Macro-Financial Modeling of the Singapore Economy: A GVAR Approach*

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MAS

Monetary Authority of Singapore

Two premises

Globalization has greatly increased interdependencies across countries.

National economic issues should be considered from a global perspective, and particularly so for small open economies such as Singapore.

Modern economies feature strong macro-financial interactions.

Monetary policy must take into account the way its transmission operates within the domestic banking system.

Scope of the Project

Against this background, the Monetary Authority of Singapore (MAS) is interested in having at its disposal a modeling tool which would tackle two main issues:

On the macroeconomic side

Provide a compelling representation of the interactions between the Singapore economy and the rest of the world

On the banking side

Characterize the network of Monetary and Financial Institutions (MFIs) & the two-way feedback loop with the real economy

The Challenge

On the macroeconomic side

Many countries & many transmission channels to take into account:

- Trade and financial linkages
- Common shocks (e.g. oil or food prices)
- Other channels (technology, uncertainty…)

On the banking side

Examining the monetary policy transmission requires considering many MFIs & complex interactions among them

To model all of the above, we need to build high-dimensional systems

Problem: **"curse of dimensionality"**

too many parameters to estimate for too few data

The GVAR Approach

We overcome this issue via the Global Vector Autoregressive (GVAR) modeling approach

The GVAR is a simple yet effective way of **capturing interactions in high-dimensional systems**

Originally developed as a model for the global economy...

... it can deal with large networks of regions, sectors, firms, banks...

Foreign variables capture interactions

- Each country is linked to others by **foreign variables**: weighted averages of other countries' variables
- Weights capture the relative role of each country (e.g. trade- or financial-based)

2-step modelling strategy

1. Estimation on a country-by-country basis (under small open economy assumption)
2. Combine estimates to form the global VAR

The SINGVAR Model

Inspired on the GVAR, we build the SINGVAR: a tractable model of the Singapore economy

Macroeconomic side

A VARX model for the key macroeconomic indicators of the Singapore economy

The model is linked to the rest of the world via foreign variables that capture the relative role of key partners of Singapore

Banking side

Model each MFI as a VARX, using data on credit, lending rates, non-performing loans

Each MFI is connected to others via foreign variables that capture the relative importance of the rest of MFIs

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Macroeconomic aggregates affects all MFIs (common factors)

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In turn, developments in the banking sector feed back to the real economy

