The effect of monetary policy on real house price growth in South Africa: A factor-augmented vector autoregression (FAVAR) approach

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Abstract

This paper assesses the impact of monetary policy on real house price growth in South Africa using a factor-augmented vector autoregression (FAVAR), estimated using a large data set comprising of 246 quarterly series over the period 1980:01 to 2006:04. The results based on the impulse response functions indicate that, in general, house price inflation responds negatively to monetary policy shock, but the responses are heterogeneous across the middle-, luxury- and affordable-segments of the housing market. The luxury-, large-middle- and medium-middle-segments are found to respond much more than the small-middle- and the affordable-segments of the housing market. More importantly, we find no evidence of the *home price puzzle*, observed previously by other studies that analyzed house prices using small-scale models. We put this down to the benefit gained from using a large information set.

Keywords: Monetary policy; Real house price growth; FAVAR

1. Introduction

The recent global economic downturn attributed to the sub-prime crisis in the US with rapid contagion worldwide, particularly in the housing sector, has attracted the attention of academics, policymakers, and economic agents at large. Stock and Watson (2003) pointed out that housing prices are leading indicators for real activity, inflation, or both, and, hence, can serve as an indicator as to where the real economy is heading. Evidence in the recent literature, for example, (Iacoviello, 2005), (Case et al., 2005), (Iacoviello and Neri, 2008), (Vargas-Silva, 2008a) and (Vargas-Silva, 2008b) amongst others, show a strong link between the housing market and economic activity in the US. Moreover, the recent emergence of boom–bust cycles in house prices have been an issue of concern for policy makers (Borio et al., 1994, Bernanke and Gertler, 1995 and Bernanke and Gertler, 1999), since the bust of the house price bubble is always followed by significant contractions in the real economy (Iacoviello and Neri, 2008). Given this, it is crucial for central banks to analyze thoroughly the effects of monetary policy on asset prices

in general, and real estate in particular, which, in turn, would lead to the understanding of effects of policy on the economy at large.

In this backdrop, this paper assesses the impact of monetary policy shocks on real house price growth, i.e., the growth rate of the ratio of nominal house price to the Consumer Price Index (CPI), for the luxury, large-, medium- and small-middle-segments and affordable housing for the South African economy¹ by exploiting a data-rich environment that includes 246 quarterly series, such as income, interest rates, construction costs, labour market variables, stock prices, industrial production, and consumer confidence index over the period 1980:01 to 2006:04. For this purpose, the framework used in this paper is a factor-augmented vector autoregression (FAVAR) model proposed by Bernanke et al. (2005). As Bernanke et al. (2005) indicate, monetary authorities analyze literally thousands of variables in their decision-making process, hence, it is aberrant for anyone, who tries to mimic actions of a central bank, to ignore this fact. Furthermore, the recent literature (Stock and Watson, 2004 ; Rapach and Strauss, 2007 ; Rapach and Strauss, 2009 ; Das et al., 2008 ; Das et al., 2009 and Das et al., forthcoming) provide evidence of the fact that numerous economic variables are potential predictors of house price growth. Intuitively, the FAVAR approach boils down to extracting a few latent common factors from a large matrix of many economic variables, with the former maintaining the same information contained in the original data set without running into the risk of the degrees of freedom problem.² Note, the motivation to use the three major segments of the housing market, with the middle-segment subdivided further into three categories based on sizes, and not just the aggregate housing market, emanates from the fact that the market for different house-types are found to behave differently (Burger and van Rensburg, 2008). Clearly then, the impact of monetary policy on the different segments of the South African housing market is less likely to be homogenous. This is more so, when one realizes that different housing segments cater to different income-groups.

To the best of our knowledge, this is the first study to analyze the effect of monetary policy on real house price growth in South Africa using a FAVAR. The only other paper that deals with the impact of monetary policy on the South African housing market is that by Kasai and Gupta (2008). The authors investigated the effectiveness of monetary policy on house prices in South Africa, before and after financial liberalization, with financial liberalization being identified with the recommendations of the De Kock Commission (1985). Using both impulse response and variance decomposition analysis performed on three-variable structural VARs (SVARs), comprising of the growth rate of the real GDP, house price inflation and the Treasury Bill rate, estimated separately on the three categories of the middle-segment of the housing market, the authors found that irrespective of house sizes, during the period of financial liberalization, interest rate shocks have had relatively stronger effects on house price inflation. But, given that the size of these effects were nearly negligible, the result seems to indicate that house prices are exogenous, and, at least, are not driven by monetary policy shocks.

Though insightful, the paper by Kasai and Gupta (2008), just like (Iacoviello, 2002), (McCarthy and Peach, 2002), (Iacoviello and Minetti, 2003) and (Iacoviello and Minetti, 2008),³ Vargas-Silva (2008a), is based on a small-scale model, which, in turn, limits it to only three variables. In fact, all the other studies, being based on either reduced-form Vector Autoregressive (VAR), Vector Error Correction (VEC), SVAR or DSGE models, could handle at most 8 to 12 variables

only. Arguably, and as indicated above, there are a large number of variables that affects monetary policy and the housing market, and not including them often leads to puzzling results, for example the *home price puzzle*⁴ in (McCarthy and Peach, 2002) and (Kasai and Gupta, 2008),⁵ which are not in line with economic theory due to the small information set ([Sims, 1992] and [Walsh, 2000]). Moreover, in these studies, the authors often arbitrarily accept specific variables as the counterparts of the theoretical constructs (for example the gross domestic product as a measure of economic activity or the first difference of the logarithm transformed consumer price index as a measure of inflation), which, in turn, may not be perfectly represented by the selected variables. In addition, previous studies can only obtain the impulse response functions (IRFs) from those few variables included in the model, implying that in each VAR, VECM, SVAR or DSGE, the IRFs are typically obtained with respect to only one variable related to the housing market. Given its econometric construct, the FAVAR model addresses all these problems.

