE-band. As evident from a graphical inspection of the results condition two and three is satisfied and will thus not be presented here. However, condition one (depicted in graph 6-10) indicates that the series is not stable during some periods of the sample. It should be noted that the error bands will not be calculated but the individual error bands are included in appendix A together with the two TVP-series. The results from the estimation are as expected from the theory and are much alike does obtained from the TVP-AR(1) estimation. Interestingly Sweden now shows indication of explosive behavior almost throughout the sample range. Only a few periods in the mid-1990s does the parameter value dip below one and after 2007Q4 fluctuate around one.

Graph 6-10. Filtered State Variable Estimates For TVP-AR(2)

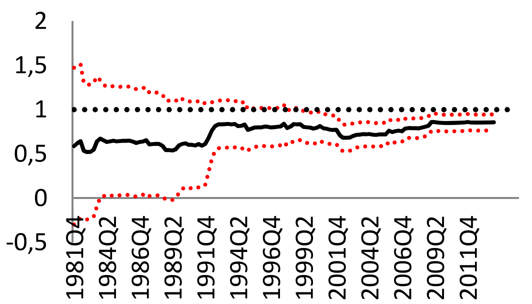


When including more covariates the coefficient values of lagged house prices are lower and generally more stable than before, results from the TVP-VAR(1) model are depicted in graph 11-24. The results from the TVP-

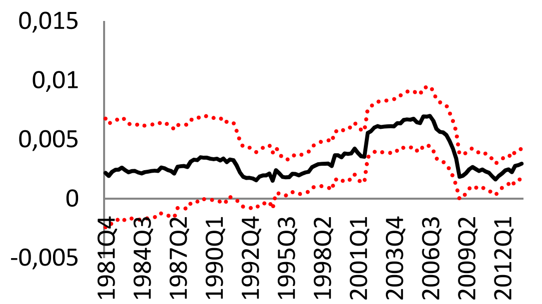
VAR models are not as clear as for the TVP-AR(1) model where parameter values are around unit for lagged house prices and other covariates not significant different from zero. The parameter on lagged house prices value fluctuate around one throughout the sample for all countries. Only for US does the parameter rise above unit at 95%-significance level during the period 2004Q2 and 2005Q4.

Graph 11-26. Filtered State Variable Estimates For TVP-VAR(1) with 1.96*Standard Error (SE) Band

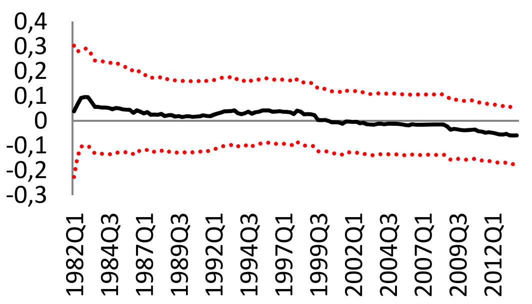
Graph 11. Lagged House Prices, Ireland



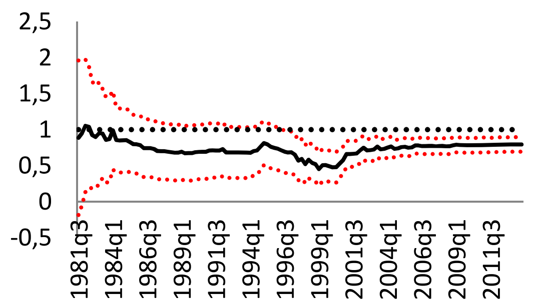
Graph 12. Lagged Income, Ireland



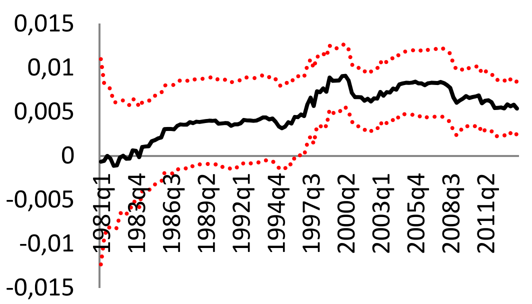
Graph 13. Lagged Interest Rate, Ireland



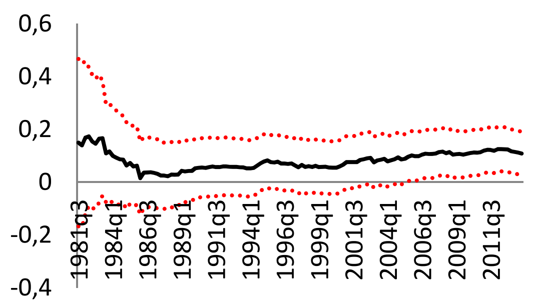
Graph 13. Lagged House Prices, Spain



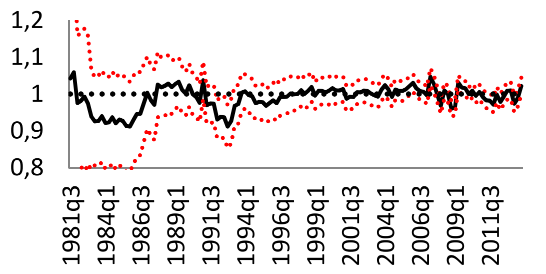
Graph 14. Lagged Income, Spain



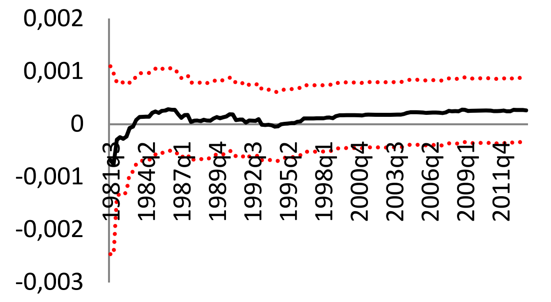
Graph 15. Lagged Interest Rate, Spain



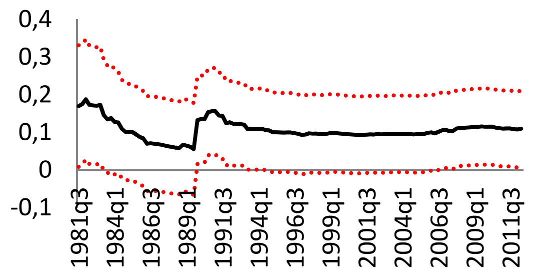
Graph 16. Lagged House Prices, Sweden



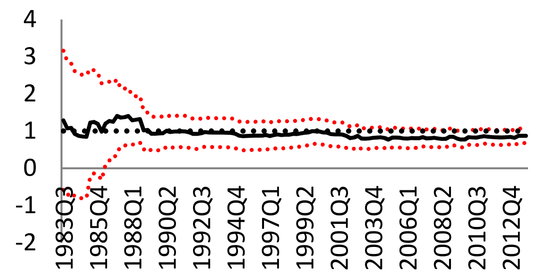
Graph 17. Lagged Income Sweden



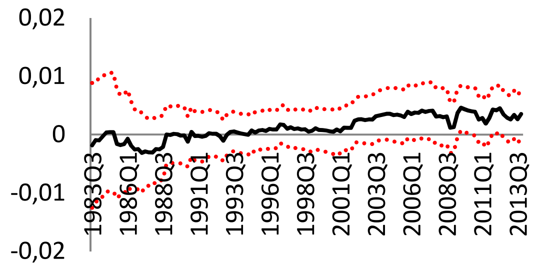
Graph 18. Lagged Interest Rate, Sweden



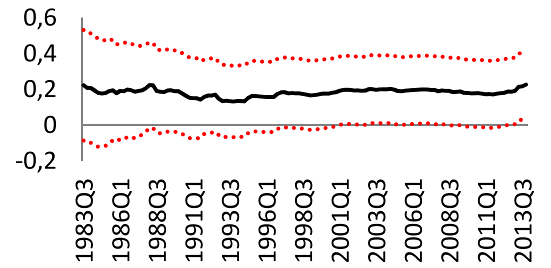
Graph 19. Lagged House Prices, United Kingdom



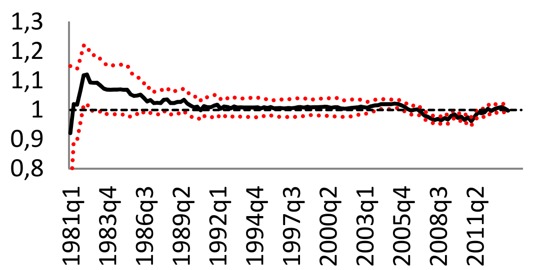
Graph 20. Lagged Income, United Kingdom



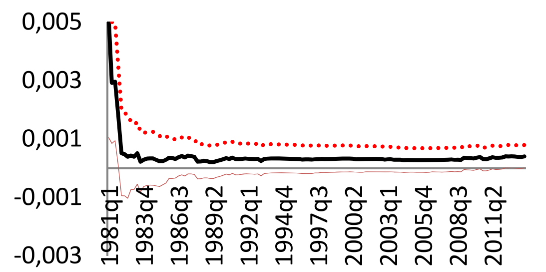
Graph 21. Lagged Interest Rate, United Kingdom

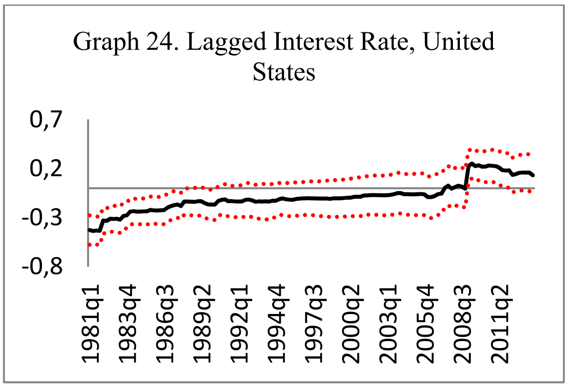


Graph 22. Lagged House Prices, United States



Graph 23. Lagged Income, United States





The parameter on real disposable income show explanatory power from the mid-1990s for Ireland and Spain but not for Sweden, UK and US. The interest rate coefficient is not significant different from zero for Ireland and UK. For the other countries the parameters have periods where it is above zero generally in the end of the sample. This is probably a result of lower interest rates and decreasing house prices during the bust of the housing bubble.

