AN UNOBSERVED COMPONENTS PHILLIPS CURVE FOR INDIA

12TH RESEARCH MEETING OF NIPFP-DEA RESEARCH PROGRAMME

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WHAT IS THE PHILLIPS CURVE (PC)

- Relationship between Inflation and output gap

Output Gap: Difference between actual and potential GDP	
If positive, it is called an inflationary gap. Indicates the growth of aggregate demand is outpacing the growth of aggregate supply—possibly creating inflation	If negative: may imply deceleration in prices

- Output gap proxies demand pressures
- PC quantifies this relationship: positive relationship

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MOTIVATION

- Resurgence of PC literature:
  - World
    (JME 2005 special edition)
  - India
    - dismissal
      [Dholakia 1990, Rangarajan 1983 , Bhattacharya and Lodh 1990, Ghani 1991, Balakrishnan 1991, Callen and Chang 1999, Nachane and Laxmi 2002, and Brahmananda and Nagaraju 2002 and Srinivasan et. al. 2006]
    - to gradual acceptance
      [Paul 2009, Singh et. al. 2011, Kapur 2013]

- Informing monetary policy: agnostic → believer

- The main objective of the Reserve Bank of India (RBI), is "…formulation and implementation of monetary policy with the objectives of maintaining price stability…[and] to promote economic growth…"
  [Reserve Bank of India: Functions and Working]

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EVOLUTION OF THE PC I

- PC determines inflation
- Inflation= linear combination of persistence/expectations + demand + supply
- The great Bifurcation [Gordon 2011]

Keynesian/ Inertial/ Backward-looking PC	New Keynesian Phillips Curve/ Forward- looking PC
$\pi_t = \sum_{i=1}^{n} \alpha_i \pi_{t-i} + \beta(Y_t - Y_t^n) + \gamma z_t + \varepsilon_t$	$\pi_t = \alpha E_t \pi_{t+1} + \beta(Y_t - Y_t^n) + \varepsilon_t$
Persistence captured by past lags	Forward looking expectations
Supply shocks enter explicitly	Relegated to error term

π_t:	inflation	α, β, γ:	constants
Y_t:	GDP	$E_t \pi_{t+1}$:	expectations at time t for inflation at time $t+1$
Y_t^n:	potential GDP		
z_t:	catch-all supply shock variable	ε_t:	White noise error term

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$E_t \pi_{t+1}$: expectations at time t for inflation at time $t+1$
ε_t: White noise error term

EVOLUTION OF THE PC II

- Empirically, NKPC is a failure [Gordon 2011]
- "Expectations are the *sine-qua-non* of Macroeconomics" [Harvey 2011]
- Hybrid New Keynesian Phillips curve [Gali and Gertler 1999]
    - Most of the fit comes from backward looking part! [Rudd and Whelan 2005 and 2007]
    - Large robust confidence intervals [Kleibergen and Mavroeidis 2009]

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WHAT IS NEW I:UNOBSERVED COMPONENTS PC

Simple modification of a backward-looking PC [Harvey 2011]

❖ lagged inflation is replaced by an unobserved random walk component: from ARDL to UC

captures the underlying level of inflation

[Stock and Watson 2007, Cogley and Sargent 2008, Domenech and Gomez (2003), Watson (1986)]

WHAT IS NEW II: WHY A UC MODEL?

❖ Allows flexible treatment of non-stationary time series

- Convenient trend-cycle decomposition

- Computation of Output gap: Hodrick Prescott (HP) filter vs. Kalman (1960) filter
  - HP unsuitable for developing countries

    [Ozbek and Ozlle 2005]
  - HP's end point bias

    [Mise *et. al.* 2005, Harvey and Trimbur 2008 and Harvey and Delle Monache 2009]
  - Ambiguity of HP's smoothing parameter (λ)

WHAT IS NEW III

- Use of quarterly GDP over annual GDP
  - ➢ Less use for policy
  - ➢ Structural breaks
- Use of GDP over convenient proxies like IIP
  - ➢ Captures only small part of economy
  - ➢ IIP vs. economy wide WPI is imprudent
- Sequential growth rates Q-o-Q over Y-o-Y figures
- Out of sample extrapolative tests

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MODELING OUTPUT GAP I

❖ A trend-cycle decomposition is set up

- y_t is log (GDP), ε_t is white noise, μ_t is an integrated random walk:

$$\left.\begin{aligned} y_t &= \mu_t + \psi_t + \gamma_t + \varepsilon_t && \varepsilon_t \sim NID(0, \sigma_\varepsilon^2) \\ \mu_t &= \mu_{t-1} + \beta_{t-1} && \\ \beta_t &= \beta_{t-1}, + \zeta_t && \zeta_t \sim NID(0, \sigma_\zeta^2) \end{aligned}\right\} t = 1, \dots, T \qquad \begin{aligned} &\dots(1) \\ &\dots(2) \\ &\dots(3) \end{aligned}$$

- γ_t is the seasonal, ψ_t is the cyclical and β_t is the slope component and the normal white noise disturbances are independent of each other