The remainder of the paper is organized as follows: Section 2 briefly discusses the FAVAR framework, while, Section 3 discusses the data and the identification structure. Section 4 reports and analyzes the impulse response functions, and Section 5 concludes.

2. The FAVAR⁶

Let Y_t be a $M \times 1$ vector of observable economic variable assumed to drive the dynamics of the economy. In the standard approach, we would proceed by estimating a structural VAR (SVAR), or other forms of multivariate time series model using data for only Y_t . In many cases, however, additional economic information that cannot be fully captured by Y_t may be required to model appropriately the dynamics of these series. Assume that F_t is a $K \times 1$ vector of unobserved factors, with K being small, that summarizes additional important information not fully captured by Y_t . Note F_t can also represent theoretical concepts such as price pressures, credit conditions, or even economic activity that are a combination of economic variables which cannot be represented by one particular series. Assume that the joint dynamics of (F_t, Y_t) are given by the following equation:

$$(1) \quad \begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + v_t \quad (1)$$

where $\Phi(L)$ is a conformable lag polynomial of finite order p and v_t is the error term with zero mean and a covariance matrix Q .

Eq. (1) is a standard VAR in (F_t, Y_t) and nests a standard VAR in Y_t , if the terms of $\Phi(L)$ that relate to Y_t to F_{t-1} are equal to zero. In its current form we refer to Eq. (1) as a factor-augmented vector autoregression (FAVAR). Clearly the system defined by Eq. (1) helps in assessing the marginal contribution of the additional information content of F_t . Moreover, if Eq. (1) is estimated without the factors then we would obtain biased estimates of coefficients for both the VAR and the impulse responses.

However, the difficulty here is that the vector of factors F_t is unobserved, which means that the model cannot be estimated based on standard econometric techniques, such as the ordinary least squares (OLS). The proper estimation of the model entails the use of factor analysis, as proposed by Stock and Watson (1998). For this purpose, we interpret the factors as summarizing information contained in a large panel of economic time series. Given this, we can hope to infer about the factors from these variables. Let X_t be a $N \times 1$ vector of informational variables, where N is large, such that $N \gg K + M$. Assume X_t is related to both the observed variables Y_t and unobserved factors F_t as follows:

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t \quad (2)$$

where Λ^f is a $N \times K$ matrix of factor loadings, Λ^y is $N \times M$, and e_t is a $N \times 1$ vector of the error term, which, in turn, is assumed to be weakly correlated with mean zero. In essence, Y_t and F_t are common forces that drive the dynamics of X_t . Note, it is not restrictive to assume in principle that X_t is dependent only on the current values of F_t and not its lagged value, since the factors can always be interpreted to capture arbitrary lags of some fundamental factors. Excluding the observable factors from Eq. (2), we have what Stock and Watson (1998) refer to as a dynamic factor model (DFM).

The estimation procedure consists of a two-step principal components approach proposed by Bernanke et al. (2005), which, in turn, provides a non-parametric way of uncovering the space spanned by the common components, $C_t = (F_t', Y_t')$. In the first step, the common components, C_t are estimated using the first $K + M$ principal components of X_t , defined as $\hat{C}_t$. Note the estimation of the first step does not use the fact that Y_t is observed. Stock and Watson (2002) demonstrates that with a large N and if the number of principal components is at least as large as the number of factors, the principal components can consistently recover the space spanned by both F_t and Y_t . However, $\hat{F}_t$ is obtained as the part of the space covered by $\hat{C}_t$ not spanned by Y_t . In the second step, the FAVAR model (1) is estimated via standard methods with F_t replaced by $\hat{F}_t$. As discussed by Stock and Watson (2002), this approach imposes fewer distributional assumptions, when compared to the alternative single-step Bayesian likelihood approach, and also allows for some degree of cross-correlation in the idiosyncratic error term e_t , besides being computationally simple and easy to implement. In the second step, the two-step approach, however, implies the presence of “generated regressors”, and given this uncertainty in the factor estimation, we need to implement a bootstrap procedure to obtain accurate confidence intervals. In this regard, we follow Kilian (1998).

Next, we need to discuss the identification of the model described by Eqs. (1) and (2). In other words, we need to impose restrictions necessary to identify uniquely the factors and the associated loadings. Given that, in two-step estimation method, based on principal components, the factors are obtained entirely from the observation Eq. (2), identification of the factors is standard. Formally, we can choose either to restrict loadings such that: $\Lambda^f \Lambda^f' / N = I$ or the factors to ensure that $F'F/T = I$. Either way we obtain the same common component $F\Lambda^f$ and the same factor space. Following Bernanke et al. (2005), we impose the factor restriction to obtain $\hat{F} = \sqrt{T} \hat{Z}$, where the Z are the eigenvectors corresponding to the K largest eigenvalues of

XX' , ordered in a descending fashion. This approach allows us to identify the factors against any rotations.

A separate identification issue concerns the identification of innovations in the VAR part of the model, which in our case involves the identification of the monetary policy innovations.⁷ This is what we discuss next. In this paper, we assume that the only observable factor is the nominal 91 days Treasury Bill rate (TB_t), i.e., the only variable included in Y_t is TB_t . Thus, we treat the 91 days Treasury Bill rate as a factor and interpret it as the monetary policy instrument. This can be motivated on the presumption that monetary policy has pervasive effect on the economy. It must be noted that macroeconomic data is generally subject to multiple rounds of revisions and are never free of measurement error. But the 91 days Treasury Bill rate should not suffer from measurement error issues, since this would then imply the presence of an idiosyncratic component in the monetary policy instrument. With theoretical concepts not necessarily aligned with specific variables in the data, real activity and inflation can be treated as unobserved in the empirical analysis. Also treating these variables as latent factors allows one to acknowledge the issues with real-time data. Finally, speaking specifically, there is no evidence in the history of monetary policy of South Africa that could suggest that the South African Reserve Bank (SARB) was controlling for any other variables, i.e., using anything else than a measure of the short-term interest rate as an instrument.⁸

We order the short-term interest rate measure last and treat its innovations as monetary policy “shocks”, in the standard way. This ordering imposes the identifying assumption that latent factors do not respond to monetary policy innovations within the quarter. To implement this identification scheme, as in Bernanke et al. (2005), we defined two categories of variables, namely, “slow-moving” and “fast-moving”. *Slow moving* variables are those that do not respond contemporaneously to unanticipated monetary policy shocks. They include variables such as measures of output and production, consumption, employment, interest rates and prices. In contrast, *fast moving* variables respond contemporaneously to policy shocks. They mainly comprise of financial variables, such as asset-price, which, in turn is highly sensitive to contemporaneous economic shocks.