Both the Aikaike Information Criterion (AIC) and the Schwartz-Bayesian Information Criterion (SBC) show mixed result between TVP-AR(1) and TVP-AR(2) although it generally favor a TVP-model. The results from the two information criteria's are generally in line with each other except for Spain where AIC favor TVP-AR(2) and SBC the TVP-AR(1) which is most likely due to fact the SBC punishes more for variables. Although it should be noted that this difference in based on the fourth decimal for the AIC. The reason for TVP-VAR(1) not being the best fit is likely due to the amount of parameters one need to estimate given the TVP-model specification.

Table 2. Information Criterion

	AR(1)	TVP-AR(1)	TVP-AR(2)	TVP-VAR(1)
Aikaike Information Criterion				
Ireland	4.4255	3.4739	**3.1389**	3.5647
Spain	4.4135	2.9469	**2.9467**	3.1672
Sweden	3.8770	3.3078	**3.2929**	4.3890
United Kingdom	5.2807	**4.1664**	4.4679	4.8631
United States	2.8768	**1.1481**	1.2383	1.6439
Schwartz-Bayesian Information Criterion				
Ireland	4.4470	3.5165	**3.1389**	3.6508
Spain	4.4462	**2.9895**	3.0116	3.2529
Sweden	3.8986	3.3508	**3.3587**	4.4751
United Kingdom	5.3133	**4.2315**	4.5328	4.8632
United States	2.8983	**1.1912**	1.3032	1.7300

Bold numbers indicates the most favorable value

5.1 Robustness

Given the Kalman filter estimation these results will be a sensitive of the sample at hand. A few things can be considered to assert the robustness of the result. First, the Kalman filter estimation is dependent on the priors chosen and could potentially affect the results through the estimation period. However, when assigning different priors when estimating the models the results differed minimally and the conclusions drawn from them did not change.

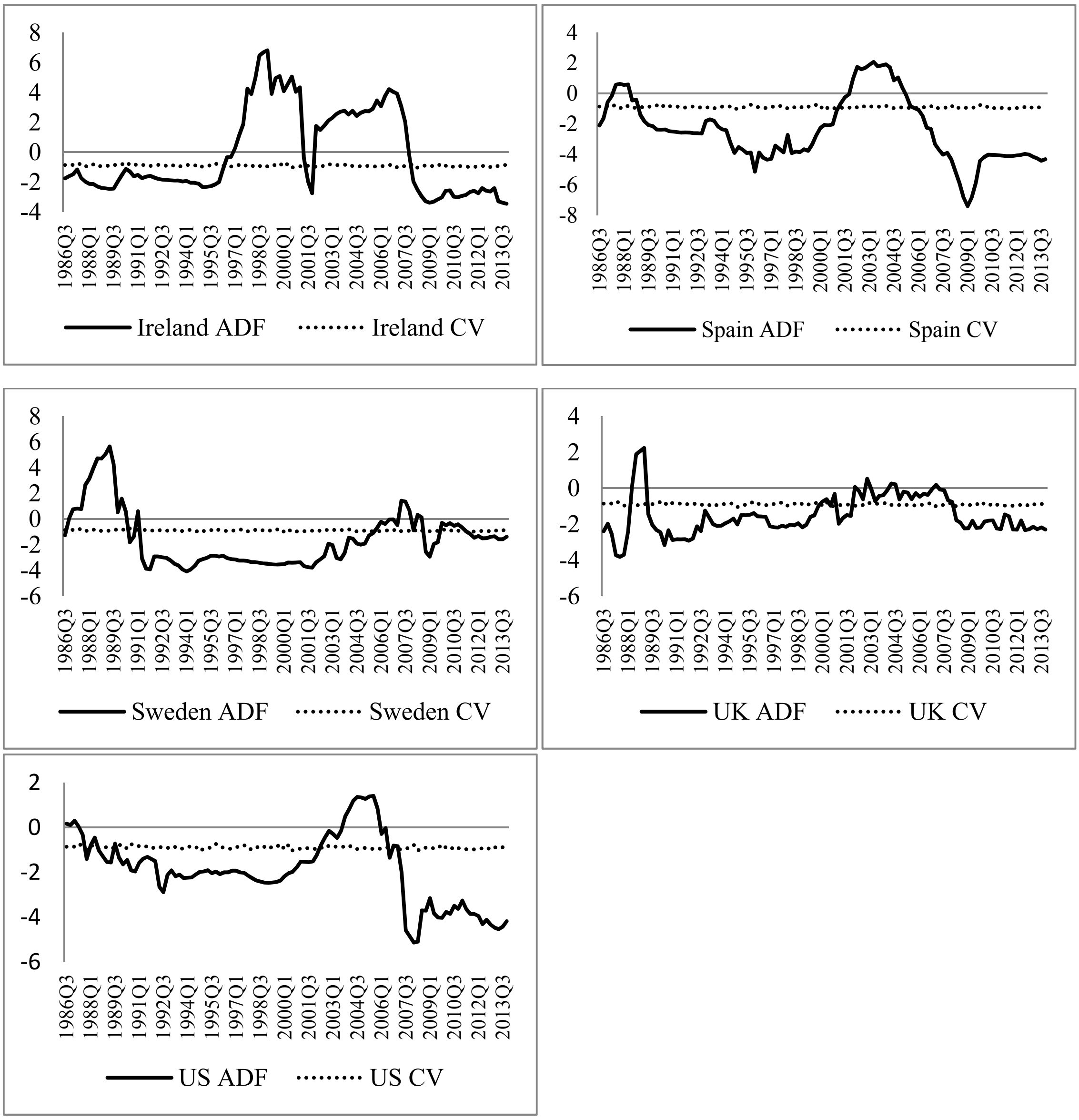
Secondly, the start date and what happens in the sample will also affect the estimation. Trimming the sample in the start will give a suggestion if the result in the later part of the sample suffers from what happens in the early data points. This is not a problem for the forecast as the window length is set and rolling. When trimming the sample the result stayed almost the same with the same periods being above unit and the TVP-VAR model still not giving parameter results above unit. The results from the robustness test are excluded from the thesis as they do not point to any issues in the estimation and will be to space consuming.

5.2 Comparison with the Forward Recursive ADF-Test

To better study the state series the forward recursive ADF-test will help with dating the periods were the model should estimate periods with higher parameter values. The ADF-test is used because it has shown to detect periods with explosive behavior well (see Phillips et. al. (2011), Phillips and Yu (2011)) and can help with guidance of the parameter interpretation. The test is performed with 8 lags, intercept and without trend, the trend can be excluded as the estimation period is short which usually means that the trend is small if present (Phillips & Yu (2011).

The results from the ADF-test are shown below the TVP estimates and support the model as it detects the same periods as the model. A few things are different, first the ADF-test suggest mildly explosive behavior between mid-2001 and late 2007 whereas the TVP-AR(1) model gives indication of explosive behavior from the start of the sample to 2007 with a short period of unit root in the early 1990s. For Spain both the TVP-AR(2) and TVP-AR(1) models show explosive behavior between 2007 and 2008 whereas the test cannot reject unit root from 2005 and onwards. In the 1980s Sweden experienced a boom and a bust which the ADF-test capture but clearly the TVP-AR(1) do not. However the TVP-AR(2) model seems to capture the market condition in the 1980s and a potential bubble in the late 2000s much alike the result from the RTADF-test. Overall the estimations from the TVP-AR(1) and TVP-AR(2) are much alike those expected after performing the ADF-test. A comparison with the TVP-VAR(1) is however redundant as the model did not show any signs of any periods of mildly explosive behavior.

Figure 25-30 RTADF (CV=Critical Value)



6 Forecast results

To better evaluate the models out-of-sample forecast was performed. Two different forecast windows were considered, a short-term one-period ahead forecast and a medium-term four-periods ahead forecast. The models was evaluated against the performance of a simple AR(1) process and are presented below starting with the on- step ahead forecast and follows with the results from the four-step ahead forecast.

6.1 One-Step Ahead Forecast Results

The forecast results can be found below in table 3. Just looking at the root mean square forecast error (RMSFE) the results are hard to interpret as the values are close to each other. The models appear to have similar RMSFE but they all have lower RMSFE than the linear AR(1) process. The models do not seem to consistently over or under shoot the real series and the bias is fairly close to zero.

Continuing with the forecast error variance Sweden stands out with highest variance which is due to the relatively poor forecast performance during the last financial crisis. The TVP-AR(2) model is however considerable better than the other models with lower RMSFE and MAFE. It should be pointed out that the measures MAFE and RMSFE do come to the same conclusion in all cases. For US MAFE suggest that TVP-AR(1) is the most favorable model although the difference is not that significant. During the years 2008-2013 the forecast errors was considerably higher than the run up to the crisis for Sweden and US. This indication of heteroskedasticity suggest that the TVP models might not be that suited to perform forecasting on house prices as it performs worse when in periods with higher volatility.

The U-statistic show most promising results for US where the it lies between 0,4 and 0,5 which can be considered good. For the other countries the results from the U-statistic are not particular promising as the values lie above 0,54 and some even above 0,9. For Sweden the U-statistic is lowest for the TVP-AR(2) model and above 0,94 for TVP-AR(1) and TVP-VAR(1) which is close to as good as the standard AR(1) process and not worth the effort of doing compared to the AR(1)-process. The TVP-Models are not particular better than the AR(1)-process for UK either if one only considers the U-statistic.

Table 3. Loss Function Results from One-Step Ahead Forecast

	AR(1)	TVP-AR(1)	TVP-AR(2)	TVP-VAR(1)
Ireland				
Bias	-1,2629	-0,0946	-0,1252	**-0,0089**
FEV	8,1324	3,5503	2,8568	3,1286
MAFE	2,3414	1,4309	**1,3442**	1,3754
RMSFE	3,1188	1,8866	**1,6948**	1,7688
U	-	0,6049	**0,5434**	0,5671
Spain				
Bias	-0,8612	-0,0882	**-0,0795**	0,0831
FEV	4,1555	2,0303	1,6037	1,8371
MAFE	1,7844	1,1294	**1,0392**	1,0854
RMSFE	2,2129	1,4276	**1,2689**	1,3579
U	-	0,6451	**0,5734**	0,6136
Sweden				
Bias	-0,3422	**0,0139**	0,0497	-0,0343
FEV	22,4451	21,5376	12,0431	20,0877
MAFE	3,4373	2,9697	**2,3322**	3,1249
RMSFE	4,7499	4,4819	**3,4707**	4,6409
U	-	0,9436	**0,7307**	0,9771
United Kingdom				
Bias	-0,4135	-0,1319	-0,1395	**0,0572**
FEV	11,3333	9,3846	9,0023	10,4709
MAFE	2,5152	2,4885	**2,3624**	2,5177
RMSFE	3,3918	3,0663	**3,0036**	3,2364
U	-	0,9040	**0,8856**	0,9542
United States				
Bias	-0,2461	-0,0117	**-0,0024**	-0,0058
FEV	1,9238	0,3642	0,3814	0,3615
MAFE	1,0291	**0,4051**	0,4164	0,4059
RMSFE	1,4087	0,6036	0,6176	**0,6012**
U	-	0,4285	0,4384	**0,4268**

Bold numbers indicates the most favorable value

To complement these measures significance testing were performed through the Diebold-Mariano test and the Morgan-Granger-Newbold test. Both test indicates that all TVP models outperforms the AR(1) process at the 1% level for Ireland, Spain and US at the 5% level. For Sweden and UK the tests give different results where MGN gives a more conservative result. For UK the MGN-test cannot reject the null hypothesis at the 5%-level for any of the TVP-models, DM on the other hand all reject the null hypothesis at the 5%-level for all TVP-models. Much like the U-statistic the tests indicates that the TVP-AR(2) model outperform the AR(1) model for Sweden at the 5%-level. The DM-test also suggests rejection of the null hypothesis for the TVP-models whereas the MGN-test cannot reject the null hypothesis.

