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Abstract

We estimate the unobserved time-varying natural interest rate (NIR) and potential output for the Indian economy using the Kalman Filter. Estimation is a special challenge in an emerging market because of limited length of data series and ongoing structural change. A key result in the literature is the NIR is imprecisely estimated. Structural aspects of the economy used in our estimation turn out, however, to improve the precision of the NIR estimates, although potential output continues to be imprecisely estimated. Turning points are well captured and estimates obtained for the output gap elasticity of aggregate supply and the interest elasticity of aggregate demand.The estimated NIR is used as an indicator of the monetary policy stance, which is found to be broadly contractionary and procyclical for the period under study.

Keywords: Natural interest rate; potential output; Kalman filter; monetary policy

JEL Code: E32, E43, E52

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Estimating the Indian Natural Interest Rate and Evaluating Policy

1 Introduction

We estimate the unobserved time-varying natural interest rate (NIR) and potential output for the Indian economy for the period 1990Q2-2011Q4 using the Kalman Filter. While there is a literature on such estimation[1], estimating the NIR for an emerging market (EM) poses special challenges because of limited length of data series and ongoing structural change.

A key result in the literature is the NIR is imprecisely estimated. But it turns out structural aspects of an EM, such as the impact of food price inflation, used in our estimation improve the precision of the NIR estimates, although potential output continues to be imprecisely estimated. Turning points are also well captured, and insights obtained on the structure of aggregate demand and supply.

The combination of maximum likelihood estimation and parameter calibra-

[1]For example, Laubach and Williams, 2003, (LW) Mesonnier and Renne, 2007 (MR), Orphanides and Williams (2002), Rudebusch (2001), Fabiani and Mestre (2001).

tion shows theoretical and empirical consistency is best attained when the output gap elasticity of aggregate supply (AS) is low (0.13) and interest elasticity of aggregate demand (AD) is in line with international estimates (-0.21). As noted in the literature, estimating interest elasticity in a specification, which uses the excess of the policy rate over the NIR or the interest rate gap (IRG) tends to raise interest rate elasticity compared to one with only the interest rate as an argument. The interest elasticity of Indian AD has not yet, to our knowledge, been estimated using an IRG.

The estimated NIR is used as an indicator of the monetary policy stance. We find monetary policy stance to be broadly contractionary for the period under study, since the real interest rate mostly exceeded the NIR. Policy also tended to miss turning points and to be procyclical.

The NIR is the real short-term interest rate, consistent with a zero output gap and a constant rate of inflation. That is, the natural rate is the real rate of interest that keeps AD equal to the natural or potential output. Since an output gap affects inflation, the latter reaches its steady-state value with a zero output gap. Output is at its potential when the real marginal cost of supplying each good equals the marginal revenue for any firm that is thinking of changing its price, when all firms charge identical prices. But when this condition holds no firm wants to charge a different price, so inflation is either zero or equal to an expected trend rate. These results follow from firms' optimization[2].

[2]Woodford (2003) extended the early Wicksellian notion by developing these microfoundations. As in the Wicksellian concept, a deviation of the policy or short-term rate from the natural rate, implies macroeconomic disequilibrium manifested in inflation or

Basic consumer optimization tells us that the steady-state real interest rate is given by consumer preferences and the rate of growth of consumption. The NIR deviates from its steady-state value when real disturbances change the natural output. The generic disturbances that affect natural output can be divided into two sub-groups 1) those affecting demand, and therefore requiring variation in log output to maintain a constant marginal utility of real income, and 2) those affecting supply and therefore requiring variation in log output to maintain a constant marginal disutility of labour supply.

The first category includes normalized deviation of government purchases from their steady-state level, and shifts in consumer preferences. Shocks to technology and to labour supply due to shifts in the disutility of labour function, are in the second, or supply shock, category. The result is the NIR rises for any temporary demand shock and falls for any temporary supply shock. Given these shocks, the change in natural output depends on consumers' intertemporal elasticity of substitution (IES), and the elasticity of real marginal cost with respect to firms' own output.

Optimal policy requires insulating the output gap from these shocks, so that the policy rate should move in step with the natural rate. Thus policy should accommodate supply shocks by lowering interest rates and offset demand shocks by raising interest rates. The required interest rate variation is higher the more temporary the shock[3]. The monetary stance can be inferred

deflation.

[3]Most Central Banks prefer to smooth policy rates, which may reduce the optimal

from the IRG. That is, if the policy rate exceeds the NIR, monetary policy is tight and vice versa if the policy rate is below the NIR.

In advanced economies (AEs) log linear approximations of equilibrium conditions are adequate for analysis since the policy focus is on small fluctuations around a steady state. But in EMs, NIR estimation requires attention to be paid to structural change and to multiple steady states on the transition path towards becoming an AE.

