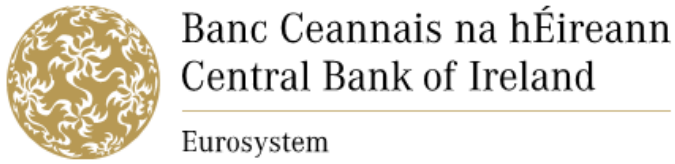

Measuring the Irish Economic Cycle:

Estimates from a Multi-Model Approach

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Motivation

- Output, unemployment and wage inflation gaps are key metrics for informing policy makers on the cyclical position / productive capacity of the economy
  - Domestically important for determining the stance of economic policy
  - Internationally important for the SGP and structural reforms
- As potential output is unobserved, it must be determined using either a purely empirical approach, or through the empirical calibration of a theoretical model.
- Assumptions regarding the estimation of potential output and the output gap are non-trivial
  - A large output gap with strong underlying trend growth rates requires the use of demand-side policy instruments
  - Output gaps caused by declining trend growth rates necessitates the implementation of supply-side policy measures

Motivation

- Additional complexities arise when considering the process for the Irish Economy
  - Revisions to existing calculations / the availability of new data can cause considerable changes to the estimates of potential output for a given year
  - As reliable output data only extends back to 1960 (at annual frequency), there are a large class of models for which small-sample problems could affect both the estimated error distributions and parameter values
- Further issues may arise with using models calibrated for large European countries, given:
  - Ireland's role as a production and financial intermediary
  - Asymmetric economic and financial linkages
  - Ireland's relative vulnerability as a SOE to international capital flows and skilled labour demand

Modelling Approach

- Potential output and the output gap are unobservable and an objective definition of the business cycle does not exist
- Consequently, there is a vast body of literature relating to the identification and estimation of the output gap
  - Univariate filtering techniques, e.g. the HP filter, the BK filter, Band pass filters
  - Univariate modelling approaches, e.g. linear detrending, structural modelling, Markov-switching models
  - Multivariate modelling approaches, e.g. Okun's law-style VAR models, Phillips curve-style models, production function approaches, theoretical models (RBC & DSGE).
- However, these alternate techniques require the imposition of different hypotheses, either statistical or theoretical in nature, making model comparability less than straightforward

Modelling Approach

- Univariate filtering and modelling techniques are simple methods, which require no judgmental assumptions about the structure of the economy. However:
  - They lack any form of economic theory underlying their application
  - They do not incorporate potentially useful information on some other variables into the analysis
- In contrast, multivariate approaches rely on economic theory to estimate potential or trend output
  - Nature of the variables and economic characteristics that drive the cycle may differ across researchers
  - Models that fit large, economically diverse countries or regions may not be structurally suited to smaller, less diverse countries
- Important to recognise that no one model outperforms or optimizes over the suite of models available to the researcher

Modelling Approach

- Given these conditions, there are three multivariate models that the CBI employs in its thinking regarding the Irish economic cycle
  - A multivariate filtering approach, expressed in state-space form, incorporating information about the financial cycle
  - A combined unobserved component & production function model, again expressed in state space form, employing a filtering approach to decompose key variables into trend and cyclical components using relevant economic relationships
  - A Bayesian model averaging method, relying on stochastic model specification search, estimating the output, unemployment and wage inflation gaps

Modelling Approach

Table 1: Summary of Estimation Method Characteristics

Model	State Space + Financial Cycle	Unobs. Component Supply Side	Bayesian Model Averaging
Decision Variables	Output gap time series process with financial cycles	Production Function / Cyclically adjusted inputs	Trivariate VAR-type model with binary switching indictors
Adaptable to Structural Breaks	No	No	Yes
Complexity	Single equation	Multi-equation	Multi-equation
Underlying Economic Theory	None	Production Function	Okun's Law / Phillips Curve
Accounts for Financial Cycles	Yes	No	No

