



BANK OF ENGLAND

The Bank of England's forecasting platform

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Macroeconomic forecasting at Bank of England



BANK OF ENGLAND

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What does the Bank of England do?

Promoting the good of the people of the United Kingdom by maintaining monetary and financial stability

- Monetary policy: independent MPC since 1997
- Note issuance: Bank has been issuing notes for over 300 years
- Management of UK foreign currency and gold reserves
- Financial policy: independent FPC from April 2013
- Resolution and lender of last resort for UK financial institutions
- Regulation and supervision of banks: PRA became part of the Bank in April 2013



Monetary policy at Bank of England

Deliver price stability – low inflation – and, subject to that, to support the Government's economic objectives including those for growth and employment

- Inflation target of 2% (annual percentage change in CPI)
- MPC meets monthly, announcing policy at 12pm on first Thursday of each month
- Since 2009 policy announcement includes level of Bank Rate and stock of asset purchases (QE)
- Inflation Report published every quarter:
 - Forward-looking discussion as aid to decision-making (forecasts)
 - Opportunity to share thinking and explain decisions



What is relevance of forecasting for monetary policy?

1. Long and variable lags
 - Any change in policy will take time to have its full impact on the economy
2. Expectations matter
 - Expectations of future policy actions affect economic outcomes today



Alternative methods for forecasting

- Judgemental
 - MPC's forecasts are judgemental, but informed by....
- Statistical
 - “Naïve”: eg sample average
 - Simple univariate: eg ARMA models
 - Simple multivariate: eg VARMA models
 - Data rich: eg FAVAR models
 - Macroeconometric: eg DSGE models
 - Model combination: eg Bayesian model averaging



Example: ARMA model for inflation

- Take a time series of quarterly seasonally adjusted consumer price inflation
- Use the “arima” class and the “estimate” method in the MATLAB econometrics toolbox to estimate an ARMA(1,1) model