Table 4. Significance Test

	TVP-AR(1)	TVP-AR(2)	TVP-VAR(1)
Ireland			
DM	10,3244	6,8381	11,4935
MGN	6,0384	6,0384	4,6984
Spain			
DM	7,7665	3,6461	8,2372
MGN	4,8955	2,3550	4,0247
Sweden			
DM	6,3291	2,3550	2,2608
MGN	0,2324	4,8955	0,6137
United Kingdom			
DM	4,5502	2,2062	3,8643
MGN	1,6434	1,6435	0,9858
United States			
DM	6,7702	2,5735	6,7514
MGN	8,2079	8,2079	8,1781

Critical value from t-distribution with 67 degrees of freedom
2,3833=1%, 1,6679=5%, 1,2943=10%.

6.2 Four-Step Ahead Forecast Results

Continuing with the medium-term forecast which now show signs of heteroskedasticity for all countries (shown in appendix C), however, the average bias is still fairly close to zero. Where the measures from the one-step ahead forecast in some cases suggested different models based on MAFE and RMSFE the two measures are now in line with each other. All measures are lower for the time varying parameter models for all countries, in some countries considerably lower. For example the bias for UK is 3,8217 for the AR(1) and -0,0256 for the TVP-VAR(1) model compared to the naïve AR(1) model. Except performing better than the AR(1) model it is hard to say something generally as no pattern that one model among the TVP-models perform better than the others. Where the TVP-AR(2) model seems to perform better short-term forecast the results for the medium-term forecast is mixed. In the one-step ahead forecast the TVP-AR(2) model is preferred in four cases whereas in the four-step ahead forecast there is an even spread over all TVP-models. It should however be noted that the forecast results from the TVP-Models in Sweden's case are still close to the AR(1)-process.

The lowest U-statistic is less than 0.5 for all countries and models except Sweden where it is now above 0.8. This is largely due to the fact that the linear AR(1) model have much higher RMSFE than earlier and the increase is not proportionally large for the TVP-models.

Table 5. Loss Function Results from Four-Step Ahead Forecast

	AR(1)	TVP-AR(1)	TVP-AR(2)	TVP-VAR(1)
Ireland				
Bias	3,8217	0,4261	0,5478	**-0,0256**
FEV	59,2318	4,6579	7,2160	9,4137
MAFE	5,3349	**1,7565**	2,1119	2,4805
RMSFE	8,5929	**2,1999**	2,7415	3,0683
U	-	**0,2560**	0,3190	0,3571
Spain				
Bias	1,7659	-0,4309	**-0,0457**	-0,5081
FEV	35,6868	2,7676	1,8251	3,6614
MAFE	4,8242	1,4078	**1,0709**	1,6131
RMSFE	6,2294	1,7185	**1,3517**	1,9798
U	-	0,2759	**0,2170**	0,3178
Sweden				
Bias	0,4540	0,0142	**-0,0019**	0,1321
FEV	23,6023	20,7476	17,3515	19,8128
MAFE	3,5617	3,0847	**2,7784**	3,0484
RMSFE	4,8794	4,5550	**4,1655**	4,4531
U	-	0,9335	**0,8537**	0,9126
United Kingdom				
Bias	1,4905	0,1716	0,2121	**0,0245**
FEV	60,9918	15,2760	18,6039	12,5090
MAFE	5,5470	3,1513	3,4545	**2,6990**
RMSFE	7,9507	3,9122	4,3184	**3,5369**
U	-	0,4921	0,5432	**0,4449**
United States				
Bias	0,6679	0,0441	0,0310	**-0,0028**
FEV	15,2012	0,9523	1,1525	1,4284
MAFE	2,7931	**0,6594**	0,7370	0,8416
RMSFE	3,9557	**0,9769**	1,0740	1,1952
U	-	**0,2470**	0,2715	0,3021

As the MGN-test is not applicable on forecast length longer than 1-step only the DM-test are performed. These results can be found in table 6. below. The null hypothesis of equal forecast performance is rejected on the 1%-level for all models this is not surprising for most of the countries however as the u-statistic was quite high for Sweden one might suspect that the DM still suffers from the relatively small sample.

Table 6. Significance Test

	TVP-AR(1)	TVP-AR(2)	TVP-VAR(1)
Ireland			
DM	21,2851	20,5401	20,4402
Spain			
DM	18,5575	19,3121	18,0579
Sweden			
DM	4,0058	12,7439	6,3254
United Kingdom			
DM	19,8802	18,9509	21,6389
United States			
DM	10,8610	10,7642	10,6221

2,3870=1% t-statistic with 63 degrees of freedom

7 Discussion

From the theory it was expected that the TVP-models would perform better than a AR(1) process as it would update the parameter values over time and thus take non-linearities into account. Other studies have found that this generally is the case for example when forecasting UK house prices their time varying approach outperformed all non-varying parameter models considered. Guirgius et. at. (2005) arrive at a similar conclusion on the US market where they find that a rolling GARCH and a TVP-AR model perform better than linear comparison models. The results in this thesis further compliment these results with a more up to date sample for UK and US with a relatively simple state space representation. The results for the countries is quite diverse with different models performing better dependent on what the purpose is whether one is performing short or medium-term forecast or trying to find the best fit.

The right tailed ADF-test, TVP-AR(1) and TVP-AR(2) model comes to same conclusion for most countries and show that the countries experiencing a boom and a bust had parameter values larger than one in the run up. This is not all that surprising as the methods are related to each other i.e. both make use of recursive estimation. For Sweden this were not the case, the TVP-AR(1) parameter fluctuate one and it could not be concluded that it were above one in the run-up. This result diverts some from the result from the RTADF-test which suggested a mildly explosive series between 2004 and 2008. It is unclear if one should trust the results of RTADF-test or the TVP-model is unclear as there has been much speculation whether Sweden is in a housing bubble or not. What adds to the conclusion given by the RTADF-test is the result from the TVP-AR(2) models which is more in line with the test. For the other countries the RTADF and the TVP-AR models are in line with each other and both methods capture the bubble behavior.

The forecast results are in general in favor of the TVP-models base on the different measures used with the exception of Sweden where the forecast is only slightly better than an linear AR(1) model. A probable explanation for this is the fact that the Swedish house price series' did not experience the same non-linearity as the other countries making the linear model relatively less bad than the TVP-models. The values from AIC and SBC suggest the same where the difference between the TVP-models and the linear model is the smallest for Sweden. The AIC also favors the more parsimonious TVP-AR(1) model over the TVP-VAR(1) model in all cases a side from Sweden.

The results from Hort (1998) that there is a tendency of speculative bubble behavior in the Swedish house prices is somewhat supported in this thesis. The TVP-AR(2) model clearly show signs of mildly explosive behavior but neither the TVP-AR(1) nor the TVP-VAR(1) gives this indication. In Hort (1998) the authors comes to the conclusion that the fundamentals seems to account for much this behavior which is also the case in this thesis as the TVP-VAR(1) lowers the parameter estimate of lagged house prices. The results seen in this thesis show the same pattern for the other countries except US as the effect we expect during a speculative bubble disappears when just including two more variables.

In Meen (2001) the author concluded that the difference between house prices in UK and US were not that different from each other. The results from this thesis which, also use a common methodology to explain house prices in UK and US, suggest differently where it seen that state series' from the two countries clearly experienced different movements. From the results it would make more sense to adopt a common methodology for Ireland, Spain and US as these countries have more similar behavior.

Reasons for real disposable income and interest rate not having a significance impact on house prices could be that the functional form is not correct or that the boom period was not fully driven by a speculative bubble. The problem one is facing when extending the model to a more complex model is that the estimation of the parameters grows rapidly and estimation might not be possible this problem could potentially be solved with including restrictions on the VAR system. This was not done in this thesis as it would be too great of an under taking given the time constraint. Including more lags in the VAR system used in this thesis was not possible due to this and including lags after the first two in the TVP-AR model resulted in an insufficient number of observations.

If the bubble had been driven solely by speculation we would have seen parameter values above one in all models this is however not the case. Studies on both US and UK have pointed to a different type of bubble called intrinsic bubble where the house price is driven by a factor other than the fundamental variables which might have been a driven factor causing a downward bias in the TVP-VAR(1) model (see Black et al (2006) and Nneji et al (2013) for a more in-depth discussion on intrinsic bubbles in the housing market).

8 Concluding Remarks

In this thesis the performance of time varying parameter models have been evaluated. The models evaluated all have parameters model as random walks to capture the mildly explosive behavior of the house price index time series. Three different specifications are examined, two autoregressive models, one with one lag and one with two lags. The third model considered is a vector autoregressive system which includes real disposable income and a long term interest rate in addition to the house price index. The method is chosen as to represent the theory of rational expectations where the homebuyers' expectations are revisited in each point in time.

The models are evaluated from the first quarter of 1980 to fourth quarter of 2013 this to ensure a reliable data set and to have enough data points before the run up to the latest financial crisis. The results from the estimation are compared to those obtained from a right tail ADF-test and are generally similar for TVP-AR(1) and moderately similar for TVP-AR(2). The TVP-VAR(1) model does not indicate mildly explosive parameter values on lagged house prices. Indicating that no there was no housing bubble but rather a pure demand shock, which could be argued for some markets but clearly not the US. For Sweden where the presence of a bubble is indetermined the results points in both directions. Accounting for interest rates and disposable income does not suggest a bubble but studying the Swedish housing market with an AR-model does suggest a bubble. The result also show that the models perform significantly better than a AR(1) process for both medium-term forecast and short-term forecast. Generally no model is preferred but the TVP-AR(2) appear to perform best for short-term forecast. Medium-term forecast results suggest that the TVP-models are considerably better than the AR(1)-process but not one model can be said to perform better for all countries. It should however be noted that the models performed worse for Sweden and US the years before and after the bubble burst.