With the two-step estimation, the identification requires first controlling for the part of C_t that corresponds to the monetary policy measure. To achieve this, first, the “slow-moving” factors, F_t^s , are estimated as the principal components of the “slow-moving” variables, and then, second, the following regression,

$$\hat{C}_t = b_{F^s} \hat{F}_t^s + b_Y Y_t + e_t \quad (3)$$

is estimated and F_t^s obtained from $C_t - b_Y Y_t$. Note that since F_t^s and Y_t are correlated, so are F_t^s and Y_t . Finally, the VAR in F_t^s and Y_t , is estimated and identified recursively as discussed above.

The reduced-form VAR, based on Eq. (1), then has the following structural form:

$$\Gamma(L) \begin{bmatrix} \hat{F}_t^s \\ Y_t \end{bmatrix} = u_t \quad (4)$$

where $\Gamma(L)$ is a conformable lag polynomial of finite order p and u_t is a vector of structural innovations. Given this, we compute the impulse response functions (IRFs) of F_t and Y_t as follows:

$$\begin{bmatrix} \hat{F}_t \\ Y_t \end{bmatrix} = \Psi(L)u_t \quad (5)$$

where $\Psi(L)$ is a lag polynomial of order h and $\Psi(L) = \Gamma(L)^{-1}$. Given that X_t is estimated by $X_t' = \Lambda^f F_t' + \Lambda^y Y_t' + e_t'$, based on Eq. (2), the IRFs of X_t are given by:

$$\hat{X}_t' = [\hat{\Lambda}^f \hat{\Lambda}^y] \begin{bmatrix} \hat{F}_t' \\ Y_t' \end{bmatrix} = [\hat{\Lambda}^f \hat{\Lambda}^y] \Psi(L)u_t'. \quad (6)$$

3. Data

Besides the real house price of the five segments of the housing market, the FAVAR is estimated based on 241 other quarterly series of South Africa, with the data covering the real, nominal, and financial sectors. We also have intangible variables, such as confidence indices, and survey data. The sample period contains data from 1980:01 to 2006:04.⁹ All series are seasonally adjusted and were made covariance stationary when estimating the DFM. The more powerful DF-GLS test, instead of the more popular ADF test, is used to assess the degree of integration of all series. All non-stationary series are made stationary through differencing. The Schwarz information criterion (SIC) is used in the selecting the appropriate lag length in such a way that no serial correction is left in the stochastic error term. Where there were doubts about the presence of unit root, the KPSS test, with the null hypothesis of stationarity, was applied.

There are various statistical approaches in determining the number of factors in the DFM. For example, Bai and Ng (2002) developed a set of criteria to guide the selection of the number of factors in large dimensional panels. The principal component analysis (PCA) can also be used in establishing the number of factors in the DFM. The PCA suggests that the selection of a number of factors q be based on the first eigenvalues of the spectral density matrix of X_t . Then, the principal components are added until the increase in the explained variance is less than a specific $\alpha = 0.05$. The Bai and Ng (2002) approach proposes five static factors, while Bai and Ng (2007) suggest two primitive or dynamic factors. Similar to the latter method, the principal component technique, as proposed by Forni et al. (2000) suggests two dynamic factors. The first two dynamic principal components explain approximately 99% of variation, while the eigenvalue of the third component being equal to $0.005 < 0.05$. So we use two dynamic factors in the estimation of a FAVAR with a lag length, p , equal to 4.¹⁰ Furthermore, we find that increasing the number of factors, reducing the lag length or breaking the sample period into smaller sub-samples¹¹ does not change the results substantially. To account for uncertainty in the estimation of the factors, a bootstrap technique based on Kilian (1998) is implemented. This is necessary in constructing the 90% confidence intervals of the impulse responses.

4. Empirical results

Fig. 1 displays the impulse response functions of real house price growth rate of the five segments over 20 quarters, resulting from an increase in the *TB*. The *TB* increases to approximately 0.25%, and stays significant for a short period. Following the contractionary monetary policy, the impact on real house price growth rate across categories is negative in general. These results are in line with theory and we find no evidence of the so-called *home price puzzle* observed by Kasai and Gupta (2008). We attribute this difference to misspecification in small-scale VARs, due to their inability to take into account various potential predictors of house prices. The gain witnessed here suggests that a FAVAR methodology, which exploits a large set of information, improves the accuracy of econometric models in predicting the effects of monetary policy, and therefore, could address the puzzling effects observed otherwise.¹²

Fig. 1. IRFs of house price inflation following a monetary policy shock.