$$\pi_t = 0.5 + 0.1\pi_{t-1} + 0.3\epsilon_{t-1} + \epsilon_t$$

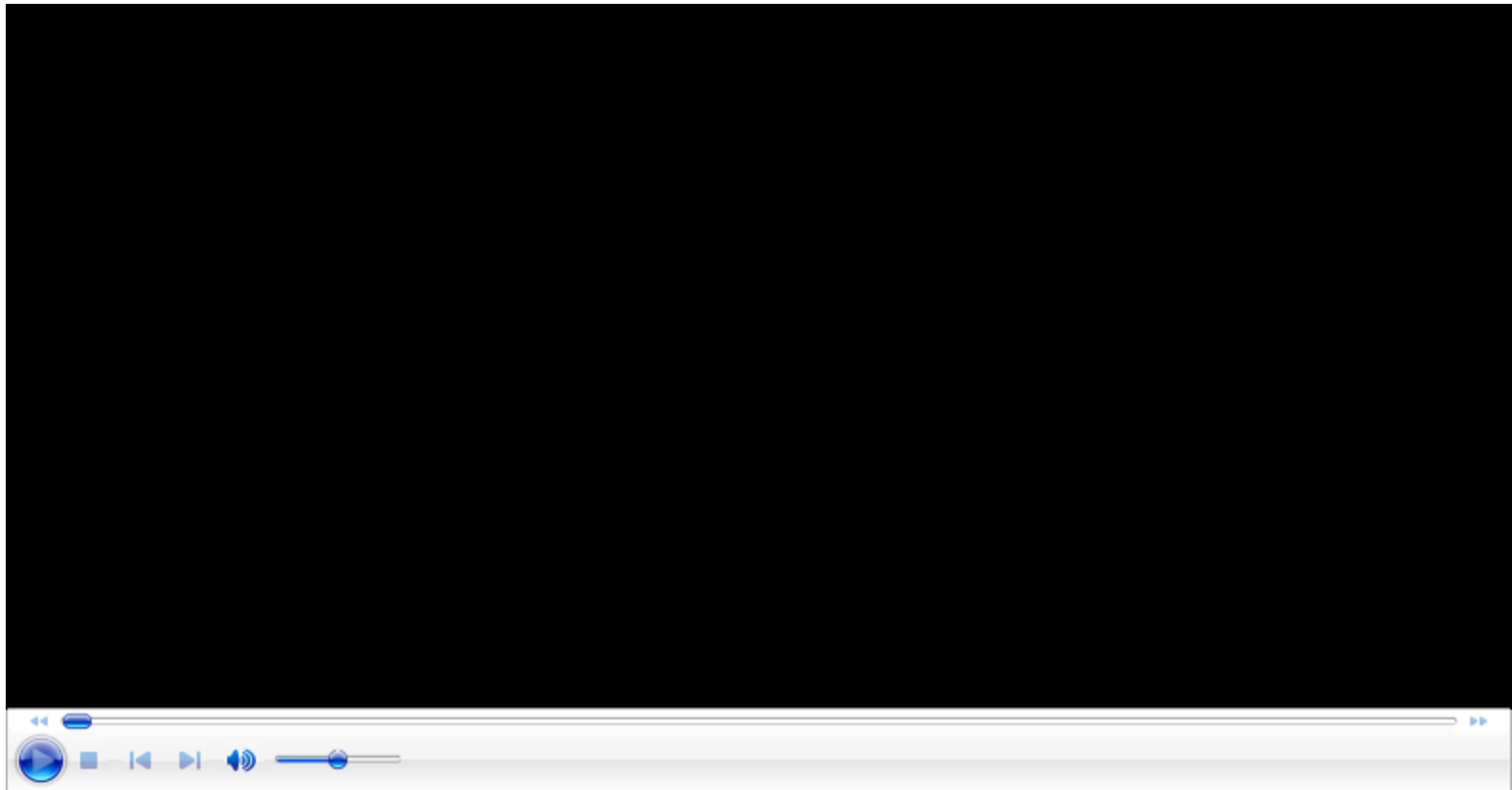
$$\epsilon_t \sim N(0, 0.1)$$



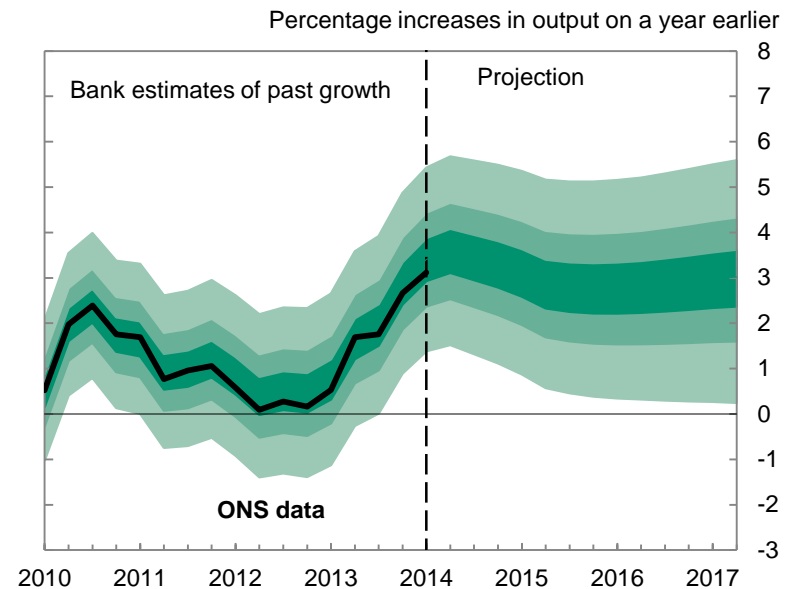
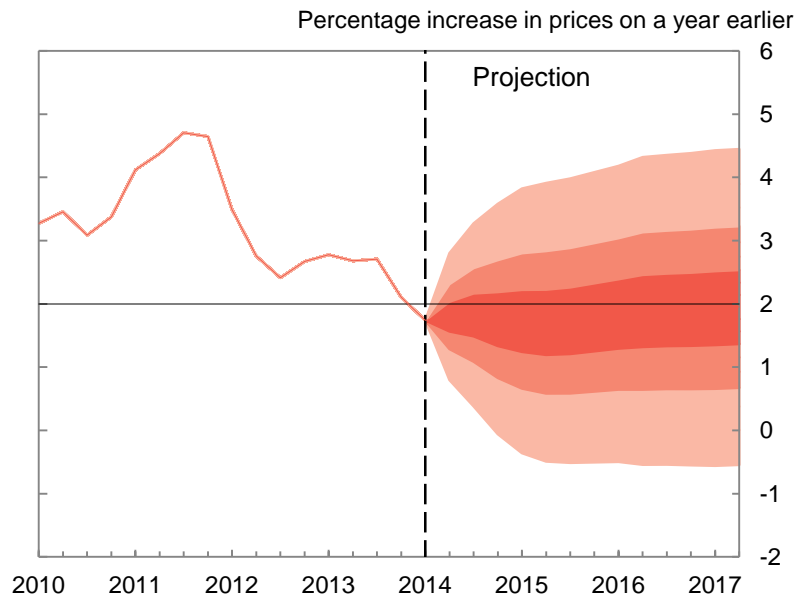
Example: ARMA model point forecast for inflation