Lastly the results in this thesis give an indication of the importance of accounting for non-linarites when studying and forecasting the housing market. Further research and evaluation of the TVP approach on house prices would benefit from including structural VAR models to the evaluation. Accounting for the different characteristics between housing markets will likely improve both detection and forecasting of during periods of speculative bubbles.

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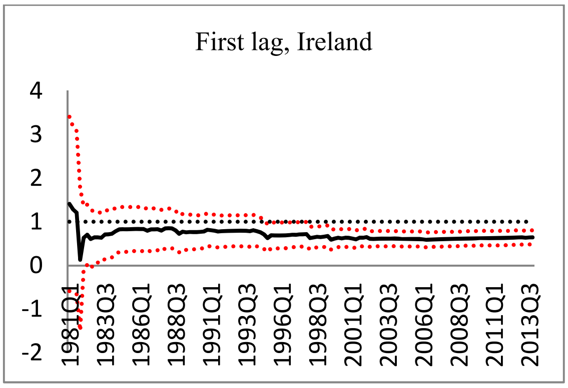
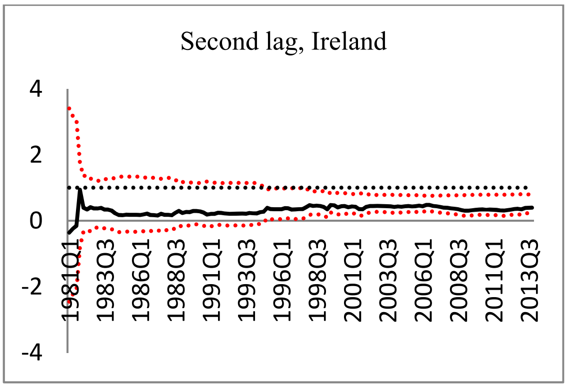
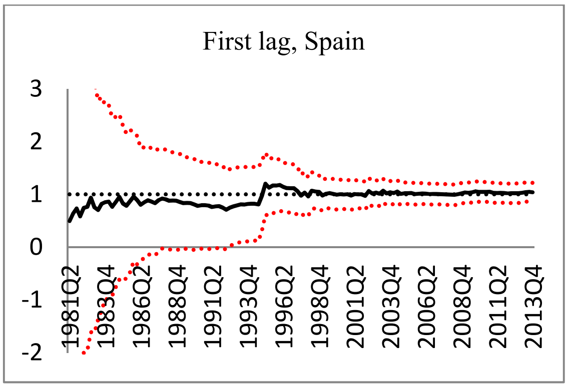
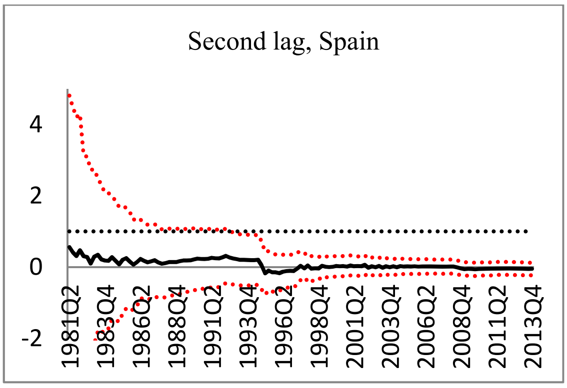
10 Appendix

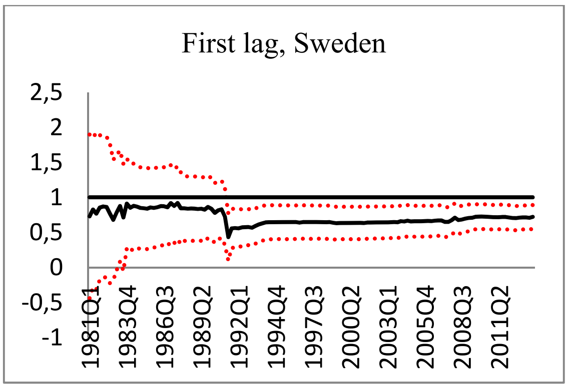
Appendix A. Parameter values from TVP-AR(2) estimation with 2*SE-bands

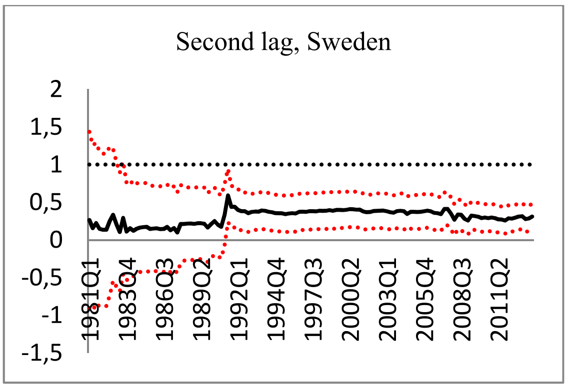


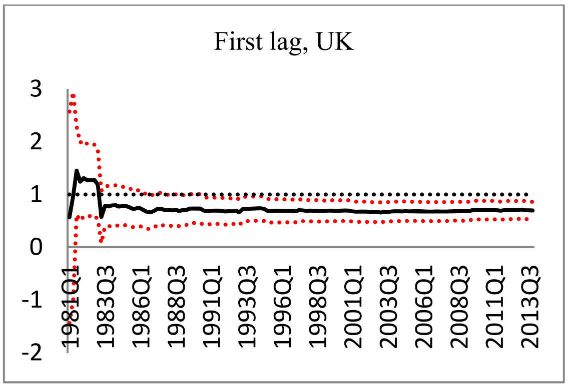











First lag, UK
3
2
1
0
-1
-2
1981Q1
1983Q3
1986Q1
1988Q3
1991Q1
1993Q3
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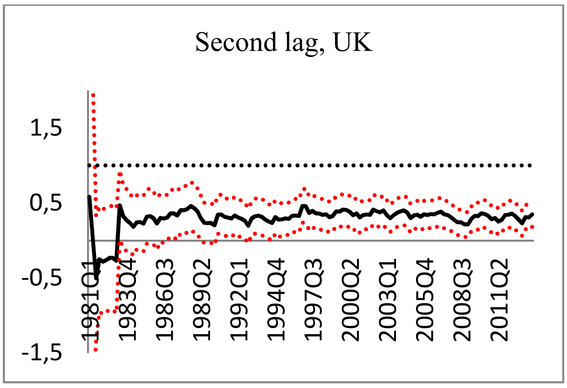
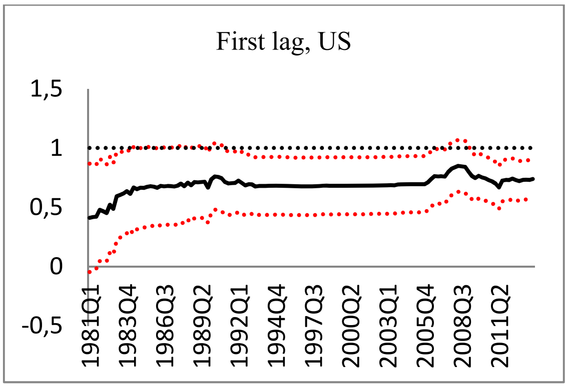
1998Q3
2001Q1
2003Q3
2006Q1
2008Q3
2011Q1
2013Q3


Second lag, UK
1,5
0,5
-0,5
-1,5
1981Q1
1983Q4
1986Q3
1989Q2
1992Q1
1994Q4
1997Q3
2000Q2
2003Q1
2005Q4
2008Q3
2011Q2


First lag, US
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1
0,5
0
-0,5
1981Q1
1983Q4
1986Q3
1989Q2
1992Q1
1994Q4
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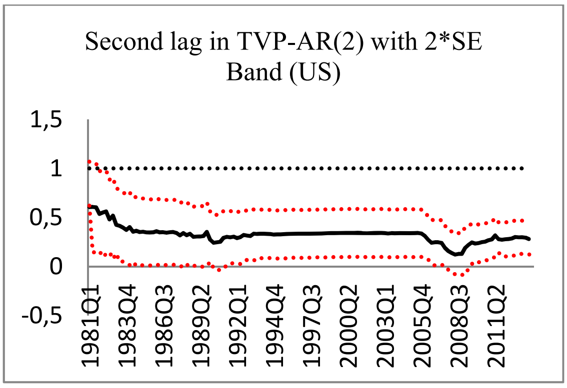
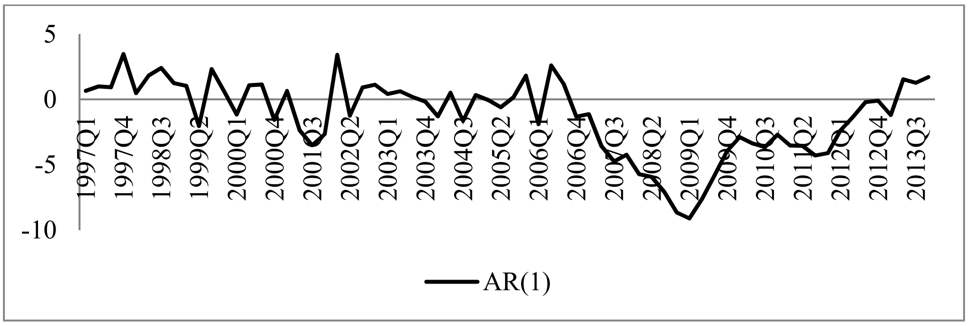
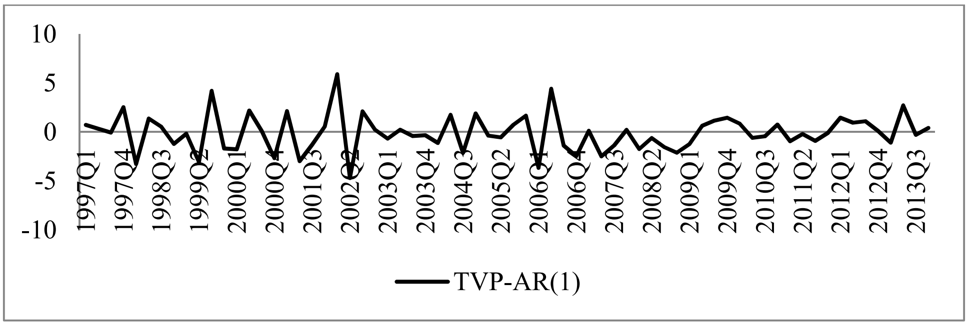
2000Q2
2003Q1
2005Q4
2008Q3
2011Q2

