Special Feature A

Macro-Financial Modelling Of The Singapore Economy: A GVAR Approach

by Filippo di Mauro and Alessandro Galesi [1]

Introduction

Globalisation has greatly increased the degree of interdependence across countries. Macroeconomic policy must therefore take a global perspective, particularly in the case of small open economies such as Singapore. From a modeller's point of view, this requires considering many countries, regions and markets, as well as multiple channels of transmission, including trade and financial linkages. Cross-country interdependencies are increasingly reflected in the effects of global shocks, to oil or food prices for example, as well as technology and policy uncertainty spillovers.

As the GFC has vividly illustrated, there are also strong bi-directional links between the banking sector and the real economy. To model such complex interactions—global and financial—high-dimensional systems are needed, which however would be quickly affected by the so-called 'curse of dimensionality' or too many variables for too few observations, thus rendering robust empirical estimation unfeasible.

To resolve this issue, we build a vector autoregressive model for Singapore called SINGVAR that is aimed at analysing how the macroeconomy interacts with the domestic banking system. SINGVAR is based on the Global Vector Autoregression model (GVAR) first developed by Pesaran *et al*. (2004), further estimated for the Euro area by Dees *et al*. (2007) and recently updated by Smith and Galesi (2014).

In the spirit of the GVAR, each of the model blocks in SINGVAR contains just a few basic macroeconomic and banking variables. However, as a novel feature and following Gross *et al*. (2016), individual banks are modelled in a similar way to countries. In this approach, the firm-level variables of individual banks are related to institution-specific 'foreign variables'—constructed as the weighted averages of the corresponding variables across the banking system. These foreign variables also include domestic macroeconomic aggregates, which are assumed to be weakly exogenous to reduce the number of parameters for estimation. The result is a model which includes a parsimonious, yet comprehensive, set of linked macroeconomic and banking variables.

This Special Feature briefly introduces the GVAR methodology before presenting the conceptual framework and model specification of SINGVAR. Following this, some estimation results are reported, with a focus on analysing the model's dynamic responses to foreign and domestic shocks.

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The Modelling Framework And Specification

The GVAR Methodology

The GVAR model is a collection of country-specific time series models, in which domestic variables are related to country-specific foreign variables in a consistent way. The latter are constructed so as to match the international trade and financial patterns of the country under consideration, and also to serve as a proxy for common unobserved factors (di Mauro and Pesaran, 2013).

Specifically, country i is modelled as a vector autoregression with exogenous variables (VARX*):

$$\Phi_i(L,p_i)x_{it} = a_{io} + a_{i1}t + \Lambda_i(L,q_i)x^*_{it} + \Psi_i(L,q_i)d_t + u_{it} \quad (1)$$

where Φ_i, Λ_i and Ψ_i are polynomials in the lag operator L, p_i is the lag order of x_i, q_i is the lag order of x^*_{it}, and u_{it} is a serially uncorrelated disturbance term. There are multiple channels of international transmission in GVAR: (i) the impact of rest-of-the-world variables through x^*_{it}; (ii) the effects of common shocks such as oil price changes and common trends, represented by d_t; and (iii) the correlation of shocks to variables within and across countries, as captured by u_{it}.

Foreign variables x^*_{it} are computed as weighted averages of the corresponding domestic variables of all countries:

$$x^*_{it} = \sum_{j=0}^{N} w_{ij} x_{jt} \quad (2)$$

with the weights w_{ij} being country-specific and based on bilateral trade shares. With the notable exception of the US, the foreign variables are assumed to be weakly exogenous for all countries, which essentially implies that they are small economies. Due to this assumption, which is testable, country models can be estimated separately and the number of parameters decreases substantially.

The GVAR links and aggregates the country VARX* models based on trade weights. The global model is then solved recursively and used for impulse response analysis or forecasting. In the current version of the model, the GVAR consists of 33 countries and has been estimated using quarterly data over the period Q2 1979 – Q1 2013 (for details of country and region coverage, refer to Smith and Galesi, 2014).

