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Monetary Policy and Asset Prices in a Small Open Economy: A Factor-Augmented VAR Analysis for Singapore

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Abstract

The ongoing global financial turmoil has revived the question of whether central bankers ought to tighten monetary policy preemptively in order to head off asset price misalignments before a sudden crash triggers financial instability. This study explores the issue of the appropriate monetary policy response to asset price swings in the small open economy of Singapore. Empirical analysis of monetary policy based on standard VAR models, unfortunately, is often hindered by the use of sparse information sets. To better reflect the extensive information monitored by Singapore's central bank, including global economic indicators, we augment a monetary VAR model with common factors extracted from a large panel dataset spanning 122 economic time series and the period 1980q1 to 2008q2. The resulting FAVAR model is used to assess the impact of monetary policy shocks on residential property and stock prices. Impulse response functions and variance decompositions suggest that monetary policy can potentially be used to lean against asset price booms in Singapore.

Keywords: Monetary Policy; Asset Prices; Dynamic Factors; Vector Autoregression.

Relevance to Practice

The ongoing financial turmoil and the ensuing global economic crisis have raised questions about the appropriate policy responses (or the lack thereof) during asset price booms. In particular, the effectiveness of tightening monetary policy pre-emptively to limit asset price bubbles as well as the output costs of such policy actions are key issues for reconsideration. This paper illustrates the application of a factor-augmented VAR model to examine the usefulness of monetary policy in mitigating asset price swings and their destructive fallout for a small open economy like Singapore.

1 Introduction

The collapse of an asset price bubble often leads to financial market distress and may even destabilize the economy, as clearly evidenced by the recent US mortgage market meltdown. Indeed, the ongoing global financial turmoil has revived the question of what should be the appropriate monetary policy response to an asset price boom. In particular, should central bankers tighten monetary policy preemptively in order to head off asset price misalignments before a sudden crash triggers financial instability? After all, the onset of financial instability can lead to adverse macroeconomic consequences, such as inflation and economic activity falling below desired levels, which monetary policy may not readily rectify after the fact. However, some are skeptical about the practicality of such a proposition given the uncertainties about the existence of asset price bubbles and hence, the difficulties in identifying them in the first place.[1] Even if policymakers could identify asset price bubbles, whether monetary policy actions can influence them remains open to question. And when monetary policy is effective in offsetting asset price movements, there could still be costs associated with deflating the bubble in terms of slower economic growth and higher unemployment.

Two opposing views on the usefulness of monetary policy in containing asset price bubbles are found in the literature. On the one hand, some commentators argue that monetary policy should serve exclusively as a counter-cyclical tool and asset price fluctuations that do not affect inflation within the central bank's forecast

[1] Although the definition of a bubble is subjective, it can generally be characterized as a misalignment of an asset price resulting from sharp increases that are not fully justified by fundamentals but are caused by speculative activity, and occurs mostly in periods of easy credit and high leverage.

horizon should be ignored (see, for example, Bernanke and Gertler, 2001; Kohn, 2006). On the other hand, others like Cecchetti *et al.* (2003) and Bean (2003) propose that monetary policy should be used to lean against rapid and excessive increases in asset prices and that central bankers should extract information provided by price developments on the outlook for output and inflation in the medium term, such as in a forward-looking flexible inflation-targeting framework. There are also instances when selective asset inflation does represent a threat to the goal of overall price stability, perhaps by raising inflation expectations unduly or by over-stimulating consumption and investment spending. For example, swings in house prices can have potent effects on the economy via their impact on household wealth, while a stock price boom could be costly to the extent that it encourages excessive business investment in sub-optimal projects.

To determine empirically whether monetary policy should be used as a tool for limiting upswings in asset prices, it is necessary to gauge: (a) the impact of monetary policy changes on asset prices and real activity; (b) the effects of asset price inflation on consumer price inflation over the medium to long term. In this connection, Assenmacher and Gerlach (2008) examined the monetary transmission mechanism in a broad cross-section of industrialized countries[2] to study the responses of asset prices and key macroeconomic variables to monetary policy shocks. They found that, while monetary policy has predictable effects on asset prices, using it to offset price movements is likely to induce pronounced swings in economic activity, thus reducing the attractiveness of a pro-active policy.

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[2] Singapore is not included in the sample of countries considered in this study.

As for econometric methodology, a popular approach following Bernanke and Blinder (1992) and Sims (1992) is to apply a vector autoregression (VAR) to the empirical analysis of monetary policy.[3] The key advantage of the VAR approach is that it explicitly allows for the endogeneity of policy reaction functions, thereby accommodating the interdependence between monetary policy and economic and financial developments, while imposing minimal assumptions about the underlying structure of the economy. Consequently, the emphasis of VAR analyses is on policy innovations, or unanticipated changes in monetary policy.

Unfortunately, the findings from standard VAR analyses hinge on identifying monetary policy correctly, which is often hindered by the use of sparse information sets. In order to conserve degrees of freedom, low-dimensional VAR models with no more than eight variables are frequently employed. Hence, only a limited amount of information is used in standard VAR analyses — in contrast to the huge number of macroeconomic variables typically tracked by central banks. When the information monitored by the central bank is not adequately captured in the specification of the VAR model, it could potentially result in inaccuracies in the estimation of monetary policy innovations and hence, wrong conclusions about the effects of policy.

A case in point is the “price puzzle” widely found in the monetary VAR literature. This refers to the seemingly contradictory positive response of prices to a contractionary monetary policy shock and is often attributed to the model’s failure to include information about future inflation that is available to policymakers (Sims, 1992). As such, monetary policy tightening may be associated with higher prices

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[3] See Christiano *et al*. (1999) for a survey of the extensive literature on VAR analysis of the effects of monetary policy.

because the former partly reflects systematic policy responses to signals of oncoming inflation. Controlling for endogenous policy responses is thus necessary to facilitate the identification of exogenous monetary policy changes and calls for the enrichment of the information sets used in VAR analyses. However, the inclusion of additional variables in VAR models will result in a proliferation of parameters and a loss of efficiency.

As a remedy, one could consider factor-augmented VAR (FAVAR) models that permit the incorporation of information from large datasets in a parsimonious manner (see Bernanke *et al.* 2005; Favero *et al.* 2005; and Stock and Watson, 2005, amongst others). Factor models view all macroeconomic fluctuations as being driven by a small number of common shocks and an idiosyncratic component that is peculiar to each economic time series. The central idea of factor analysis is that information from a large number of data series can be summarized by a small number of common factors. Augmenting the standard VAR model with these estimated factors enriches the specification of the model for a better identification of monetary policy innovations while avoiding the “curse of dimensionality”.