State Space Model with Financial Cycle information

Established State-space Methodology

- HP Filter in state space form, with y_t^* as the unobserved component

$$\Delta y_t^* = \Delta y_{t-1}^* + \varepsilon_{0,t} \text{ (state, random walk)}$$

$$y_t = y_t^* + \varepsilon_{1,t} \text{ (measurement/observation equation)}$$

- Ratio of the variances $\varepsilon_{1,t}/\varepsilon_{0,t}$ is the HP filter's λ parameter

Methodological Enhancement: Financial Variables

- Borio, Disyatat & Juselius (2013, 2014)

$$\Delta y_t^* = \Delta y_{t-1}^* + \varepsilon_{0,t}$$

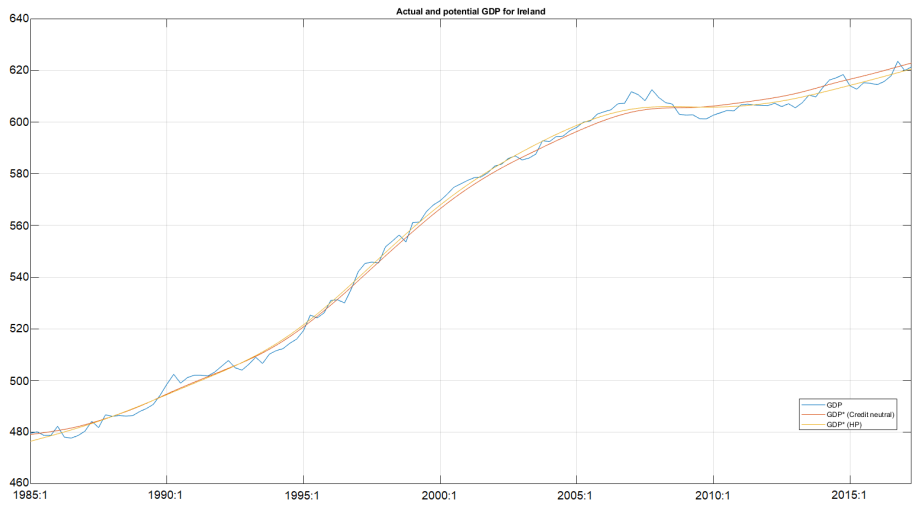
$$y_t - y_t^* = \beta(y_{t-1} - y_{t-1}^*) + \gamma X_t + \varepsilon_{alt,t}$$

where X_t is a $T \times M$ matrix containing the macro-financial variables e.g. aggregate credit growth, residential property prices, etc.

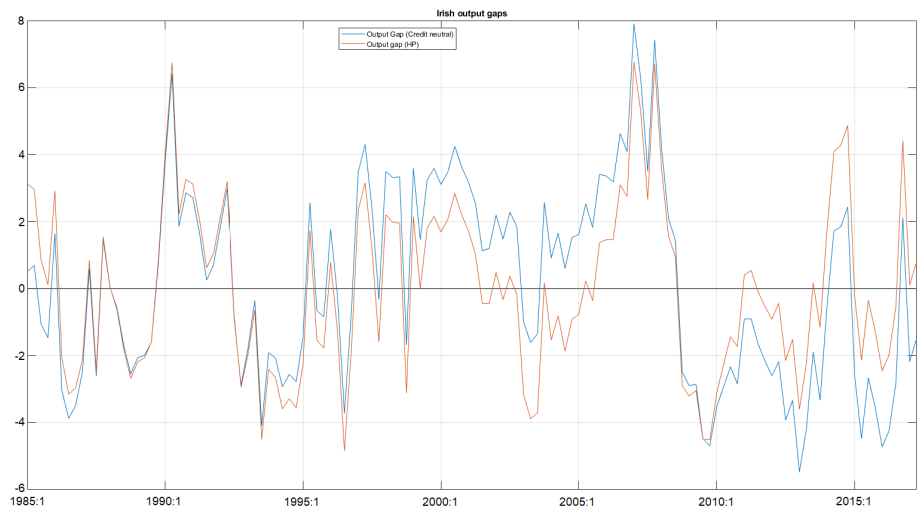
State Space Model: Credit Neutral Results