- The smoothed components of the cycle give us the output gap

MODELING OUTPUT GAP II

- Seasonal and cyclical components are given by trigonometric formulations

1) SEASONAL COMPONENT: γ_t is given by:

$$\gamma_t = \sum_{j=1}^{[\frac{s}{2}]} \gamma_{j,t} \qquad \text{...(4)}$$

where each $\gamma_{j,t}$ is generated by

$$\begin{bmatrix} \gamma_{j,t} \\ \gamma_{j,t}^* \end{bmatrix} = \begin{bmatrix} \cos\lambda_j & \sin\lambda_j \\ -\sin\lambda_j & \cos\lambda_j \end{bmatrix} \begin{bmatrix} \gamma_{j,t-1} \\ \gamma_{j,t-1}^* \end{bmatrix} + \begin{bmatrix} \omega_{j,t} \\ \omega_{j,t}^* \end{bmatrix} \qquad \begin{matrix} j = 1, \dots, \left[\frac{s}{2}\right], & \omega_t \sim NID(0, \sigma_\omega^2), \\ t = 1, \dots, T & \omega_t^* \sim NID(0, \sigma_\omega^2), \end{matrix} \qquad \text{...(5)}$$

where $\gamma_j = 2\pi j/s$ is the frequency, in radians, and the seasonal disturbances ω_t and ω_t^* are mutually and serially uncorrelated (with common variance, as above).

MODELING OUTPUT GAP III

2) CYCLICAL COMPONENT: ψ_t is specified by a 'balanced cycle model' of order $k = 2$ [Harvey and Trimbur 2003]

$$\begin{bmatrix} \psi_t^{(k)} \\ \psi_t^{*(k)} \end{bmatrix} = \rho_\psi \begin{bmatrix} \cos\lambda & \sin\lambda \\ -\sin\lambda & \cos\lambda \end{bmatrix} \begin{bmatrix} \psi_{t-1}^{(k)} \\ \psi_{t-1}^{*(k)} \end{bmatrix} + \begin{bmatrix} \psi_{t-1}^{(k-1)} \\ \psi_{t-1}^{*(k-1)} \end{bmatrix} \qquad t = 1,\ldots\ldots,T, \qquad \ldots(7)$$

- where λ is frequency, in radians, in the range $0 \leq \lambda \leq \pi$; ρ_ψ is the dampening factor, with $0 < \rho_\psi \leq 1$, are mutually and serially $\psi_t^{*(k)}$ is an auxiliary process.
- The period of the cycle is equal to $2\pi/\lambda_c$. For computing the output gap, this value is fixed at 20 quarters (five years), which is the length of a typical business cycle (Koopman *et. al.* 2007).

MODELING OUTPUT GAP IV

- The reduced form of the model is an Autoregressive Moving Average ARMA (2,1) process with complex roots for the autoregressive part.

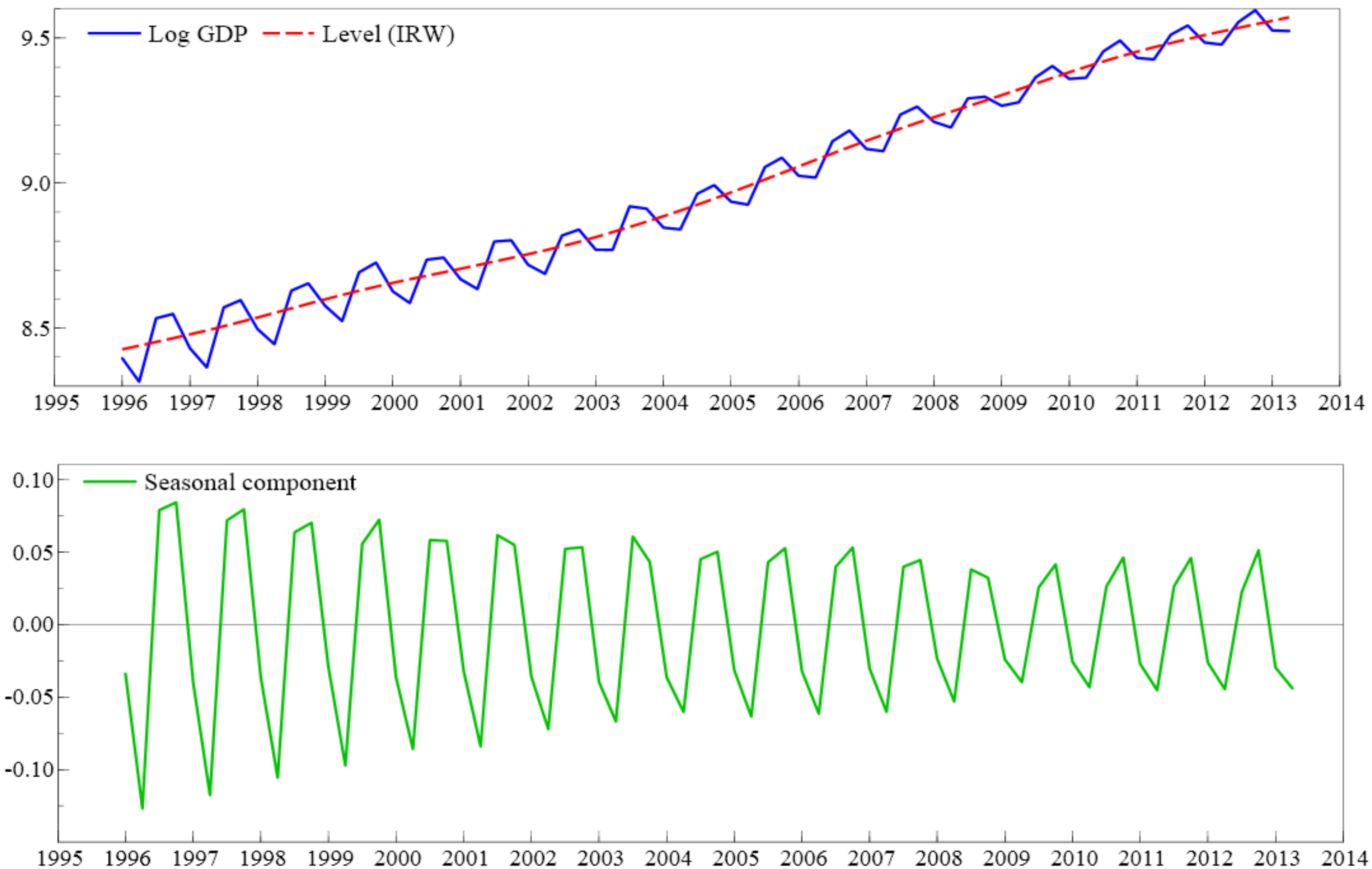
- The model is assumed to be Gaussian and the hyperparameters $(\sigma_\varepsilon^2, \sigma_\eta^2, \sigma_\zeta^2, \sigma_\kappa^2, \lambda_c, \rho_\psi)$ are estimated using Maximum Likelihood.