The SINGVAR Model

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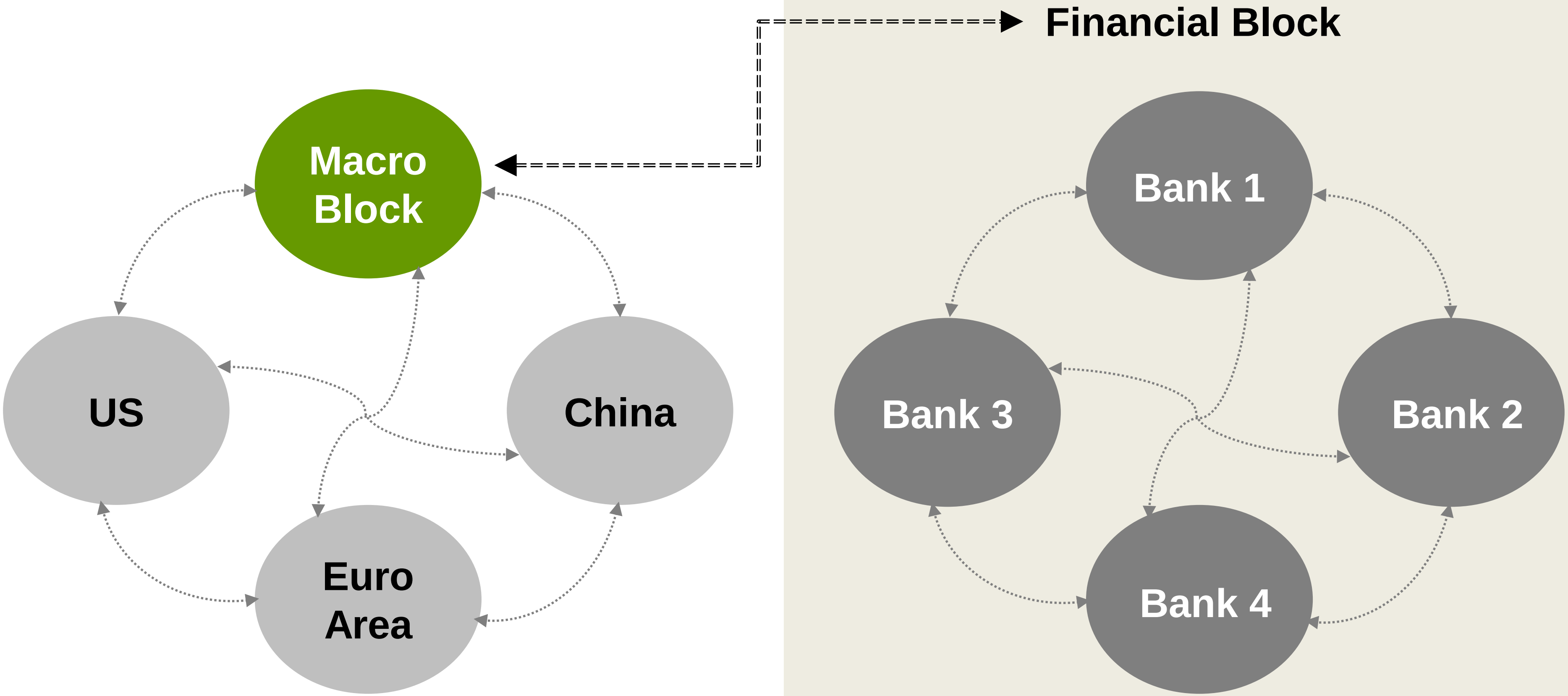
Macroeconomic side		**Banking side**
A VARX model for the key macroeconomic indicators of the Singapore economy	→	Model each MFI as a VARX, using data on credit, lending rates, non-performing loans
The model is linked to the rest of the world via foreign variables that capture the relative role of key partners of Singapore	←	Each MFI is connected to others via foreign variables that capture the relative importance of the rest of MFIs

The model is suited to answer several interesting questions, for instance

- **Effects of US or China shocks to the Singapore economy**
- **Effects of Singapore downturns to the distributions of MFIs' credit flows & lending rates**

Schematic Overview of SINGVAR



The Macro Block

Each country-specific model is a VAR with (weakly) exogenous variables (VARX)

$$\mathbf{\Phi}_i\left(L, p_i\right)\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{\Lambda}_i\left(L, q_i\right)\mathbf{x}^*_{it} + \mathbf{\Psi}_i\left(L, q_i\right)\mathbf{d}_t + \mathbf{u}_{it}$$

Domestic variables

Real output & inflation, real equity prices & FX wrt USD, short- & long-term rates

Foreign variables

Weighted averages of other countries' domestic variables (trade-based weights)

Global variables

- Oil price
- Raw material price
- Metal price

Twist for the **Macro Block of SINGVAR,** which

also includes
- Real Credit
- Real Property Price
- Real Private Consumption

uses the Nominal Effective Exchange Rate instead of bilateral FX (NEER is the monetary policy lever)

Explicitly model 33 world countries as in Dées et al. (2007)

- Cross-country quarterly data over 1979Q2-2013Q1 (available in the GVAR Toolbox 2.0 of Smith & Galesi, 2014)
- For Singapore, extend up to 2016Q4 (MAS data)

The Financial Block

Each bank-specific model is also a VAR with (weakly) exogenous variables (VARX)

$$\mathbf{A}_j\left(L, p_j\right)\mathbf{y}_{jt} = \mathbf{b}_{j0} + \mathbf{b}_{j1}t + \mathbf{B}_j\left(L, q_j\right)\mathbf{y}^*_{jt} + \mathbf{C}_j\left(L, q_j\right)\mathbf{x}_{SING,t} + \mathbf{v}_{jt}$$