One strand of NIR estimation derives from dynamic stochastic general equilibrium (DSGE) models for AEs, where the emphasis is on high frequency or short-run movements of the NIR that continuously equate aggregate demand with potential output. Another strand, following Laubach and Williams (LW) (2002) is semi-structural. It uses a combination of theory and estimation since it combines an AD and a Phillips or AS curve [4] with Kalman Filter estimates of unobserved variables such as trend growth, natural output and interest rates. The estimated NIR is identified as that which keeps output at potential and therefore inflation stable in the medium-run when the effects of shocks have worn off. Inflation may be stable even with a widening output gap if prices are preset (Mesonnier and Renne) (MR) (2007). The maximum likelihood parameter estimation is consistent with the theoretical relationship between inflation and output and actual fluctuations in these variables. It picks up large low-frequency movements and structural changes in the NIR, and is thus more suited to economies in transition. Our esti-

policy response to a temporary shock.

[4]The term aggregate supply is more appropriate since we work with the output gap rather than the unemployment gap.

mation follows this approach. The specific structural aspect captured is the special impact of food price inflation in an EM where food forms a large part of the consumption basket [5].

We also draw on the literature on Bayesian estimation of New-Keynesian (NKE) models. This lies between classical estimation and calibration. It puts more theoretical structure than classical pure data-based estimation such as variance auto-regression (VAR) approaches. It therefore avoids the price puzzles that arise in VAR because the absence of behavioural constraints prevents proper identification in a simultaneous equation structure (Carabenkiov et. al. 2008). And it is consistent with the data, unlike calibration in pure theory-based DSGEs. Data consistency in such estimations is sometimes achieved by relaxing model consistency on the basis of experts' judgement calls. A common method of reducing forecast errors in such NKE models is specifying and estimating a flexible and rich set of stochastic processes. The underlying theoretical discipline and the modelling of rational expectations based on forward-looking maximization remains, even as relevant frictions are incorporated.

We also use results and calibrations from a small open emerging market (SOEME) DSGE (Goyal 2011) to estimate the shocks to the NIR. In the model, two types of labour reconcile a large share of less productive labour in the process of being absorbed into the modern sector, with the optimizing labour supply decisions typical of DSGE models. There are also two

[5] See Goyal and Tripathi (20112) for formal analysis of the wage-price cycle triggered by food inflation.

types of consumers, those at subsistence and those smoothing consumption at international levels. This captures consumption heterogeneity and exclusion from capital markets. These aspects help adapt the estimated model to make it more suitable for an economy under transition, which is modelled as all consumers reaching the international consumption level. Subsistence consumption and the gap from world income levels, tend to raise natural output in an EM because of potential catch-up, while technology and infrastructure backwardness reduce it. Trend rates of growth are driven by catch-up in all these dimensions.

Shocks to trend growth follow an independent first-order autoregressive process. For stability, the respective autocorrelation coefficients must each be less than unity. Among the standard shocks affecting the NIR, technology shocks due to catch-up are highly persistent. Since only part of the economy is linked to the external world, the impact of shocks to external output is reduced. Calibrations show temporary shocks to subsistence consumption, therefore, have the largest size among shocks affecting the NIR and tend to reduce it (Goyal, 2009). A fall in the subsistence consumption level serves as a negative demand shock, as demand for industrial mass consumer goods reduces. It also serves as a positive supply shock as willingness to supply labour to maintain consumption rises.

The paper is structured as follows: section 2 presents the model and data, section 3 discusses estimation issues and results, section 4 analyses monetary policy stance for the period of study and section 5 concludes.

2 Model and data

Our state-space model has two observation equations and three transition equations. Output, core inflation, interest rate, food and oil price inflation are observed series. The unobserved series that are to be inferred from these are NIR, potential output, and its trend growth rate.

Output (y_t) is defined as deseasonalised log real gross domestic product at factor cost (base: 2004-05)[6], real interest rate (r_t) is real call money rate calculated after subtracting one period ahead core inflation from the nominal call money rate ($i_t - \pi_{t+1}^{core}$), π_t^{core} is quarterly non-food manufacturing inflation, π_t^{food} is log quarterly food inflation, smoothed using a 3-period moving average, and π_t^{oil} is log quarterly domestic petroleum products inflation. Inflation figures are derived from wholesale price index, all commodities (WPI) with base 2004-05. The time period extends from 1990Q2 to 2011Q4, that is, 84 observations. The model equations are presented and discussed below.

Observation equations:

$$\widetilde{y_t} = \alpha_1 \widetilde{y_{t-1}} + \alpha_2 \widetilde{y_{t-2}} + \phi(r_{t-1} - r_{t-1}^*) + e_y \quad (1)$$

Output gap, $\widetilde{y_t}$, as defined as $(y_t - y_t^*)$ where $y*$ is potential output. The output gap is a function of two lags of its own and one lag of the real interest rate gap. It is a reduced form of the AD or IS curve. We have erred on the

[6]For the output series, values before 1996 were made available by Mr. Ramesh Kohli, who retired as Additional Director General, Central Statistics Office, New Delhi. We thank him for his help.

side of not including too many lags to save degrees of freedom.

$$\pi_t^{core} = \beta_1 \pi_{t-1}^{core} + \beta_2 \widetilde{y_{t-1}} + \beta_3(\pi_t^{food} - \pi_t^{core}) + \beta_4(\pi_{t-1}^{oil} - \pi_{t-1}^{core}) + e_{pi} \quad (2)$$

This equation can be interpreted as a standard backward-looking AS equation or Phillips curve. We estimate core inflation in this equation. It is a function of one lag of its own, one lag of output gap, current period relative food inflation, and last period's relative oil inflation. The observation equations identify the NIR as the rate that closes the output gap and keeps inflation at a constant rate.