- Diffuse initialisation is used to deal with the problem of unobserved state at the beginning of the time series.

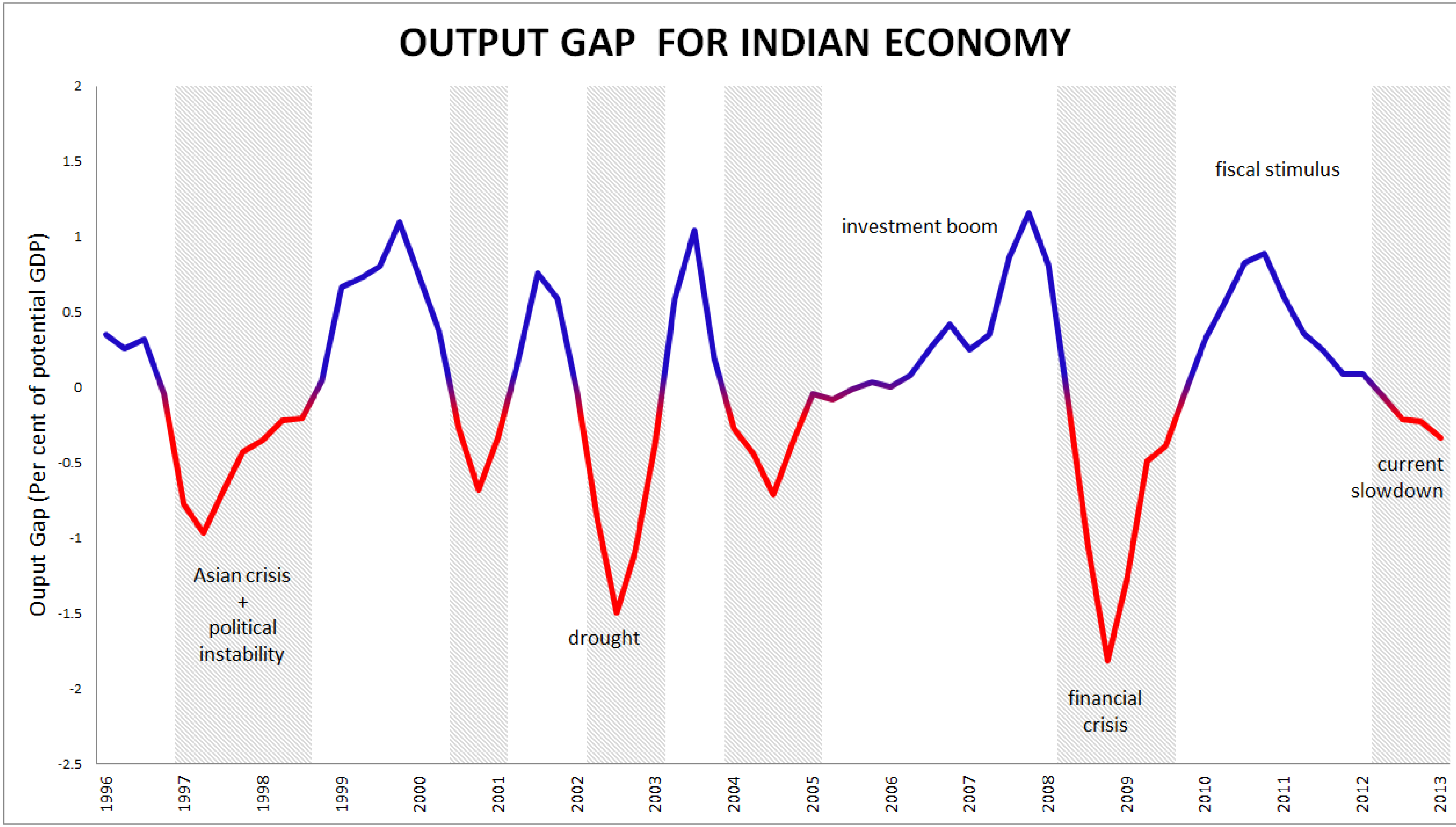
- Estimates of trend, cyclical, seasonal, and irregular components are given by a smoothing algorithm in STAMP.