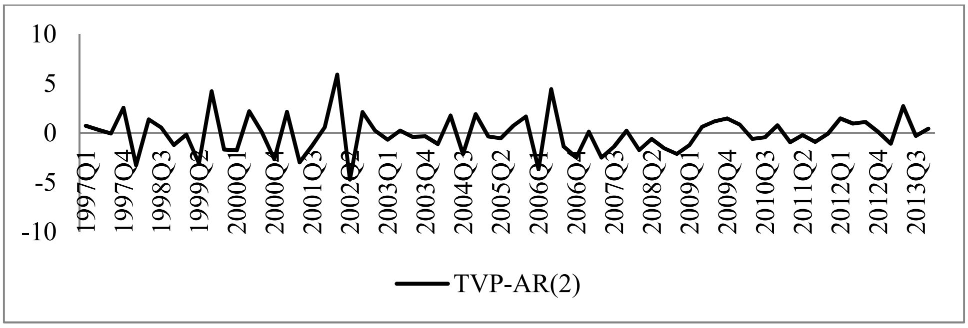

Second lag in TVP-AR(2) with 2*SE Band (US)
1,5
1
0,5
0
-0,5
1981Q1
1983Q4
1986Q3
1989Q2
1992Q1
1994Q4
1997Q3
2000Q2
2003Q1
2005Q4
2008Q3
2011Q2

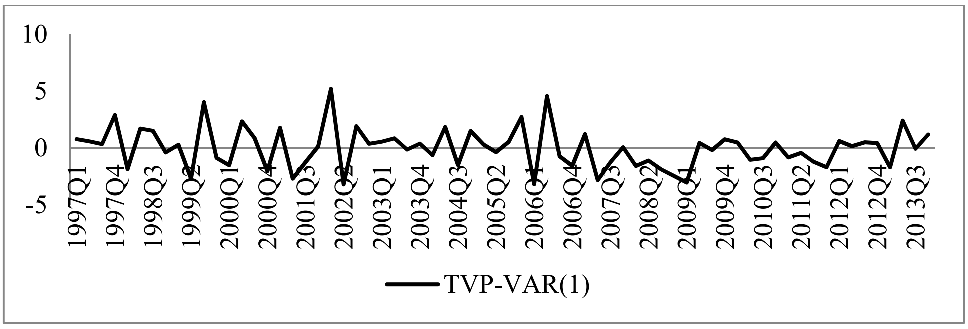
Appendix B. One-Step Ahead Forecast Errors

Ireland

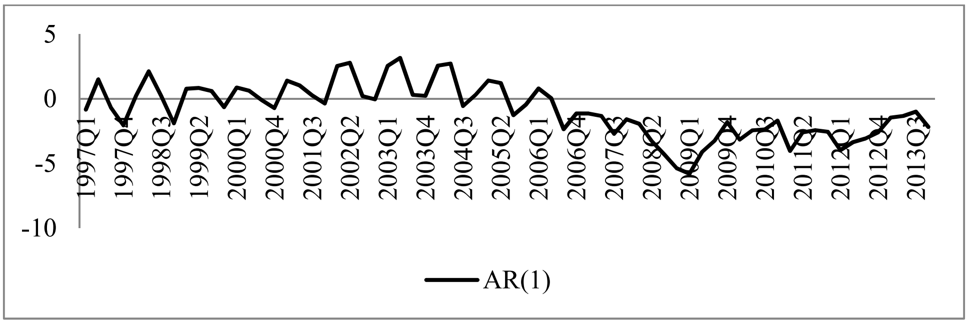








Spain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1997Q1
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2004Q3
2005Q2
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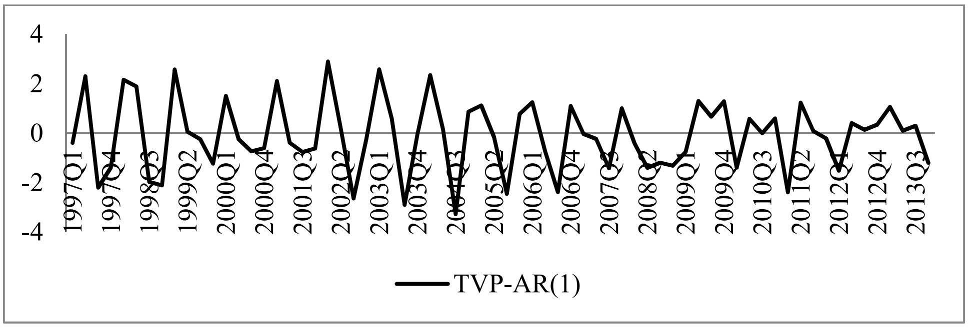
2012Q4
2013Q3
AR(1)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2004Q3
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2006Q1
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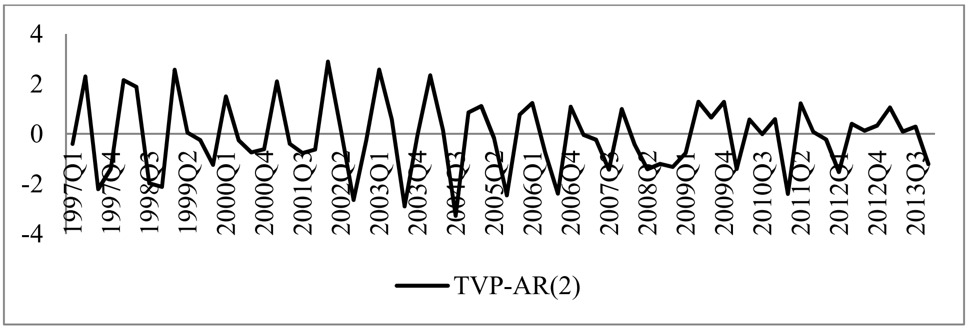
2012Q1
2012Q4
2013Q3
TVP-AR(1)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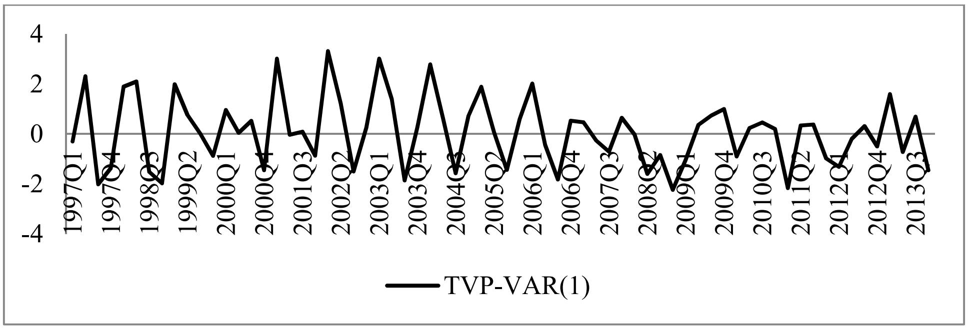
2013Q3
TVP-AR(2)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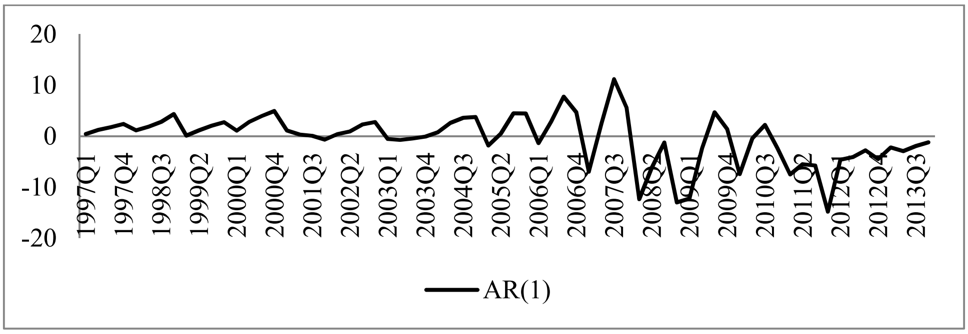
2010Q3
2011Q2
2012Q1
2012Q4
2013Q3
TVP-VAR(1)

