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Unravelling India's Inflation Puzzle

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Abstract

From 2003, the Indian economy enjoyed a boom in growth coupled with moderate inflation for five years. The economy grew at a rate close to 9 percent per year, until it was punctured by the global financial crisis of 2008. Since then, the persistence of inflation in an environment of falling economic growth has come out as a "puzzle" to policymakers' and many in the financial market. Why has the current slowdown in growth not been disinflationary? This paper contends that there were two important policy errors that are behind the stagflationary outcome. The rapid deterioration in public finances in response to the global economic crisis while stimulating demand temporarily managed to pull down the potential growth rate of the economy. The RBI compounded the problem by being sluggish and soft on inflation after the economy bounced back from the effects of the global economic crisis because it systematically overestimated the potential growth rate of the economy. This meant that by the time monetary policy was tightened, high inflation and inflation expectations had already become entrenched. That is why the current growth slowdown has not been disinflationary.

Keywords: *India; Inflation; Potential Output; Taylor Rule*

JEL Codes: *E31; E32; E52*

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INTRODUCTION

From 2003, the Indian economy enjoyed a boom in growth for five years. The economy grew at a rate close to 9 percent per year, until it was punctured by the financial crisis of 2008 (see Figure 1). In the face of rising uncertainty and slowing global growth, India's investment rate and GDP growth dropped sharply. Growth decelerated to 6.2 percent in 2011-12 and further to a decadal low of 5 percent in 2012-13. The investment rate dropped from close to 33 percent in 2007-08 to 29.5 per cent of GDP in 2012-13.

What has made matters worse is that in spite of the deceleration in growth the economy continues to suffer from stubbornly high inflation. Headline WPI inflation recorded an annual average rate of around 8.5 percent during the three years ending 2012-13 while headline CPI inflation averaged almost 10.0 percent during the same period.[1] The persistence of inflation in an environment of falling economic growth has turned out to be a puzzle.[2]

Why has the current slowdown in growth not been disinflationary? It is tempting to ascribe the reason to adverse supply shocks. But that would be misleading. In fact, core WPI inflation (inflation in the non-food and non-fuel group) averaged 6 percent while

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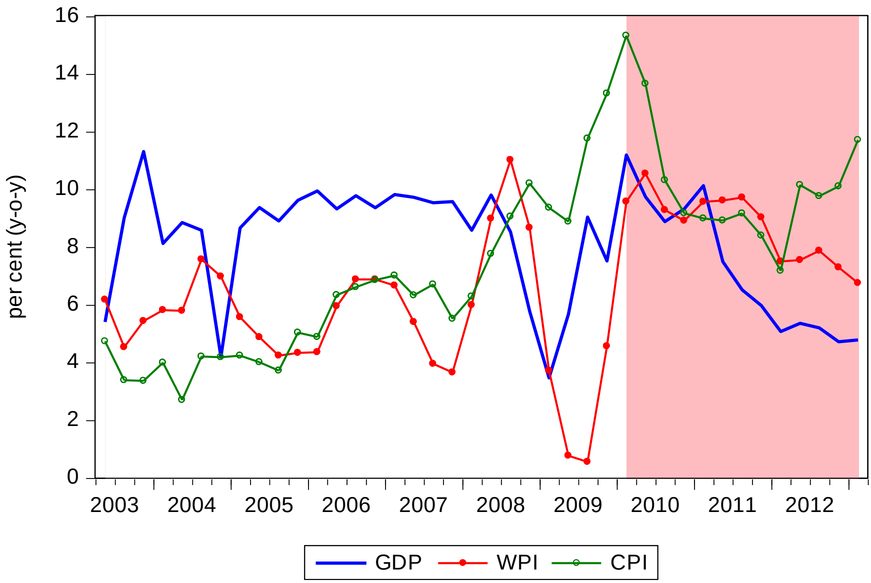
[1] WPI inflation has abated somewhat during the current financial year bringing some respite, even though the CPI inflation continues to remain high (see the shaded portion of Figure 1).

[2] a. "Why, even with growth deceleration, inflation hasn't come down?...As per RBI's estimates, potential growth rate was 8.5% pre-crisis, *(but)* may have declined to 8% post crisis. It is possible *(that)* potential growth has further declined below 8% as core inflation *(has)* not *(been)* softening significantly even as growth has been moderating. But the potential growth rate needs to be estimated more robustly." (Presentation by RBI Governor Dr. D. Subbarao to the Indian Merchants' Chamber on June 19, 2012)

b. "Given India's good track record of inflation management, the persistence of elevated inflation for over two years is apparently puzzling....The deceleration of growth and emergence of a significant negative output gap has failed to contain inflation." (Speech by RBI Executive Director Mr. Deepak Mohanty on January 31, 2013) core CPI inflation averaged around 9.5 percent during 2010-13, way above the RBI's comfort zone. The persistence of core inflation in an environment of falling economic growth raises serious questions about the potential growth rate of the economy and the size of the output gap.[3]

Against this backdrop, this paper seeks to shed light on the potential growth rate of the Indian economy. Specifically, it asks: (i) What is the potential growth rate for the Indian economy and how has it changed over time? (ii) What is the estimated output gap (i.e., the difference between actual and potential output)? (iii) Can it shed light on why the current slowdown has not been disinflationary?

Figure 1: Recent Growth-Inflation Dynamics



[3] In fact, RBI Governor Dr. D. Subbarao in an interview to the The Wall Street Journal on February 13, 2012 asked "What is our potential growth rate, noninflationary stable growth rate? We said before the crisis it was 8.5%. After the crisis, some studies showed it was about 8%. But now we've seen inflation, even when the economy was growing at 7.5%, indicating the noninflationary growth rate is about 7% or so."

To this end we use several statistical techniques to estimate India's potential growth rate. We find a substantial decline in the potential growth rate of the economy after the 2008 crisis. Our estimates suggest that it fell from an average of 9.0 percent during 2005-08 period to less than 5 per cent in 2012-13. Moreover, the actual growth rate of the economy consistently outstripped our estimate of the potential growth rate (positive growth gap) during the post-crisis period. We go on to examine the Reserve Bank of India's (RBI) policy response to these developments. We find that the monetary authority systematically underestimated this gap (or overestimated India's potential or trend growth rate).[4] As a result monetary policy was too loose for too long. This has in turn fanned inflation.

Rest of the paper is organised as follows. In section II we use a variety of statistical techniques to estimate India's potential growth rate and the size of the output gap. In section III we estimate both a contemporaneous and a forward-looking version of the Taylor rule to gauge the monetary policy stance both in the pre- and post-crisis period. We find that the central bank systematically overestimated India's potential growth rate in the post-crisis period. As a result policy response was sub-optimal. Section IV provides concluding remarks.