MODELING OUTPUT GAP V

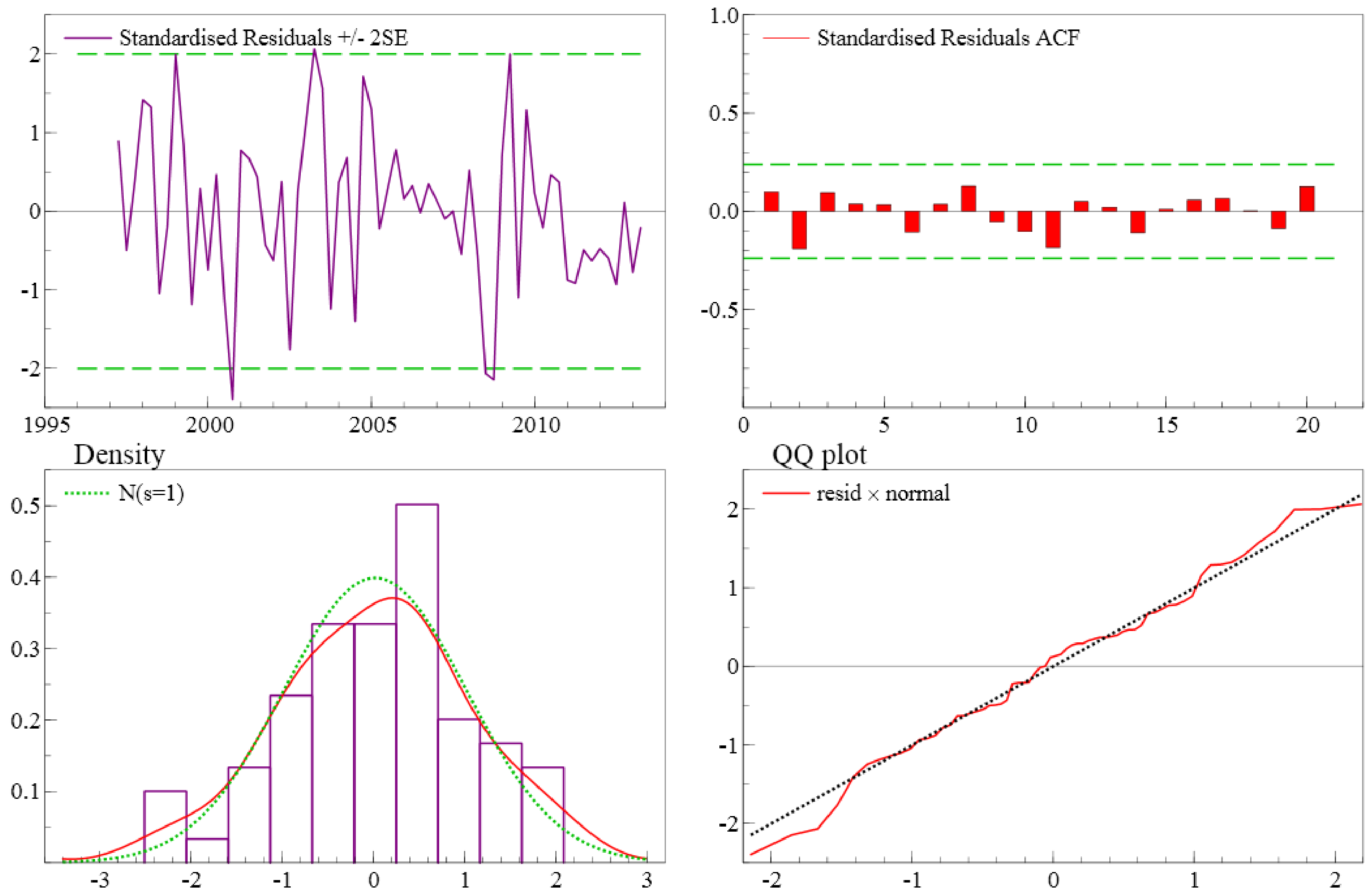
Log (GDP) and its decomposition into stochastic level and seasonal components



MODELING OUTPUT GAP VI



MODELING OUTPUT GAP VII: RESIDUAL GRAPHCS



MODELING OUTPUT GAP VIII: DIAGNOSTICS

- The diagnostic tests of state space time series models are based on properties of residuals:
  1. Independence
  2. Homoskedasticity
  3. Normality

- Is IRW a suitable model?

TABLE 1: Diagnostic Tests for the GDP Model

Diagnostic	Test	Value	Critical value (at10%)	**p-value**
Independence**	Box-Ljung Q(q)	10.273	12.017	**0.174**
	r(1)	0.100		
	r(q)	0.021		
Homoskedasticity**	1/H(20,20)	0.971	1.768	**0.474**
Normality**	Bowman-Shenton	0.202	4.605	**0.904**

** INDICATES THAT NULL HYPOTHESIS IS NOT REJECTED EVEN AT10% LEVEL OF SIGNIFICANCE

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UNOBSERVED COMPONENTS PC I

MODEL A: A parsimonious 'pure' PC with output gap as the only explanatory variable.

$$\pi_t = \mu_t + \psi_t + \beta_1(OG_t) + \varepsilon_t, \qquad \varepsilon_t \sim NID(0, \sigma_\varepsilon^2),$$

$$t = 1,\ldots,T \qquad \ldots(8)$$

$$\mu_t = \mu_{t-1} + \eta_t \qquad \eta_t \sim NID(0, \sigma_\eta^2)$$

- $OG_t = Y_t - Y_t^n$
- μ_t, measures trend inflation
- Modification of the backward looking PC

UNOBSERVED COMPONENTS PC II

MODEL B: An 'extended' PC with controls for supply shocks built in (Kapur 2013).