Indeed, the use of a FAVAR model is particularly apt for a small open economy like Singapore. The vulnerability of small open economies to international macroeconomic fluctuations often enhance the volatility of their business cycles beyond that caused by domestically generated disturbances. Hence, the central bank of such economies would typically track a large set of time series that not only includes local economic indicators but also a plethora of foreign variables. Unfortunately, published work on the empirical investigation of the monetary transmission mechanism of small and open economies are hampered by the need for parsimony and often use only a limited number of foreign variables to capture external influences (see, *inter alia*, Fung, 2002 and Chow, 2005 for the Singapore economy[4]). By adopting a factor augmented VAR approach, we can take into adequate account the information related to the impact of international events on domestic economic fluctuations.

This paper addresses the issue of what role monetary policy could play in curtailing asset price booms in Singapore. With a mission to promote sustained non-inflationary economic growth, the Monetary Authority of Singapore (MAS) targets the effective exchange rate instead of the more conventional benchmark policy interest rate as its operating tool (MAS, 2000). To do this, it monitors a large set of domestic and global economic indicators, which coupled with the relatively short length of Singapore's economic time series, makes the application of a FAVAR framework to study monetary policy especially apposite. We mimic the central bank's behavior in our analysis by augmenting the standard monetary VAR model with common factors extracted from a large panel dataset spanning 122 economic time series and the period 1980q1 to 2008q2.

It is the use of the exchange rate as an intermediate target that contributes to the unique nature of monetary policy in Singapore, so we interpret the estimated innovations to the effective exchange rate as unexpected changes in the monetary policy stance. Impulse response functions generated from the FAVAR model could

[4] Fung (2002) used a semi-structural VAR model while Chow (2005) used a recursive VAR model to examine the monetary transmission mechanism in Singapore. However, neither paper dealt with the impact of monetary policy on asset prices.

then be used to measure the responses of house prices and stock prices to monetary policy disturbances, thereby providing an assessment of the extent to which official policy could influence asset prices. At the same time, the impulse responses of inflation and output growth serve as an indication of both the benefits and costs of such policy actions. Furthermore, forecast error variance decompositions offer an insight into the role of asset prices in the determination of the inflation rate in Singapore.

The rest of this paper proceeds as follows. Section 2 gives an introduction to Singapore's monetary policy framework while Section 3 describes the datasets employed. Section 4 introduces the FAVAR model and performs a factor analysis of the time series data. Section 5 reports the empirical results from using the FAVAR model to simulate the impact of monetary policy shocks. Finally, Section 6 concludes the paper.

2 Singapore's Monetary Policy Framework

Singapore operated a currency board system when the Monetary Authority of Singapore (MAS) is first established in 1971. With the collapse of the Bretton Woods system in the early 1970s, instabilities in the world currencies led Singapore to develop its own exchange rate policy framework. The Singapore dollar has officially been on a managed float by the MAS since June 1973. By 1981, the MAS has adopted an exchange rate centered monetary policy by managing the Singapore dollar under a basket-band-crawl (BBC) system (Khor et al, 2004). Under this system, the Singapore dollar is related to a trade-weighted basket of currencies of its major trading partners and competitors. Additionally, the domestic currency is (more than) fully backed by Singapore's foreign reserves. With the exception of the Asian crisis period, the MAS has successfully deterred speculators from attacking the domestic currency over the past three decades. Even during the crisis period, flexibility accorded by the managed float system aided Singapore in escaping from the crisis relatively unscathed.

With reference to the open-economy trilemma,[5] the policy makers' inability to control interest rates, exchange rates, and maintain an open capital account simultaneously means that the central bank needs to choose between interest rate targeting vis-à-vis exchange rate targeting. The MAS has chosen to use the exchange rate as opposed to the more conventional benchmark policy interest rate as its policy operating tool since the early 1980s (MAS, 2000). The rationale of this decision is revealed when we consider the structure of the Singapore economy as well as its monetary transmission mechanism. Firstly, Singapore is highly dependent on external demand which constitutes two thirds of aggregate demand. Secondly, domestic consumption has a high import content—out of every Singapore dollar spent in Singapore, about fifty cents go to imports. Being a price taker in the international markets, it follows that Singapore is highly susceptible to imported inflation. Hence, the highly open and trade-dependent

[5] Obstfeld *et al.* (2004) gives a treatise on the open economy trilemma which says that monetary policy can only achieve fully two of the following three dimensions: monetary policy independence, fixed exchange rates, and open capital accounts.

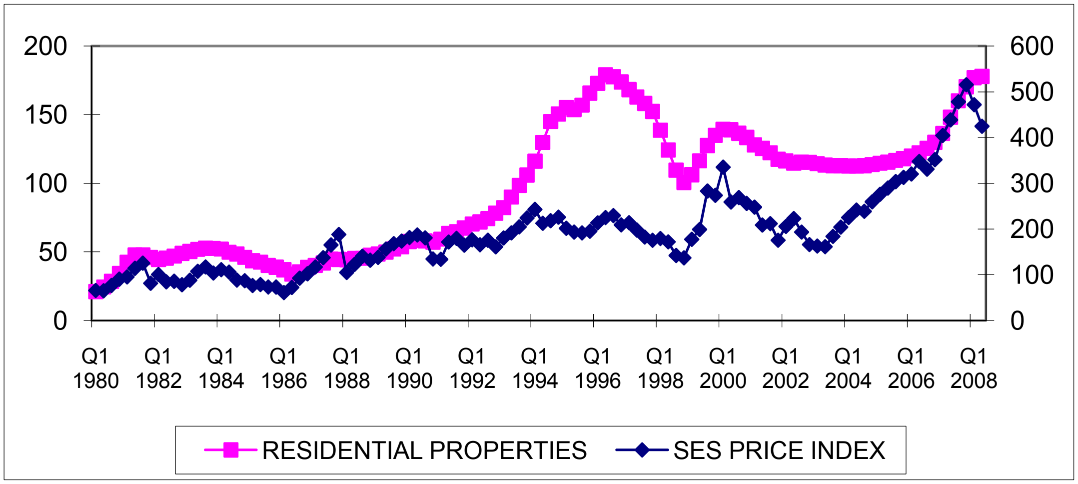
nature of the economy implies that the exchange rate is the most effective tool in controlling inflation.

By comparison, the Singapore economy is less interest rate sensitive, notwithstanding its status as a financial hub. MAS does not focus on the interest rate variable or a monetary aggregate in its conduct of monetary policy due to a lack of control over them — a reflection of Singapore's openness to capital flows and a very liberal policy towards foreign direct investment. As a result of the exchange rate-centered monetary policy framework and free capital mobility in Singapore, domestic short-term interest rates are significantly determined by foreign interest rates. Findings from a monetary VAR analysis in Chow (2005) suggest the exchange rate is indeed more influential than the interest rate as a source of macroeconomic fluctuations. The paper showed further that the interest rate does not appear to be an important channel of monetary transmission in Singapore.