Transition equations (3), (4) and (6) model the unobserved variables:

$$y_t^* = y_{t-1}^* + g_{t-1} + e_{y^*} \quad (3)$$

Potential output is a function of its own lag and trend growth rate.

$$g_t = g_{t-1} + e_g \quad (4)$$

Trend growth rate follows a random walk process. We allow for covariance between shocks to output gap and to trend growth rate (γ), which is also estimated.

Theoretical determinants of the steady-state NIR, rr^*, which is obtained by consumer intertemporal utility maximization, are:

$$rr_t^* = \frac{1}{\sigma_r} g_c + \theta \quad (5)$$

The steady-state NIR equals the representative consumer's time discount rate, θ, plus the rate of growth of consumption multiplied by the coefficient of risk aversion (inverse of the intertemporal elasticity of substitution,

σ_r, (IES)). NIR changes with shocks to growth and to consumer preferences.

We model NIR itself then as a function of trend growth rate and residual relative food inflation, that is food inflation that does not affect aggregate inflation in the AS curve (2). The latter is used since Goyal (2009) finds shocks to subsistence consumption have the largest impact on the NIR in an EM. A sharp rise in relative food prices, that is not passed on in wage increases, has a large impact on subsistence consumption. Therefore in equation (6) these negative shocks are proxied by a share (ψ) of food inflation that is not passed on to general inflation. The reasoning is, to the extent nominal wages rise in response to inflation, they protect subsistence consumption, but also pass food price shocks into general inflation.

The impact of the excess of food price inflation over general inflation, on core inflation, is estimated in equation (2). So one minus this estimated coefficient proxies shocks to NIR due to subsistence consumption. Relative food prices are volatile so the restriction $\psi < 1$ reduces their impact on r_t^* reflecting a general preference for smoothing rates.

$$r_t^* = \omega g_t - \psi(1 - \beta_3)(\pi_t^{food} - \pi_t^{core}) \tag{6}$$

During catch-up the consumption growth rate is normally lower than the trend output growth rate (equation (4)) because of the larger share of investment in such an economy. So ω multiplying the trend rate of growth in equation (6) can be expected to be less than unity although the IES is low in an EM[7].

NIR is identified by the output gap eventually going to zero if real interest rate is equal to natural interest rate ($r_t = r_t^*$) in equation (1). Given the non-linear structure of state space models to be estimated, our observations are few, especially compared to studies for AEs. In all Kalman Filter based NIR estimations it is necessary to calibrate some parameters. In addition to such calibration, cross correlations across shocks were found to ease convergence. Sensitivity analysis with values ranging from high to low helped identify the best fit calibrations.

3 Estimation

The equations specified in the previous section can be written in a state-space form and the parameters estimated by maximizing the likelihood function provided by the Kalman Filter. This gives the best linear unbiased estimate of the state variables. We present results of the smoothed series, which is a two-sided estimate and uses information from the whole sample [8].

However, as noted in the literature (LW, MR), problems often arise in direct

[7] Lack of analysis on transition results in uncritical application of frameworks that are more appropriate for mature economies. For example, Mohan (2007, pp.5) then deputy governor of the Indian Reserve Bank, wrote since GDP growth averaged 8.6 per cent per annum over 2003-04 to 2006-07, significantly higher than world economic growth, so Indian equilibrium real interest rates would exceed world interest rates.

[8] The Marquardth algorithm provided by Eviews is applied to get the ML estimator of the parameters.

estimation through the maximum likelihood (ML) function, for coefficients or innovations linking two unobserved variables. For example:

1. In equation (6), ω is difficult to estimate as it relates two unobserved series, g_t and r_t^*. Estimation is ambitious especially given the small size of our sample. But the theoretical restrictions and EM structure discussed above suggest calibrations for ω.

2. The standard deviation of $\widetilde{y}$, σ_y, turns out to be centered around zero. This pile up problem commonly arises in separating the innovations of non-stationary unobserved variables. Therefore calibration of the ratio of standard deviations (s.d.) of shocks e_g and e_y, σ_g/σ_y, is required.

3. Estimation of coefficient ψ in equation (6) is also difficult. But again theory and structure suggest possible calibration. Since food price shocks tend to be volatile, they need to be moderated when being used as a proxy for shocks to subsistence consumption. Their persistence should also be taken into account. They are likely to be more persistent the higher is their impact, β_3, on core inflation.