A. Food : $Rain_t$
   - rainfall shortage during the month of July – the critical month for kharif sowing
   - $Rain_t$ measures per cent deviation in actual rain from normal rainfall during July.
   - Impacts inflation with a lag

B. Crude oil: $croil_t$ (IMF)

C. Non-oil commodity inflation: $nfuel_t$ (IMF)

UNOBSERVED COMPONENTS PC III

D. Exchange rate: $NEER_t$

- Depreciation in the Rupee may increase price of imports without requisite demand pressure
- Nominal Effective Exchange Rate (NEER)
- Measures variation (y-o-y) in the 36-currency trade-weighted nominal effective exchange rate index of the Indian rupee complied by the RBI
- A decrease in NEER implies depreciation

- Thus the extended PC specification is:

$$\pi_t = \mu_t + \psi_t + \beta_1 OG_t + \beta_2 Rain_t + \beta_3 Croil_t$$

$$+ \beta_4 NFUEL_t + \beta_5 NEER_t + \varepsilon_t$$

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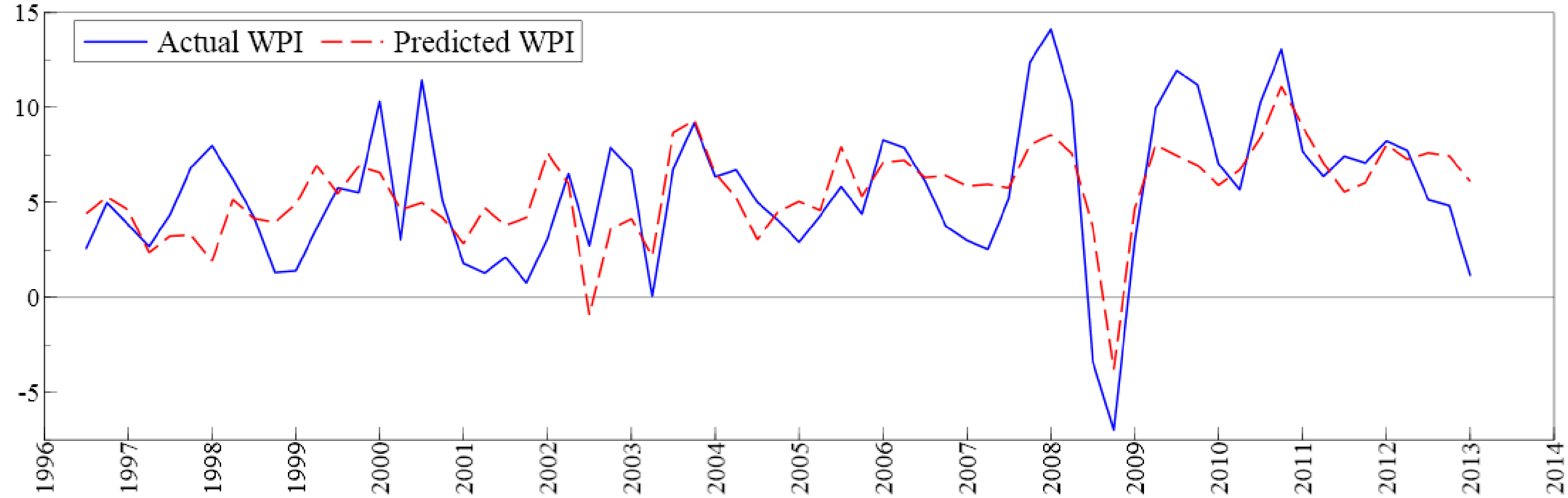
RESULTS I

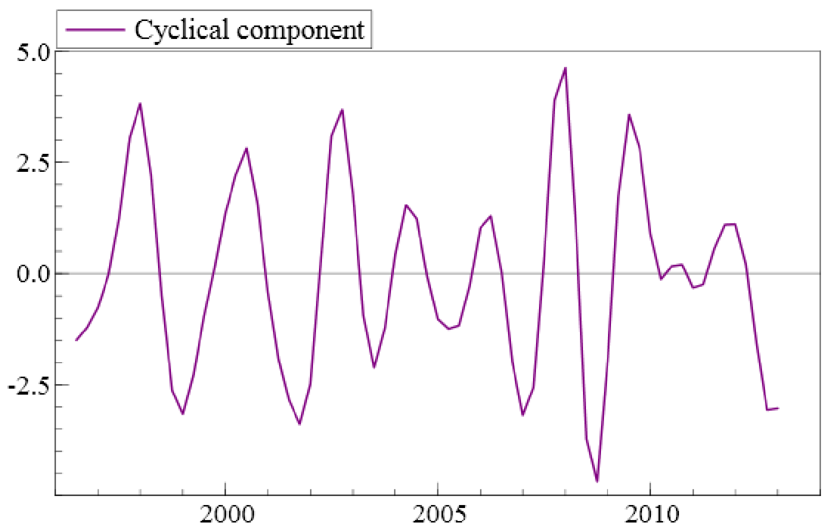
Estimated Equations for Quarterly Changes in the WPI 1996:Q3 to 2013:Q1
Dependent variable: Annualized sequential growth rate of WPI