Endogenous variables

- Lending Rate
- Real Credit (housing & other loans)
- Non-performing Loans Ratio

Foreign variables

Weighted averages of other banks' endogenous variables (weights based on **cross-bank lending exposure data**)

Common variables

Variables of the Macro Block

(excluding Real Credit, which will be endogenously determined by banks)

The Financial Block includes 30 major MFIs (18 banking groups) over the period 2004Q1-2016Q4

Highly representative sample: it covers 97% of total assets & 99.9% of credit by all MFIs shortlisted by MAS

Accounting for the Two-Way Macro-Financial Loop

We allow for developments at the banking level to feed back to the real economy

2-step procedure of Chudik and Pesaran (2013):

1) Estimate the Macro Block by allowing for potential cointegration among variables

2) For each Macro variable (indexed by i) estimate the following **augmented regression**

$$\Delta x^{(i)}_{SING,t} = c_i + \sum_{j=1}^{\tilde{q}_i - 1} \boldsymbol{\theta}'_{j,i} \tilde{\mathbf{y}}_{t-j} + \sum_{j=1}^{\tilde{p}_i - 1} \gamma'_{j,i} \Delta \mathbf{x}_{SING,t-j} + \sum_{s=1}^{r} \delta_{s,i} E\hat{C}M_{s,t-1} + e^{(i)}_t$$

Feedback variables

Weighted averages of banks' variables

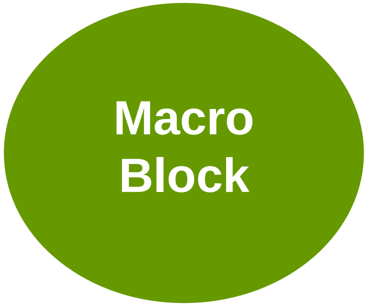
They capture feedbacks of the banking sector to real economy

Weights are based on size (assets) of each bank in the sector

Estimated error correction terms

Estimation deals with missing observations prior to 2004 for the Financial Block

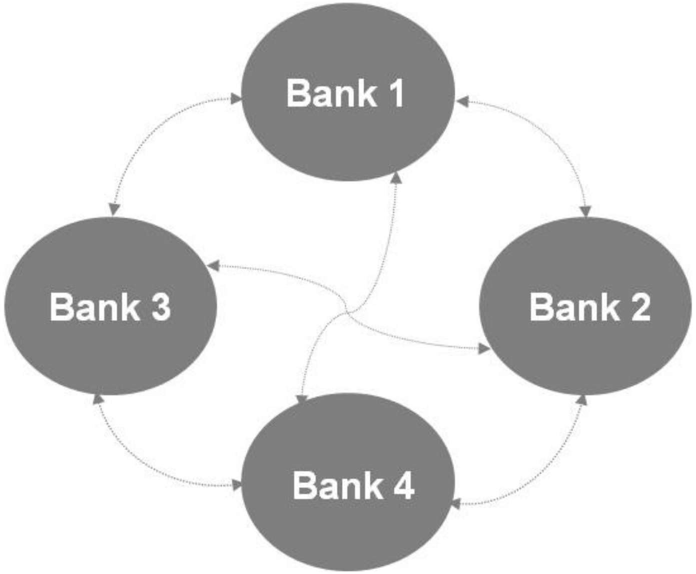
The transmission channels of a monetary policy shock