Example: ARMA model density forecast for inflation



MPC fan charts for annual inflation and GDP growth



The Inflation Report more broadly

- The fancharts have been the centre piece of the report for some time
- Report includes a large amount of analysis explaining staff and committee thinking – May 2014 report included:
 - Over 50 charts and tables
 - 5 chapters and 8 boxes
- Recent reports have been more explicit about the key judgements underpinning the committee's forecasts
 - Internationally, policymakers are able to maintain growth...
 - Domestically, a revival in productivity...
 - The pace at which slack is absorbed slows...
 - ...recovery in wage growth and margins is consistent with the inflation target



The role of models in forecasting at Bank of England

- Published forecast is MPC's best collective judgement and is expressed in probability distributions for inflation and GDP growth
- Forecast is owned by MPC and ultimately determined by judgement, but models and model-based forecasts are an important input in the process

“The Bank's use of economic models is pragmatic and pluralistic. In an ever-changing economy, no single model can possibly assimilate in a comprehensible way all the factors that matter for policy. Forming judgements about those factors, and their implications for policy, is the job of the Committee, not something that can be abdicated to models or even modellers. But economic models are indispensable tools in that process.”



The nature of the model-based forecasts

“Economics is neither a pure subject like mathematics, of which one does not ask that the theories should be applicable to actual phenomena, nor is it a collection of facts, like the objects on a junk heap, of which one does not ask how they are related.”

- There are many potential ways of explaining the relationships between economic variables that may be observationally equivalent
- Typically use theory to distinguish between these
- Furthermore, a key objective of the *Inflation Report* is to explain MPC thinking on the economy and so communicate why the MPC have arrived at their policy decision
- There is a high premium on models that elucidate economic mechanisms that can be related to theory (rather than just black box forecasting)