To assess if monetary policy can potentially be used to combat the instability caused by asset price bubbles, we consider residential property price and stock price fluctuations in Singapore. Figure 1 depicts the Singapore residential property price index and the Stock Exchange of Singapore (SES) Price Index from 1980q1 to 2008q2. The Singapore housing market experienced several boom-bust cycles during this period, with an average quarter-on-quarter growth of 1.9%. Sharp appreciations in house prices occurred in periods of rapid economic growth and are mostly associated with the liberalization of the housing finance sector, in particular

Central Provident Fund (CPF) regulations.[6] Conversely, downturns in house prices coincide with economic recessions or the implementation of anti-speculation measures such as direct credit controls. The quarter-on-quarter house price inflation rates range from -12.6% to 21.6%, partly reflecting the rise and fall of foreign investor interest in the Singapore property market.

Figure 1. Singapore Residential Property and Stock Price Indices



In comparison to house prices over the same period, stock prices in Singapore have a lower average quarter-on-quarter growth rate of 1.7%. As expected, the swings in the stock price cycles are more pronounced with the quarter-on-quarter growth rates spanning a wider range of -58.2% to 35.2%. The cyclical behavior in the stock prices is related to the business cycle as well as the ebb and flow of foreign portfolio investment in the local stock market.

[6] The CPF is a government-administered mandatory retirement fund that can be partially withdrawn to finance housing (see Phang, 2004).

3 Datasets

There are three vectors of variables employed in our study: $\boldsymbol{Y}_t$, $\boldsymbol{X}_t$ and $\boldsymbol{f}_t$. The first two consists of observable time series included in the VAR and factor models respectively, and are described in this section. The last is a collection of unobserved common factors that jointly drive the other series and will be dealt with in the next section. These can also be thought of as the primitive sources of shocks that generate Singapore's business cycles.

The $\boldsymbol{Y}_t$ vector is made up variables that are relevant to a VAR analysis of the dynamic effects of monetary policy on asset prices: $\left[gdp_{t,} cpi_t, hp_t, sp_t, twi_t\right]'$, where gdp is the gross domestic product, cpi is the consumer price index, hp is the private residential property price index, sp is the stock price index and twi is the trade-weighted exchange rate of Singapore against her major trading partners. The first two series are conventional activity and price arguments in the literature on monetary reaction functions and are crucial for identifying policy shocks.

The inclusion of the exchange rate variable in the VAR model is not only necessary for the case of a small open economy (Cushman and Zha, 1997) but more importantly, changes in the effective exchange rate variable are viewed as an indicator of the monetary policy stance in Singapore. As discussed in the previous section, an interest rate variable and a monetary aggregate are excluded from the model since the MAS does not focus on these variables in its conduct of monetary policy. We use Singapore residential property price index and the Stock Exchange of Singapore (SES) Price Index to represent asset prices in the economy.

In contrast to the small number of variables in Y_t, the X_t vector represents a large panel dataset of 122 quarterly economic indicators, comprising 33 foreign and 89 local variables.[7] Their sample period is 1980q1 to 2008q2, with the choice of the start date reflecting a trade-off between having more variables and maintaining a relatively large time dimension.[8] The variables covered and their data sources are listed in the appendix.

As mentioned earlier, the MAS closely watches not just domestic macroecononomic series but also numerous international economic indicators. For instance, an external variable such as the global oil price captures early inflationary pressures while foreign interest rates and world output presage impending changes in international financial conditions and external demand. It is thus imperative to incorporate information not only from domestic variables but also from foreign series into the FAVAR model to be estimated. The indicators selected can be loosely grouped as follows:

- Real GDPs of Singapore's major trading partners and their weighted average (10 countries and one region); composite leading indexes of the US and major European and Asian economies; foreign stock prices and interest rates
- US technology cycle index; world oil price and global consumer prices

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[7] The five endogenous variables explicitly specified in the Y_t vector are also part of the panel dataset for factor analysis.

[8] For instance, the inclusion of Singapore's rebased monthly industrial production series available publicly only from January 1989 shortens substantially the overlapping data sample period for all the series. Hence, these series are excluded from the panel dataset in order to maintain a balanced panel. In the same vein, various electronic indicators are missing from the dataset due to their late start date at 1992q1.

- Singapore’s real GDP and expenditure components; gross value-added output in manufacturing and major service sectors; business expectations surveys; official composite leading index
- Construction and housing related series e.g. residential investment, building contracts awarded and property prices
- Sectoral indicators such as tourist arrivals, electricity generation and new company formations in different sectors
- Foreign trade series: exports and imports of goods and services, domestic exports and re-exports — all disaggregated into oil and non-oil categories
- Export and import price indices; terms of trade; consumer and producer price indices; GDP and sectoral deflators
- Labour market variables: unit labour and business costs
- Financial series such as share prices, interest rates and exchange rates; monetary aggregates and bank credit

The application of factor analysis requires pre-treatment of data. If available, we download the seasonally adjusted time series supplied by data sources. Otherwise, we performed the adjustment ourselves using the Census X-12 software (these instances are noted in the appendix). All variables, except interest rates and those with negative values, are measured in natural logarithm units and scaled by a factor of 100.

Since the estimation of factors also requires the time series to be stationary, variables that manifest long-term trends are differenced to yield either quarter-on-quarter changes or growth rates. Following Watson (2003), we identify outliers as observations that differ from the sample median by more than six times the interquartile range and replace them by the respective outside boundary of the interquartile.[9] Further, all raw and transformed variables used in the factor analysis are standardized by subtracting their means and dividing by their standard deviations to avoid overweighting any one series.

4 Factor Models and Vector Autoregressions

Let $X_{it}, t = 1,\ldots,T, i = 1,...,N,$ index the panel of stationary time series discussed above. Then a factor model for these variables is given by:

$$X_{it} = \lambda_i(L) f_t + \varepsilon_{it} \tag{1}$$

where the $q \times 1$ vector $\boldsymbol{f}_t$ contains the unobserved common factors alluded to previously, ε_{it} is an idiosyncratic disturbance term that is unique to each economic variable, and $\lambda_i(L) = \lambda_{i0} + \lambda_{i1}L + \cdots + \lambda_{is}L^s$ is an s-th order polynomial in the lag operator L that represents a vector of factor loadings. In the dynamic model described by (1), current realizations of variables can be affected by the past values of factors through a distributed lag structure.