Figure 1: Output Gap and Potential Output: Credit Neutral vs HP Filter

(a) Potential Output



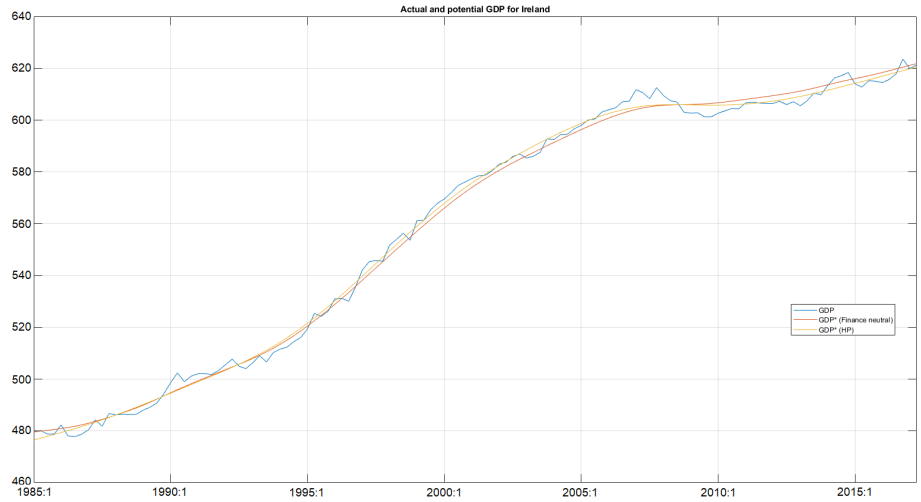
(b) Output Gap



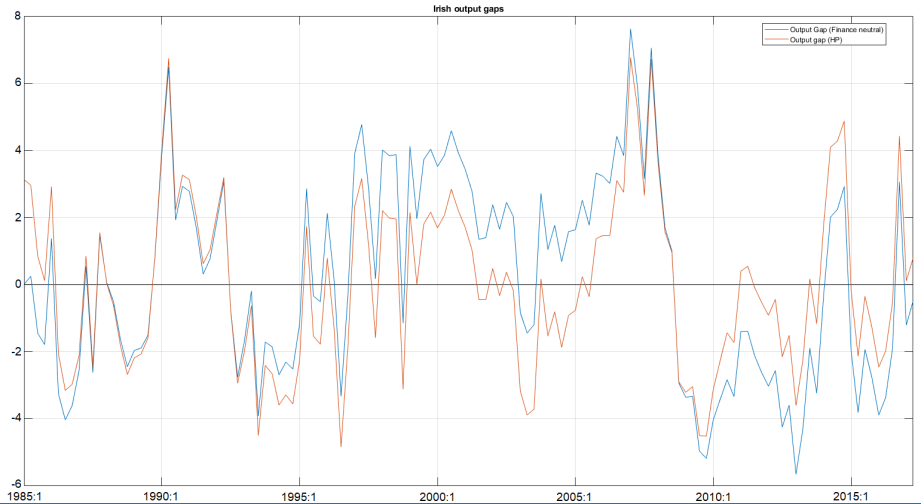
State Space Model: Finance Neutral Results