ESTIMATING INDIA'S POTENTIAL GROWTH: A TIME SERIES APPROACH

Both potential output as well as the output gap are unobserved time varying variable, and therefore need to be estimated. A number of statistical and economic approaches have been developed to estimate potential output and the corresponding output gap. There are two basic methodologies for estimating potential output: purely statistical trend-

[4] One can gauge this from the Macroeconomic and Monetary Developments Report of January 28, 2013, which noted: "Headline inflation has not declined at a pace commensurate with the negative output gap that has now prevailed for the fifth successive quarter." See footnote 2 and 3 also.

cycle decomposition and estimation of structural relationships. The statistical methods attempt to separate a time series into a long-term trend (or permanent) component and a short-term cyclical (or transitory) component without referring to any economic theory. Potential output is typically the non-stationary permanent component and the output gap is typically the stationary transitory component. The structural methods, on the other hand, isolate the effects of permanent and transitory influences on output, using economic theory. Since alternative methodologies give varied results, this paper uses both approaches (statistical and structural) for cross-validation and robustness.

We use both univariate Hodrick-Prescott filter and multivariate Beveridge-Nelson decomposition, both of which are statistical methods for estimating potential output. Amongst the structural methods, we estimate a two-equation Structural VAR model using an identification strategy similar to that used by Blanchard and Quah (1989) to isolate the pure permanent and transitory shocks. While the details of the techniques are provided in the appendix, we give a brief non-technical overview of these techniques here.

The univariate Hodrick-Prescott (HP) filter is the most popular filter for estimating potential output. This filter extracts a trend component by introducing a trade-off between a good fit to the actual series and the degree of smoothness of the trend series. The degree of smoothness of the trend estimate depends on the choice of smoothing parameter λ, which is the relative weight placed on the trend smoothing term (rate of change in trend growth) of the objective function being minimized. A low value of λ will produce a trend that follows actual output very closely while a high value of λ reduces the sensitivity of the trend to short-term fluctuations in actual output. For very large λ, the filter will converge to the linear time trend method, with a linear time trend close to the mean growth rate of real GDP over the sample. The arbitrariness in the choice of λ makes the trend estimate subjective.[5]

Beveridge and Nelson (1981) (BN) showed how to decompose any ARIMA(p,1,q) model into the sum of a random walk plus drift (the general trend) and a stationary component (irregular component). The BN estimate of stochastic trend of an integrated time series {say log(GDP)} is defined to be the limiting forecast as horizon goes to infinity, adjusted for the mean rate of growth. In lay terms, the trend is the "long-term" forecast when all transitory dynamics have worked themselves out. To proceed with the decomposition, an appropriately identified univariate ARMA(p,q) model of the first differences of the integrated time series (first differences of log(GDP)) is estimated in order to forecast the long-run level of the series (i.e., log(GDP)), which is the BN trend component. The univariate BN decomposition can be easily extended to the multivariate space. In this paper, in addition to log(GDP), we also include log(WPI) and estimate their BN trend using VAR(p) model of their first differences.

Structural VAR method of estimating potential output and output gap is based on a vector autoregressive model using structural assumptions about the nature of economic disturbances. We estimate a two variable VAR model of first differences of log(GDP) and log(WPI). The reduced form shocks are composites of the pure supply (permanent) and demand (transitory) shocks that drive potential output and output gap, respectively. To recover these structural shocks a minimal set of identifying restrictions is imposed on the system. The key identifying restriction (only one required in a two variable structural VAR) is that demand shocks do not affect output in the long run whereas supply

[5] Another shortcoming of the HP filter is its high end-sample bias, stemming from the nature of the minimisation problem that makes the smoothed series to always converge to the original sample at both ends of the series. This filter traces trend through all the observations, regardless of any structural breaks that may have occurred (Cotis et. al., 2004).

shocks do. The restriction is imposed on the long-run dynamics of the variables. Once the structural shocks have been recovered the variables of the system can be expressed as the sum of current and past realisation of the pure shocks. Finally, potential GDP can be represented by the accumulated supply shocks alone, with demand shocks assumed to have no impact on the level of potential GDP.

Estimates of Potential Growth

As mentioned above, to address the question of why inflation has been resolutely high amidst sharp deceleration in growth, it is important to have an estimate of potential growth (growth gap to be precise) of the economy. We present our estimates of potential growth in Figure 2 based on the approaches outlined above. It is noteworthy that actual growth rate of real GDP fell steadily from the high of over 10 per cent in 2010Q1 to under 5 per cent in 2013.[6] While actual growth fell significantly, potential growth appears to have fallen much more.[7] Indeed, estimates of potential growth based on BN decomposition and BQ SVAR approach have consistently undershot the actual growth rate during this period implying a positive growth gap with potential inflationary implications.[8]

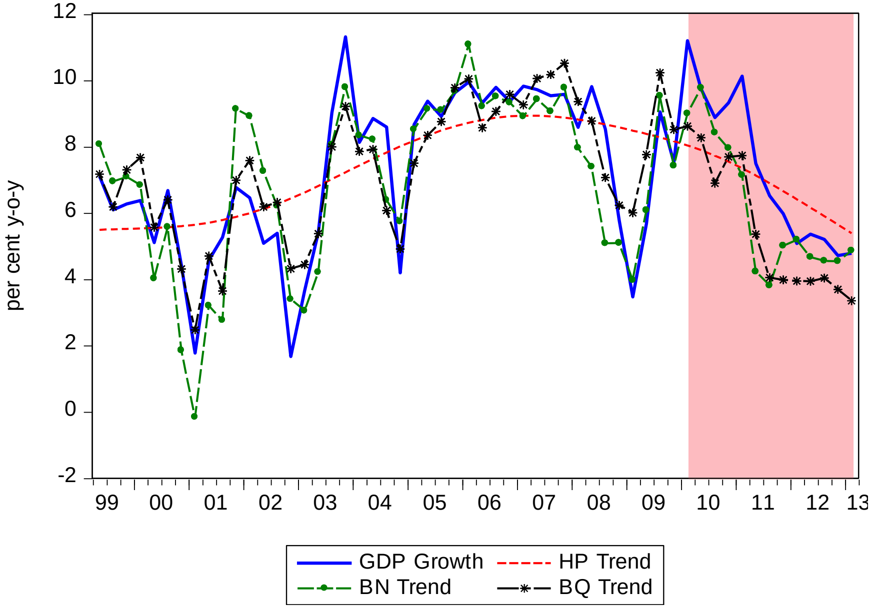
[6] Bai-Perron test for structural break provides evidence for a break around 2011:Q1.