4. There were some issues in convergence, so that additional structure had to be imposed as suggested by Carabenciov et.al.(2008). Past experience and the knowledge of the economy's structure suggested imposing a negative covariance between shocks associated with y_t and π_t, since shocks that raise costs and prices also tend to reduce demand. This calibration made convergence issues disappear to a great extent.

As a result, along with ω and ψ, we also calibrate the following parameters:

$$\frac{\sigma_g}{\sigma_y} = \sigma \tag{7}$$

$$cov(e_y, e_{pi}) = \zeta \tag{8}$$

Parameters values ranging from high to low are applied, within theoretical restrictions, for robustness cum sensitivity analysis. For example, consider the calibration of ω in equation (6).

Table 1 reports results of regressions with the different parameter values.

Table 1: Parameter estimates for different specifications

Specification	I	II	III	IV	V	VI	VII	VIII	IX
Parameters	ω =0.7	ω = 0.7	ω = 0.7	ω = 0.7	ω =0.7	ω = 0.7	ω = 0.7	ω = 0.2	ω = 1.2
	σ = 0.4	σ = 0.4	σ = 0.4	σ = 0.4	σ =0.4	σ =0.8	σ =1.2	σ =0.4	σ = 0.4
	ζ = -0.65	ζ = -0.65	ζ = -0.65	ζ = -0.25	ζ =-0.90	ζ =-0.65	ζ = -0.65	ζ = -0.65	ζ = -0.65
	ψ = 0.2	ψ = 0.5	ψ =0.8	ψ = 0.5	ψ =0.5	ψ = 0.5	ψ = 0.5	ψ= 0.5	ψ = 0.5
α_1	0.99***	0.64***	0.54***	0.99***	0.93***	0.21***	0.13***	0.58***	0.43***
α_2	-0.36***	-0.26***	-0.45***	-0.11***	0.06***	0.57***	-0.53***	-0.40***	-0.72***
ϕ slope	-0.21***	-0.02***	-0.07***	-0.18***	-0.27***	-0.48***	-0.29***	-0.37***	-1.78***
β_1	0.98***	0.97***	0.70***	0.37***	-0.39**	0.45***	0.86***	0.91***	0.79***
β_2 slope	0.13***	0.38***	0.06***	-0.53***	0.33***	-0.17***	0.05***	0.30***	0.10***
β_3	0.10**	0.02	0.11	0.11***	0.04	0.13**	0.11	0.15	0.26***
β_4	0.02***	0.03	0.04**	-0.03**	0.01	0.002	-0.01	0.02	0.00***
γ	2.15e-05	-0.003***	-0.01***	0.002***	-0.00	0.02***	-0.13***	-0.003***	0.009
s.d(e_y)	0.14***	0.13***	0.09***	0.08***	0.13***	0.7***	0.31***	0.18***	0.22***
s.d(e_{pi})	4.7538***	5.60***	5.58***	4.02***	5.32***	4.33***	4.04***	4.46***	3.60***
s.d(e_{y^*})	0.06***	0.07***	-0.11***	0.03***	0.08***	-0.04***	0.22***	0.20***	0.08***
Log-L	-218.61	-199.85	-206.13	-135.29	-193.89	-217.25	-299.79	-248.14	-272.00

Note: *** significance at 1% level; ** significance at 5% level; * significance at 10% level; s.d: standard deviation

The Ogaki, Ostry and Reinhart (1996) estimates of the IES, in a large cross-country study for EMs, vary from 0.05 for Uganda and Ethiopia to a high of 0.6 for Venezuela and Singapore. This implies the coefficient of constant risk aversion 1/IES, multiplying consumption growth in equation (6), varies between 20 and 1.67. Goyal (2011) takes the IES to be zero for the section at subsistence, and unity for the 40 percent at international consumption levels, giving a weighted average estimate of IES for India of 0.58 implying 1/IES to be 1.7. Taking 40 percent of 1/IES captures the share of per capita consumption growth in trend output growth g. The coefficient of g in equation 6, ω, therefore takes the value 0.7 in our benchmark estimation. Sensitivity analysis is done taking values from 0.2 to 1.2.

IRG, (ϕ) has the correct negative sign, implying a rise in policy rates reduces the output gap. Specifications (such as I) where relative food and oil inflation (β_3 and β_4) have a positive and significant effect on core inflation tend to have a small positive coefficient (β_2) on the output gap in the AS curve and a realistic negative slope (ϕ) of the AD curve. The results imply growth and inflation combinations are better explained by a flatter AS subject to frequent shifts, compared to a steeper AS without significant exogenous shocks. The sensitivity analysis establishes that specification I also better satisfies overall theoretical criteria.