Figure 2: Output Gap and Potential Output: Finance Neutral vs HP Filter

(a) Potential Output



(b) Output Gap



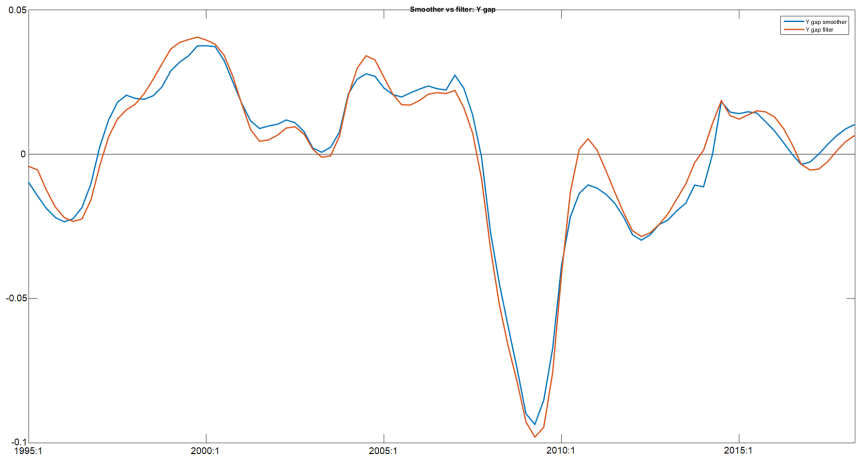
Unobserved Component Supply Side Model

- Super-Core Elements
  - State-space model with a Cobb-Douglas production function
  - Trend labour input, estimated using: working age population; trend participation rates; NAIRU; trend average hours worked
  - Capital stock
  - Trend TFP, calculated endogenously within the model
- Core Elements
  - An Okun's law relationship, connecting cyclical components of output and the unemployment rate
  - Observable components that inform the output and unemployment gaps
  - Time invariant parameters
  - Stochastic trends
- Non-Core Elements
  - Long term unemployment rate informing the path of the NAIRU
  - Prior densities and their associated hyperparameters