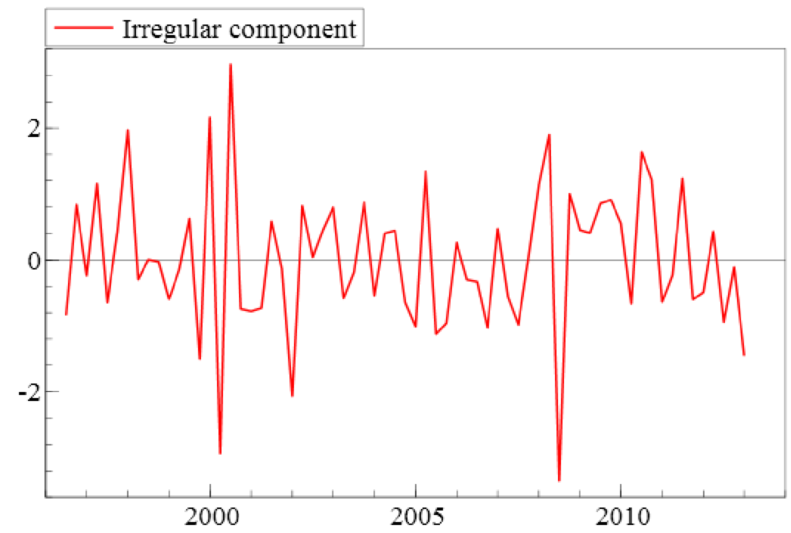
	A	B
OG_{t-1}	1.71883 **	1.542**
	(2.15845)	(2.047)
$Rain_{t-1}$	-	0.010 ***
		(2.678)
Oil_{t-1}	-	0.015*
		(1.916)
Oil_{t-2}	-	-0.013 **
		(-2.008)
$Nfuel_{t-1}$	-	0.045**
		(2.355)
$NEER$	-	-0.141***
		(-3.101)

t-values are reported in parentheses.
*, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