[7] a. Several structural factors have been documented for the decline in growth. Saving and investment activity have been muted in the recent period. There has been a sharp fall in domestic savings rate from the peak of 36.8 per cent in 2007-08 to 30.8 per cent of GDP in 2011-12. In line with the fall in savings rate, there has been a fall in the investment rate, mainly driven by the subdued investment activity of the private corporate sector. Nagaraj (2013) argues that private corporate investment is unlikely to revive anytime soon as high interest rates and a depreciating currency have raised debt servicing costs.

b. Other factors such as delays in project implementation and governance issues which have grabbed headlines recently have not helped either. A recent paper by Anand et al (2014) attributes the fall in India’s potential growth to the decline in trend TFP growth resulting from heightened regulatory and policy uncertainties, delayed project approvals and implementation and continued bottlenecks in the energy and infrastructure sector.

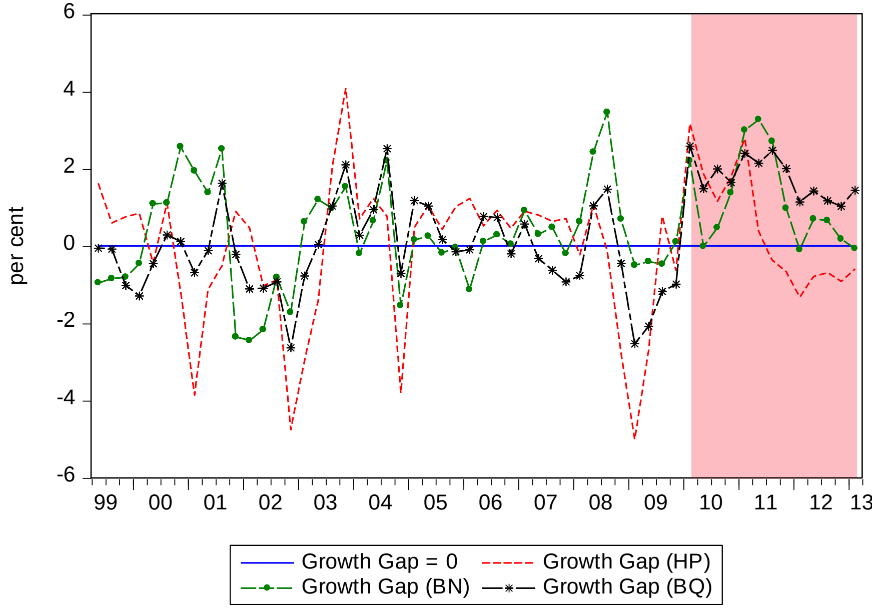
[8] Estimates based on Christiano-Fitzgerald filter tells a similar story. Other approaches undertaken to estimate potential output for India also paint a similar picture (see Mishra, 2013, for example).

Figure 2: Estimates of India's Potential Growth



In Figure 3 we plot the gap between the actual and the estimated potential growth rate. It can be seen that barring the gap estimated using HP methodology (this too, however, is sensitive to the smoothing parameter, λ, as noted above), other methods imply a positive growth gap for the period since 2010. Even according to the HP method, the positive growth gap persisted from 2010Q1 up to 2011Q2 before turning slightly negative there after.

Figure 3: Estimates of Growth Gap



Next, we isolate the pure shocks affecting output using our SVAR model - both supply shocks (having permanent effect) and demand shocks (having transitory effect) - from the reduced from error of the VAR system of equations. We examine these shocks to understand the dynamics of growth and inflation over the sample period. Figure 4A plots supply shocks (reflecting capital accumulation brought about by higher saving rate and/or productivity growth) while Figure 4B plots the demand shocks (reflecting fiscal and/or monetary policy shocks).

Looking at the pattern of the shocks, it is clear that the high growth phase of 2003-08 was primarily dominated by favourable supply shocks, whereas the latter phase saw supply shocks tapering off and turning negative on the whole. This is also reflected in a sharp downturn in the potential growth rate of GDP. On the other hand, while demand shocks remained muted during the period 2003-08 (coinciding with fiscal probity brought about by the FRBM Act), the growth of 2008-13 was mostly driven by demand shocks, which combined with a collapse in the potential growth rate of the economy, fanned inflation.

The Government during this phase undertook an unprecedented fiscal stimulus package in the wake of the financial crisis aided by an accommodative monetary policy to pumprime the economy (see Figure 5). Large public sector pay increases (following the Sixth Pay Commission) and the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) were rolled out and the RBI cut interest rates substantially. The RBI played its part by reducing the repo rate (the rate at which the RBI lends to banks) by 4 percentage points between September 2008 and March 2009. Indeed, the stellar GDP performance of 2009-10 and 2010-11 was the result of a huge demand push. In short, policy successfully managed to stimulate demand while choking supply. As a result inflation raised its ugly head.