An important assumption essential for estimation of the factor model is that the factors and idiosyncratic errors are mutually uncorrelated at all leads and lags. Moreover, the method of principal components used below to estimate the factor model requires the factors to be orthogonal to one another. In contrast to exact factor models, however, the idiosyncratic disturbance ε_{it} in (1) is permitted to have

[9] The outlying observations can mostly be attributed to the 1997–1998 Asian financial crisis, the outbreak of the SARS disease in 2003 or the credit crisis of 2007–2008.

limited serial and cross-correlation (Forni *et al.*, 2000 and Stock and Watson, 2002b). Autocorrelation in the idiosyncratic errors can be eliminated through the transformation in (2) below while the contemporaneous correlations between them can be handled by identifying the shocks in the VAR model (see Section 4).

Multiplying both sides of (1) by $1-\delta_i(L)L$ yields[10]

$$X_{it} = \tilde{\lambda}_i(L) f_t + \delta_i(L) X_{it-1} + \nu_{it} \tag{2}$$

where $\tilde{\lambda}_i(L) = (1-\delta_i(L)L)\lambda_i(L)$ and $\nu_{it} = (1-\delta_i(L)L)\varepsilon_{it}$ is white noise. If it is assumed that the common factors evolve dynamically according to a multivariate VAR process, we can write

$$\boldsymbol{F_t} = \Phi\boldsymbol{(L)}\boldsymbol{F_{t-1}} + \boldsymbol{G}\eta_t \tag{3}$$

where $\boldsymbol{F_t} = (\boldsymbol{f_t'}, \ldots, \boldsymbol{f_{t-s}'})'$ is of dimension r and η_t are the factor disturbances. Combining (3) and (2) results in the hybrid FAVAR model

$$\begin{bmatrix} \boldsymbol{F_t} \\ \boldsymbol{X_t} \end{bmatrix} = \begin{bmatrix} \Phi\boldsymbol{(L)} & 0 \\ \Lambda\Phi\boldsymbol{(L)} & \delta\boldsymbol{(L)} \end{bmatrix} \begin{bmatrix} \boldsymbol{F_{t-1}} \\ \boldsymbol{X_{t-1}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{u_{Ft}} \\ \boldsymbol{u_{Xt}} \end{bmatrix} \tag{4}$$

with the $N \times r$ matrix Λ containing the factor loadings and $\boldsymbol{u_{Xt}} = \Lambda\boldsymbol{G}\eta_t + \nu_t$. The FAVAR in (4) is distinguished from the conventional VAR in two ways. First, the unobserved common factors are tagged on as exogenous variables so that $\boldsymbol{X}_t$ does not predict $\boldsymbol{F_t}$ given lagged $\boldsymbol{F_t}$. Second, $\boldsymbol{X}_t$ can potentially include a much larger number of macroeconomic variables than what is feasible in a standard VAR, thus allowing us to analyse the effects of monetary policy on any variable we like.

[10] The exposition that follows is based on Stock and Watson (2005), although we have changed the notation slightly.

For estimation purposes, the factor model in (1) is cast into the so-called static form by stacking the current and lagged values of the common factors together in $\boldsymbol{F}_t$. That is, the model in (1) is often reformulated as:

$$X_t = \Lambda F_t + \varepsilon_t \tag{5}$$

where $F_t = \left(f_t', \ldots, f_{t-s}'\right)'$ is an $r = q\left(s+1\right)$-dimensional vector of stacked common factors and Λ is now an $N \times r$ matrix of factor loadings. Notice that the *r* static factors in F_t consist of current and lagged values of the *q* dynamic factors in f_t. The advantage of the static representation is that it allows the unobserved factors to be estimated consistently by taking principal components of the covariance matrix of $\boldsymbol{X}_t$ when N is large, provided mild regularity conditions are satisfied (Stock and Watson, 2002a). The other use of the static form is that the number of dynamic factors, q, can be determined from a knowledge of the number of static factors, r. Since some factors in the static model are dynamically dependent — being lags of the others — it follows that $q \leq r$.

This observation forms the basis of Bai and Ng's (2007) method to select the number of dynamic factors by making use of the fact that q is the reduced rank of the correlation matrix for the factor disturbances in equation (3). The method proceeds in two steps. In the first, the static factors are estimated by the principal components technique and r is consistently selected using the following information criteria developed in Bai and Ng (2002).

$$IC(r) = \ln\left(V\left(r, F\right)\right) + r\left(\frac{N+T}{NT}\right)\ln\left(\min\left\{N, T\right\}\right) \tag{6}$$

$$\ln\left(V\left(r,F\right)\right)=\frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}\left(X_{it}-\Lambda_{i}F_{t}\right)^{2} \tag{7}$$

The penalty imposed by the second term in (6), which is an increasing function of *N* and *T* as well as the number of factors, serves to counter-balance the minimized residual sum of squares, thereby effecting an optimal trade-off between over-fitting and goodness of fit.

Applying the criteria to our panel data with a pre-specified upper bound of 12 on r suggests that six factors should be included in the static model. [11] In the second step, the principal components estimates of the static factors are used to fit the VAR model in (3). Subject to a maximum of eight lags, both the Akaike Information Criterion (AIC) and the Final Prediction Error (FPE) criterion selected an optimal lag length of three for the model, which we fitted accordingly to obtain the least squares residuals.

The procedure to determine q is based on the estimated eigenvalues of the VAR residual correlation matrix. Let these be denoted as $\hat{c}_1 \geq \hat{c}_2 \geq \ldots \geq \hat{c}_r \geq 0$ in descending order. Assuming that the true number of dynamic factors is q, $c_k = 0$ for $k > q$. Bai and Ng (2007) showed that the cumulative contribution of the k-th eigenvalue given by $\hat{D}_k = \sqrt{\sum_{j=k+1}^{r} \hat{c}_j^2 / \sum_{j=1}^{r} \hat{c}_j^2}$ converges asymptotically to zero for $k \geq q$ at a rate depending on the sampling error induced by estimation of the correlation matrix. Hence, for non-negative *m* and $0 < \delta < 1/2$, the smallest integer k

[11] The first six principal components altogether explain 52% of the total variance in our economic series and the consecutive difference in the subsequent eigenvalues flattens out to zero.

that satisfies the bounded set $\left\{k : \hat{D}_k < m / \min\left[N^{\frac{1}{2}-\delta}, T^{\frac{1}{2}-\delta}\right]\right\}$ is the estimated number of common factors in the model. Following the settings of $m = 1$ and $\delta = 0.1$ used in Bai and Ng (2007), the eigenvalue test picked $q = 3$ dynamic factors for the Singapore panel data, thus implying that $s = 1$.[12] This means that the bulk of the observed co-variation in the time series can be explained by three factors and their lagged values, suggesting that there are just as many underlying shocks driving Singapore's business cycles.