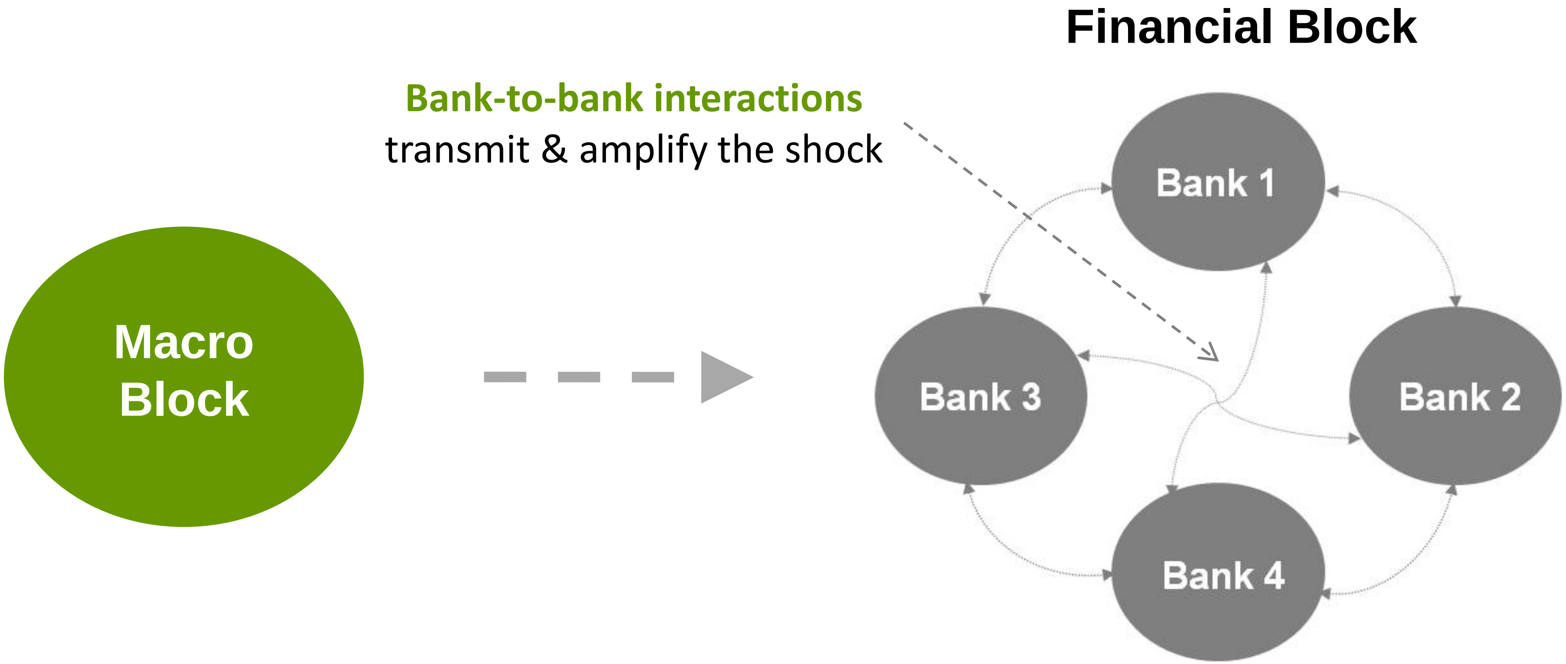
A monetary policy shock (NEER) hits all banks **(common shock)**

Effects are heterogenous due to bank-specific conditions (leverage, profitability...)