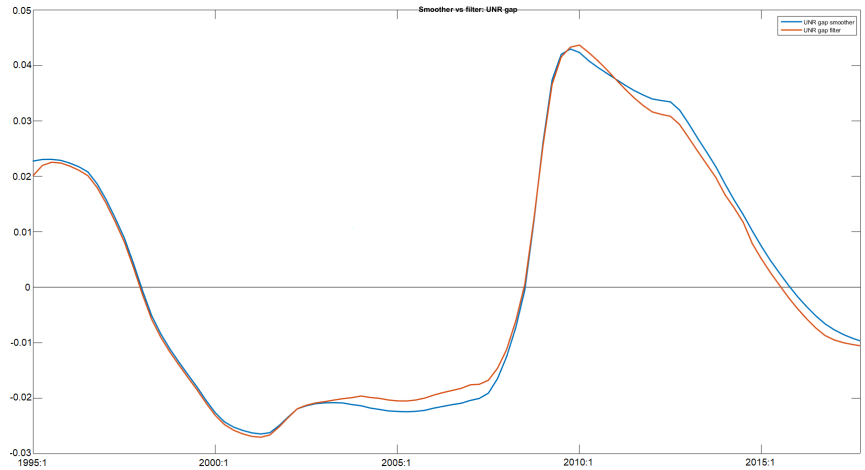
Supply Side Model: Estimation Outputs

Figure 3: Unobserved Components Estimates - Output and Unemployment Gaps

(a) Output Gap



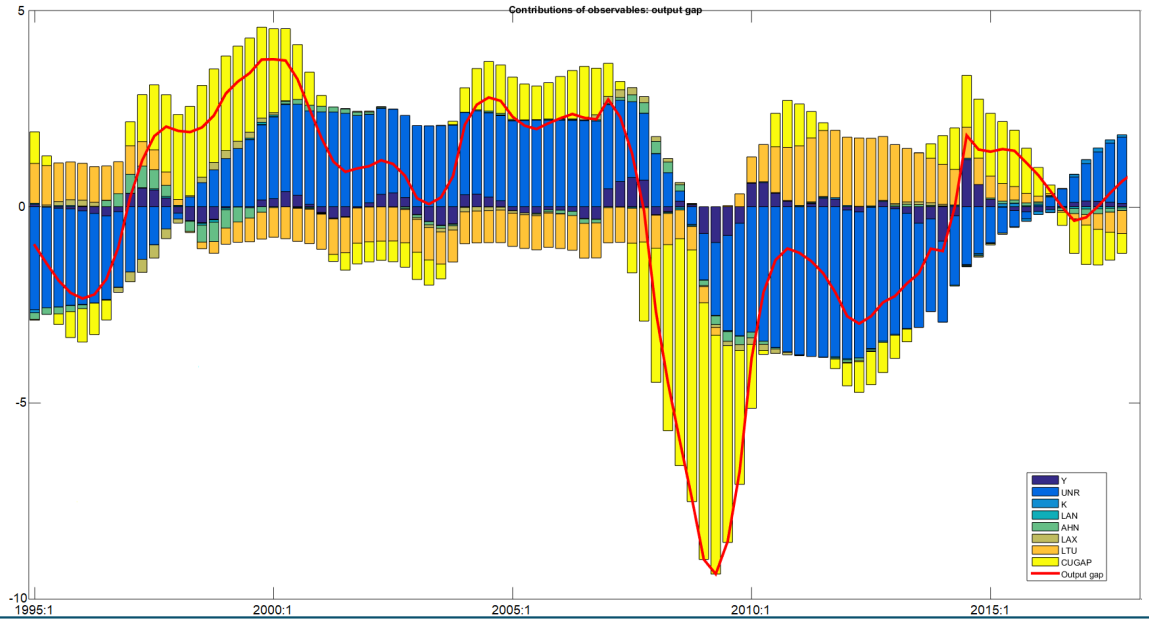
(b) Unemployment Gap



- Limited differences between filter and smoother for unemployment gap
- More pronounced differences for output gap

Supply Side Model: Estimation Outputs

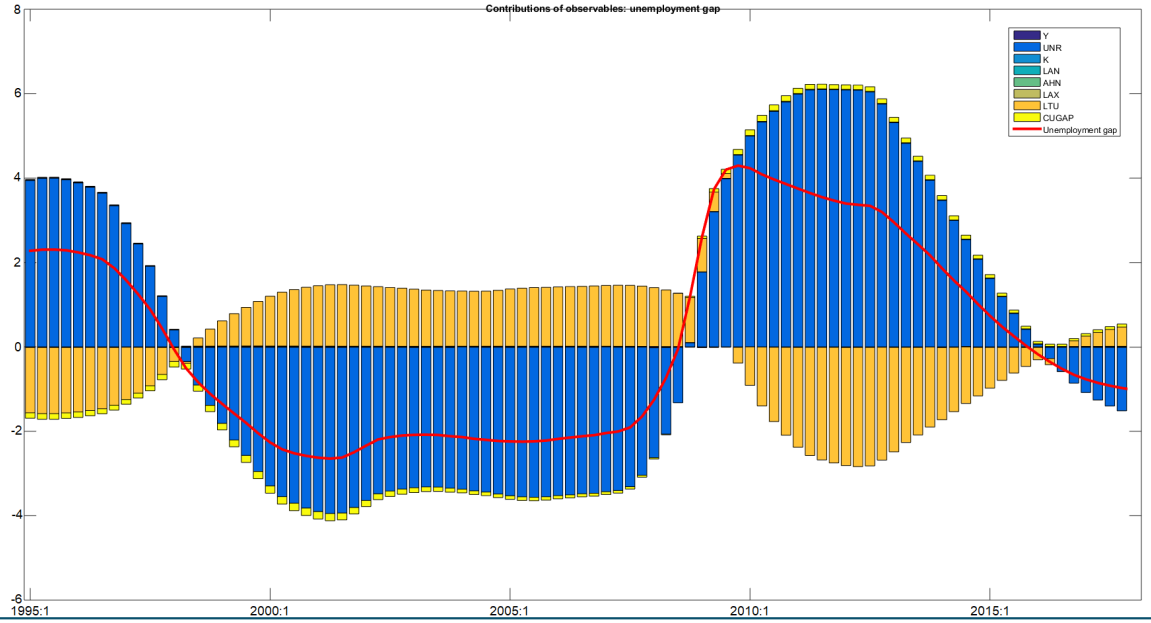
Figure 4: Unobserved Components Estimates - Output Gap (Observable Components)



- Capacity utilization gap accounts for majority of downturn mid-crisis
- Declining unemployment rate driving output gap over the forecast period

Supply Side Model: Estimation Outputs

Figure 5: Unobserved Components Estimates - Unemployment Gap



- Unemployment and Long-Term Unemployment the main driver of the unemployment gap