5 FAVAR Analysis of Monetary Policy

We start this section by estimating the FAVAR model in (4), after replacing $\boldsymbol{F}_t$ by the three dynamic factors found earlier and $\boldsymbol{X}_t$ by its subset $\boldsymbol{Y}_t$, containing the variables of interest in the monetary VAR model. Following convention, all series except for the factors, which are stationary by construction, are converted into approximate quarterly growth rates by taking first differences of their logarithms and scaled by 100. The stationarity of the transformed variables was confirmed by the DF-GLS unit root test proposed by Elliot *et al*. (1996).[13] Moreover, the AIC, FPE and Hannan-Quinn information criteria all suggested that a FAVAR model of order one be estimated, in line with the above finding of a single lag for the dynamic factors.

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[12] The factor analysis performed by Chow and Choy (2008) yielded four dynamic factors. This slight difference in the results could be attributed to their using a different panel dataset which has a much later starting date of 1992q1, a bigger number of series (177), and the use of year-on-year instead of quarterly growth rates.

[13] The DF-GLS test is an asymptotically more powerful variant of the augmented Dickey-Fuller (ADF) test that is obtained from generalized least squares detrending.

For structural interpretations of impulse response functions and variance decompositions, the error terms in the FAVAR system should be mutually uncorrelated. However, the residuals from estimating the reduced form FAVAR model in (4) were still found to be weakly correlated, mainly due to cross-correlation between the idiosyncratic disturbances in v_t. We therefore orthogonalize the residuals in the VAR part of the model by applying the Cholesky decomposition to recover the underlying structural shocks. The Wold causal ordering of variables used — real output, consumer prices, house prices, exchange rate and stock prices — is determined by their level of exogeneity and reflects an implicit assumption about how fast macroeconomic variables respond to monetary policy shocks, as represented by exchange rate innovations. Thus, the order for the exchange rate implies that output, consumer prices and house prices respond sluggishly to unanticipated policy shocks but stock prices react contemporaneously.[14]

These identification assumptions are consistent with the existing literature postulating a delay of at least one month in the impact of monetary policy changes on private sector behaviour that determines variables such as output and consumer prices (Sims, 1998). They are justified by the argument that individual consumers, workers and businessmen do not make sharp and finely calculated responses to market signals insofar as decisions on production and final goods prices are concerned. Clearly, such an assumption is inappropriate for stock prices, which are set in highly efficient financial markets.

[14] Alternatively, a structural VAR which allows for contemporaneous feedback between variables can be used. However, it has been found that more complex identification schemes remain arbitrary and tend to give similar qualitative effects of monetary policy, see Christiano *et al*. (1999).

5.1 Impulse Response Functions

Figures 2–6 plot the impulse response functions of the variables included in the FAVAR model for an innovation to the exchange rate shock. The exchange rate variable used in this study is expressed in terms of the amount of foreign exchange that can be bought for one unit of local currency. It follows that a rise in the exchange rate signals an appreciation of the Singapore dollar. Given the way the effective exchange rate is defined, an innovation represents a one-standard deviation appreciation, corresponding to a 1.2% rise in the quarterly growth rate of the twi.

We obtained bootstrap standard errors from 1000 replications for the impulse responses and then used them to construct 68% confidence bands.[15] These are shown as dashed lines in the graphs. The time horizon over which the responses are plotted following the monetary policy innovation extends to 16 quarters, by which time all the impulses are insignificantly different from zero.

An unexpected tightening of monetary policy elicits an negative but insignificant response from output growth, see Figure 2. The positive exchange rate shock causes a small decline in the real GDP growth rate which bottoms out three quarters after the initial impulse. The contractionary effect of monetary policy stemming from an appreciation of the Singapore dollar can be traced to a reduction in exports occurring through a loss of competitiveness. The output reaction obtained in the short-run is expected, in light of the external trade-driven nature of the Singapore economy (see Abeysinghe, 2000). An inverted hump-shaped response of

[15] We follow Assenmacher and Gerlach (2008) in using one-standard error bands in view of the modest degrees of freedom, leading to imprecise estimates of the impulse response functions.

output like the one we find here is a robust finding of the monetary VAR literature, documented by, amongst others, Kim (1999) for different countries and Bernanke and Mihov (1998) for various measures of monetary policy.