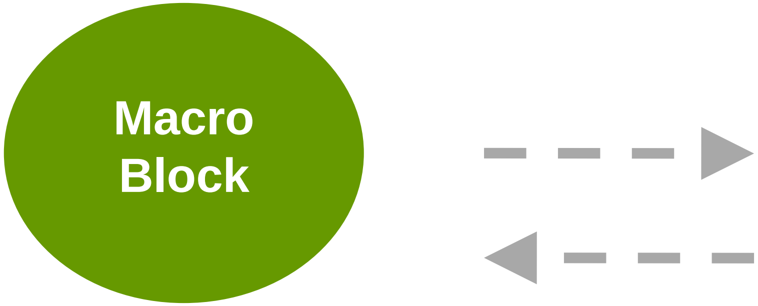
Financial Block



The transmission channels of a monetary policy shock

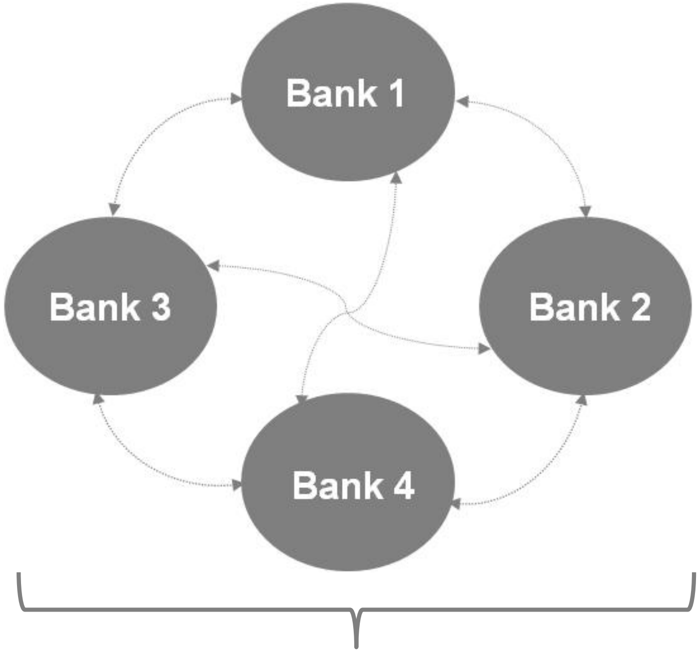


The transmission channels of a monetary policy shock



In turn, developments in the banking sector **feed back** to the macroeconomy

Financial Block



Aggregate volume of loans and lending rate

The Effects of Shocks through the Lens of the SINGVAR

We analyze the properties of the model by considering three simulations:

A fall in US real equity prices	A rise in US interest rate	A rise in Singapore's real GDP

Two foreign shocks

A domestic shock

A note about identification of shocks

Shocks are "geographically" identified …

- The var-cov matrix of residuals is close to be diagonal
- This is because the GVAR approach "cleans" the contemporaneous correlations of residuals (via foreign & common variables)

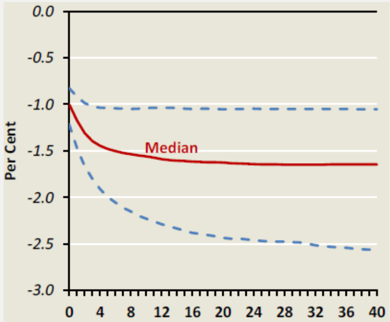
… but not structurally identified

- We do not dig deeper on primal causes of these shocks (demand, supply, financial shocks…)
- However, structural identification could be accommodated (e.g. via sign restrictions on IRFs)