Figure 4A: Supply Shocks of the SVAR Model

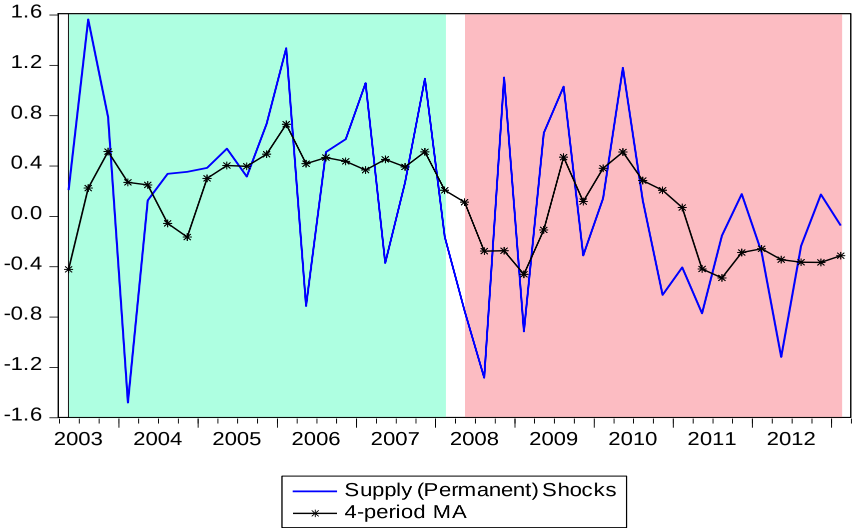


Figure 4B: Demand Shocks of the SVAR Model

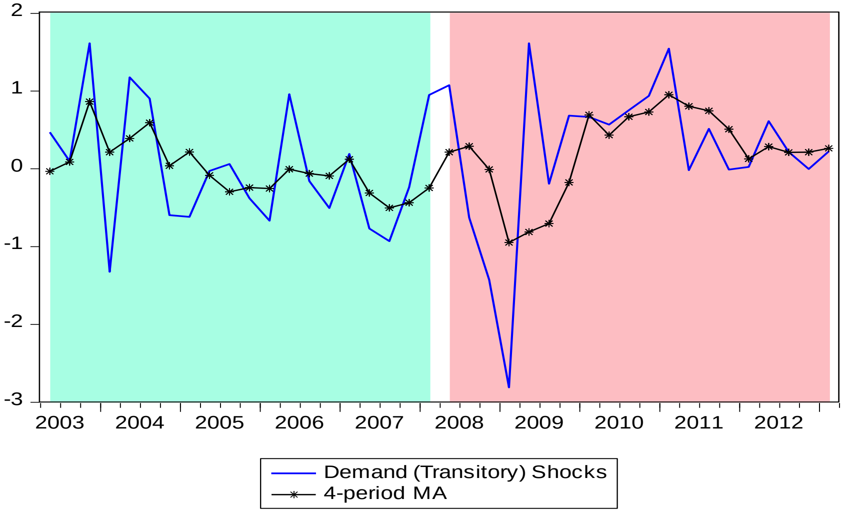
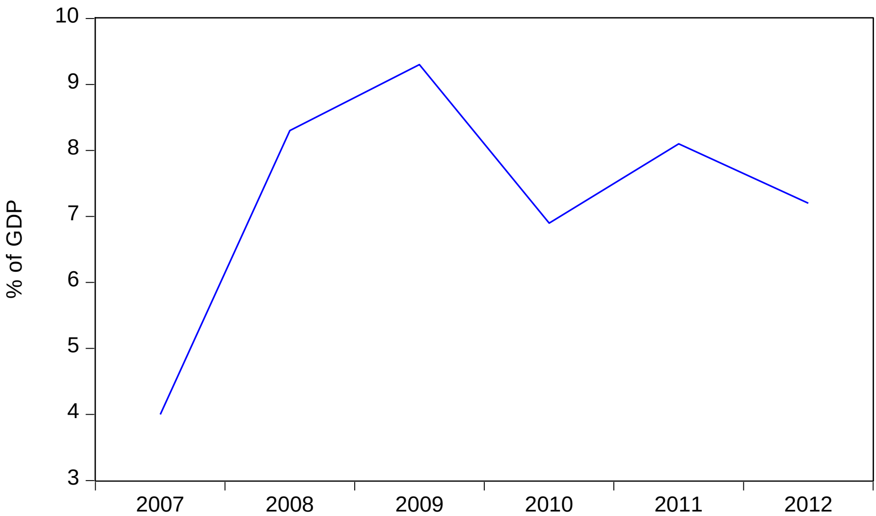


Figure 5: Combined Fiscal Deficit of the Centre and States

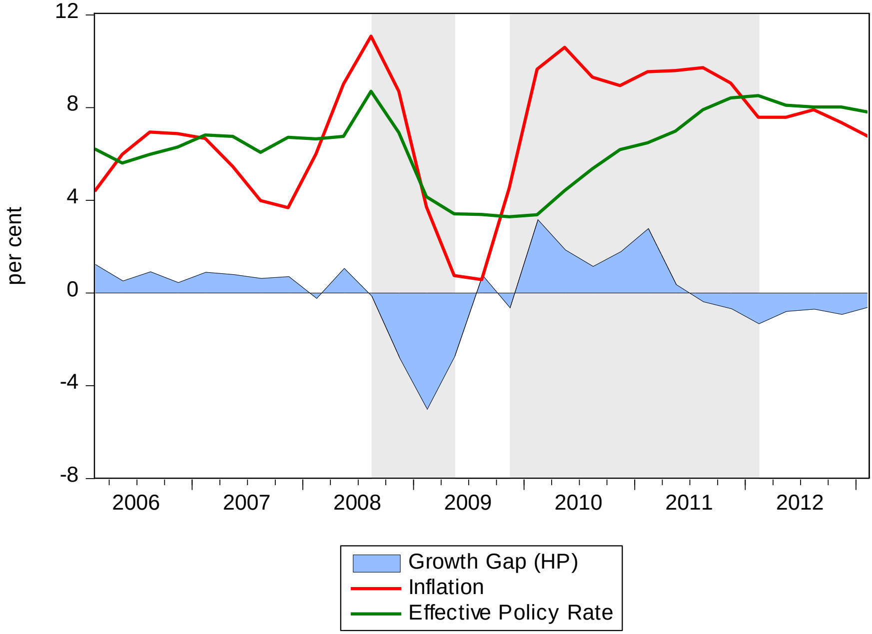


EVALUATING THE RBI'S POLICY RESPOSE TO THESE DEVELOPMENTS

Against this backdrop we now turn our attention to the RBI's monetary policy stance with particular emphasis on the post crisis period. Figure 6 plots the growth gap (based on HP filter), headline WPI inflation and and effective policy rate.[9] Notice that in response to the downturn of 2008-09 the RBI cut interest rates sharply. In sharp contrast, once the economy had bounced back from the crisis policy was tightened much more slowly. While effective policy rate came down from around 8.5 per cent to 3.5 per cent in a span of 3 quarters in order to avert the downturn of 2008-09 (see the shaded portion from 2008Q3 to 2009Q2), it took almost 9 quarters for normalisation of policy rate (see the shaded portion from 2009Q4 to 2012Q1) during which monetary policy fell way behind the curve. In other words, policy turned out to be overly accommodative with real interest rates turning negative for most of this period. In fact, in his last public appearance before he stepped down as RBI governor, Dr. Subbarao acknowledged this. He said, "*With the benefit of hindsight, I must admit in all honesty that the economy would have been better served if our monetary tightening had started sooner and had been faster and stronger* (RBI, 2014)".

[9] Although RBI has been announcing only one independently varying policy rate (the repo rate) to signal its monetary policy stance since the Annual Policy of 2011-12, both repo and reverse repo rates were announced in the past. Depending on the liquidity conditions (deficit/surplus) prevailing in the market, either the repo (deficit) or the reverse repo (surplus) signalled the policy stance. We, therefore, construct a measure of effective policy rate (EPR), which is the weighted average of repo and reverse repo rate with the weights being the share of repo and reverse repo amounts, respectively, in the total daily transactions. During the periods of liquidity deficit (e.g. the recent period since 2010:Q4), the share of repo would be predominant, and the EPR would be close to the repo rate. On the other hand, during the periods of liquidity surplus, the share of reverse repo would be dominant, and the EPR would be close to the reverse repo rate.

Figure 6: Growth Gap, Inflation and Effective Policy Rate



Why was the RBI behind the curve?