Figure 2. Impulse Response of *gdp* to *twi* Shock

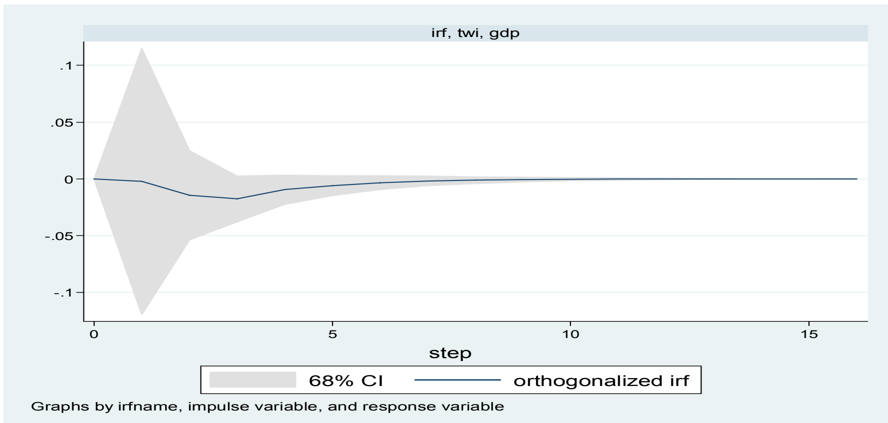


Figure 3. Impulse Response of *cpi* to *twi* Shock

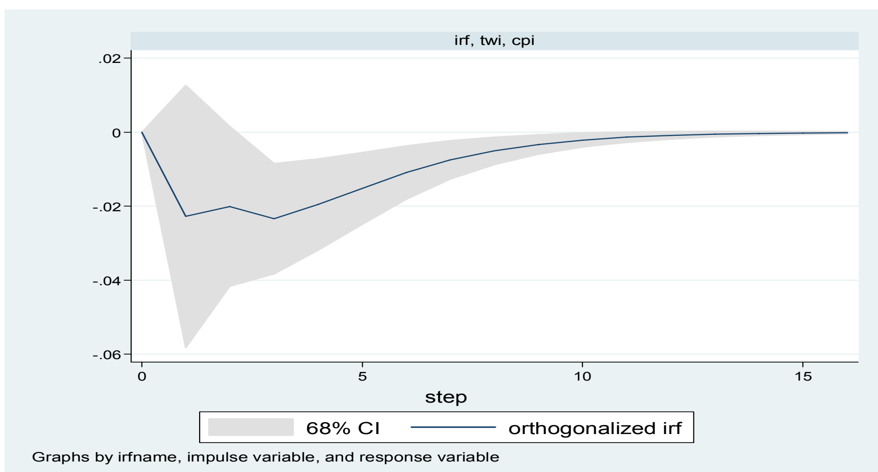


Figure 4. Impulse Response of *hp* to *twi* Shock

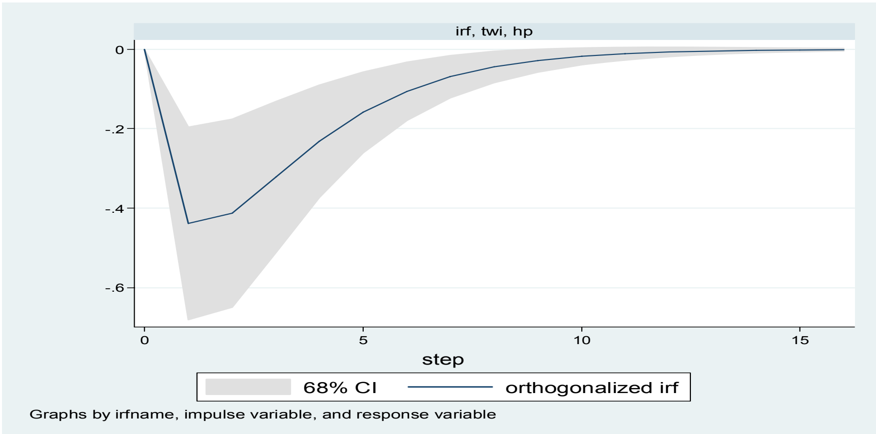


Figure 5. Impulse Response of *sp* to *twi* Shock

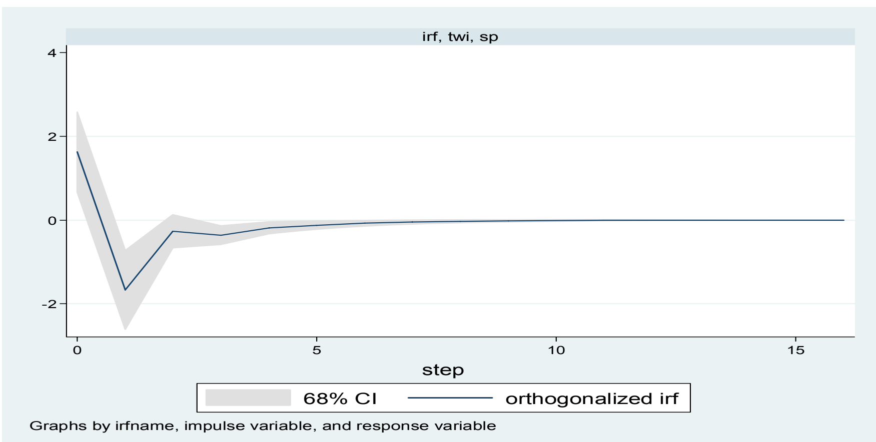
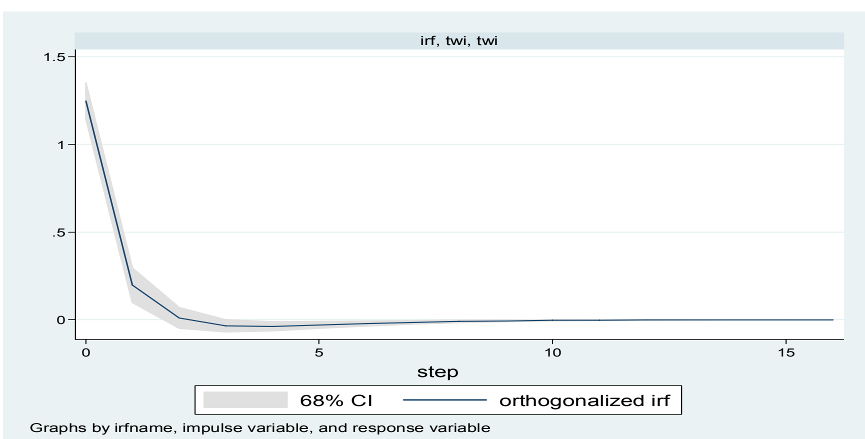


Figure 6. Impulse Response of *twi* to *twi* Shock



In Figure 3, we observe that a price puzzle is absent in Singapore due to the extra information that has been incorporated into the FAVAR model from the factor analysis. As predicted by *a prior* theory, a tightening of monetary policy eventually leads to a statistically significant fall in inflation. The deflationary impact of a Singapore dollar appreciation can occur through the direct channel of lower imported inflation, as well as the indirect channel whereby a reduction in exports eases domestic cost pressures.

Nonetheless, a decline in the strength of pass-through effects has recently been observed, particularly for countries in a low inflationary environment (see Gagnon and Ihrig, 2001). The relatively small price reaction of 0.03% obtained at lag six is therefore not surprising, given Singapore's low inflation record. Besides, Toh (1999) found the inflationary effects of an exchange rate depreciation to be more evident in producer prices rather than consumer prices.

The plot in Figure 4 shows that a positive exchange rate shock leads to an immediate negative response from house price growth. The contractionary monetary policy precipitates a substantial decline in hp growth of about 0.4% one quarter after the initial impulse and the responses become statistically insignificant only seven quarters later. This relatively large and protracted response suggests that monetary policy does have some influence over residential property prices in Singapore. To some extent, the fall in property prices can be attributed to the decline in income growth seen in Figure 1, whilst the negative wealth effect of the former also feeds back to consumption and output.

Similarly, a surprise tightening of monetary policy depresses the stock market, as depicted in Figure 5. The 1.7% drop in stock price growth occurs a quarter after the initial impulse. One possible explanation for the pronounced impact is that an appreciation of the Singapore dollar discourages financial portfolio inflows from overseas. Further, the point estimates show that the growth of both types of asset prices, but particularly stock prices, fall by a much greater extent than the decline in output growth and consumer price inflation. It follows that monetary policy could in principle be used to offset upswings in property and stock prices in Singapore without substantially depressing output growth or general price inflation.

Finally, the graph in Figure 6 shows the exchange rate impulse response to its own innovation. We see that the exchange rate shock is not so persistent, remaining significantly above the baseline level for only two quarters. This suggests a quick reversal of the trade-weighted index's growth rate to its pre-shock level. In implementing the exchange rate-centered monetary policy, the MAS manages the Singapore dollar under a managed float regime that allows various forms of adjustments including a re-centering of the policy band and a change to the slope of the crawl in the central parity.