Sweden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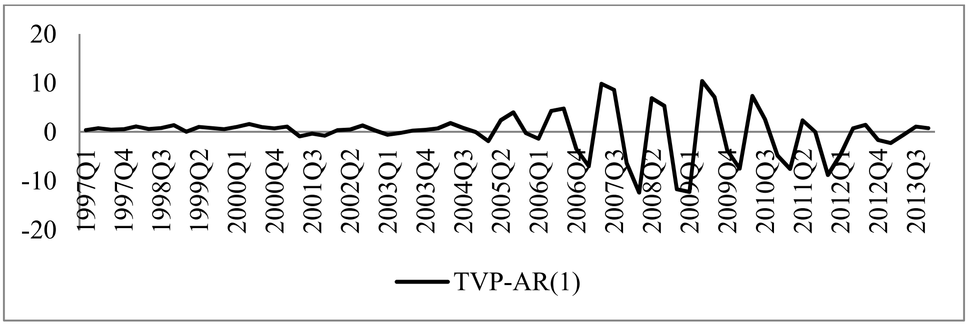
2012Q4
2013Q3
AR(1)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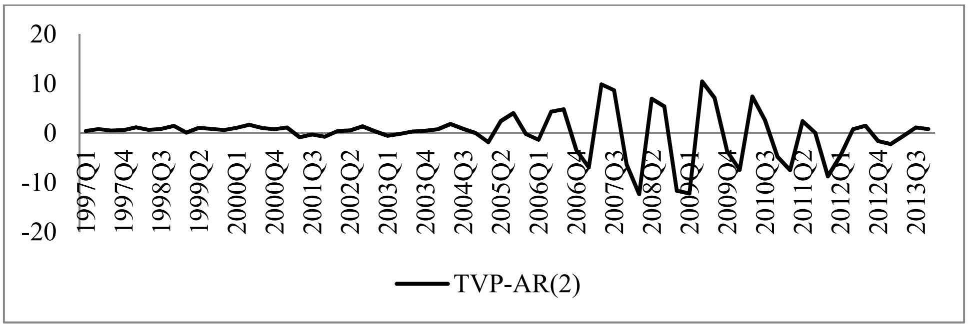
2012Q4
2013Q3
TVP-AR(1)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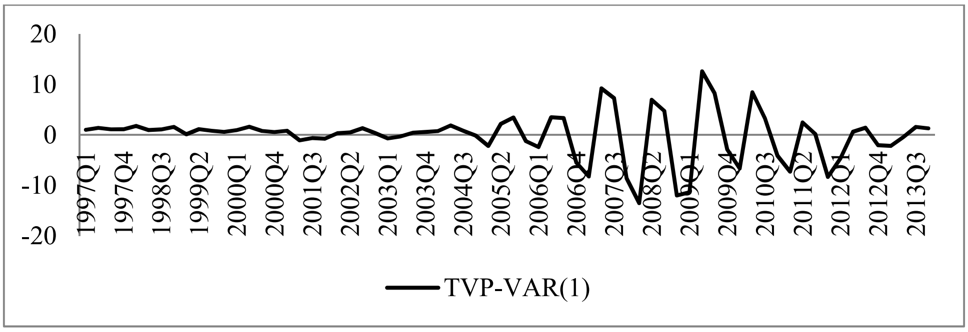
2013Q3
TVP-AR(2)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2011Q2
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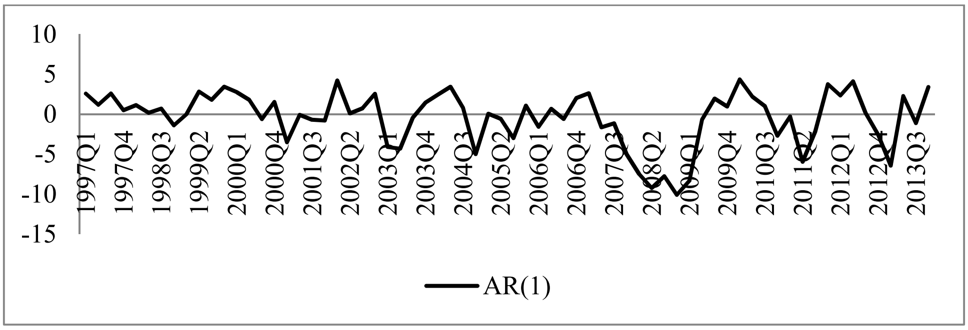
2012Q4
2013Q3
TVP-VAR(1)

UK



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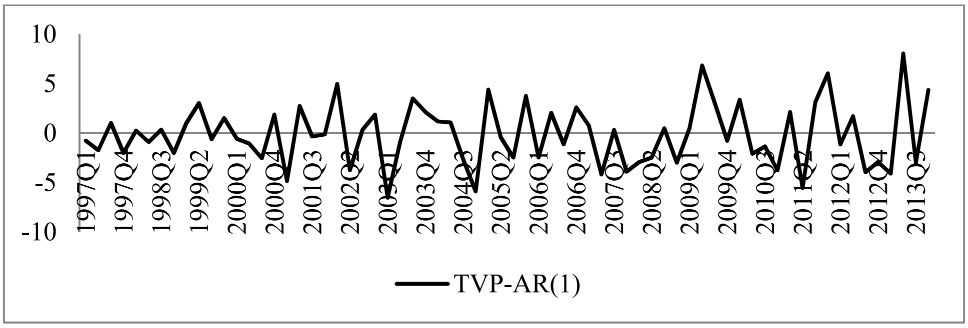
2012Q4
2013Q3
AR(1)



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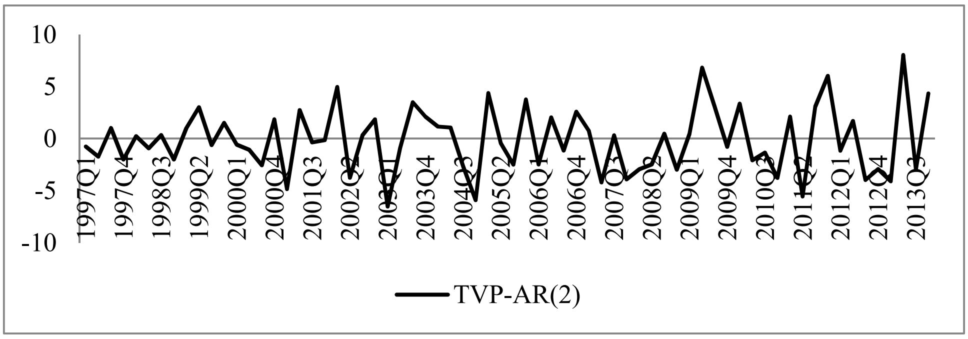

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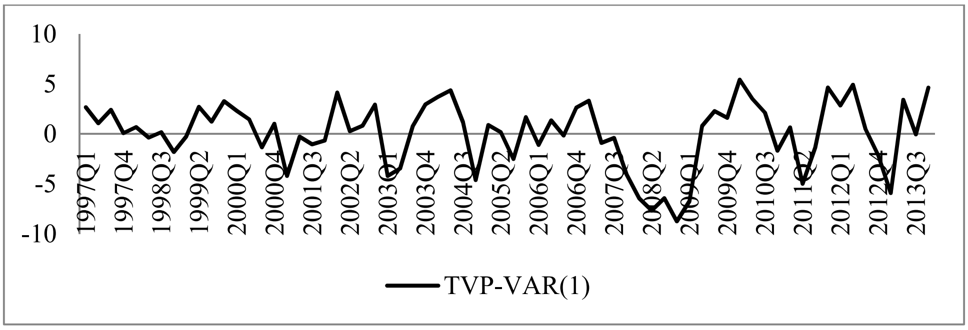
2013Q3
TVP-AR(2)



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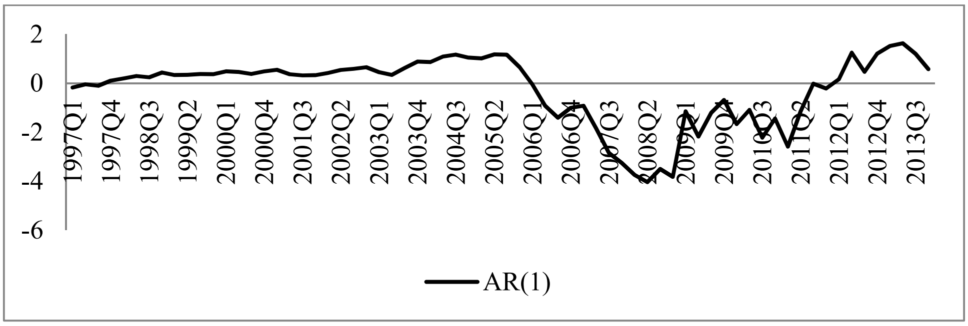
2012Q4
2013Q3
TVP-VAR(1)

US



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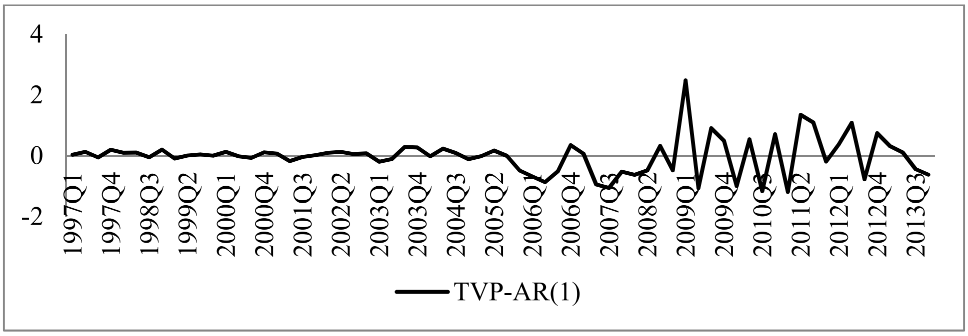
2013Q3
AR(1)



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2004Q3
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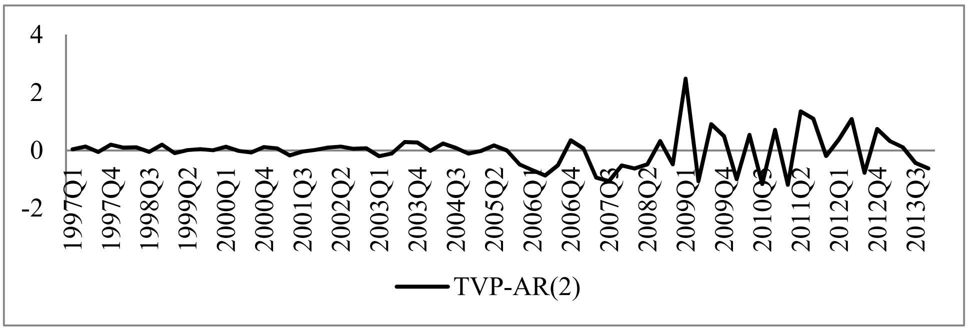
TVP-AR(1)



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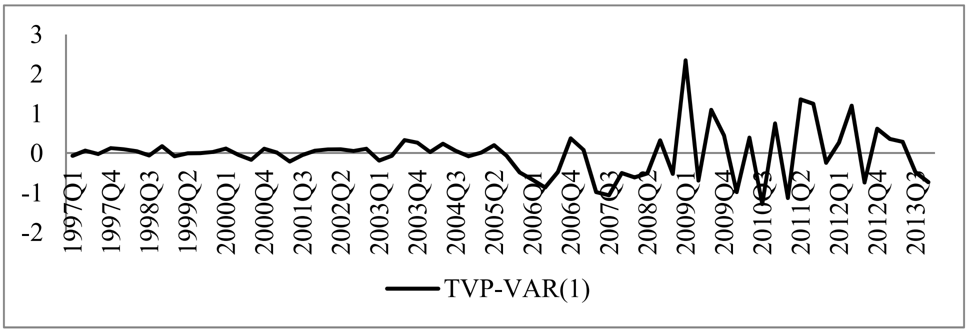