Estimating the Taylor Rule

To make an objective assessment of the policy stance, we estimate both a contemporaneous and a forward-looking version of the Taylor (1993) rule. Our contemporaneous specification is given by:

$$EPR_t = \alpha + \rho EPR_{t-1} + \beta(y_t - y_t^*) + \gamma\pi_t \ , \tag{1}$$

where EPR is the effective policy rate as defined above, $y_t - y_t^*$ is the output gap (in per cent derived from the H-P filter) and π_t is year-on-year WPI inflation. According to this specification, policy reacts to output gap and inflation. We interpret ρ as an indicator of the degree of smoothing of interest rate changes implying that in each period the Reserve Bank adjusts the effective policy rate to eliminate a fraction $(1-\rho)$ of the gap between the targeted level of policy rate and the existing policy rate.[10]

For robustness, we estimated a forward looking version of the Taylor rule (Clarida et al., 2000) as this characterisation provides a reasonably good description of the way major central banks of the world operate in practice given monetary transmission lags. Essentially, the forward looking specification will have expected inflation and output gap (given the information set Ω_t) in (1) instead of current inflation and output gap. The information set Ω_t consists of a broad array of information (beyond lagged inflation and output) to form beliefs about the future conditions of the economy. This is consistent with the RBI's multiple indicator approach to monetary policy.

In estimating forward looking policy reaction function, we use realised future inflation and output gap as proxies for expected inflation and output gap. In this case, however, regressors will be correlated with the error term which includes expectational error. In a rational expections framework, this expectaional error is uncorrelated with the information set Ω_t at time t. These act as instruments satisfying a set of orthogonality conditions, which provide the basis for the estimation of the parameter vector $(\alpha, \beta, \gamma, \rho)$ using Generalised Method of Moments estimator (Hansen, 1982).

[10] For robustness we also used the weighted average overnight call money rate in place of EPR. We also experimented with alternative inflation measures in this specification. CPI(IW) inflation turned out be insignificant. Further, we augmented the specification to include exchange rate, but found its coefficient insignificant. The estimate of ρ coefficient (indicating policy inertia) was higher for EPR as compared to call rate (see Table 1).

Our estimates based on both contemporaneous and forward looking policy reaction function for both effective policy rate and call rate for the sample period 2001Q2:2009Q4 are shown in Table 1.

Table 1: Estimates of Taylor Rule

Dependent Variable	Call Rate		Effective Policy Rate	
Regressors	Contemporaneous	Forward-looking	Contemporaneous	Forward-looking
Constant	1.72 *(1.99)*	-0.06 *(-0.22)*	0.93 *(2.12)*	-0.51 *(-2.81)*
Inflation	0.19 *(2.30)*		0.12 *(2.44)*	
Inflation (+1)		0.28 *(8.08)*		0.23 *(6.87)*
Output Gap	0.35 *(2.98)*		0.23 *(1.94)*	
Output Gap (+1)		0.13 *(1.80)*		0.13 *(3.31)*
Call (-1)	0.54 *(2.61)*	0.73 *(12.57)*		
EPR(-1)			0.72 *(6.15)*	0.86 *(17.77)*
Adjusted R-squared	0.52	0.45	0.73	0.69
Ljung-Box Q-Stat (16)	0.71	0.11	0.95	0.84
J-Statistic (p-value)		0.93		0.89

Note: 1. Output gap is derived from HP filter and inflation represents year-on-year WPI inflation.

2. Figures in parenthesis are t-statistic based on Newey-West Heteroscedasticity and Autocorrelation Consistent (HAC) robust standard errors.

3. Ljung-Box Q-Stat (16) gives significance level (p-value) for the null of no residual autocorrelation for 16 lags.

4. J-Statistic is the value of the GMM objective function. The reported p-value of the statistic is used as a test of over-identifying moment conditions. For GMM estimation, laggged values of call rate, effective policy rate, WPI inflation, CPI inflation, output gap, exchange rate appreciation/depreciation and rise/fall of average world crude oil prices were used as instruments.

The parameter estimates are the average policy response (in terms of interest rate decisions) to inflation and output gap for this sample.[11] With actual inflation on average ruling close to the implicit target (of around 5 per cent) during this phase, it appears that these estimates were the optimal policy response to shocks. Reasonably long sample size and sufficient variability in inflation and growth numbers lend credence to these estimates. Therefore, we use these parameter estimates in conjunction with the actual inflation and output gap measures for the sample 2010Q1:2013Q1 to arrive at the policy rule suggested rates (or implied rates) for the latter sample. Of course, we have three implied rates based on alternative measures of the output gap (HP, BN and BQ SVAR). These implied rates are the benchmark against which we assess the stance of monetary policy during 2010Q1:2013Q1, the period associated with high and persistent inflation. We plot the actual and implied rates for call and effective policy rates in Figure 7.

In each of the graphs, the actual policy rate is represented by the blue line and the three implied rates are red (when output gap is based on HP filter), green (when output gap is based on BN decomposition) and black (when growth gap is based on BQ SVAR), respectively. It can be seen that the actual policy rate consistently undershot the implied rates except at the fag end of the sample under study. It is no surprise that the implied rates based on the estimated output gap from HP method turn out to be lower than those based on BN and BQ methods since mid-2011. During this period, GDP growth started losing steam with the estimated output gap based on HP method quickly turning negative implying a lower desired policy rate. On the other hand, despite significant growth slowdown, the estimated output gap based on BN and BQ methods remained positive throughout, pointing to the need for a tighter policy.

[11] The forward –looking policy reaction function satisfies the Taylor Principle (i.e., policy response does not accommodate expected inflation) consistent with a recent study on interest rate rules in the Indian context (see Patra and Kapur, 2012).

Clearly the implied rates differ on account of alternative estimates of the output gap. Which implied rate(s) or output gap estimates are we to rely on? One possibility is to look at the predictive power of alternative estimates of the output gap for future inflation. We begin by examining the correlation between inflation and alternative estimates of the output gap in Table 2. We find that while output gap estimates (both contemporaneous as well as lagged) based on BN and BQ are strongly correlated with WPI inflation, those based on HP filter are far less so for the sample 1998Q4:2013Q1.

Next, we generate recursive one-step ahead forecasts of inflation using alternative measures of output gap using a standard Phillips curve model for inflation. We compare their forecast accuracy using root mean squared error (RMSE) criterion. We find that among the alternative output gap estimates, the lowest RMSE is obtained for estimates based on the BQ method for the (forecast) sample 2010Q1:2013Q1.[12] Intuitively, methods which make use of an inflation equation (such as BN and BQ methods) are likely to track inflation better as against univariate HP method. Therefore, implied rates based on BN and BQ output gaps estimates may score over those based on HP output gap estimates in providing the appropriate guidance for policy.