Bayesian Model Averaging: Approach

- Given the complexities of the Irish economy, a Bayesian modelling averaging approach allows for considerable structural flexibility, aggregating estimates across key specifications
  - Variable selection
  - Trend / Cycle decomposition
  - Error specification
- We allow for specifications that consist of univariate models of output, bivariate models of output and either wage inflation or unemployment, and trivariate models incorporating all variables
- Trend possibility-space confined to specifications where the output trend is either stochastic or deterministic, and the growth rate of the trend is either constant or time-varying
- Finally we allow for stochastic volatility in innovations to the model, and for innovations to follow either Gaussian or t-distributions

Bayesian Model Averaging: Identification

- In selecting the equations that govern the system, the approach is consistent with classical macroeconomic research
- Output gap estimated as an augmented, time varying form of Okun's law, driven by
  - The standard component that estimates the unemployment gap
  - An additional term that represents the cyclical component of output
- Wage inflation dynamics represented as a New-Keynesian Phillips curve, incorporating a time-varying trend rate of wage inflation
  - Allows for stationarity in the rate of wage inflation
  - Slope of the Phillips curve able to change over time
- Unemployment gap follow and AR(2) process with stochastic volatility, so that the variance of permanent shocks to the labour market can change over time

Bayesian Model Averaging: Identification

- Given the above system structure, we can represent our system as

$$\begin{aligned} y_t - y_t^* &= \beta_{\theta^u}\theta^u(u_t - u_t^*) + \omega_t \\ \omega_t &= \tau_1^\omega \omega_{t-1} + \tau_2^\omega \omega_{t-2} + \varepsilon_t^\omega \\ \pi_t - \pi_t^* &= \tau^\pi(\pi_{t-1} - \pi_{t-1}^*) + \beta_{\gamma^u}\gamma^u(u_t - u_t^*) + \beta_{\gamma^y}\gamma^y(y_t - y_t^*) + \varepsilon_t^\pi \\ u_t - u_t^* &= \tau_1^u(u_{t-1} - u_{t-1}^*) + \tau_2^u(u_{t-2} - u_{t-2}^*) + \varepsilon_t^u \end{aligned} \tag{1}$$

  where y_t^* is the trend output, π_t^* is the trend wage inflation rate, and u_t^* is the non-accelerating wage rate of unemployment (NAWRU).
- To allow for the Bayesian modeling average component of our strategy, we include three β_i terms in the set of equations
  - Coefficients are binary, taking values of 0 or 1 depending on the specification under consideration
- Three more binary indicators are incorporated into the trend specification component
- Two final binary indicators are used to determine error distributions

Bayesian Model Averaging: Estimation

- With eight binary indicators, there are $2^8 = 256$ potential models to consider
- However, to sample the model space, we must assign priors to the binary indicators, structural model coefficients, and error variances in the state and measurement equations
  - Structural model coefficients are assumed to follow Normal distributions
  - Binary indicators are assumed to follow independent Bernoulli distributions
  - Innovation variances in both the state and measurement equations are assumed to follow Gamma distributions
- As we are allowing for stochastic volatilities and non-Gaussian distributions, the state-space model is highly non-linear
  - Standard solution techniques, such as the Kalman filter or maximum likelihood, are not feasible
- Instead, we employ an 11-step Markov Chain Monte Carlo (MCMC) mixed sampler

Bayesian Model Averaging: Results

Table 2: Posterior Inclusion Probability Estimates of the Indicator Variables

β_{θ^u}	β_{γ^u}	β_{γ^y}	β_{α_0}	β_{y^*}	β_{α}	β_{z^π}	β_{z^ω}
1.00	0.6986	0.2077	0.8688	0.6112	0.9471	0.6709	0.9691

- Results from the model strongly support the inclusion of the unemployment gap in explaining the output gap, stochastic trend output with a time-varying rate of growth, and innovations to the output equation being characterized by a t-distribution
- Some support for the inclusion of the unemployment gap in driving wage inflation, permanent level shocks to trend output, and innovations to wage inflation following a t-distribution
- No support for the output gap driving wage inflation, once we have accounted for the unemployment gap and past wage inflation