Note that the reaction of real house price growth rate to a contractionary monetary policy shock is different, especially with regards to the size and length of the impact, across the alternative housing categories, thereby vindicating the need to look at different segments of the housing market. Small-middle-segment and affordable housing display a small but negative effect at the impact. Following the increase in interest rate, real house price growth rate of small-middle and affordable-segments decreases by less than 0.05%. However, for the small-middle-segment

housing, the initial negative effect turns out to be insignificant and short lived. In the case of affordable houses, the early negative impact is significant but does not last long either. Interestingly, for both these categories, the real house price growth rates start to fall again after the initial recovery and reaches negative levels that are similar in size to their initial impact. Further, for both these categories, the real house price growth rate becomes positive at around 8 quarters, and stays that way for the remainder of the period until the effect dies off. The drop in real house price growth for the large-middle-segment, the medium-middle-segment and luxury houses are significant, and lasts relatively longer than what is observed for the small-middle-segment and the affordable housing. Real house price growth rate of the large-middle- and medium-middle-segments plummet initially to approximately 0.1%, and rise thereafter, and drop again sharply. They stay negative for about 15 quarters, before becoming positive and then die out progressively. For the luxury-category, the real house price growth rate displays a negative and significant response of approximately 0.07% at the impact, followed by another drop to 0.1% and then a sudden recovery that causes the effect to taper off after about 5 quarters.

At this juncture, some possible explanations about the behavior of the real house price growth rates of the five segments, following a contractionary monetary policy shock, is desired. Note, except for the luxury-segment, and irrespective of the size and significance of the impact, a common feature is observed amongst the four other categories of housing. We witness an initial decline of the real house price growth rate at the impact of the shock, followed by a recovery and then a decline again, before the effect starts to taper off. This we believe is possibly due to two reasons: First, this could indicate that house prices are *slow moving* variables, and second, and perhaps the more important of the two, the result is in line with Stock and Watson's (2003) suggestion that house prices lead to economic activity. Hence, the delayed effect could be because of the downturn in the economy, which in turn, originated from the decline in the housing sector. The second line of explanation is in line with Iacoviello and Neri (2008), who indicate significant spillovers from the housing market into the real economy, followed by economic activity affecting further the other sectors of the economy, including housing. This downturn could cause owners of the large-middle- and medium-middle-segment of the housing industry to start demanding more of small-middle-segment housing, causing the price of the latter to recover much quicker, while, the real house price growth rates of the other two larger middle-segment housing have to wait for a significant period of time. Besides, Gupta and Das (2008) indicate that for the small-middle-segment housing, what seems to be more important in the determination of its price is its past own price, and hence, the role of fundamentals is not too important. This is more so for affordable housing especially when one realizes that these are government provided and as such, have a controlled and rigid pricing structure. Finally, as far as the luxury-segment of the housing market is concerned, we observe an initial decline followed by a larger decline but a quick recovery. Given that the real house price growth rate falls further after the initial negative impact, seems to suggest the sluggishness of the market for this particular housing category, where the segment gets hit by the economic downturn before it could recover. The inherent lavish nature of the luxury housing, owned by people in the highest strata of income, as well as by foreigners, makes it a difficult market for quick transactions and movements of buyers and sellers. The resultant slow moving nature of house prices is, thus, quite logical. At the same time, luxury houses being bought mainly by the most affluent of the country with diverse portfolios, and by foreigners or South African citizens residing abroad, all of who are quite well-insured against the downturn, the fast recovery is not surprising.

Other than impulse response functions, another exercise typically performed in the standard VAR context is variance decomposition, which determines, at a given horizon, the fraction of the forecasting error of a variable attributable to a particular shock. Formally, fraction variance of $Y_{t+k} - \hat{Y}_{t+k}$ due to the monetary policy shock (ε_t^{MS}) is expressed as follows:

$$\frac{\text{var}(Y_{t+k} - \hat{Y}_{t+k|t} | \varepsilon_t^{MS})}{\text{var}(Y_{t+k} - \hat{Y}_{t+k|t})} \quad (7)$$

Note, as indicated by Eq. (2), part of the variance of the macroeconomic variables comes from their idiosyncratic component, which in part might be capturing measurement error and should not be affected by business cycle determinants. Given this, the variance decomposition of the FAVAR framework measures the relative importance of a structural shock only to the portion of the variable explained by the common factors. More precisely, this variance decomposition for X_{it} can be expressed as:

$$\frac{\Lambda_i \text{var}(C_{t+K} - \hat{C}_{t+K|t} | \varepsilon_t^{MS}) \Lambda_i'}{\Lambda_i \text{var}(C_{t+K} - \hat{C}_{t+K|t}) \Lambda_i'} \quad (8)$$

where Λ_i denotes the i th line of $\Lambda = [\Lambda^f, \Lambda^y]$ and

$\text{var}(C_{t+K} - \hat{C}_{t+K|t} | \varepsilon_t^{MS}) / \text{var}(C_{t+K} - \hat{C}_{t+K|t})$ is the standard VAR variance decomposition based on Eq. (1).

Table 1 reports the variance decomposition results for real house price growth rate in the five categories of the South African housing market analyzed in Fig. 1. The first column reports the contribution of the monetary policy shock to the variance of the forecast of the common component, at the 20 quarter horizon, while, the second column contains the R^2 of the common component for each of these variables. The product of the two columns is the equivalent of the variance decomposition that would be obtained from a standard VAR. The results suggest small effect of monetary policy on real house price growth, with the same explaining between 0.39% (Affordable) to 4.88% (Luxury) of the variation. Looking at the R^2 of the common component, we can make the following observations: First, the factors explain a sizeable fraction of these variables, especially for the large- and medium-middle-segments and affordable housing. This confirms that the FAVAR framework does capture important dimensions of the business cycle movements, at least for three categories of the South African housing market. Second, given the R^2 of the common components, the discrepancies in the variance decomposition between the standard VAR and that of the FAVAR are quite considerable. Finally, the differences in the sizes of variance decomposition is also indicative of the inherent structural heterogeneity within these five categories, but more importantly, their sizes tend to match the (initial) impact of the monetary policy shock on the real house price growth rates of the different categories.

Table 1.

Variance decomposition of real house price growth in five categories of the South African housing market.