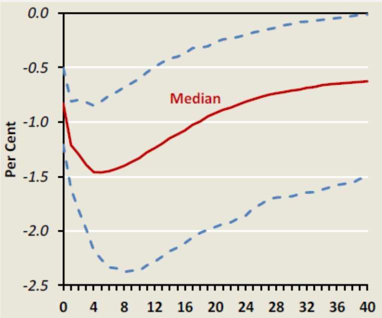
A 1% Fall in US Real Equity Prices

Real equity price

US

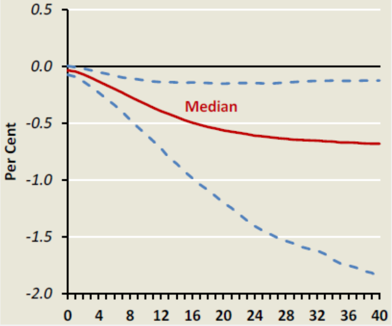


Singapore

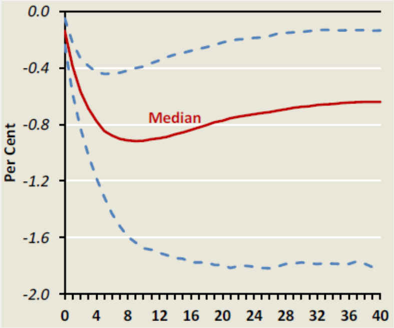


The US equity shock has an almost 1-to-1 impact on Singapore's equity prices

Real Credit

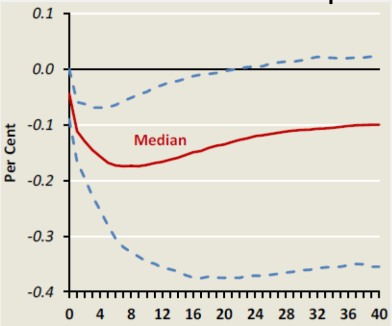


Real Property Prices

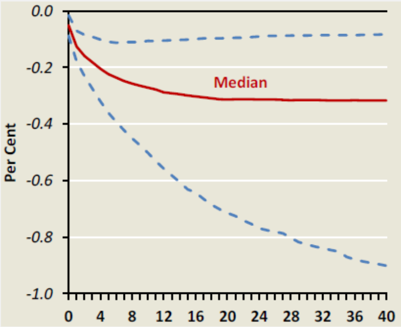


Similarly, real credit and property prices fall

Real Private Consumption



Real GDP



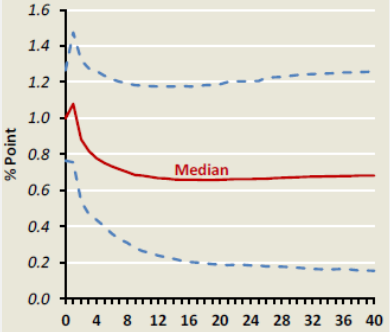
Singapore's real consumption and GDP drop, partly also because US GDP drops (not reported)

A 1% Rise in US Interest Rate

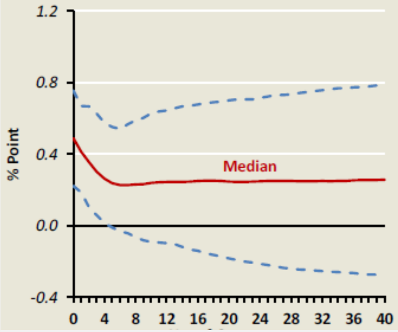
Singapore's interbank & long-term rates increase in tandem with the US rate rise, but by a smaller amount

Short-term Interest Rates

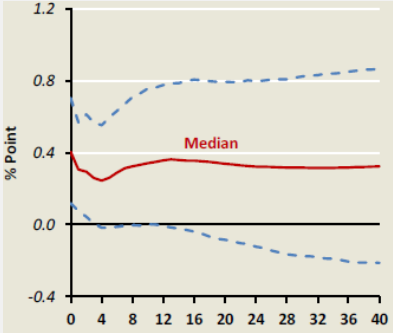
US



Singapore

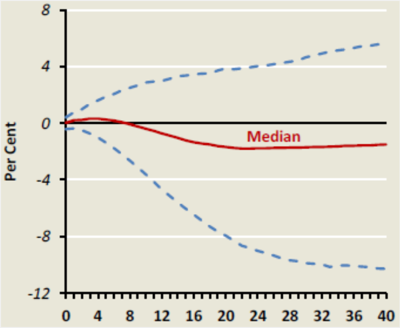


Singapore Long-term Interest Rate

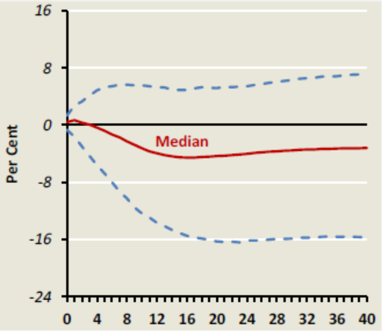


Credit & property prices decrease (even though not significantly)