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2005Q2
2006Q1
2006Q4
2007Q3
2008Q2
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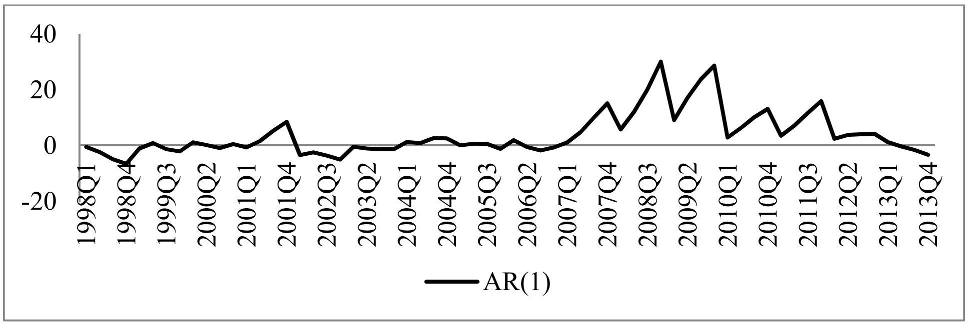
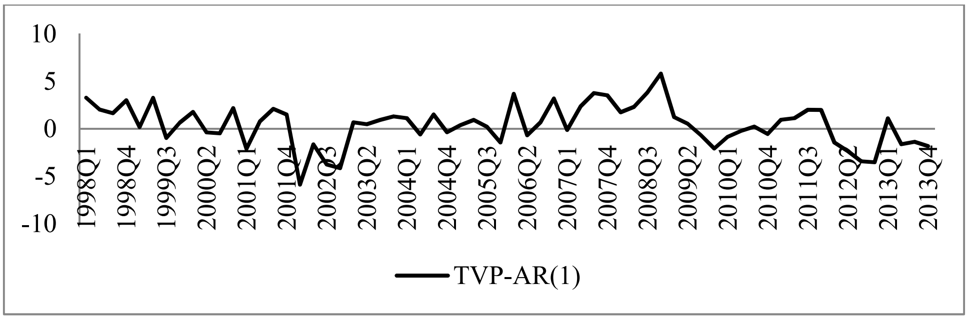
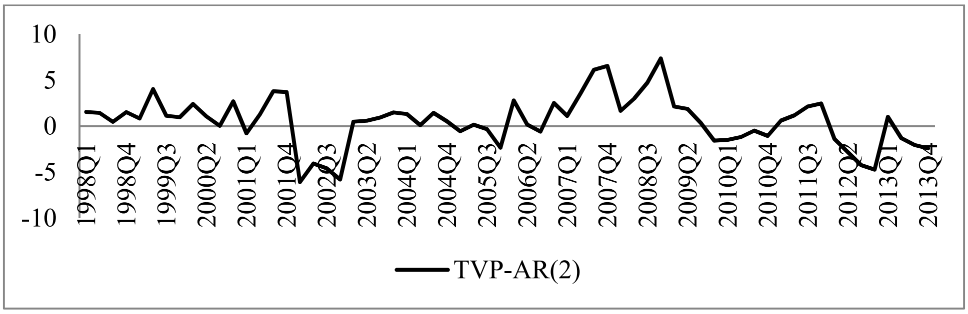
2012Q4
2013Q3
TVP-VAR(1)

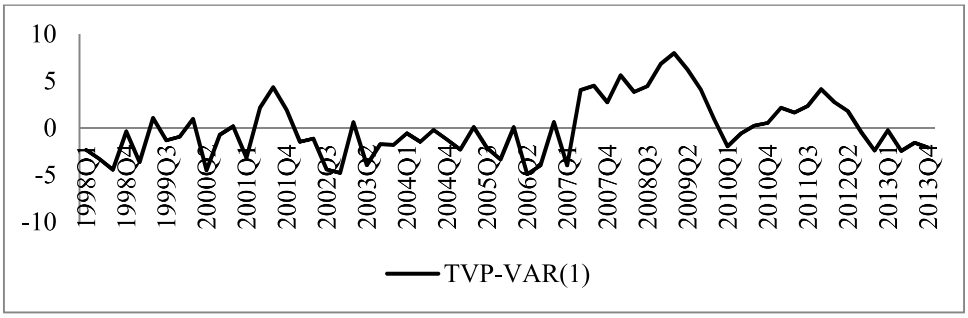
Appendix C. Four-Step Ahead Forecast Errors

Ireland









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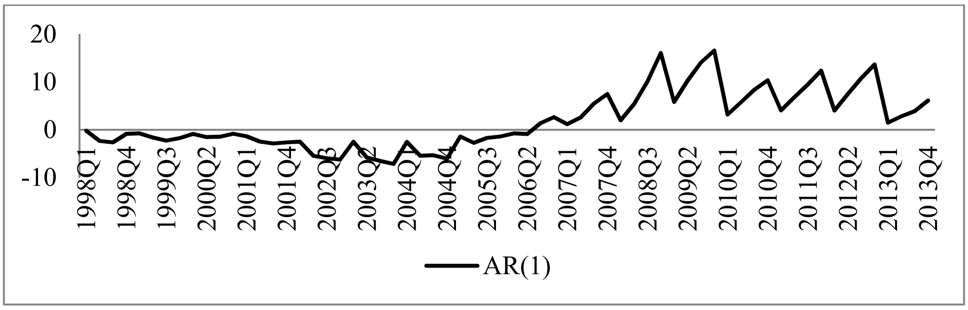

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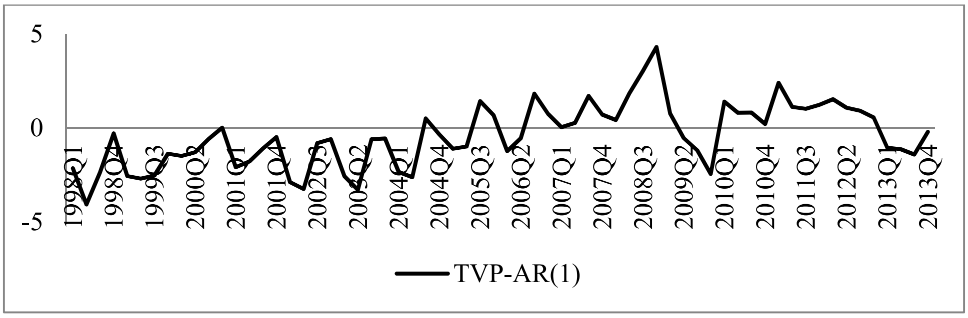
2013Q1
2013Q4
AR(1)



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2001Q4
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2006Q2
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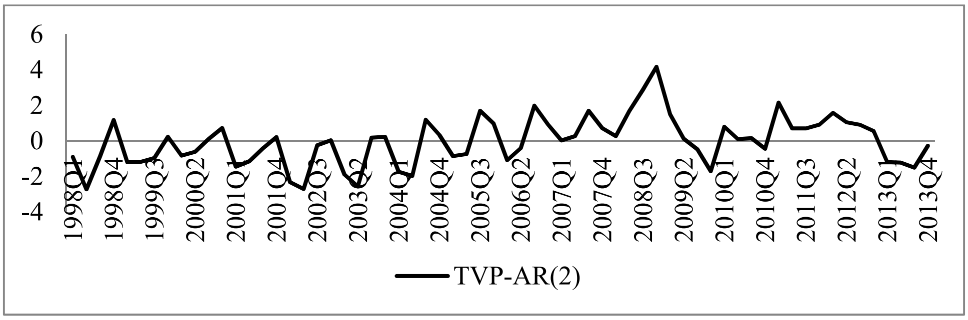
TVP-AR(1)



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2006Q2
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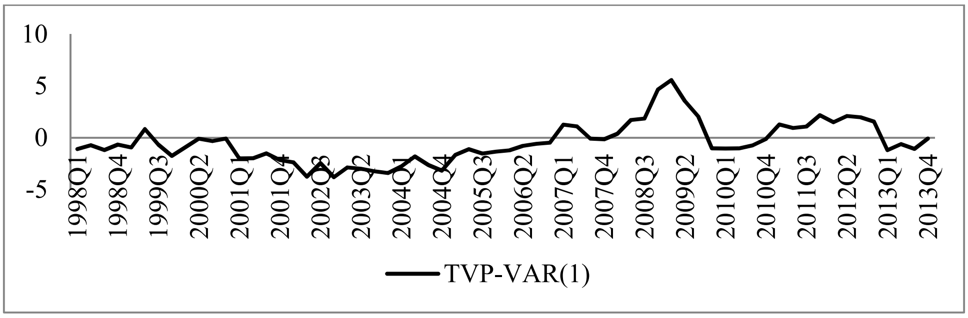
2013Q4
TVP-AR(2)



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2001Q1
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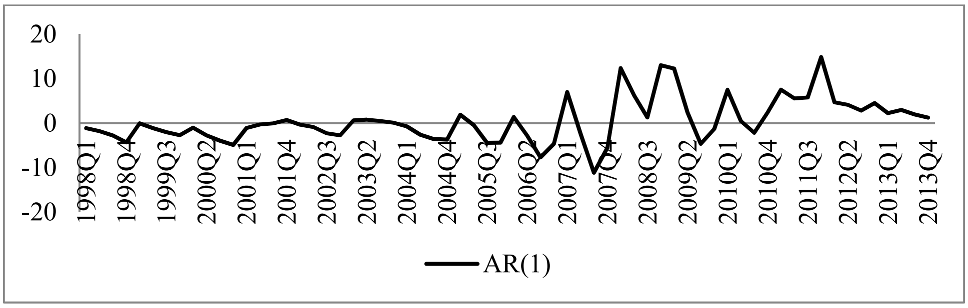
TVP-VAR(1)