Notwithstanding the debate about which output gap estimate to rely on and the fall out of that on the estimates of the implied rate, the

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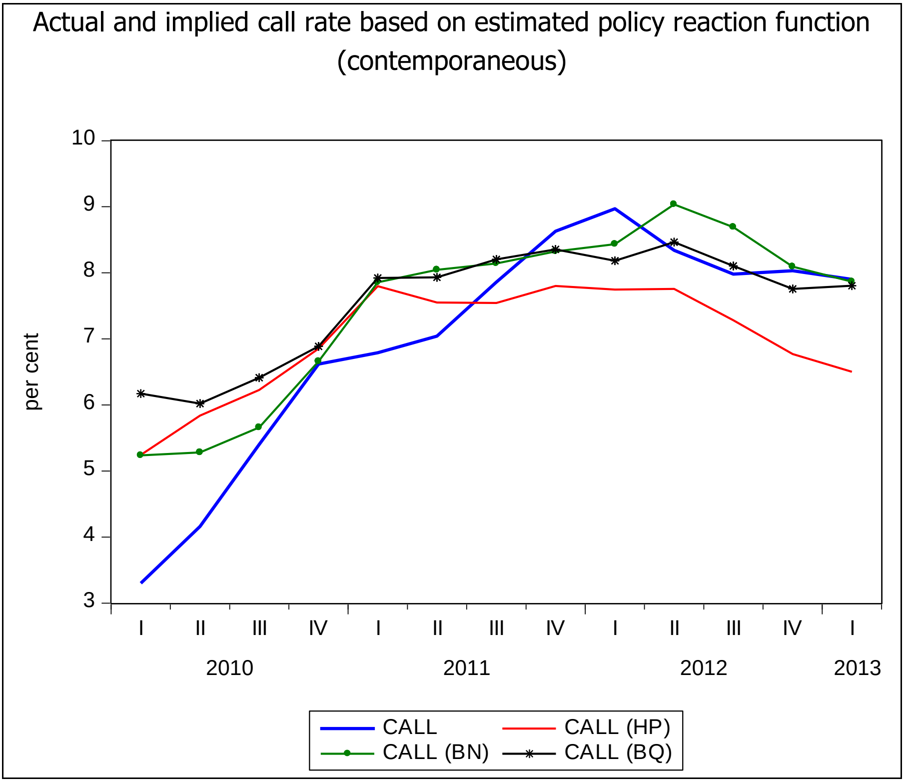
[12] We estimate the following Phillips curve specification:

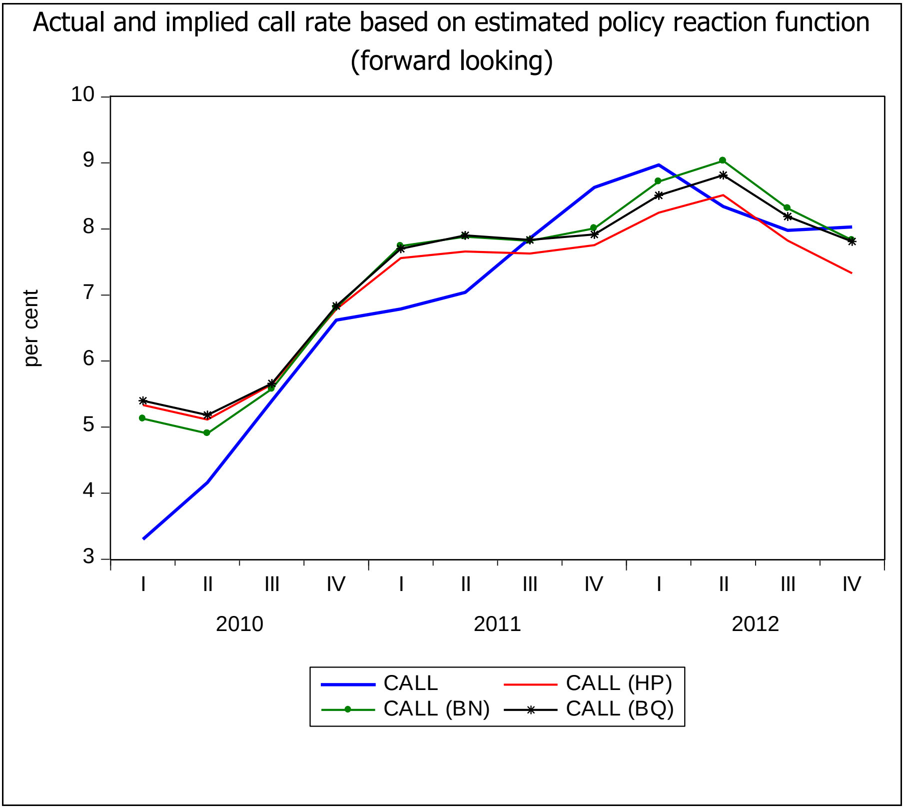
$$\pi_t = \alpha + \sum_{j=1}^{2} \rho_j \pi_{t-j} + \sum_{j=1}^{2} \gamma_j \tilde{y}_{t-j} + \sum_{j=0}^{1} oil_{t-j} + \varepsilon_t$$

, where π is quarter-on-quarter inflation, $\tilde{y}$ is alternative output gaps and *oil* is quarter-on-quarter changes in international oil prices. RMSE of inflation forecast during 2010Q1-2013Q1 based on alternative output gaps were found to be 0.0078 for HP, 0.0094 for BN and 0.0072 for BQ. For a somewhat larger forecast sample 2007Q1:20131Q1, these were 0.0111 for HP, 0.0120 for BN and 0.0107 for BQ. For the forecast sample 2007Q1:2013Q1, the Diebold and Mariano's (1995) test for the equality of forecast accuracy suggests that the forecast errors associated with BQ output gap estimate is statistically lower than those for HP output gap estimate.

gap between the actual and implied rates is telling especially during 2010 and 2011. It is broadly clear that the monetary policy tilted on the accommodative side for much of 2010, 2011 and 2012 in comparison to its own past standards encapsulated in the policy reaction function estimates for 2001Q2:2009Q4. In other words, had the RBI responded to inflation and the output gap the way it did in 2001Q2:2009Q4 (see Table 1), this would have meant much higher policy rates during the latter phase. This meant that by the time monetary policy was tightened, high inflation expectations had already become firmly entrenched.