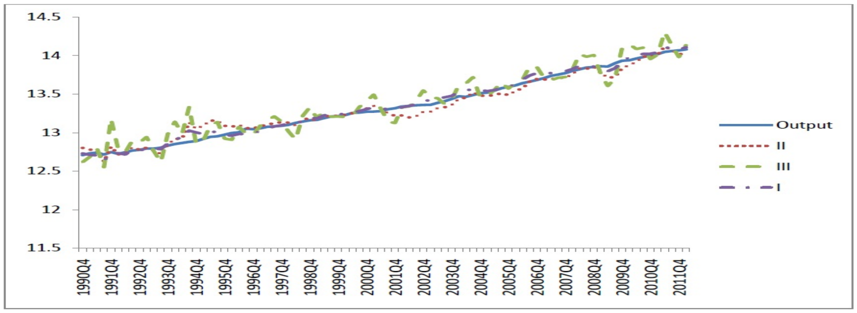
In specification I ($\omega = 0.7, \sigma = 0.4, \zeta = -0.65, \psi = 0.2$), persistence of output gap and core inflation is high. IRG reduces output gap by 0.21 percent quarterly. The value for interest elasticity is close to that obtained in other studies such as LW and MR. As MR point out, a general result is that interest elasticity of output is generally higher when the NIR is included in the estimation of the IS curve, compared to estimations without an IRG but only a real interest rate. Positive output gap increases inflation by 13 basis points–the AS is relatively flat. Both relative food and oil inflation affect core inflation significantly.

In specification II ($\omega = 0.7, \sigma = 0.4, \zeta = -0.65, \psi = 0.5$), we raise the effect of residual relative food inflation on NIR, by raising ψ. This lowers the NIR compared to specification I, thus raising the IRG. As a result, the interest elasticity has to fall steeply to be consistent with the data. The slope of the AS doubles, and β_3 and β_4 both become insignificant. Potential output and inflation estimates of this specification show greater volatility, and the persistence of output gap falls. In specification III ($\omega = 0.7, \sigma = 0.4, \zeta = -0.65, \psi = 0.8$), ψ rises even more. This reduces the persistence of output gap further to 0.54 percent. IRG elasticity rises mildly compared to the previous specification to -0.07 percent. Relative food inflation remains insignificant whereas oil inflation becomes significant, and the slope of the AS falls steeply. The unrealistically low IRG elasticity and the reversal of key AS coefficients across specifications II and III, suggest that the correct value of ψ must be around 0.2.

In specifications IV and V, the value of the ζ parameter, which represents covariance between output gap and inflation, is changed. In specification IV ($\omega = 0.7, \sigma = 0.4, \zeta = -0.25, \psi = 0.5$), a lower ζ value forces a negative slope to the AS even as oil and food relative inflation become significant. A rise in relative oil prices, however, shifts the AS downwards. In specification

V ($\omega = 0.7, \sigma = 0.4, \zeta = -0.90, \psi = 0.5$), with increased covariance value, the effect of both relative food inflation and oil inflation become insignificant, and the slope of the AS rises. The coefficient of lagged inflation in the AS curve becomes large and negative, compared to its positive value in every other estimation. Since historical inflation tends to be persistent, this contrary result, and that of the slope and shift of the AS in specification IV, suggest the correct value of ζ is closer to -0.65.

In specification VI ($\omega = 0.7, \sigma = 0.8, \zeta = -0.65, \psi = 0.5$) and VII ($\omega = 0.7, \sigma = 1.2, \zeta = -0.65, \psi = 0.5$), a rise in the ratio of standard errors σ_g to σ_y, implies a higher variation of trend growth. Intuitively, this reduces the persistence of output gap. The AS slope first becomes negative, and as σ rises further, the slope becomes low positive. Potential output series is most volatile under specification VII. The large variability in the output gap, and sign reversals in the AS slope suggest that around 0.4 is the correct calibration for this ratio.



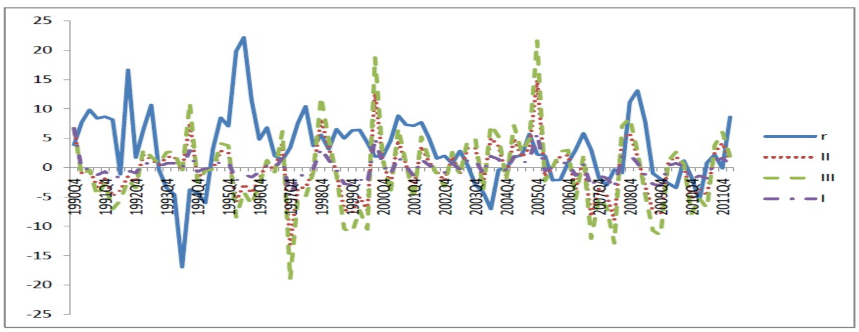


Figure 1: Historical log output (upper figure) and real interest rate (lower figure) with results for log potential output and NIR repectively for specifications I, II and III.