The Macro Block

Figure 1 provides a schematic overview of SINGVAR. On the left, the macro block incorporates a basic representation of the Singapore economy. This block interacts with the rest of the world economy, as described by the currently available version of the GVAR in Smith and Galesi (2014). In the first instance, the international transmission of economic and financial shocks originating from abroad flows through this block.

Although the choice of macroeconomic variables in SINGVAR follows the standard country specifications in the GVAR closely, it also includes additional variables that are needed to flesh out the two-way interactions of the real economy with the banking sector. (Table 1) These are credit, the property price level and private consumption, all expressed in real terms. Moreover, to accurately represent MAS' monetary policy framework, the real bilateral exchange rate has been replaced by the S$NEER.

Figure 1
A Schematic Overview of SINGVAR

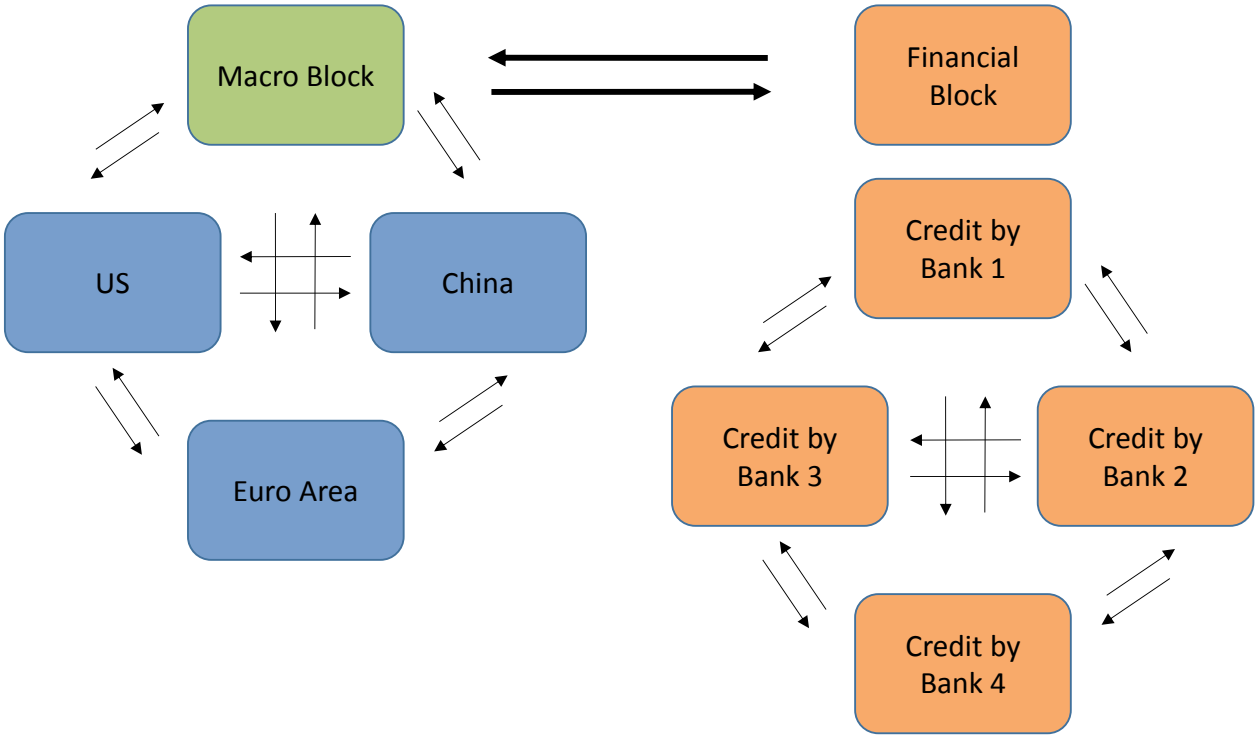


Table 1
Macroeconomic Variables in SINGVAR

	SINGVAR	Standard GVAR
Real Output	✓	✓
Inflation	✓	✓
Real Bilateral Exchange Rate	X	✓
Nominal Short-term Interest Rate	✓	✓
Nominal Long-term Interest Rate	✓	✓
Real Equity Price	✓	✓
Real Credit	✓	X
Real Property Price	✓	X
Real Private Consumption	✓	X
Nominal Effective Exchange Rate	✓	X