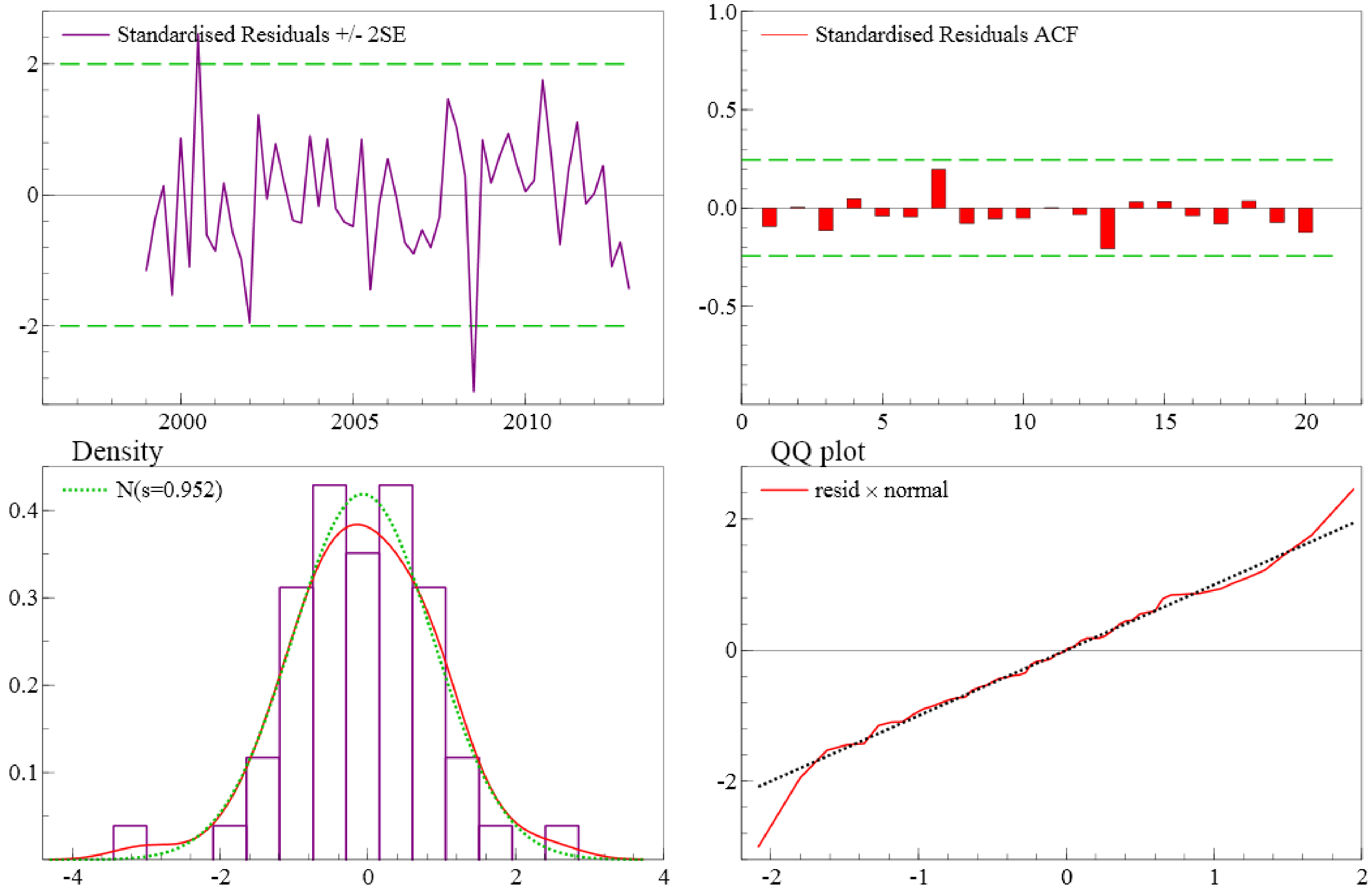
RESULTS II: COMPONENTS OF MODEL B







RESULTS III: RESIDUAL GRAPHICS OF MODEL B



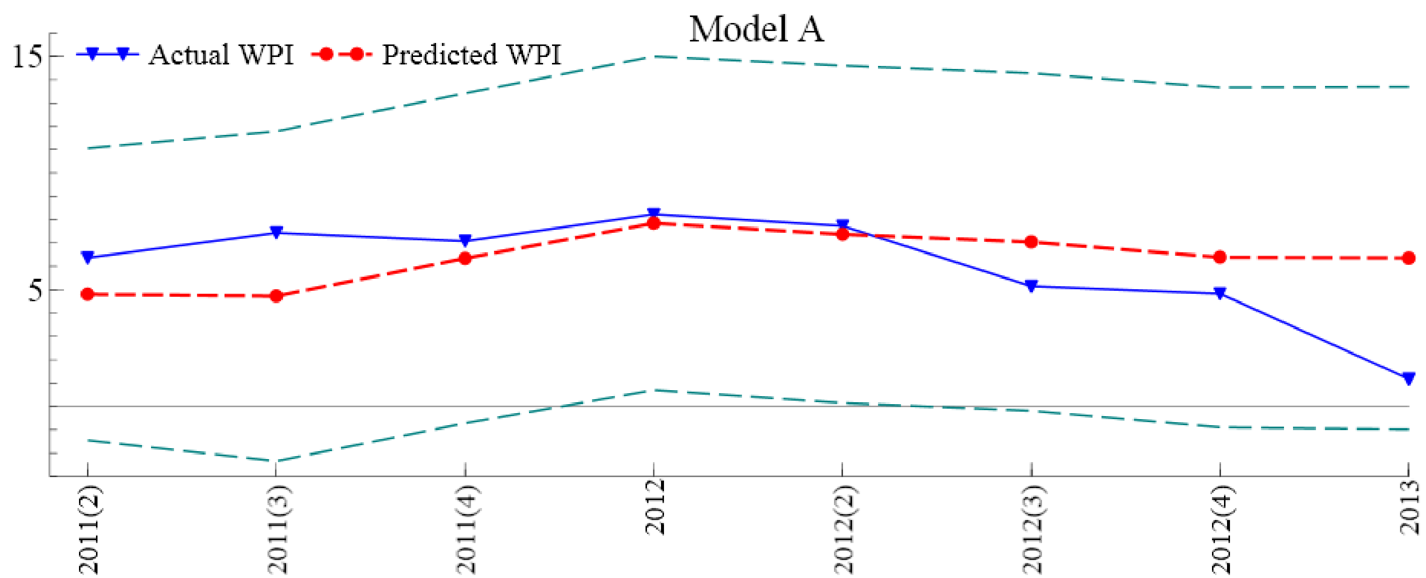
RESULTS IV: DIAGNOSTIC TESTS

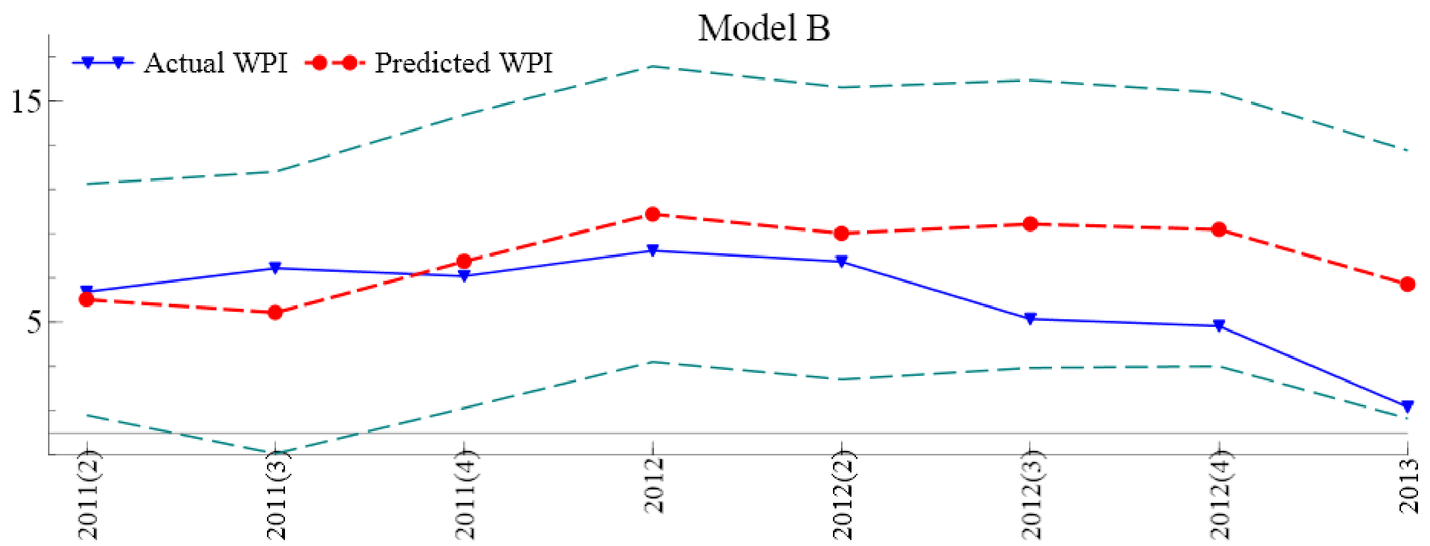
Diagnostic Statistics		
	A	B
Std.error	2.886	2.219
PEV	8.328	4.927
R^2	0.465	0.709
Normality	0.789** (4.605)	3.677** (4.605)
H(h,h)	1.399** (1.794)	1.0025** (1.822)
DW	1.979	2.1128
r(1)	-0.028	-0.091204
r(q)	-0.087	0.0030983
Q(q,q-p)	6.629** (10.646)	5.0586** (10.646)
AIC	2.299	1.923