Both specification VIII ($\omega = 0.2, \sigma = 0.4, \zeta = -0.65, \psi = 0.5$), where a fall in ω implies a lower rise in the NIR with growth, and IX ($\omega = 1.2, \sigma = 0.4, \zeta = -0.65, \psi = 0.5$), where a rise in ω implies a greater rise in the NIR with growth, compared to specification II, IRG sensitivity rises to unrealistic levels. It takes the maximum absolute value in specification IX, where 1 percent point increase in IRG reduces output gap by 1.78 percent. This suggests that around 0.7 is the correct calibration for ω.

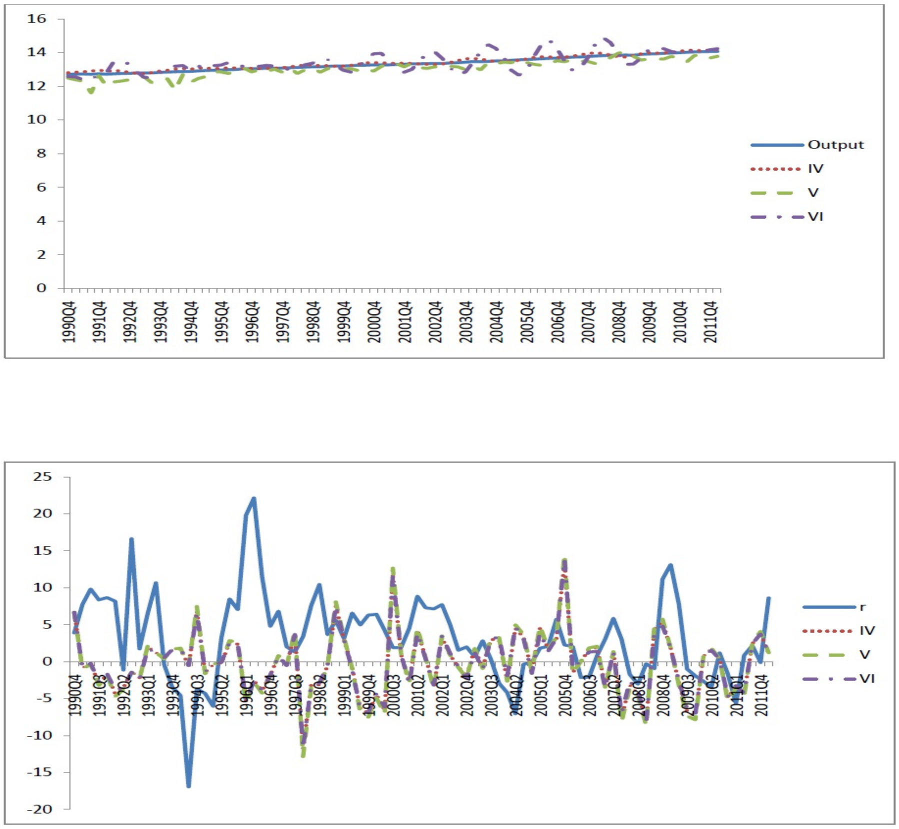


Figure 2: Historical log output (upper figure) and real interest rate (lower figure) with results for log potential output and NIR repectively for specifications IV, V and VI.

The NIR and log potential output obtained in the different specifications are graphed in Figures 1-3. In the light of the sensitivity results the preferred specification, which is most theoretically satisfactory, is specification I.