Source: ABS, Haver Analytics, IMF and EPG, MAS estimates

Note: Real output is represented by Singapore's real GDP. Inflation is measured by the percent change in the headline CPI. The nominal short-term interest rate used is the three-month S$ SIBOR while the long-term rate is proxied by the 10-year government bond yield. The equity price is proxied by the Singapore Straits Times Index (STI) and credit is the sum of resident non-bank loans extended by banks and finance companies, as well as debt securities issued in Singapore (defined by operation or incorporation). The property price is based on the private residential property price index. The real equity price, real property price and real credit are obtained by deflating the respective nominal variables by the CPI.

The Financial Block

The financial block in SINGVAR allows individual bank variables to interact amongst themselves, as well as with aggregate macroeconomic variables. It aims to capture in some detail the transmission mechanisms of monetary policy in Singapore by explicitly modelling the heterogeneity found in individual banking groups operating in the country. Further, it allows the effects of foreign shocks to transmit to the banking sector via the macro block, which are then amplified by interbank linkages and subsequently affect the real economy.

Individual banks are modelled in the same way as in the macro block, i.e., by considering 'domestic' variables and 'foreign' covariates, as set out in Equation (1). However, the interpretation of the dependent and independent variables in the equation is different; x_{it} contains the endogenous variables of bank i; x_{it}^{*} collects those of other banks and d_t now consists of macroeconomic aggregates which are common to all banks. (Table 2)

The x_{it} vector contains basic information on the structure of the balance sheets of individual FIs. This includes asset composition (bank credit in real terms), borrowing cost (lending rate), and financial fragility (share of non-performing loans in total loans). Where possible, and for a subset of banks, real credit is disaggregated into two components: real housing loans and other loans. The balance sheet structure, in turn, determines the way in which monetary policy and other shocks affect the bank lending volume and lending rates. Thus, the behaviour of individual FIs is made to depend on macroeconomic shocks in a manner that accounts for firm-level heterogeneity.

Each FI interacts with its peers in the banking system through the foreign variables, and together they determine the aggregate volume of loans supplied to the economy and the average lending rate. These in turn feed back on the real economy and influence growth and inflation outcomes, thus creating important feedback loops between the macro and financial blocks in SINGVAR.

In terms of scope of coverage, the financial block includes the major FIs in Singapore with substantial shares of financial activities. In total, the sample captures the vast majority of aggregate loans extended to non-bank borrowers in Singapore. It should also be noted that interbank lending in Singapore, which has been rising over time, is taken into consideration. In sum, the modelling strategy adopted for the financial block ensures that the interconnectedness of FIs is taken into account.

Table 2
Financial Variables in SINGVAR

Endogenous (x_{it})	Foreign (x_{it}^{*})	Common (d_t)
Lending Rate	Lending Rate	Real Output
Real Credit	Real Credit	Real Private Consumption
Non-performing Loans Ratio	Non-performing Loans Ratio	Inflation
		Real Equity Price
		Real Property Price
		Nominal Effective Exchange Rate
		Nominal Short-term Interest Rate
		Nominal Long-term Interest Rate

Source: ABS, Haver Analytics, IMF and EPG, MAS estimates

Note: In addition to the variable definitions in Table 1, the lending rate is proxied by the ratio of interest income to interest-bearing assets, while the non-performing loans ratio is the share of non-performing loans in total loans.

Estimation Results

Estimation of the SINGVAR follows the standard procedures used for the GVAR as described in di Mauro and Pesaran (2013). Initially, a time series analysis of the data is carried out, followed by the estimation of the macro and financial blocks, which are then stacked up and solved simultaneously. The sample period for the two blocks are Q2 1979 – Q4 2016 and Q1 2004 – Q4 2016, respectively, with the shorter period for the financial block imposed by data constraints.