* *INDICATES THAT NULL HYPOTHESIS IS NOT REJECTED AT 10% LEVEL OF SIGNIFICANCE

PARANTHESIS CONTAIN 10 PER CENT CRITICAL VALUES

RESULTS V: Out of sample multi-step ahead predictive test*





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CONCLUSION I

- The Phillips curve does exist for India!
- The simple UC Phillips Curve is parsimonious and provides a good fit to the data.
- Improvements in econometric implementation
- UC models such as the UC Phillips curve can fit well in a good deal of Dynamic Stochastic General Equilibrium (DSGE) models
- Disentangling and quantifying demand and supply pressures
- Forecasting inflation

FURTHER RESEARCH

- Embodying unobserved components in a theoretical New-Keynesian Framework [Harvey 2011].
- Can the UC Phillips curve fit DSGE models for India?
- Improving over supply shock controls [Mankiw and Ball 1994, Gordon 1988].
- Model selection

THANK YOU!

The End

APPENDIX 1: DIAGNOSTIC TESTS

- The Box-Ljung test for serial correlation has been used to test serial correlation. It is based on residual autocorrelation of the first q lags. The test statistic is distributed as χ^2 with $(q - p - 1)$ degrees of freedom where p is the number of hyper-parameters to be estimated.
- For verifying homoskedasticity of the residuals, the H statistic is used which tests whether the variance of the residuals in the first third part of the series is equal to the variance of the residuals corresponding to the last third part of the series. This is tested employing a two tailed test against an F-distribution with (h, h) degrees of freedom. h is the nearest integer to $(n - d)/3$, where n= number of observations, d= number of diffuse initial elements.
- Normality of residuals is tested against the Bowman-Shenton statistic which is based on the third and fourth moments of the residuals and has a χ^2 distribution with 2 degrees of freedom.

APPENDIX 2: WORKING OF THE KALMAN FILTER

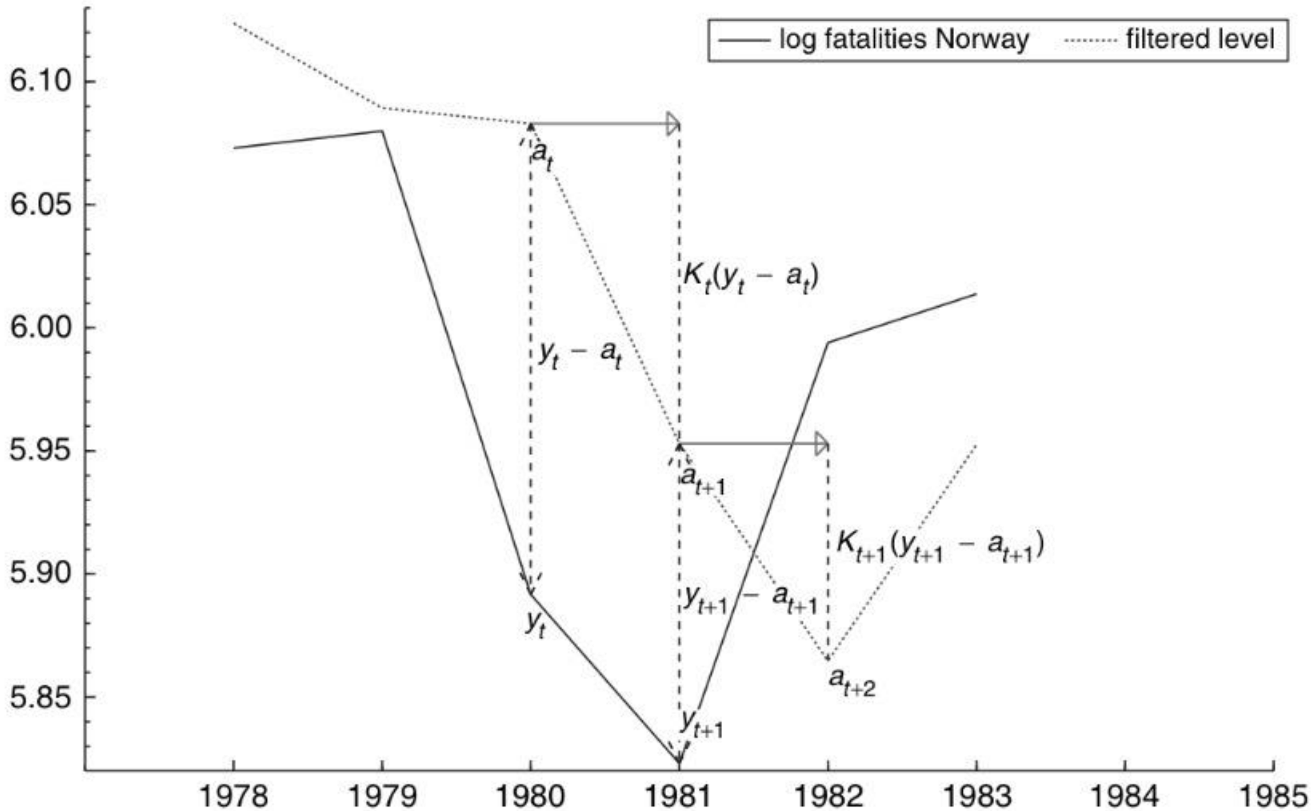

Figure 8.6. Illustration of computation of the filtered state for the local level model applied to Norwegian road traffic fatalities.