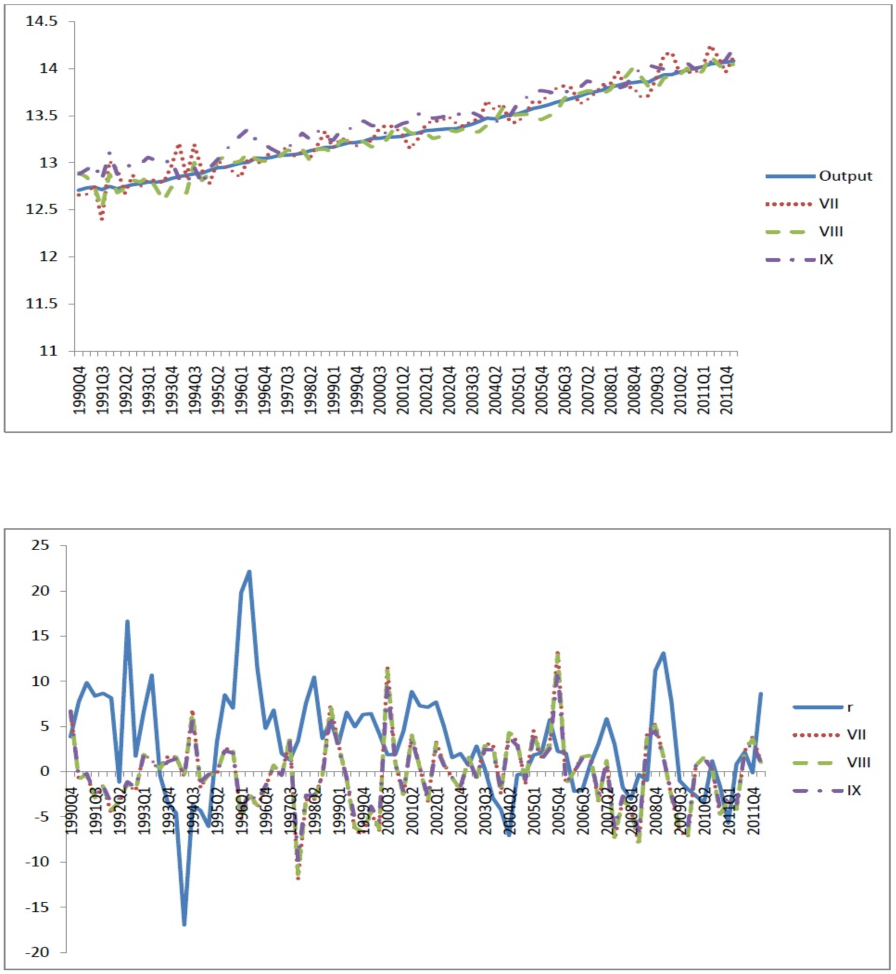


Figure 3: Historical log output (upper figure) and real interest rate (lower figure) with results for log potential output and NIR repectively for specifications VII, VIII and IX.

For robustness, we also ran regressions with a different measure of real interest rate, where it was calculated by subtracting headline inflation instead of core inflation from nominal call money rate. Since headline inflation is the measure of inflation sometimes used by India's Central Bank and implies a lower and more volatile real rate. The results show that IRG comes down when this measure of real interest rate is used. However, results related to monetary policy stance are qualitatively similar.

The estimated NIR is similar across the specifications although they differ in potential output estimate. The NIR is also estimated with high precision, although the potential output has wider error bands (Figure 4). In the literature both are normally imprecisely estimated. The reason for the difference in our result is the use of the estimated coefficient on food inflation in extracting the unobserved NIR. This exploits more information both from data and the structure of the economy. The level of the NIR depends on the proxy used for shocks, but seems to be robust since using a headline based real interest rate did not change the evaluation of the monetary stance. Large fluctuations in the NIR reflect those in real rates.

As MR note, semi-structural approaches have a better ability to capture regime changes and turning points in the economy. The potential output estimates, however, are also driven by medium-run unobserved trends affecting growth rates and therefore are not so precise.

Consider turning points: potential output peaks as expected in 1995, 2008, and 2011. These were peaks in India's output cycle. The estimated NIR is largely positive in the boom years of the mid-nineties and mid-noughties of the new century. It is largely negative during the slowdown of the late nineties. The pattern of the NIR in the period of the global financial crisis implies there were multiple supply shocks. The NIR peaked positive in

2008Q3, 2010Q2 and 2011Q3 but was negative otherwise.

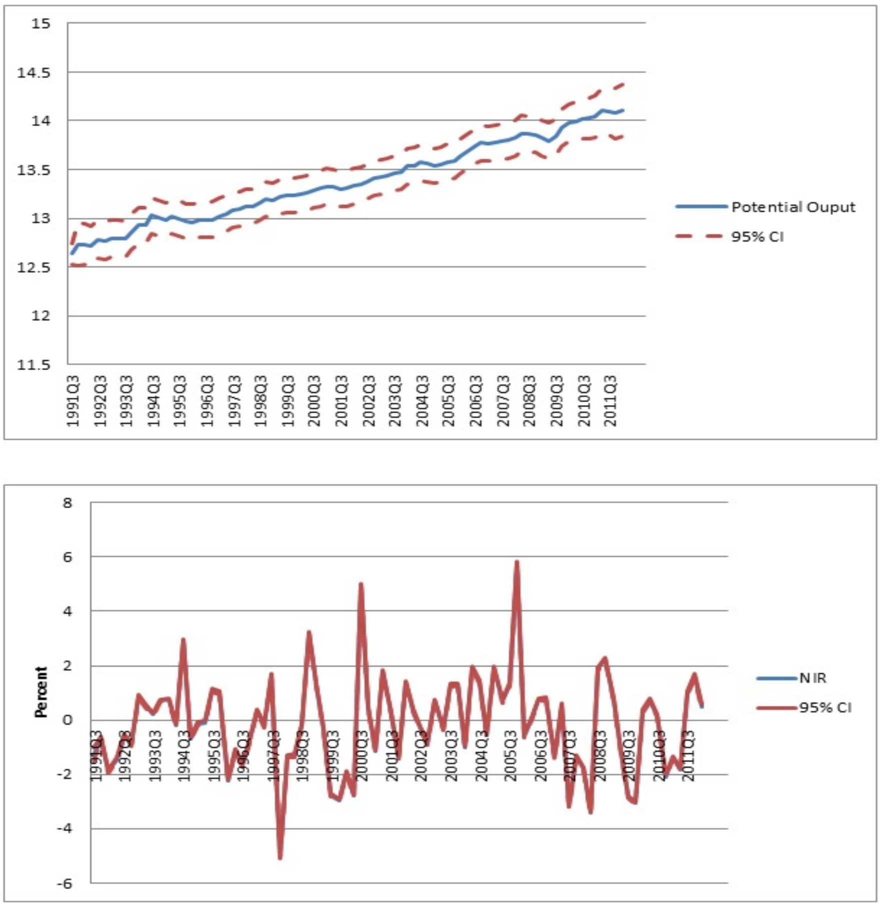


Figure 4: Precision bands for potential output (upper figure) and NIR (lower figure) for the specification I.