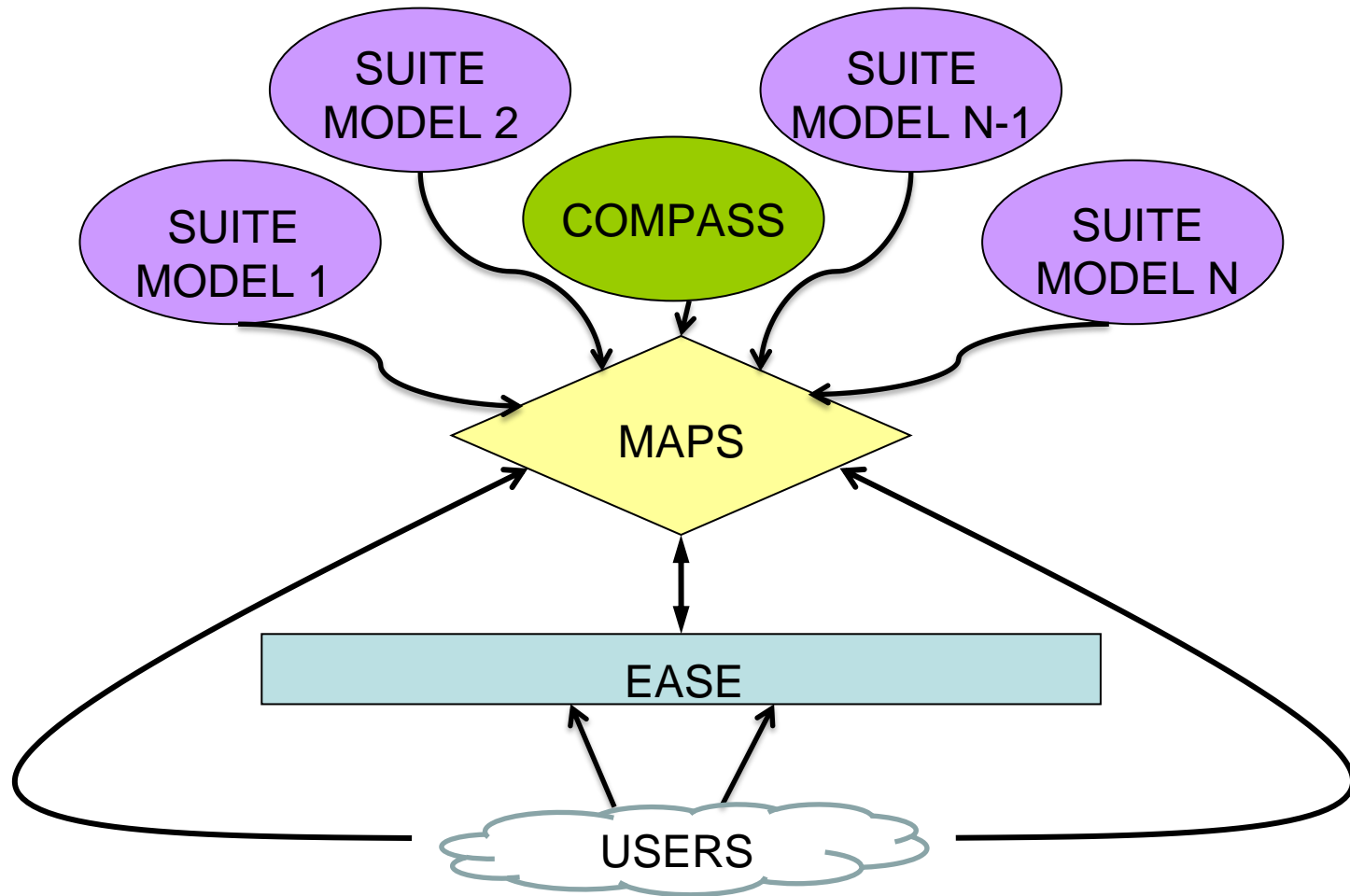


A project to build a new forecasting platform

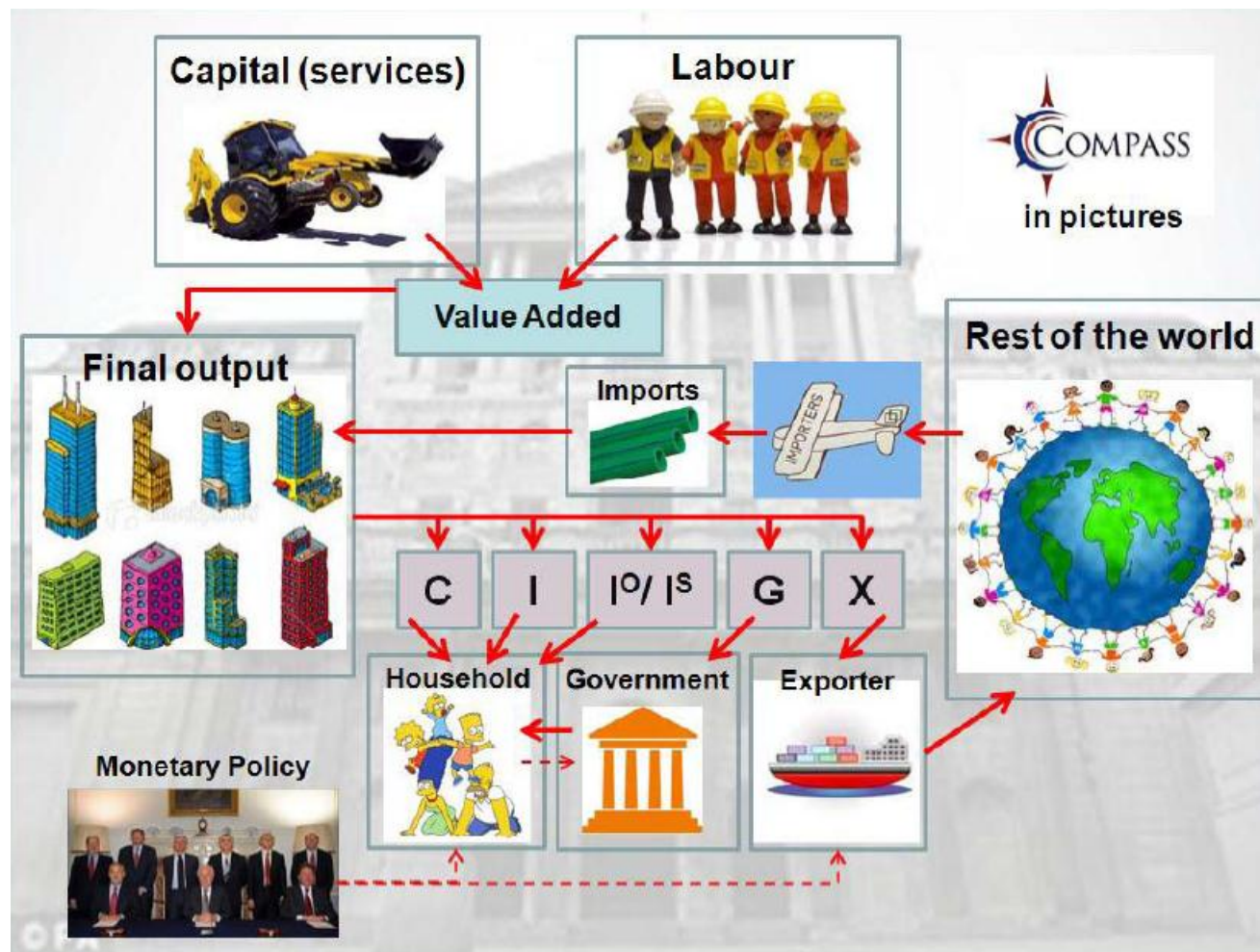
- Undertook a project to build a new macroeconomic forecasting platform in 2010
- Why?
 - Experience of previous forecasting platform (formally reviewed)
 - Advances in modelling and IT
- Project lasted 18 months and was run along “agile” lines:
 - Team of 2 building a new “central model”: COMPASS
 - Team of 3 building a MATLAB toolkit: MAPS
 - Team of 6 building a user interface: EASE
 - Included a business analyst and a full-time user
 - Team of 2 translating existing models into the new platform: suite of models
 - 1 full-time project manager