Clearly, such adjustments will result in a change to the growth rate of the trade-weighted index. The movements in the exchange rate, however, do not exclusively reflect policy actions but also market developments, which means that the monetary policy shock is not perfectly identified in the FAVAR model. Notwithstanding that, our choice of the effective exchange rate as the measure of monetary policy in Singapore produces results that are generally consistent with conventional thinking about the monetary transmission mechanism in small open economies.

5.2 Variance Decompositions

We turn our attention now to assessing the relative importance of the various structural shocks in determining the consumer inflation rate in Singapore. Table 1 allocates to the different sources of disturbances the variance of the forecast errors in the *cpi* variable over the four years displayed in the impulse response charts. The first row of the table reports the variance decompositions for the estimated FAVAR model. They suggest that most of the observed variation in consumer prices comes from its own innovations, followed by house price shocks and then output innovations. Interestingly, housing asset inflation contributes about 18% of the variance in consumer inflation after 16 quarters, which may be partly explained by the fact that more expensive housing translates into higher accommodation costs in the *cpi*. Furthermore, it is likely that the positive wealth effect from rising house valuations will stimulate domestic demand and exert further pressure on prices.

In contrast, the role of stock prices and monetary policy are negligible. Results like this do not imply that monetary policy has not been responsible for Singapore's low inflation record. They merely suggest that unpredictable variation in the effective exchange rate has not been needed to offset the shocks impinging on the Singapore economy. Indeed, research based on a structural macroeconometric model has shown that the exchange rate can be used as an effective buffer against external inflationary pressures (Abeysinghe and Choy, 2009).

Table 1. 16-quarter variance decompositions for inflation (in %)

	gdp	*cpi*	*hp*	*sp*	*twi*
FAVAR	6.5	73.8	17.8	1.1	0.8
VAR + oil price	7.9	58.2	26.6	1.1	2.4
VAR + commod	8.2	58.1	29.2	1.3	2.1
VAR + import price	7.6	57.2	26.6	1.1	2.7

Note: Numbers may not add up to 100 because of rounding

As a check on the robustness of our results, we adopt the usual solution to the price puzzle of including an index of commodity prices into the monetary VAR model in lieu of the common factor. The variance decomposition findings for three different price indexes are reported in Table 1: the spot oil price, world non-oil commodity prices and the overall import price index in Singapore.[16] The empirical decompositions do not alter very much across the various specifications, indicating that our results are quite robust. Housing price inflation accounts for a larger proportion of between 27 to 29% of final price inflation while the contribution of output shocks rises marginally. The results have another implication — the use of the FAVAR model seems to be as good as the traditional fix of adding commodity prices to standard VAR models in order to remedy the omitted information problem. In fact, it is actually better as the impulse responses from using the price indexes do not resolve the price puzzle fully.

[16] The first two series are obtained from *International Financial Statistics* and the last from the Singapore Time Series database.

6 Conclusion

In this study, we explore the issue of what should be the appropriate monetary policy response to asset price swings in the context of Singapore. To this end, we employ a FAVAR model to examine the effects of monetary policy on key macroeconomic variables and asset prices in Singapore. The choice of this model as a tool for the empirical analysis of the monetary transmission mechanism is motivated by the problem of omitted variable bias in standard VAR models. Due to their inherent difficulty in accommodating large numbers of economic variables, we augment one such model with common factors estimated by a dynamic factor model from a large panel dataset.

Overall, the impulse response functions recovered from the monetary FAVAR model are broadly consistent with conventional results on the effects of monetary policy. Furthermore, the responses of both house prices and stock prices to a monetary tightening reveal that they are significantly influenced by exchange rate disturbances. Consequently, it would appear plausible to tighten monetary policy to dampen asset price booms in Singapore. The case for taking preemptive action is strengthened by the finding from a variance decomposition analysis suggesting that a substantial proportion of consumer price inflation originates from the housing market.

It is, nonetheless, important to consider the costs of such policies in terms of their impact on real activity and inflation. The impulse response analysis reveals that the growth rates of asset prices fall by a much greater extent than the declines in output growth and inflation when there is a contractionary monetary policy shock. In light of these findings, this paper lends tentative support to the use of monetary policy to lean against upswings in property and stock prices in Singapore.

However, policymakers need to be discerning when using monetary policy to mitigate asset price swings and their destructive fallout. In cases where sharp increases in asset prices can be attributed to productivity changes, interventions are not warranted and could even be counter-productive. Further, if the surges in asset valuations are concentrated in selective sectors, directed prudential policies may be more appropriate. Nonetheless, a tighter monetary policy may be called for to counter pronounced increases in asset prices that are broad-based and fuelled by credit expansions, particularly if they materially heighten financial and systemic risks to the economy. Additionally, there is also a need for monetary policy to work in tandem with financial policies on regulation and oversight to combat instabilities caused by asset price bubbles.

Appendix: Datasets

	Series	Mnemonic	Source	Transformation	SA Status
Foreign real GDPs (12)					
1.	USA*	USAGDP			Source SA
2.	Japan	JAPGDP			Own SA
3.	Korea	KORGDP	*Econometric*		Own SA
4.	Rest of the OECD*	ROECDGDP	*Studies*		Source SA
5.	Malaysia	MALGDP	*Unit,*	Logarithm	Own SA
6.	Indonesia*	INDOGDP	*National*	difference	Own SA
7.	Thailand	THAIGDP	*University*		Own SA
8.	Philippines	PHILGDP	*of Singapore*		Own SA
9.	Taiwan	TAIGDP			Own SA
10.	Hong Kong	HKGDP			Own SA
11.	China	CHINGDP			Own SA
12.	Foreign GDP	FORGDP			Source SA
Foreign leading indexes (6)					
13.	USA	USACLI			
14.	Japan	JAPCLI		Deviations	
15.	Germany	GERCLI	*SourceOECD*	from	Source
16.	UK	UKCLI		trend	SA
17.	4 big European	EUROCLI			
18.	5 major Asian	ASIACLI			
Foreign stock prices (8)					
19.	US	USASPI			NSA
20.	Japan	JAPSPI			NSA
21.	Germany	GERSPI			NSA
22.	UK	UKSPI			Own SA
23.	Korea	KORSPI	*Bloomberg*	Logarithm	NSA
24.	Malaysia	MALSPI		difference	NSA
25.	Thailand	THAISPI			NSA
26.	Hong Kong	HKSPI			NSA
Foreign real interest rates (3)					
27.	US (3-mth LIBOR – CPI % Δ)	USAIR	*International*	No	
28.	Japan (3-mth LIBOR – CPI % Δ)	JAPIR	*Financial*	transformation	NSA
29.	UK (3-mth LIBOR – CPI % Δ)	UKIR	*Statistics*		
World electronics (2)					
30.	US Tech Pulse Index	TECH	*New York Fed*	Logarithm	NSA
31.	Nasdaq index	NASDAQ	*Bloomberg*	difference	NSA
World prices (2)					
32.	Real oil price (deflated by World CPI)	OIL	*International*	Logarithm	NSA
33.	World CPI	WORLDCPI	*Financial Stats*	difference	NSA