Categories	Variance decomposition	R^2
Large-middle-segment	0.0192	0.6679
Medium-middle-segment	0.0092	0.5897
Small-middle-segment	0.0045	0.1022
Luxury	0.0488	0.1147
Affordable	0.0039	0.3653

Notes: The column entitled “Variance decomposition” reports the fraction of the variance of the forecast error of the common component, at the 20-quarter horizon, explained by the monetary policy shock. “ R^2 ” refers to the fraction of the variance of the variable explained by the common factors, (F_t^*, Y_t) .

5. Conclusions

This paper assesses the impact of a positive monetary policy shock on real house price growth for the five segments of the South African economy using a FAVAR estimated with 246 variables spanning the period of 1980:Q1 to 2006:Q4. Overall, the results show that real house price growth responds negatively to a positive monetary policy shock, suggesting that the framework does not experience the *home price puzzle*, encountered by Kasai and Gupta (2008) while analyzing monetary policy shocks with three-variable SVARs for the middle-segment of the South African housing market. This result points to the benefit gained by using a large information set. Not surprisingly, the reaction of real house price growth rate is found to differ across the five housing categories, indicating the segmented nature of the market. Specifically, we find the luxury, the large-middle- and the medium-middle-segments to experience the biggest negative impacts following a contractionary monetary policy. However, unlike the two middle-segments, the effect on luxury housing recovers back to its original level much faster. The lower end of the market, i.e., the small-middle-segment and affordable housing witness small and short-lived negative effects.

As part of future research, it would be interesting to analyze the robustness of the results based on a large-scale Bayesian VAR (LBVAR), developed recently by Banbura et al. (2008), since just like the FAVAR, the LBVAR, given its estimation methodology, can also handle a data set of any size. Moreover, unlike the FAVAR, the LBVAR, via appropriate design of the interaction matrix of the variables, can account for spatial influences of neighboring regions and also asymmetric effects of regional variables and national variables on each other. Note, regional

variables are likely to have minor effects on national variables, while, the national variables are more prone to affect the regional variables strongly. However, given that regional (provincial) level house price data in South Africa is only limited to the middle-segment, we would have to restrict our analysis to this section of the housing market only. Nevertheless, a regional analysis would be worth the endeavor in understanding which province(s) in South Africa plays an important role in determining the dynamics of the national house price. Finally, given that the Bayesian methodology does not require us to ensure stationarity of variables, we can analyze house prices at levels rather than their growth rates, if necessary.

Appendix A. Macroeconomic series

Number	Variable name	Log	Stationarity
<i>Interest rates</i>			
1	Treasury Bill rate	nl	0
2	Money market rate	nl	0
3	Deposit rate	nl	0
4	Lending rate	nl	0
5	Discount rate	nl	0
6	Government bond yield	nl	0
<i>House prices</i>			
7	House price growth large	nl	0
8	House price growth medium	nl	0
9	House price growth small	nl	0
10	House price growth luxury	nl	0
11	House price growth affordable	nl	0
<i>Stock prices</i>			
12	All share industrials	1	1
13	Banks	1	1
14	Financials	1	1
15	Industrials and financials	1	1

Number	Variable name	Log	Stationarity
16	Property unit trust	1	1
17	Resources	1	1
<i>Confidence BER</i>			
18	Business confidence index — RMB/BER	1	1
19	Coincidence indicator	1	1
20	Lagging indicator	1	0
21	Leading indicator	1	1
<i>Exchange rates</i>			
22	Rand/dollar	1	1
23	Rand/euro	1	1
24	Rand/pounds	1	1
25	Exchange rate index 2000 = 100	1	1
26	NNEER from INS (index)	1	1
27	REER (index)	1	1
<i>Velocity</i>			
28	Income velocity of circulation of money: V1(A)	1	1
29	Income velocity of circulation of money: V1	1	1
30	Income velocity of circulation of money: V2	1	1
31	Income velocity of circulation of money: V3	1	1
<i>Monetary aggregates</i>			
32	Narrow money (M1) sa — units: 2000 = 100	1	1
33	Monetary aggregate (M1) sa	1	1
34	Monetary aggregate (M3) sa	1	1
35	Monetary aggregate (M2) sa	1	1

Number	Variable name	Log	Stationarity
<i>Credit to private sector</i>			
36	Monetary sector assets: total credit extended to the private sector 12-term % change	nl	0
37	Monetary sector assets: total credit extended to the private sector change over 1 term	nl	0
38	Monetary sector assets: total credit extended to the private sector	1	1
<i>Credit to private sector</i>			
39	GDP deflator	1	1
40	Consumer prices: total — % change (period)	nl	0
<i>National account</i>			
41	Gross domestic product at market prices — 2000 prices	1	1
42	Final consumption expenditure by households — 2000 prices	1	1
43	Final consumption expenditure by general government — 2000 prices	1	1
44	Gross capital formation: gross fixed capital formation — 2000 prices	1	1
45	Gross capital formation: change in inventories — 2000 prices	nl	0
46	Residual item — 2000 prices	nl	0
47	Gross domestic expenditure — 2000 prices	1	0
48	Exports of goods and services — 2000 prices	1	1
49	Imports of goods and services — 2000 prices	1	1
<i>Value added</i>			
50	GDP: primary sector — constant 2000 prices	1	0
51	GDP: primary sector — agriculture, forestry and fishing — constant 2000 prices	1	0
52	GDP: primary sector — mining and quarrying — constant 2000 prices	1	1
53	GDP: secondary sector — constant 2000 prices	1	1