Sweden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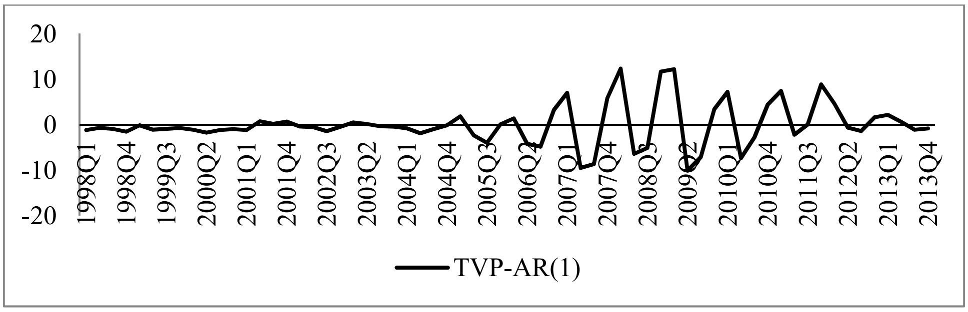
2013Q4
AR(1)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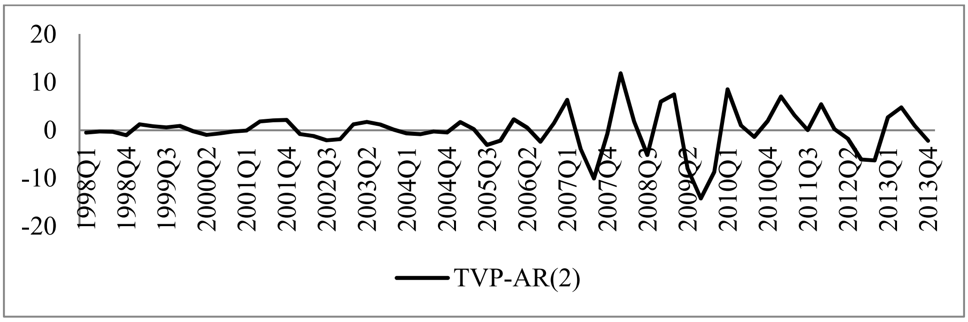
2013Q4
TVP-AR(1)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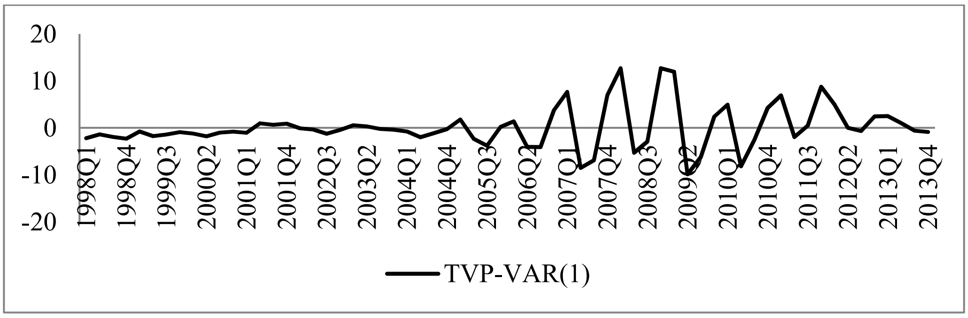
2013Q4
TVP-AR(2)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2010Q4
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2013Q1
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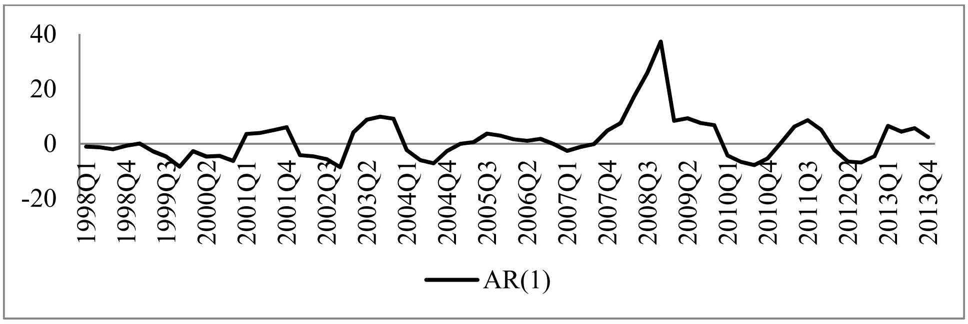
TVP-VAR(1)

UK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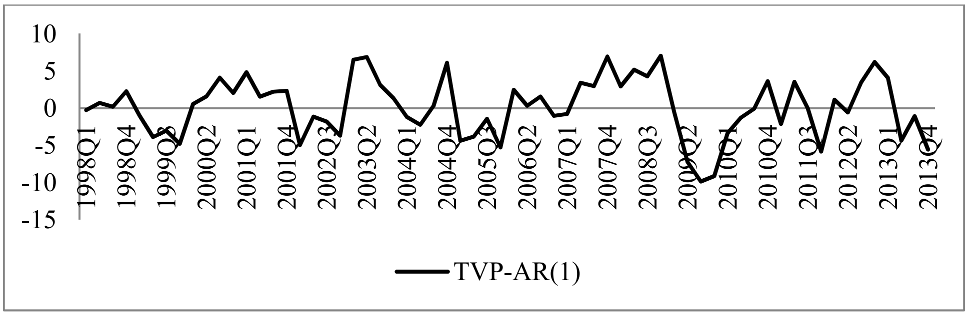
2013Q4
AR(1)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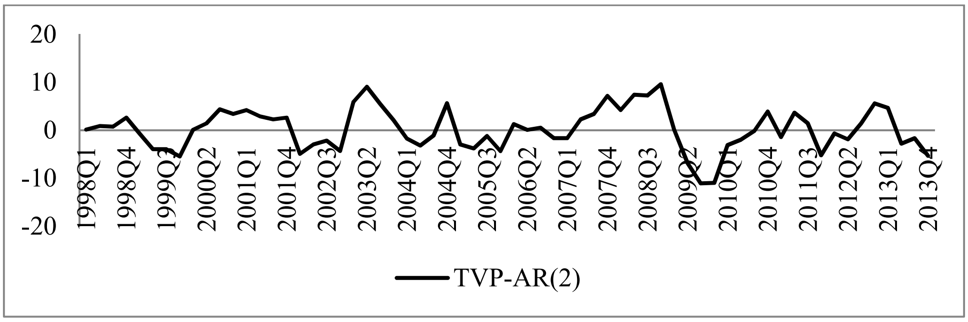
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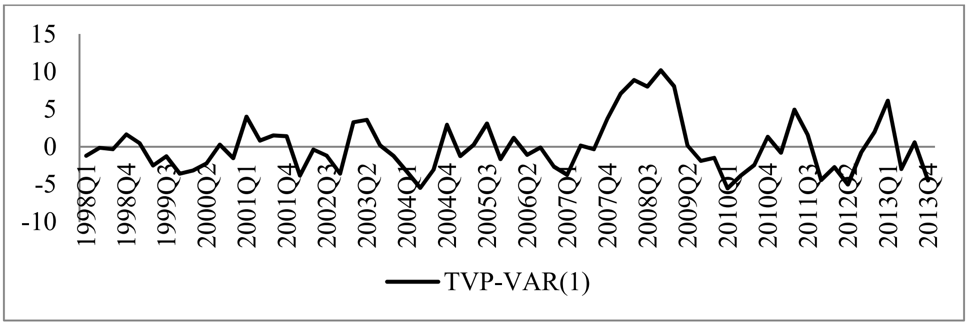
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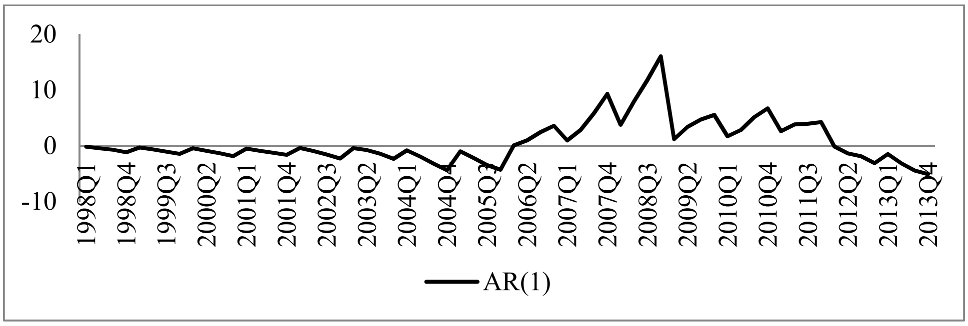
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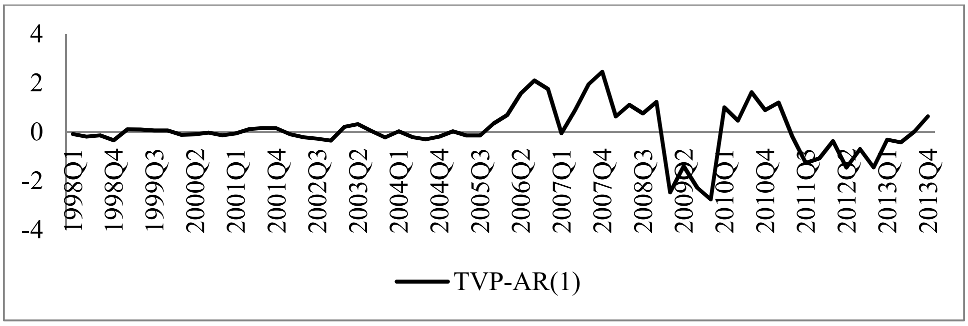
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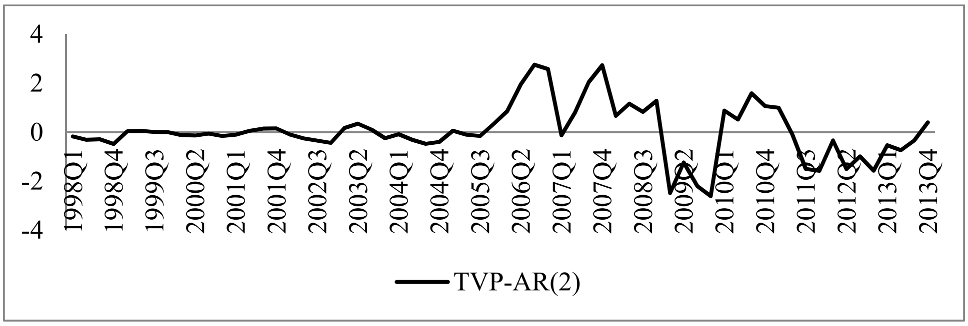
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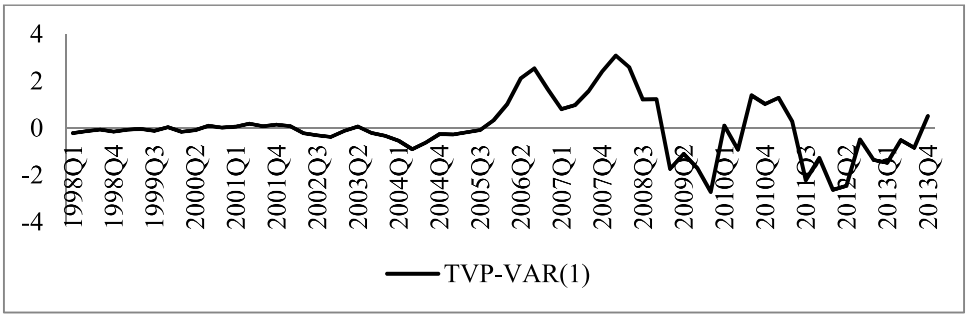
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