Based on unit root tests, it is found that most of the variables are non-stationary. Consequently, vector error-correction models corresponding to equation (1) are estimated, incorporating the cointegrating properties of variables. These VECM* models are estimated separately for the macro and financial blocks using a lag order of one, with 'dominant unit' sub-models embedded in each of them. The dominant unit feeds into each individual VECM* and this serves to drive feedback effects within the model. For the macro block, energy and commodity prices are included in the 'dominant unit' sub-model, with feedback effects to GDP and inflation. In the financial block, VECM* models are estimated for individual banks and the dominant unit model consists of the common macroeconomic aggregates. The estimation procedure in this case utilises the two-stage approach described in Smith and Galesi (2014), which was originally proposed by Chudik and Pesaran (2013). This method involves the use of an augmented regression and is also able to deal with the problem of missing observations in the financial block prior to 2004.

Several diagnostic tests are performed on the estimated models, with the results confirming the absence of serial correlation in the residuals and dynamic parameter stability. Moreover, pairwise cross-sectional correlations of the residuals—a metric of goodness-of-fit—indicate that SINGVAR explains most of the systematic co-movements in variables, so that only idiosyncratic shocks remain. Finally, tests for weak exogeneity are also not rejected for most of the variables.

The Effects Of Shocks To The Model

This section studies the dynamic properties of SINGVAR through an analysis of the impact of various shocks on key macroeconomic and financial variables in the model. For this purpose, the generalised impulse response function (GIRF) proposed by Pesaran and Shin (1998) is used.[2] Three simulations are considered: (i) a fall in US real equity prices; (ii); a rise in the US interest rate; and (iii) a rise in Singapore's real GDP.

The first two simulations illustrate how foreign shocks can be transmitted to Singapore through trade, financial and confidence channels. The third scenario could take place, for example, when the government undertakes infrastructure investment projects, which boost domestic growth.