Figure 7: Actual And Implied Rates Suggested By the Taylor Rule




Actual and implied call rate based on estimated policy reaction function
(forward looking)
per cent
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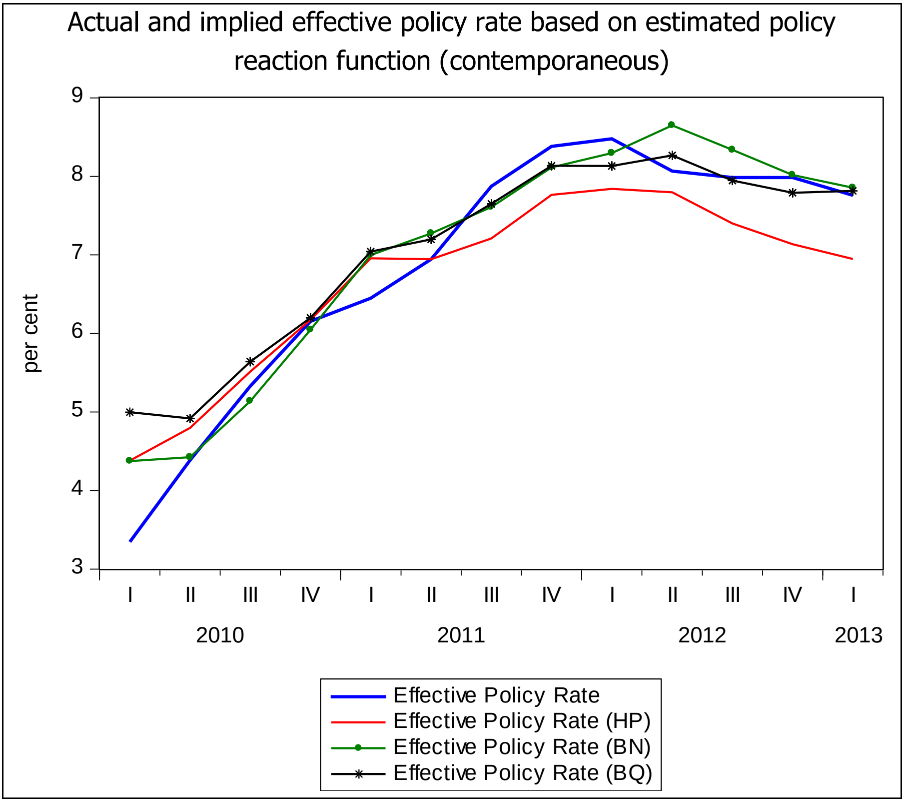
2012
CALL
CALL (HP)
CALL (BN)
CALL (BQ)


Actual and implied effective policy rate based on estimated policy reaction function (contemporaneous)
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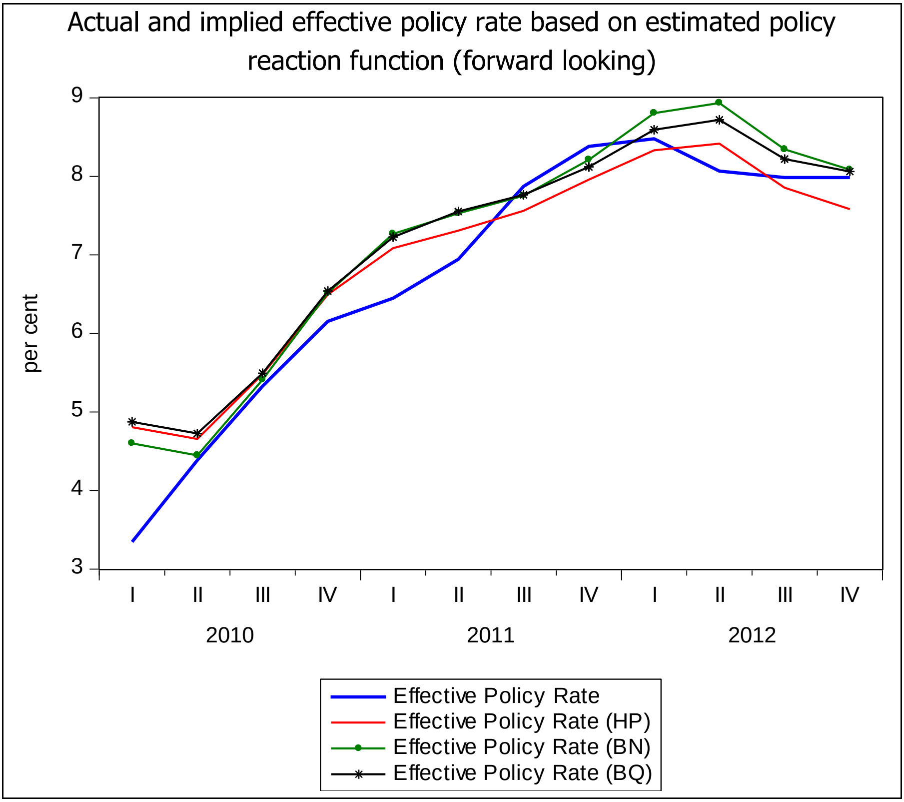

Actual and implied effective policy rate based on estimated policy reaction function (forward looking)
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I II III IV I II III IV I II III IV
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2011
2012
Effective Policy Rate
Effective Policy Rate (HP)
Effective Policy Rate (BN)
Effective Policy Rate (BQ)

Table 2: Correlation Between Inflation and Output Gap

(Sample: 1998Q4:2013Q1)

Correlation↓→	HP Gap	HP Gap (-1)	BN Gap	BN Gap(-1)	BQ Gap	BQ Gap(-1)
WPI Inflation (y-o-y)	0.16 *(0.22)*	0.31 *(0.02)*	0.55 *(0.00)*	0.45 *(0.00)*	0.33 *(0.01)*	0.51 *(0.00)*

Note: Figures in parentheses are probability value for |t| = 0.

CONCLUSION

From 2003, the Indian economy enjoyed a boom in growth coupled with moderate inflation for five years. The economy grew at a rate close to 9 percent per year, until it was punctured by the global financial crisis of 2008. Since then, the persistence of inflation in an environment of falling economic growth has come out as a "puzzle" to policymakers' and many in the financial market.

But there isn't one. There were two important policy errors that have brought us to this point. The rapid deterioration in public finances in response to the global economic crisis while stimulating demand temporarily managed to pull down the potential growth rate of the economy. The RBI compounded the problem by being sluggish and soft on inflation after the economy bounced back from the effects of the global economic crisis because it systematically overestimated the potential growth rate of the economy. This meant that by the time monetary policy was tightened, high inflation and inflation expectations had already become entrenched. That is why the current growth slowdown has not been disinflationary.

TECHNICAL APPENDIX

Hodrick-Prescott Filter

The Hodrick-Prescott Filter is a widely popular smoothing technique to obtain the trend (and cyclical) component of a time-series. The trend component y_t^τ of y_t is derived from minimising the following objective function:

$$\sum_{t=1}^{T}(y_t - y_t^\tau)^2 + \lambda\sum_{t=2}^{T-1}\{(y_{t+1}^\tau - y_t^\tau) - (y_t^\tau - y_{t-1}^\tau)\}^2$$

, where λ controls the smoothness of the trend component y_t^τ. Note that λ is the penalty parameter for non-smoothness of the trend component, captured by the square of the second difference of y_t^τ. It is easy to see that as λ becomes larger, the trend will become smoother while exaggerating the cyclical component. As $\lambda \rightarrow \infty$, y_t^τ approaches a linear trend. On the other hand if $\lambda = 0$, *i.e.,* no penalty for non-smoothness of the trend, the objective function is minimised with $y_t^\tau = y_t$ for $t = 1,..T$, with no cycle in the series. The arbitrariness in the choice of λ makes the trend subjective. If appropriate λ is not applied, then this can lead to spurious cyclicality with integrated or nearly integrated time series and an excessive smoothing of structural breaks. Unlike HP filter, which is a high-pass filter (removes lower duration cycles from the data), the Baxter-King and Christiano-Fitzgerald are the frequency (Band-Pass) filters which usually assume that a cycle lasts from 1.5 to 8 years. Once cycles in this band are passed through the data (hence the name Band Pass), and what is left is the trend component.