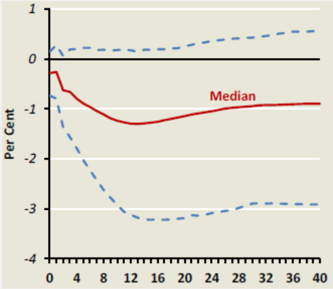
Real Credit



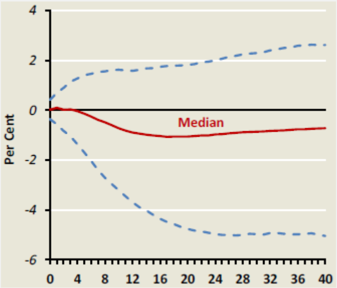
Real Property Prices



Real Private Consumption



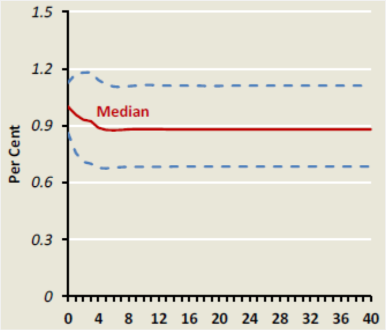
Real GDP



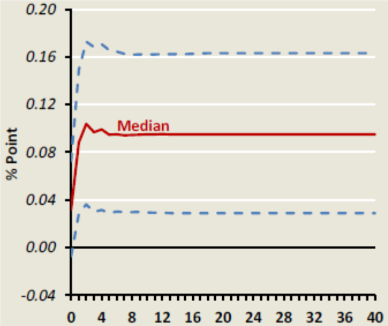
Also consumption and GDP fall, but not significantly

A 1% Increase in Singapore's Real GDP

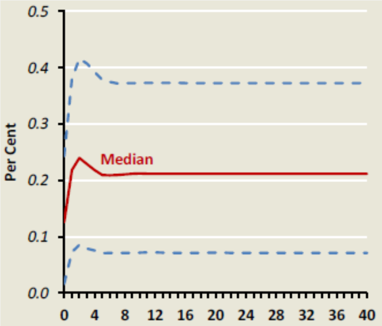
Real GDP



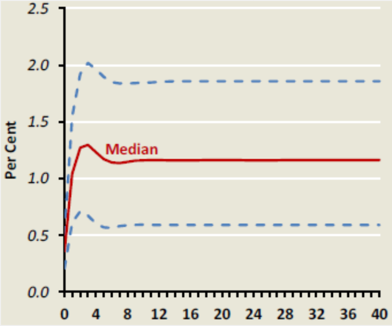
Inflation



Real Private Consumption



Real Property Prices



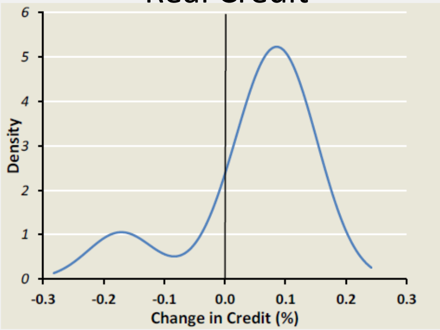
The rise in GDP is accompanied by higher inflation, as well as by rises in consumption & property prices

The large majority of banks extend more loans (even though with substantial heterogeneity)

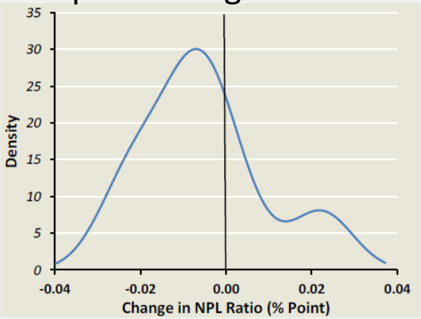
At the same time, more favorable macro conditions are associated with a reduction in the share of bad loans for most of banks

Distribution of Financial Changes Across Banks

Real Credit



Non-performing Loans Ratio



Conclusions

The SINGVAR is the latest addition to MAS' suite of macroeconometric models

It provides a very parsimonious yet compelling characterization of the Singapore economy, its interactions with the rest of the world & with its banking sector

It is entirely based on the GVAR Toolbox 2.0 (Smith and Galesi, 2014) which allows for further refinements and applications, for instance

Forecasting & scenario analysis	**Monetary policy & macroprudential analysis**

Thank you very much for your attention!