Number	Variable name	Log	Stationarity
54	GDP: secondary sector — manufacturing — constant 2000 prices	1	1
55	GDP: secondary sector — electricity, gas and water — constant 2000 prices	1	1
56	GDP: secondary sector — construction (contractors) — constant 2000 prices	1	1
57	GDP: tertiary sector — constant 2000 prices	1	1
58	GDP: tertiary sector — wholesale and retail trade, catering and accommodation	1	1
59	GDP: tertiary sector — transport, storage and communication	1	1
60	GDP: tertiary sector — financial intermediation, insurance, real estate and business services	1	1
61	GDP: tertiary sector — community, social and personal services — constant 2000 prices	1	1
62	GDP: tertiary sector — community, social and personal services — general government services	1	1
63	GDP: tertiary sector — community, social and personal services — other services	1	1
64	Gross value added at basic prices — constant 2000 prices	1	1
65	Balance of payments: value of merchandise exports	1	1
66	Balance of payments: value of merchandise exports	nl	0
67	Balance of payments: value of net gold exports	1	0
68	Balance of payments: value of net gold exports 1-term % change	nl	0
69	Balance of payments: value of merchandise imports	1	0
70	Balance of payments: value of merchandise imports, f.o.b 1-term % change	nl	0
71	Value of payments for services	1	0
72	Value of payments for services 1-term % change	nl	0
73	Ratio of balance on current account to gross domestic product at current prices (percentage) ,	nl	0
74	Ratio of real merchandise exports to gross domestic product	nl	0

Number	Variable name	Log	Stationarity
75	Ratio of real merchandise imports to gross domestic expenditure (percentage)	nl	0
<i>Utilisation of production capacity</i>			
76	Percentage utilisation of production capacity: durable goods	nl	0
77	Percentage utilisation of production capacity: non-durable goods	nl	0
78	Percentage utilisation of production capacity: total	nl	0
79	Labour productivity — index 2000 = 100	1	1
80	Nominal unit labour costs — index 2000 = 100	1	1
<i>Industrial production</i>			
81	Industrial production: manufacturing sa — units: 2000Y	1	1
82	Manufacturing — orders inflow/demand: tendency	nl	0
83	Manufacturing — orders inflow/demand: tendency	nl	0
<i>Industrial production</i>			
84	Production in total mining — units: 2000 = 100	1	0
85	Production of gold — units: 2000 = 100	1	1
86	Production in total mining sa — units: 2000 = 100	1	0
87	Production of manufactured crude steel	1	0
<i>International trade</i>			
88	Exports: excluding gold — volume — 2000 = 100	1	1
89	Exports: excluding gold — price — 2000 = 100	1	1
90	Exports: including gold — volume — 2000 = 100	1	1
91	Exports: including gold — price — 2000 = 100	1	1
92	Imports: volume — 2000 = 100	1	1
93	Imports: price — 2000 = 100	1	1
94	Terms of trade: excluding gold — 2000 = 100	1	1

Number	Variable name	Log	Stationarity
95	Terms of trade: including gold — 2000 = 100	1	1
<i>Mining</i>			
96	Mining production: total, gold included — index 2000 = 100	1	1
97	Mining production: total, gold excluded — index 2000 = 100	1	1
98	Mining production: gold — index 2000 = 100	1	1
99	Mining production: iron ore — index 2000 = 100	1	1
100	Mining production: chrome — index 2000 = 100	1	0
101	Mining production: copper — index 2000 = 100	1	1
102	Mining production: manganese ore — index 2000 = 100	1	0
103	Mining production: platinum group metals — index 2000 = 100	1	1
104	Mining production: nickel — index 2000 = 100	1	1
105	Mining production: other metallic minerals — index 2000 = 100	1	1
106	Mining production: diamonds — index 2000 = 100	1	1
107	Mining production: coal — index 2000 = 100	1	1
108	Mining production: building materials — index 2000 = 100	1	1
109	Mining production: other non-metallic minerals — index 2000 = 100	1	1
<i>Manufacturing production</i>			
110	Gross fixed capital formation: manufacturing constant 2000 prices	1	1
111	Gross value added at basic prices of manufacturing constant 2000 prices	1	1
112	Taxes on production and imports current prices	1	1
113	Employment in the private sector: manufacturing index 2000 = 100	1	1
114	Production prices of goods for domestic use produced in SA: total manufacturing	nl	0
115	Production prices of goods for domestic use produced in SA: total	nl	0

Number	Variable name	Log	Stationarity
116	Production prices of imported goods for domestic	nl	0
117	Total production prices of goods for domestic	nl	0
118	Production prices of farming requisites index 2000 = 100	1	1
119	Manufacturing: percentage utilisation of production capacity of durable goods	nl	0
<i>Car sales</i>			
120	Retail car sales incl AMH	1	1
121	Total car & commercial vehicle sales incl AMH	1	1
<i>Labour</i>			
122	Labour productivity in the non-agricultural sectors index 2000 = 100	1	1
123	Labour productivity in the non-agricultural sectors 4-term % change	nl	0
124	Unit labour costs in the non-agricultural sectors index 2000 = 100	1	1
125	Unit labour costs in the non-agricultural sectors 4-term % change	nl	0
126	Manufacturing: labour productivity index 2000 = 100	1	1
127	Manufacturing: unit labour costs index 2000 = 100	1	1
128	Employment by public authorities: general government index 2000 = 100	1	1
129	Employment by public authorities: business enterprises index 2000 = 100	1	1
<i>Labour</i>			
130	Total employment by public authorities index 2000 = 100	1	1
131	Total employment by public authorities	nl	0
132	Employment in the private sector: mining index 2000 = 100	1	1
133	Employment in the private sector: manufacturing index 2000 = 100	1	1
134	Employment in the private sector: construction index 2000 = 100	1	1
135	Employment in the private sector: trade index 2000 = 100	1	1