Bayesian Model Averaging: Results

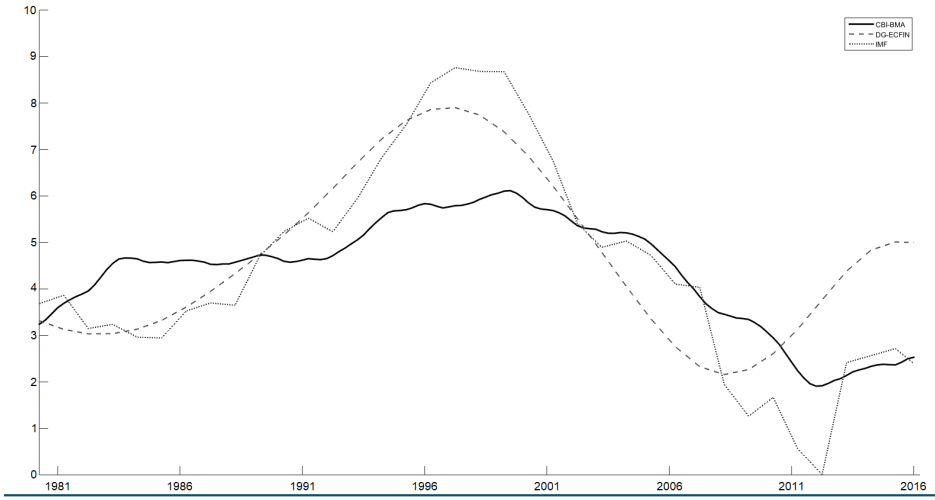
Table 3: Posterior Parameter Means and Percentiles, Model Average Estimates

Parameter	Posterior Mean	2.5 Percentile	97.5 Percentile
γ^u	-0.20	-0.55	0.00
θ^u	-2.08	-2.73	-1.41
γ^y	0.02	-0.02	0.15
τ^π	0.40	0.12	0.67
τ_1^ω	0.04	-0.43	0.47
τ_2^ω	0.18	-0.14	0.47
τ_1^u	1.88	1.74	1.96
τ_2^u	-0.89	-0.98	-0.76
ν_π	25.74	4.06	48.68
ν_ω	8.16	2.17	40.65

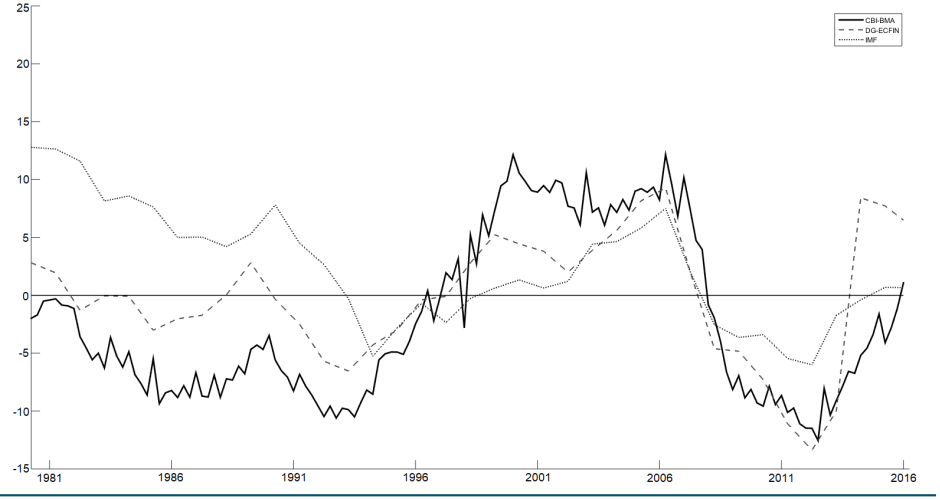
- Results consistent with downward-sloping Phillips curve, Okun Coefficient of 0.48 and fat tails in the distribution of shocks to output