4 Monetary policy stance

The estimated IRG provides a valuable insight into the monetary policy stance over the last 2 decades. On average, for the whole sample, monetary policy has been relatively tight especially given the estimated structure of Indian demand and supply. Below, the specific periods when the policy rate exceeded the estimated NIR are classified as tight monetary policy, and those when the policy rate was below the NIR are classified as loose.

Table 2: Monetary policy stance

Period	Policy stance
1990Q1-1993Q2	Tight
1993Q3-1995Q1	Loose
1995Q2-2003Q1	Tight barring a few quarters
2003Q2-2006Q4	Loose
2007Q1-2007Q4	Tight
2008Q1-2008Q2	Loose
2008Q3-2009Q3	Tight
2009Q4-2010Q4	Loose
2011Q1-2011Q3	Appropriate
2011Q4	Tight

The precision of NIR estimates, their similarity across specifications, and robustness of the monetary stance classification to different measurement of the real interest rate, adds to the credibility of our classification of the policy stance.

Periods where the policy rate exceeded the NIR far exceeded the reverse case. Barring a few transient peaks, the NIR persistently exceeded the policy rate, or policy was loose, only over 1993-1995 and 2003-2006. Thus policy was largely contractionary.

Policy was also procyclical, since it was loose in the boom periods of the mid nineties and 2000s, and tight in the late nineties and early 2000 slowdown. Under-correction in booms tended to lead to over-correction later. Policy could be classified as tight in 2011, for example, since although inflation remained high it was softening, while the output gap was widening. The NIR estimation depends on both inflation and output deviations.

The policy rate almost never captured turning points. For example, in the period after the global financial crisis it overshot the NIR in end 2008Q3 then missed its upturn in 2009Q4 and sharply over-corrected past the peak in the NIR in 2011Q3.

Generally monetary policy is not supposed to react to temporary commodity, including food price shocks. But in EMs, where food is a large part of the consumption basket and the price index, the CB cannot ignore food price inflation, and normally tightens in response.

Our analysis implies that not only should it not tighten, it should actually loosen in response. But only to the degree the shock is temporary, and is not passed on in wage increases, which make it persistent.

The sensitivity of the poor to inflation is often evoked to justify sharp tightening. But a rigorous consumer welfare based analysis here implies the opposite. Adjustment is required for the effect of shocks on the marginal utility of income and the willingness to work.

5 Conclusion

Innovations in this study include the introduction of new shocks, specific to economies in transition, affecting the NIR. It is also the first to estimate a NIR as part of an IRG for India[9]. Estimating an AD with an IRG, rather than just the real policy rate, is important because interest elasticity of output is generally higher when the NIR is included in the estimation. The value obtained for interest elasticity is close to that in studies for AEs, so that monetary policy can be expected to have a large impact.

Exploiting select high frequency data, to proxy specific structural shocks, improves the precision with which NIR is estimated compared to the literature. Semi-structural approaches have a better ability to capture regime changes and turning points in the economy. The fluctuations in NIR are large, but maybe a feature of EMs which have large fluctuations in real rates.

The estimations allow classification of the monetary policy stance and give interesting implications for the structure of Indian demand and supply.

[9] Mohanty (2013) seeks to impute it from the constant term in an estimated Taylor rule. But the constant term in such a rule normally conflates a number of factors.

Growth and inflation combinations are better explained by a flatter AS subject to frequent shifts, compared to a steeper more stable AS. The sensitivity analysis establishes the first combination also better satisfies overall theoretical criteria. The policy stance has been more frequently assessed using deviations from the policy rate given by the Taylor Rule (TR)[10]. But the output gap and inflation that enter the TR also determine the NIR. Our estimation in this paper has the advantage of also capturing some structural aspects that are difficult to include in a TR.

The results imply monetary policy has been largely contractionary and procyclical and has missed turning points. There is some improvement, in that the average gap between the NIR and the policy rate has been lower in the 2000s compared to the nineties. NIR fluctuations have fallen, but those of the policy rate have risen. The policy rate has a clear impact on the cycle. Further research is required to establish if this is rising over time, as is likely to be the case. And also to better analyze the relation between demand and supply shocks, and to calibrate the policy response to the degree of persistence of the supply shock[11].

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[10]See Goyal and Arora (2012) for such an exercise for India.

[11]Goyal and Arora (2012) apply an identification strategy to estimate demand and supply shocks and the persistence of the latter.

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