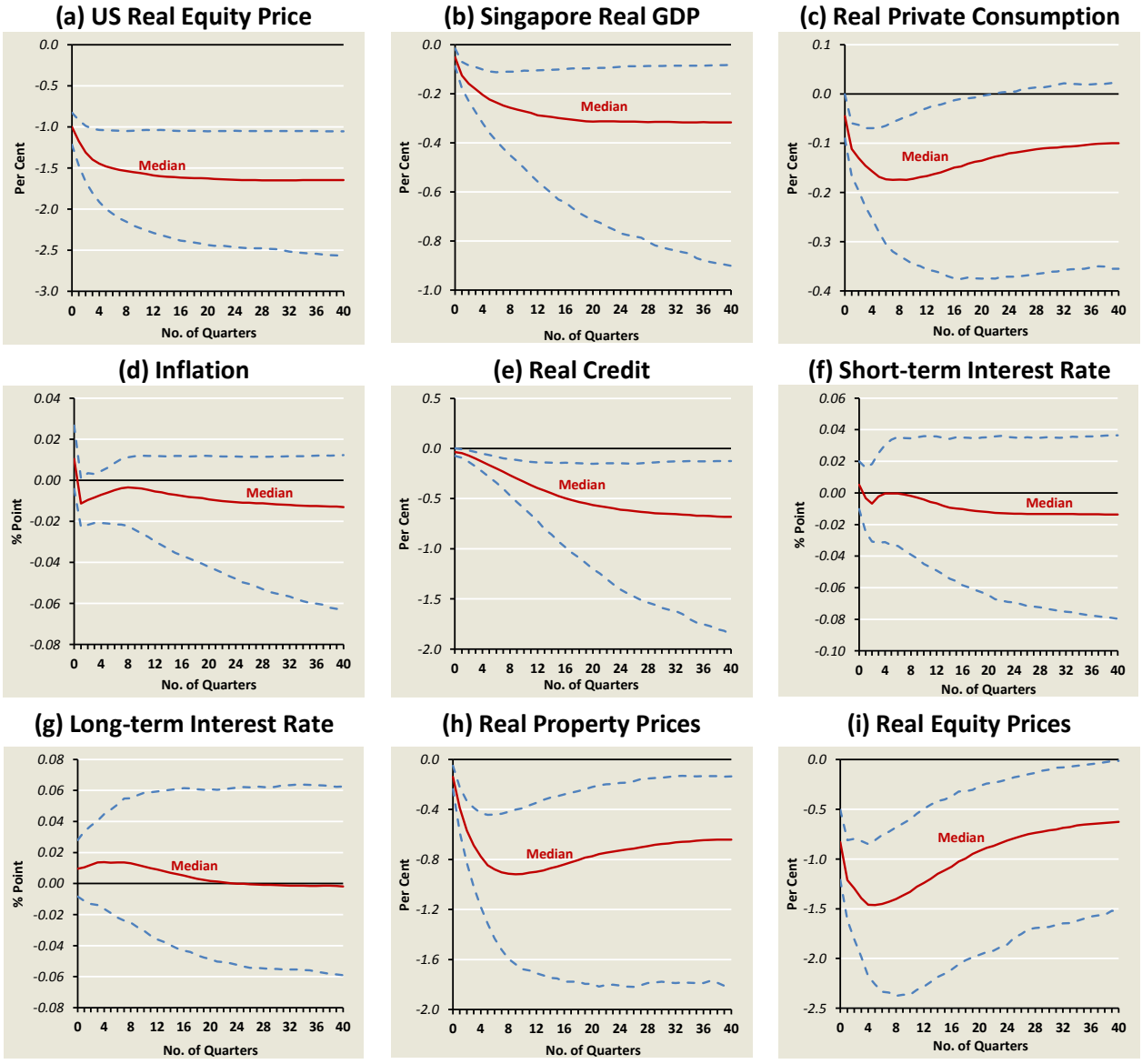
[2] The GIRF is an alternative to the impulse responses used in standard VAR analysis. It does not require the shocks in the model to be orthogonalised but integrates out instead the effects of other shocks using their observed joint distribution. As such, it can be quite informative about the dynamics of shocks transmission, although the shocks cannot be given structural interpretations. The associated 90% error bounds are obtained through the bootstrap method with 1000 replications.

A 1% Fall in US Equity Prices

Initially, a fall in real US equity prices will cause a decline in US real GDP through negative wealth effects on consumption (not reported here). Hence, Singapore's GDP would be impacted in the first instance through lower US import demand. However, the US equity shock also has an almost one-to-one impact on Singapore's real equity prices through financial and confidence channels, which precipitates a fall in domestic consumption. (Chart 1) Overall, the impact on Singapore's real GDP is more muted compared to the US, suggesting that the effect of an equity price shock is contained.

With the fall in Singapore's GDP, inflation declines in tandem and remains slightly lower in the long run. The other notable effects of the fall in US real equity prices on Singapore's economy are a decline in property prices and a real credit contraction, alongside a small decrease in the short-term interest rate. In the long run, both equity and property prices recover some of their short-term losses.