Bayesian Model Averaging: Results

(a) Potential Output



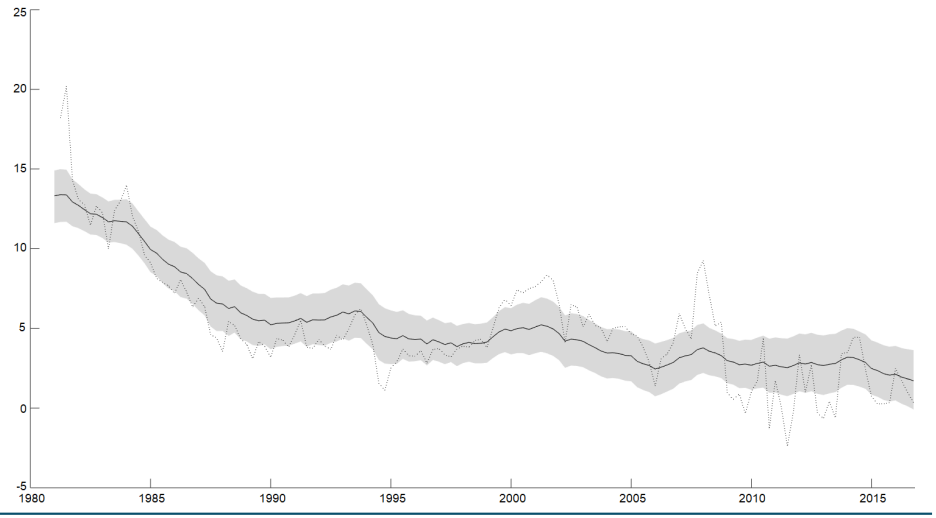
(b) Output Gap



Bayesian Model Averaging: Results

(c) NAWRU

(d) Trend Wage Inflation

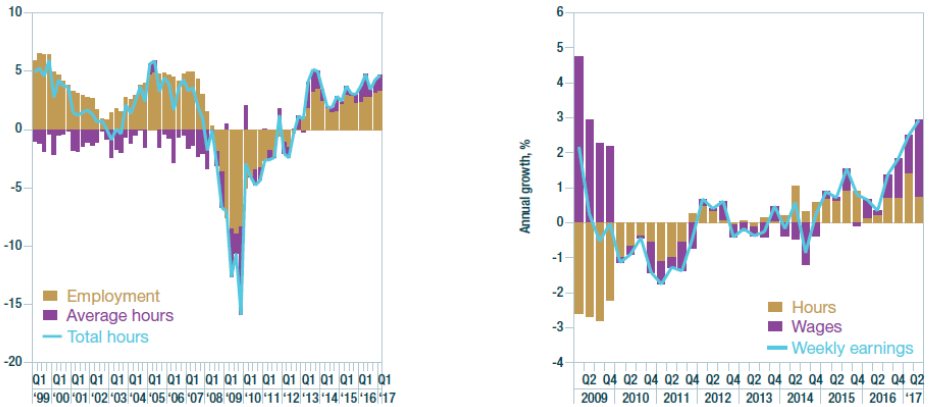


Complementary Analysis: Labour Market Conditions

- Current labour market indicators suggest ever-tightening conditions in the near-term
- Questions arise as to whether the degree of slack in the labour market is falling, and the potential consequences for wage developments
- There have been a number of structural changes in the labour market, that could/should affect dynamics
  - Compositional shift from construction to services
  - Decline in the share of industrial employment
  - Heterogeneous dynamics in labour force participation between male and female workers post-crisis
  - Decline in the degree of underemployment among workers post-crisis
- Cyclical movement in labour force changes through migration have also affected the labour market

Complementary Analysis: Labour Market Conditions

Figure 6: Wage and Employment Dynamics
(a) Total Hours Worked (b) Total Weekly Earnings



Source: CSO, QNHS & EHECS, Eurostat.

- Growth in average hours worked, providing a significant contribution to overall total hours worked
  - Employment growth also a strong factor
- Approx. 50% of growth in average weekly earnings since the 2016Q3 derived from increases in average weekly hours of work.

Complementary Analysis: Labour Market Conditions

Figure 7: Labour Market Heat Map: 2004q1-2017q1

- Rapid rise in employment coupled with rapid decline in unemployment
- Mobility indicators all signalling strong recovery in labour market dynamics