The forecasting platform



COMPASS in pictures



COMPASS in text

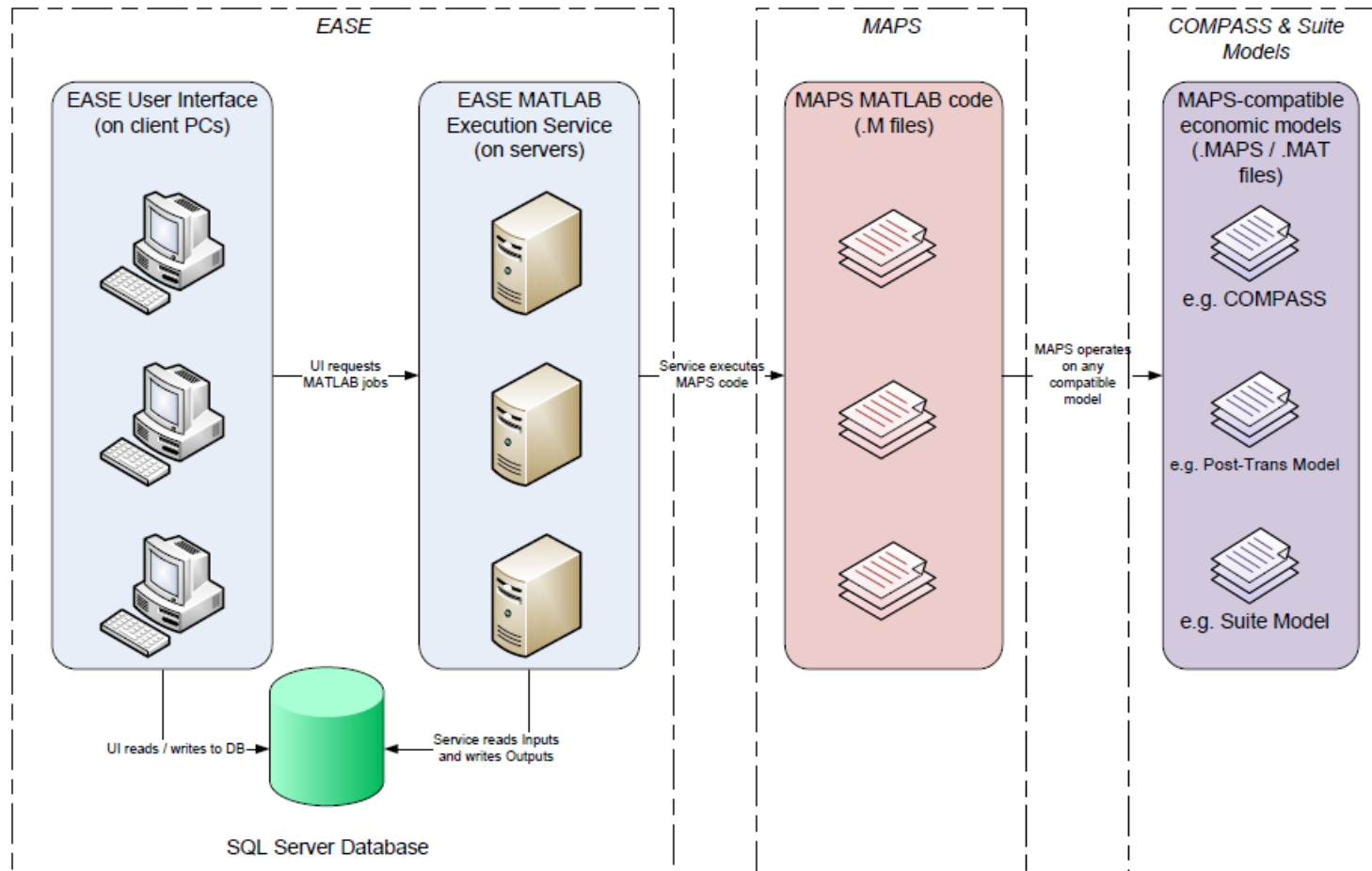
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l{t} = v{t}+pv{t}+mcv{t}-w{t}
k{t-1} = v{t}+pv{t}+mcv{t}-rk{t}+gammaz{t}
k{t} = (1-deltak)/(gammaz_ss*gammah_ss*(k{t-1}-gammaz{t}))+i_ss/(gammah_ss
v{t}=(1-alpha)*(k{t-1}+l{t})*alpha+epstfp{t}
v{t} = z{t}+mcz{t}-pv{t}+(1-alpha)/alpha*psim*((m_ss/v_ss)^2)*(m{t}-v{t})
m{t} = z{t}+mcz{t}-pm{t}-epsm{t}-psim*(m_ss/v_ss)^2*(m{t}-v{t})
z{t} = alpha*v{t}+(1-alpha)*m{t}
copt{t} = 1/(1+psic+epsilonbeta*(1-psic)/epsilon)*copt{t+1}+psic/(1+psic+epsilonbeta
crot{t} = (w_ss*1_ss/c_ss)*(w{t}+l{t})
c{t} = omegao*copt{t}+(1-omegao)*crot{t}
i{t} = 1/(1+beta*gammah_ss)*(i{t-1}-gammaz{t})+beta*gammah_ss/(1+beta*gammah_ss)*(i{t
tq{t} = (1-deltak)/(rk_ss+(1-deltak))*tq{t+1}-(r{t}-piz{t+1}+epsb{t}))+rk_ss/(rk_ss+(1
g{t}-g{t-1}+gammaz{t}=(rhog-1)*g{t-1}+epsg{t}
x{t}=xhat{t}+omegaf{t}
omegaf{t} = -gammaz{t}+(1-zetaomegaf)*omegaf{t-1}
io{t}-io{t-1}+gammaz{t}=(rhoio-1)*io{t-1}+epsio{t}
z{t} = c_ss/z_ss*c{t}+i_ss/z_ss*i{t}+g_ss/z_ss*g{t}+x_ss/z_ss*x{t}+io_ss/z_ss*io{t}
piz{t} = (((1-phiz)*(1-omegaz2-phiz*beta*gammah_ss*(1-omegaz1-omegaz2)))/(phiz*(1+xiz
piv{t} = (((1-phiv)*(1-omegav2-phiv*beta*gammah_ss*(1-omegav1-omegav2)))/(phiv*(1+xiv
piw{t} = (((1-phiw)*(1-omegaw2-phiw*beta*gammah_ss*(1-omegaw1-omegaw2)))/(phiw*(1+xiv
pim{t} = (((1-phim)*(1-omegam2-phim*beta*gammah_ss*(1-omegam1-omegam2)))/(phim*(1+xir
pic{t} = piz{t}
pv{t} = piv{t}-piz{t}+pv{t-1}
w{t} = piw{t}-piz{t}-gammaz{t}+w{t-1}
pexp{t} = piexp{t}-pizf{t}+pexp{t-1}
pm{t} = pim{t}-piz{t}+pm{t-1}
mon{t} = 1/(1-psic)*(copt{t}-psic*copt{t-1})-1/(epsilon*r_ss)*r{t}
rule{t} = (1-thetar)*(0.25*thetapi*picannual{t}+thetay*gap{t}+thetar*r{t-1})
r{t} = rule{t}+epsr{t}

```



MAPS/EASE architecture



Key elements of the IT solution

1. Ability to produce forecasts and analysis with lots of different models
 - Models represented as plain text
 - “Parser” to read and check validity of models
 - No model specific dependency in any of the functionality
2. Efficiency in the core forecast processes
 - Optimised SQL server database to handle the data
 - dot net front end designed to dovetail with the business process
 - Powerful tools for the incorporation of judgement in forecasts
 - Leveraged off existing in-house software
3. Flexibility to respond to committee demands
 - MAPS code can be operated in stand-alone mode
 - Code designed around key objects to create a modelling/forecasting language