Number	Variable name	Log	Stationarity
136	Employment in the private sector: financial intermediation and insurance index 2000 = 100	1	1
137	Total employment in the private sector index 2000 = 100	1	1
138	Total employment in the private sector seasonally adjusted at annual rate	nl	0
139	Total employment in the non-agricultural sectors index 2000 = 100	1	1
140	Total employment in the non-agricultural sectors seasonally adjusted	nl	0
<i>Prices</i>			
141	Prices of exports: goods and non-factor services, f.o.b excluding gold index 2000 = 100	1	1
142	Prices of imports: goods and non-factor services Index 2000 = 100	1	1
143	Prices of net gold exports 1-term % change	nl	0
144	Prices of merchandise exports, f.o.b 1-term % change	nl	0
145	Prices of merchandise imports, f.o.b 1-term % change	nl	0
<i>PPI</i>			
146	PPI: all groups — index 2000 = 100	1	1
147	PPI: all groups: South African — index 2000 = 100	1	1
148	PPI: all groups: imported — index 2000 = 100	1	1
149	PPI: agriculture, forestry, fishing & mining — index 2000 = 100	1	1
150	PPI: agriculture, forestry, fishing & mining: agriculture — index 2000 = 100	1	1
151	PPI: agriculture, forestry, fishing & mining: agriculture — food — index 2000 = 100	1	1
152	PPI: agriculture, forestry, fishing & mining: agriculture — other agriculture — index 2000 = 100	1	1
153	PPI: agriculture, forestry, fishing & mining: forestry — index 2000 = 100	1	1
154	PPI: agriculture, forestry, fishing & mining: fishing — index	1	1

Number	Variable name	Log	Stationarity
	2000 = 100		
155	PPI: agriculture, forestry, fishing & mining: mining & quarrying — index 2000 = 100	1	1
156	PPI: agriculture, forestry, fishing & mining: mining & quarrying — coal — index 2000 = 100	1	1
157	PPI: manufacturing — index 2000 = 100	1	1
158	PPI: manufacturing: South African — index 2000 = 100	1	1
159	PPI: manufacturing: imported — index 2000 = 100	1	1
160	PPI: manufacturing: food — index 2000 = 100	1	1
161	PPI: manufacturing: food — meat — fresh meat — index 2000 = 100	1	1
162	PPI: manufacturing: beverages — index 2000 = 100	1	1
163	PPI: manufacturing: tobacco products — index 2000 = 100	1	1
164	PPI: manufacturing: textiles & made-up goods — index 2000 = 100	1	1
165	PPI: manufacturing: wearing apparel — index 2000 = 100	1	1
166	PPI: manufacturing: leather & leather products — index 2000 = 100	1	1
167	PPI: manufacturing: footwear — index 2000 = 100	1	1
168	PPI: manufacturing: wood & wood products — index 2000 = 100	1	1
169	PPI: manufacturing: paper, paper products & printing — index 2000 = 100	1	1
170	PPI: manufacturing: products of petroleum & coal — index 2000 = 100	1	1
171	PPI: manufacturing: chemicals & chemical products — index 2000 = 100	1	1
<i>PPI</i>			
172	PPI: manufacturing: rubber & plastic products — index 2000 = 100	1	1
173	PPI: manufacturing: non-metallic mineral products — index 2000 = 100	1	1
174	PPI: manufacturing: basic metals — index 2000 = 100	1	1

Number	Variable name	Log	Stationarity
175	PPI: manufacturing: basic metals — ferrous — index 2000 = 100	1	1
176	PPI: manufacturing: basic metals — non-ferrous — index 2000 = 100	1	1
177	PPI: manufacturing: metal products — index 2000 = 100	1	1
178	PPI: manufacturing: non-electrical machinery & equipment — index 2000 = 100	1	1
179	PPI: manufacturing: electrical machinery & apparatus — index 2000 = 100	1	1
180	PPI: manufacturing: medical, precision & optical instruments — index 2000 = 100	1	1
181	PPI: manufacturing: transport equipment — index 2000 = 100	1	1
182	PPI: manufacturing: furniture — index 2000 = 100	1	1
183	PPI: electricity, gas, steam & water — index 2000 = 100	1	1
184	Production prices: South African goods — manufacturing — % change	nl	0
185	Production prices: South African goods — total — % change	nl	0
186	Production prices: imported goods — % change	nl	0
187	Production prices: South African goods — total — % change	nl	0
<i>CPI</i>			
188	CPI: all items — index 2000 = 100	1	1
189	CPI: commodities — index 2000 = 100	1	1
190	CPI: services — index 2000 = 100	1	1
191	CPI: all items, excluding housing — index 2000 = 100	1	1
192	CPI: all items, excluding food — index 2000 = 100	1	1
193	CPI: food — index 2000 = 100	1	1
194	CPI: food excluding coffee, tea and cocoa: grain products — index 2000 = 100	1	1
195	CPI: food excluding coffee, tea and cocoa: meat — index	1	1

Number	Variable name	Log	Stationarity
	2000 = 100		
196	CPI: food excluding coffee, tea and cocoa: fish and other seafood — index 2000 = 100	1	1
197	CPI: food excluding coffee, tea and cocoa: milk, cheese and eggs — index 2000 = 100	1	1
198	CPI: food — fats and oils — index 2000 = 100	1	1
199	CPI: food excluding coffee, tea and cocoa: fruit and nuts — index 2000 = 100	1	1
200	CPI: food excluding coffee, tea and cocoa: vegetables — index 2000 = 100	1	1
201	CPI: food excluding coffee, tea and cocoa: sugar — index 2000 = 100	1	1
202	CPI: beverages: coffee, tea and cocoa — index 2000 = 100	1	1
203	CPI: food excluding coffee, tea and cocoa: other — index 2000 = 100	1	1
204	CPI: non-alcoholic beverages — index 2000 = 100	1	1
205	CPI: alcoholic beverages — index 2000 = 100	1	1
206	CPI: cigarettes ,cigars and tobacco — index 2000 = 100	1	1
207	CPI: clothing and footwear — index 2000 = 100	1	1
208	CPI: clothing and footwear: clothing — index 2000 = 100	1	1
209	CPI: clothing and footwear: footwear — index 2000 = 100	1	1
210	CPI: housing — index 2000 = 100	1	1
211	CPI: fuel and power — index 2000 = 100	1	1
212	CPI: furniture and equipment — index 2000 = 100	1	1
213	CPI: furniture and equipment: furniture — index 2000 = 100	1	1
214	CPI: furniture and equipment: appliances — index 2000 = 100	1	1
215	CPI: furniture and equipment: other household equipment and textiles — index 2000 = 100	1	1
216	CPI: household operation — index 2000 = 100	1	1