Chart 1
Impact of a 1% Fall in US Real Equity Prices



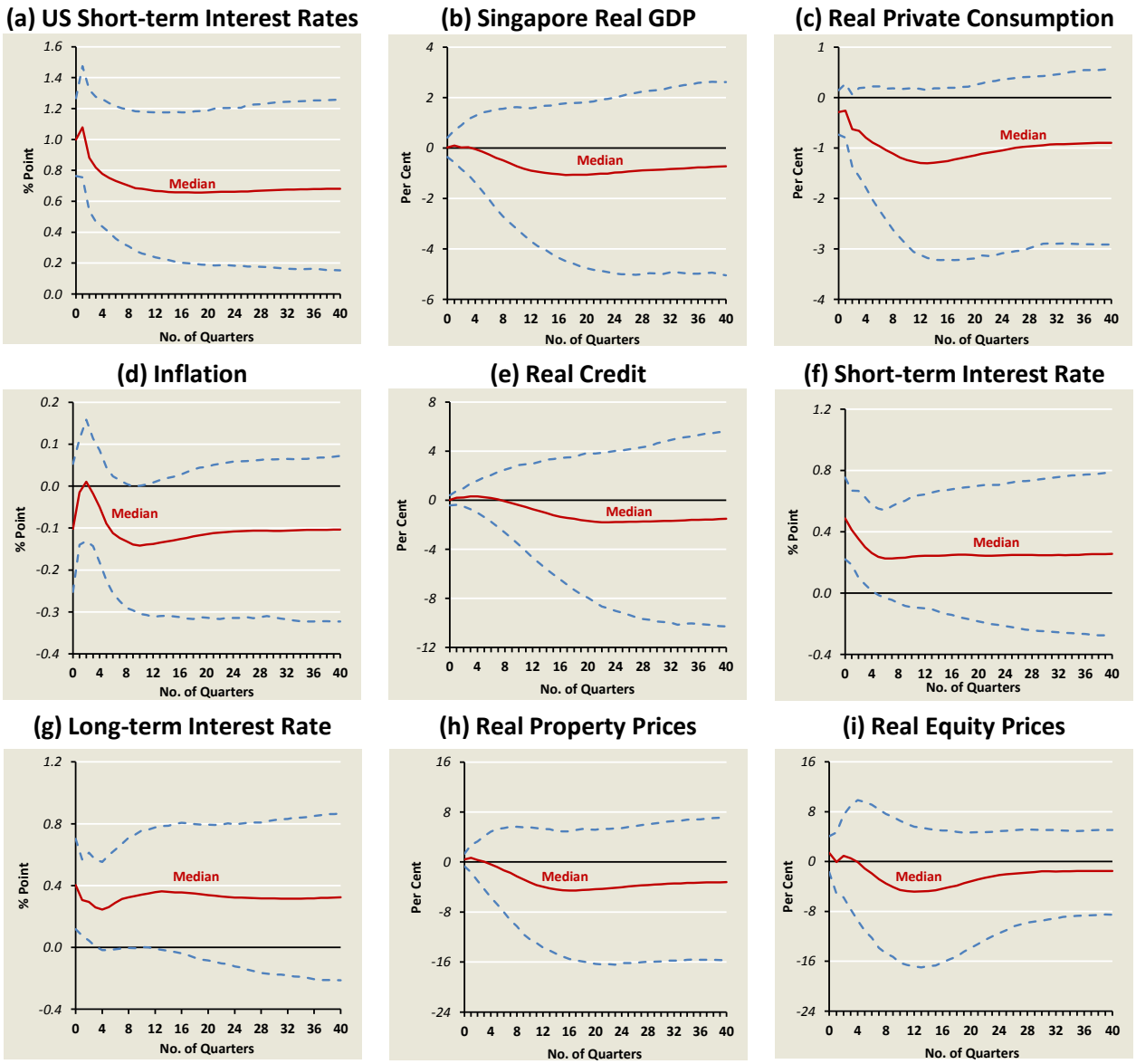
Note: Solid line represents the median estimate and dashed lines represent the 90% bootstrap bounds.

A 1% Point Rise in the US Interest Rate

When the US short-term interest rate rises by 1% point, Singapore's interbank rate will increase in tandem, but by a smaller amount. (Chart 2) Consequently, the demand for, and supply of, bank credit pulls back, alongside lower asset prices. These responses will weigh on private consumption (and investment to some extent) through higher borrowing costs and negative wealth effects. Consequently, real GDP declines and inflation falls accordingly.

Over the longer term, short- and long-term interest rates remain higher than their pre-shock levels. However, the decline in real equity valuation is largely reversed over time, so that it is only slightly lower. All in, this simulation suggests that a tightening of US financial conditions has a discernible, albeit modest, impact on the Singapore economy.