Series	Mnemonic	Source	Transformation	SA Status
Real GDP components (7)				
34. Real GDP	GDP			
35. Private consumption	CON			
36. Government consumption	GCON			
37. Gross fixed capital formation	GFCF	*STS*	Logarithm	Source
38. Transport equipment	GFCFTPT		difference	SA
39. Machinery, equipment & software	GFCFMEQ			
40. Net exports	NX		difference	
Gross value-added (13)				
41. Manufacturing	MFG			
42. Construction	CONSTR			
43. Services	SER			
44. Commerce	COMM			
45. Wholesale & retail trade	WRTRADE			
46. Hotels & restaurants*	HOTREST	*STS*	Logarithm	Source
47. Transport & Communications*	TRANSCOM		difference	SA
48. Transport & storage*	TRANSTOR			
49. Information & communications	INFOCOM			
50. Financial & Business Services	FINBIZ			
51. Financial services	FIN			
52. Business services	BIZ			
53. Other Services	OTHER			
Business surveys (2)				
54. General expectations for mfg	EXPMFG	*STS*	Net balances	Source SA
55. Employment expectations for mfg	EMPMFG		of firms	NSA
Construction (7)				
56. GFCF in construction & works	GFCFCONSTR			Source SA
57. Residential buildings	GFCFRES			Source SA
58. Non-residential buildings	GFCFNRES			Source SA
59. Others	GFCFOTHER	*STS*	Logarithm	Source SA
60. Property price index (residential)	PPIRES		difference	Own SA
61. Property price index (office)	PPIOFF			NSA
62. Property price index (shop)*	PPISHOP			NSA
Sectoral Indicators (12)				
63. Visitor arrivals	VISIT			Source SA
64. Electricity generation	ELECTRIC			Own SA
65. Composite leading index	CLI			NSA
66. Formation of companies	FORM	*STS*	Logarithm	Own SA
67. Manufacturing	FORMMFG		difference	NSA
68. Construction	FORMCONSTR			Own SA
69. Wholesale & retail trade	FORMWRTRADE			Own SA
70. Hotels & restaurants	FORMHOTREST			NSA
71. Transport & storage	FORMTRANSTOR			Own SA

	Series	Mnemonic		Source		Transformation	SA Status
72.	Information & comms	FORMINFOCOM	)		)		NSA
73.	Financial & insurance	FORMFIN	)		)		Own SA
74.	Real estate & leasing	FORMESTATE	)		)		Own SA
External Trade (14)							
75.	Exports of goods & services	X	)		)		Source SA
76.	Imports of goods and services	M	)		)		Source SA
77.	Exports of goods	GX	)		)		Source SA
78.	Oil	OGX	)		)		Source SA
79.	Non-oil	NOGX	)		)		Source SA
80.	Imports of goods	GM	)		)		Source SA
81.	Oil	OGM	)	*STS*	)	Logarithm	NSA
82.	Non-oil	NOGM	)		)	difference	Source SA
83.	Domestic exports	DX	)		)		Source SA
84.	Oil	ODX	)		)		Source SA
85.	Non-oil	NODX	)		)		Source SA
86.	Re-exports	RX	)		)		Source SA
87.	Oil*	ORX	)		)		NSA
88.	Non-oil	NORX	)		)		Source SA
Price Indices (14)							
89.	Export price index	XPI	)		)		NSA
90.	Oil	OXPI	)		)		NSA
91.	Non-oil	NOXPI	)		)		NSA
92.	Import price index	MPI	)		)		NSA
93.	Oil	OMPI	)		)		NSA
94.	Non-oil	NOMPI	)		)		NSA
95.	Terms of trade	TOT	)	*STS*	)	Logarithm	NSA
96.	Consumer price index	CPI	)		)	difference	Source SA
97.	Domestic supply price index	DSPI	)		)		NSA
98.	Manufactured price index	SMPI	)		)		NSA
99.	GDP deflator	PGDP	)		)		Own SA
100.	Manufacturing deflator	PMFG	)		)		NSA
101.	Construction deflator	PCONSTR	)		)		NSA
102.	Services deflator	PSER	)		)		Own SA
Labour Market (3)							
103.	Unit labour costs	ULC	)		)		Source SA
104.	Manufacturing unit labour costs	MULC	)	*STS*	)	Logarithm	Source SA
105.	Manufacturing unit business costs	MUBC	)		)	difference	Source SA
Financial (14)							
106.	Stock prices	SES	)			Log difference	NSA
107.	3-mth interbank rate	INTER	)	*STS*		No transformation	NSA
108.	Prime lending rate	PLR	)			No transformation	NSA
109.	Nominal effective exchange rate	NEER	)			Log difference	NSA

	Series	Mnemonic		Source		Transformation	SA Status
110.	Real effective exchange rate	REER	)		)		NSA
111.	Singapore dollar to US$	USD	)		)		NSA
112.	Singapore dollar to Pound	POUND	)		)		NSA
113.	Singapore dollar to Yen	YEN	)		)		NSA
114.	Singapore dollar to Malaysian $	RINGGIT	)	*STS*	)	Logarithm	Own SA
115.	Singapore dollar to HK$	HKD	)		)	difference	NSA
116.	Singapore dollar to Korean won	WON	)		)		NSA
117.	Singapore dollar to Taiwan $	NTD	)		)		NSA
118.	Singapore dollar to Indo rupiah*	RUPIAH	)		)		NSA
119.	Singapore dollar to Thai baht*	BAHT	)		)		NSA
Monetary (8)							
120.	M1	M1	)		)		Source SA
121.	M3	M3	)		)		Source SA
122.	Bank loans	LOAN	)		)		NSA
123.	Manufacturing	LOANMFG	)	*STS*	)	Logarithm	NSA
124.	Building & construction	LOANCONSTR	)		)	difference	NSA
125.	Commerce	LOANCOMM	)		)		Own SA
126.	Financial institutions	LOANFIN	)		)		NSA
127.	Professional & pte individuals*	LOANPRO	)		)		NSA

Notes: Figures in parentheses represent the number of variables in each category. STS is the Singapore Department of Statistics online time series database. SA (NSA) indicates series that have (not) been deseasonalised. Time series adjusted for outliers are marked with an asterisk.

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