Beveridge-Nelson Decomposition

Consider an integrated time series z_t that can be most accurately forecast using a stationary univariate AR(1) model for its first differences:

$$(\Delta z_t - \mu) = \varphi(\Delta z_{t-1} - \mu) + \varepsilon_t \qquad (A.1)$$

where $\varepsilon_t \sim i.i.d. N(0, \sigma^2)$ and $|\varphi| < 1$. It is easy to show that the minimum mean squared error (MSE) j-period ahead forecast of the first difference is:

$$E_t\left[\left(\Delta z_{t+j} - \mu\right)\right] = \varphi^j \left(\Delta z_t - \mu\right) \qquad (A.2)$$

The BN trend (BN_t^{τ}) is defined as the minimum MSE forecast of the long-run level of the series (minus the deterministic drift) or, equivalently, the present level of the series plus the infinite sum of the minimum MSE j-period ahead first difference (mean deviation) forecasts:

$$BN_t^{\tau} \equiv \lim_{J\to\infty} E_t\left[z_{t+J} - J.\mu\right] = z_t + \lim_{J\to\infty} \sum_{j=1}^{J} E_t\left[\left(\Delta z_{t+j} - \mu\right)\right] \quad (A.3)$$

Substituting (2) in (3), BN trend of z_t , *i.e.,* BN_t^{τ} for AR(1) process is:

$$BN_t^{\tau} = z_t + \frac{\varphi}{(1-\varphi)}(\Delta z_t - \mu) \qquad (A.4)$$

which means that the trend is the present level of the series plus the long-run impact of the transitory momentum in the series given by the deviation of Δz_t from its steady state level μ. The long-run impact is determined by the AR(1) model in this example. Finally, the cycle is given by $-\frac{\varphi}{(1-\varphi)}(\Delta z_t - \mu)$.

The univariate example given above can be easily extended to the multivariate space following Morley (2002). Suppose, we have now a vector of variables Z_t most accurately forecast by say a VAR model of $(\Delta Z_t - \mu)$. $(\Delta Z_t - \mu)$ can be written as linear combination of the elements of a $k \times 1$ state vector X_t. Therefore $(\Delta Z_t - \mu) = HX_t$. Suppose, X_t

evolves as a VAR(1) process (note that any VAR(*p*) model can be written as VAR(1) model).

$$X_t = FX_{t-1} + \nu_t \qquad (A.5)$$

where $\nu_t \sim N(0, \Omega)$ and the eigenvalues of F are less than one in modulus. Then, one can show that the minimum MSE j-period ahead forecast of the first difference $(\Delta Z_{t+j} - \mu)$ is:

$$E_t\left[\left(\Delta Z_{t+j} - \mu\right)\right] = HF^j X_t \qquad (A.6)$$

Therefore, the BN trend of Z_t BN_t^τ can be written as:

$$BN_t^\tau = Z_t + HF(I-F)^{-1}X_t \qquad (A.7)$$

While BN trend is the permanent component and the residual cyclical component is the transitory component of Z_t.

Blanchard and Quah (1989) Structural VAR

Blanchard and Quah provide an alternative way to obtain a structural VAR for decomposing real GNP into its temporary and permanent components. In their model, real GNP is affected by demand-side and supply-side disturbances. In accord with the vertical long run aggregate supply curve, demand-side disturbances have no long-run effect on real GNP. On the supply side, productivity shocks are assumed to have permanent effects on output. Blanchard and Quah use a bivariate VAR model consisting of two variables – real GNP and unemployment. In this paper, we deviated from their set up only in replacing the unemployment variable by WPI.

Real GDP and WPI are I(1) variables. Real GDP, therefore, has a permanent component, which can be identified using the structural VAR approach. We first difference both the series to construct $\Delta x_t = (\Delta y_t, \Delta p_t)$, where y_t, p_t stand for natural log of real GDP and WPI, respectively. Suppose the vector Δx_t has moving average structural representation given by:

$$\Delta x_t = C(L)u_t \qquad (A.8)$$

where $C(L)$ is a 2×2 matrix where each term $C_{ij}(L)$ are polynomials in the lag operator L. u_t is a vector of exogeneous, unobserved pure structural shocks (u_t^y, u_t^p) where u_t^y is the supply or permanent shock and u_t^p is the demand or transitory shock. These shocks are serially uncorrelated and have a variance-covariance matrix normalised to the identity matrix. Since the vector of structural shocks is not observed directly, the objective is to recover u_t by estimating an unrestricted VAR, which can be inverted to yield the moving-average representation:

$$\Delta x_t = A(L)e_t \qquad (A.9)$$

The first matrix in the polynomial $A(L)$ is the identity matrix and e_t is a vector of reduced form residuals with the variance-covariance matrix Σ. The critical insight is that the VAR residuals e_t are composites of the pure innovations or structural shocks u_t. Equation 8 and 9 imply a linear relationship between the reduced form residuals and the shocks of the structural model:

$$e_t = C_0 u_t \qquad (A.10)$$

It is necessary to identify the 2×2 matrix C_0 to be able to recover the vector of structural shocks u_t from the estimated reduced form error vector e_t. The symmetric matrix $\Sigma = C_0 C_0^{'}$ imposes three of the four restrictions that are required, and therefore we need just one more identifying restriction. Following Blanchard and Quah (1989), we impose the restriction that u_t^p as the demand or transitory shock does not affect the level of output in the long run. With this, the four restrictions in four unknowns enable identification of C_0.

The long-run representation of equation 8 can be written as:

$$\begin{bmatrix} \Delta y \\ \Delta p \end{bmatrix} = \begin{bmatrix} C_{11}(1) & C_{12}(1) \\ C_{21}(1) & C_{22}(1) \end{bmatrix} \begin{bmatrix} u^{y} \\ u^{p} \end{bmatrix} \qquad (A.11)$$

where $C(1) = \sum_{j=0}^{\infty} C_j$ is the long-run impact matrix of u on Δx. We have imposed the long-run restriction that $C_{12}(1) = 0$. The restriction implies that in the long-run, output is affected only by supply shocks. The residuals from the unrestricted VAR and the estimated parameters of C_0 can be used to construct the vector of exogeneous structural shocks (see equation 10). Since potential output corresponds to the permanent component of output in the system, the equation for change in potential output can be derived as the accumulated supply shocks alone (ignoring the demand shocks):

$$\Delta y_t^{\tau} = \sum_{k=0}^{\infty} c_{11}(k) u_{t-k}^{y} \qquad (A.12)$$

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