Chart 2
Impact of a 1% Point Rise in the US Interest Rate



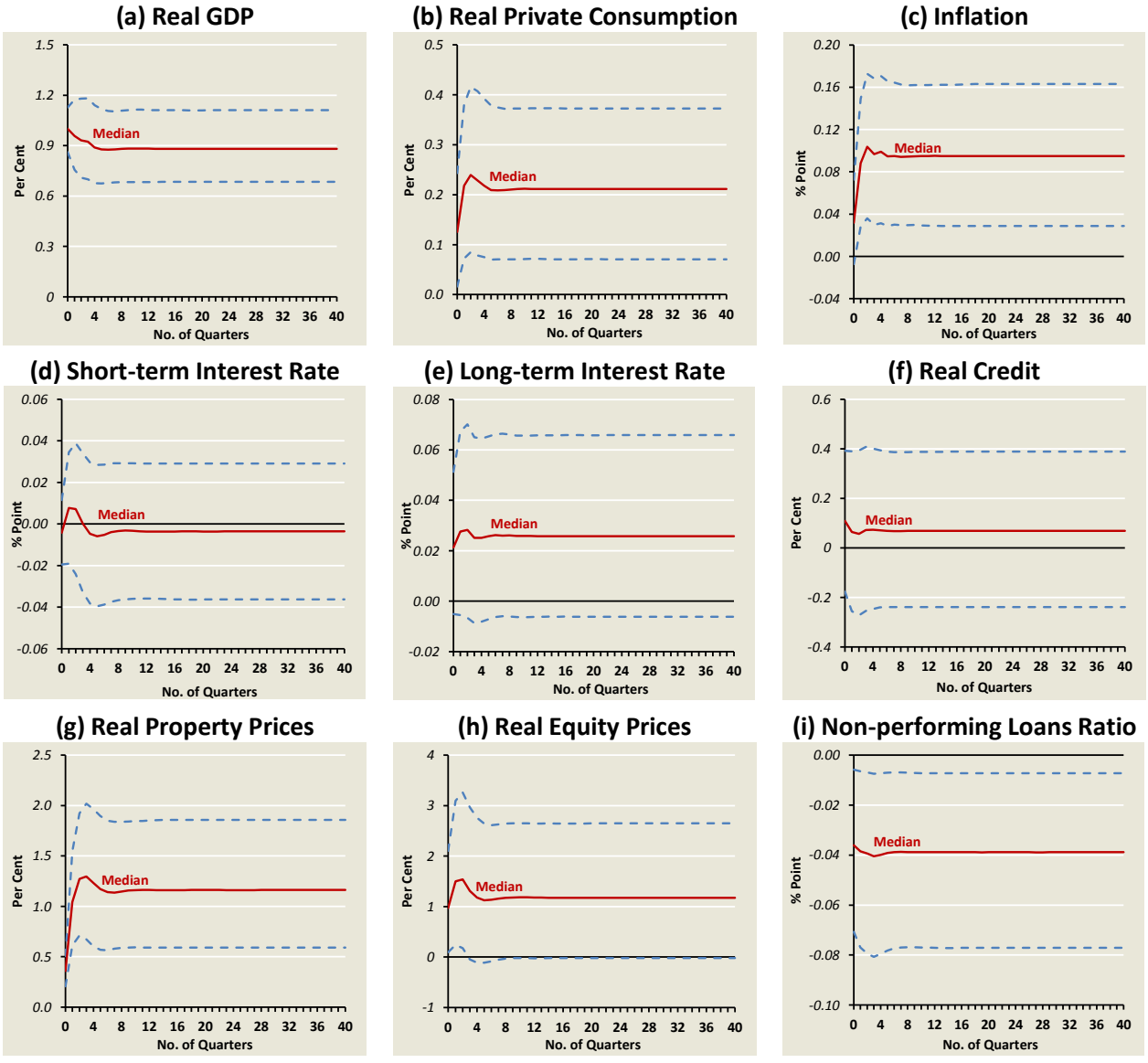
Note: Solid line represents the median estimate and dashed lines represent the 90% bootstrap bounds.