Number	Variable name	Log	Stationarity
217	CPI: household operation: household consumables — index 2000 = 100	1	1
218	CPI: household operation: domestic workers — index 2000 = 100	1	1
219	CPI: household operation: other household services — index 2000 = 100	1	1
<i>CPI</i>			
220	CPI: health — index 2000 = 100	1	1
221	CPI: transport — index 2000 = 100	1	1
222	CPI: transport: vehicles — index 2000 = 100	1	1
223	CPI: transport: running cost — index 2000 = 100	1	1
224	CPI: transport: public and hired transport — index 2000 = 100	1	1
225	CPI: miscellaneous goods and services: communication — index 2000 = 100	1	1
226	CPI: leisure entertainment and culture: recreation and entertainment — index 2000 = 100	1	1
227	CPI: leisure entertainment and culture: reading matter — index 2000 = 100	1	1
228	CPI: education — index 2000 = 100	1	1
229	CPI: miscellaneous goods and services: personal care — index 2000 = 100	1	1
230	CPI: miscellaneous goods and services: other — index 2000 = 100	1	1
231	Consumer prices: services — housing — % change	nl	0
232	Consumer prices: services — total — % change	nl	0
233	Consumer prices: goods: food — % change	nl	0
234	Consumer prices: goods: total — % change nl		
<i>Remuneration per worker</i>			
235	Remuneration per worker in non-agriculture: public sector constant 2000 prices. Index 2000 = 100	1	1

Number	Variable name	Log	Stationarity
236	Remuneration per worker in non-agriculture: public sector index 2000 = 100	1	1
237	Remuneration per worker in non-agriculture: public sector 4-term % change	nl	0
238	Remuneration per worker in non-agriculture: public sector 4-term % change at constant prices	nl	0
239	Remuneration per worker in the private sector constant 2000 prices. Index 2000 = 100	1	1
240	Remuneration per worker in the private sector index 2000 = 100	1	1
241	Remuneration per worker in the private sector 4-term % change	nl	0
242	Remuneration per worker in the private sector 4-term % change at constant prices	nl	0
243	Total remuneration per worker constant 2000 prices. Index 2000 = 100	1	0
244	Total remuneration per worker index 2000 = 100	1	1
245	Total remuneration per worker 4-term % change	nl	0
246	Total remuneration per worker 4-term % change at constant prices	nl	0

Nota bene: Integrated of order 0 = 0 and 1 = 1; not integrated of order 1 = NS; natural log variables = 1; no transformation = nl.

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Notes

¹ Data on house prices are obtained from the ABSA Housing Price Survey, with ABSA being one of the leading private banks of South Africa. The ABSA Housing Price Survey, distinguishes between three price categories as — luxury houses (R2.6 million to R9.5 million), middle-segment houses (R226,000 to R2.6 million) and affordable houses (R226,000 and below with an area in the range of 40 m²–79 m²); and further subdivides the middle-segment category based on the square meters of house area into small (80 m²–140 m²), medium (141 m²–220 m²) and large (221 m²–400 m²).

² See Section 2 for further details.

³ Note, besides the empirical part of the paper, Iacoviello and Minetti (2003) uses a calibrated Dynamic Stochastic General Equilibrium (DSGE) model to analyze the impact of monetary policy on house prices. More recently, Iacoviello and Neri (2008) used a more elaborate estimated DSGE model for this purpose. However, the model is restricted in the sense that it used only 10 macroeconomic variables including only a few housing market variables.

⁴ The *home price puzzle* occurs when the home price increases, instead of declining, following a contractionary monetary policy.

⁵ As will be seen below in Section 2, the FAVAR model nests a simple VAR. Given this, when we estimated the VAR model comprising of the real house price growth rates of the five categories and the interest rate measure, using our data set, as in Kasai and Gupta (2008), we too observed the prevalence of the home price puzzle for not only the large-, medium- and small-middle-segment housing, but also for affordable housing. These results are available upon request from the authors.

⁶ This paper follows the econometric framework of the FAVAR model described in Bernanke et al. (2005).

⁷ Note, once the factors are estimated, other identifying procedures like those of (Bernanke and Mihov, 1998) and (Uhlig, 2005) can be also be applied for identifying innovations. However, as recently shown by Fry and Pagan (2007), there is no reason to believe that sign restrictions will

generate better quantitative estimates of the effects of shocks than the recursive identifying scheme. The fact that additional structure might not be empirically supported by the data, refer to the results of the Bayesian estimation of the model, reported in footnote 14.

⁸ Please refer to Ludi and Ground (2006) for further details.

⁹ Details about the data and the statistical treatment of the variables used to estimate the FAVAR are reported in Appendix A of the paper.

¹⁰ The choice of 4 lags is based on the unanimity of the AIC and FPE criterion. In addition, given that there is ample evidence that monetary policy takes about a year or longer to affect the economy, the choice is not unjustified. Keeping in line with this argument, our results remain qualitatively the same with 3 lags.

¹¹ Using sub-samples covering the periods of 1980:01-1994:04 and 1995:01-2006:04 to account for the change in political regime in South Africa in the year 1994, with the exception of the small-middle-segment housing which was seen to experience an insignificant short-lived increase in the real house price growth rate for a quarter or so, no evidence was found for the *home price puzzle*.

¹² As in Bernanke et al. (2005), the FAVAR model was also estimated using likelihood-based Gibbs sampling techniques. However, the results indicated exceptionally wide confidence bands implying the imprecision involved in the parameter estimates. In addition, we also observed the prevalence of the *home price puzzle* in all the categories, barring the medium-middle-segment housing. This is, perhaps, an indication of the Bayesian approach imposing additional structure, not supported empirically by the data. Given this, the results have not been reported. They are, however, available upon request.

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