 - Model modifier to make it easy to amend models
 - Black box operation of m files to execute forecast runs in EASE



What is MAPS?

- MATLAB toolbox used by BoE for macroeconomic forecasting
- Mixture of mainly procedural, but with some object oriented code
- ~600 MATLAB files covering more than 30,000 active lines of code
- ~2,500 error messages
- ~700 automated test cases
- Change control processes which have become tighter as the toolbox has grown



What does MAPS do?

1. Modelling language

- Converts text files with economic models in them to “objects” in MATLAB
- Tools for the manipulation of economic models

2. Model analysis

- Range of tools to aid understanding of a model’s properties
 - What is the effect of monetary policy on the macro economy?

3. High-level forecasting language

- Combines models with data to produce forecasts
- Contains tools for manipulating and analysing those forecasts

4. Bayesian estimation of medium to large-scale economic models

- Posterior optimisation and simulation tools
- Automated results reporting



Use of MATLAB tools in MAPS

1. **Symbolic Toolbox™** used in process of translating text equations to object
2. **Statistics Toolbox™** used in the Bayesian estimation toolkit
3. **Optimization Toolbox™** used in estimation toolkit
4. **MATLAB Report Generator™** used to create model analysis and estimation PDF reports
5. **Parallel Computing Toolbox™** used to speed up estimation
6. **GUI Layout Toolbox** (not official MATLAB) used for interactive model analysis



Why MATLAB?

- MATLAB is the leading software used by economists in universities
- Core level of MATLAB proficiency in the Bank
 - Lowers maintenance cost/risk
- A lot of the functionality is based around linear matrix algebra
- Developing new code is fast
 - Policymakers often want results very quickly
- Toolboxes are generally of a high quality
- Flexibility in mixing procedural and object-oriented design



The future ...

- MAPS was designed to be extensible
 - Plans to develop more tools for policy analysis
- Reaping the rewards
 - MAPS is beginning to be used more broadly in the Bank for publishable research
- Bank's strategic review
 - “Big data”
 - Research hub
 - More resources for research and forecasting



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“Some things are so unexpected that no one is prepared for them”



Finding out more about forecasting at the Bank

- Bank of England working paper number 471:

<http://www.bankofengland.co.uk/research/Pages/workingpapers/2013/wp471.aspx>