A 1% Increase in Singapore's Real GDP

The third simulation considered is a 1% increase in Singapore's GDP, which can be expected to affect the domestic financial sector and induce changes in individual bank behavior. Insofar as the macroeconomic variables are concerned, an autonomous shock to real GDP leads to the expected responses, including stronger private consumption, higher inflation and a rise in property prices. (Chart 3) In turn, stronger economic activity associated with a higher GDP level induces banks to increase their lending, even as the ratio of non-performing loans falls. Accordingly, the real volume of credit in the economy rises.

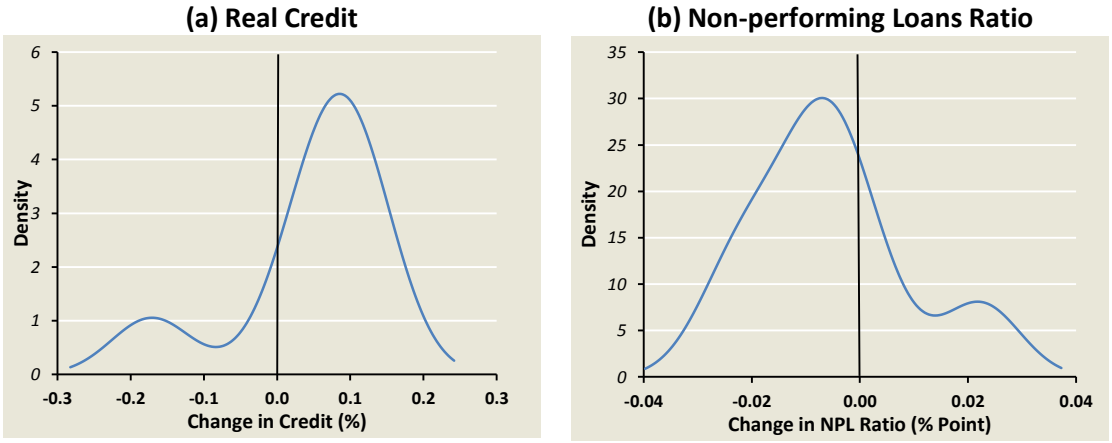
However, the empirical distribution of credit increases across individual institutions suggests that there is some heterogeneity in banks' responses, which is captured in SINGVAR. The distribution shows that the large majority of FIs extend more loans. (Chart 4a) Concomitantly, the distribution of non-performing loans suggests that most banks will see a reduction in bad loans when macroeconomic conditions improve. (Chart 4b) Short- and long-term interest rates also show initial increases, though the rise is not persistent for the former.

Chart 3
Impact of a 1% Rise in Singapore's Real GDP



Note: Solid line represents the median estimate and dashed lines represent the 90% bootstrap bounds.

Chart 4
Distribution of Financial Changes Across Banks



Sum-Up

The new SINGVAR model presented above is the latest addition to MAS' suite of macro-econometric models. It provides a parsimonious, yet rather compelling representation of the interactions between the Singapore economy, the rest of the world and the domestic banking sector. Moreover, the impulse responses obtained by simulating shocks to the model are plausible.

Apart from analysing the impact of foreign and domestic shocks, SINGVAR can be used for forecasting and scenario analysis. Moreover, one can carry out conditional forecasting to examine how the model responds to pre-specified trajectories of the relevant 'shock' variables.

By capturing the structure of the banking system in Singapore, SINGVAR can provide relevant information to policymakers on the two-way interactions between the real economy and the banking sector. This renders the model potentially useful for both monetary policy and macroprudential analysis. For example, the model can be used to gauge the potential impact of macroprudential measures, or to assess the impact of monetary policy changes, taking into consideration interactions within the domestic banking system. A comparison with the results from other models available, which do not consider such interactions, would inform EPG's ongoing work to refine SINGVAR and its properties.

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