Revisiting the empirical existence of the Phillips Curve for India

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9 February 2010

Revisiting the Empirical Existence of the Phillips Curve for India

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Abstract

This paper revisits the empirical existence of the Phillips curve in the Indian context. To estimate the Phillips curve we need two variables – inflation and the output gap. In the case of India, incorrect measurement of both variables causes much difficulty in estimating the Phillipscurve. We use a non-linear Kalman filter approach to estimate the output gap and find that the Kalman filter estimate captures all the dynamics of the economy. Our results show that after taking supply shocks into consideration, there is clear evidence as to the existence of the Phillips curve in India for recent years.

JEL Classification: C32;E31; E50

Keywords: Kalman Filter; Output Gap; Inflation

A revised version of this paper was published in:
Journal of Asian Economics, Vol. 22 No. 3, June 2011, 247-258

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1. Introduction

Non-inflationary growth has been a major objective of economic planning in India, more so since it was first explicitly stated in the fourth five-year plan (1969-73). In fact, the 1970s saw the emergence of high inflation the worldover, and there was a renewed interest in the monetary policy and the role of the central banks in ensuring price stability. In 1991, the Maastricht Treaty marked the consensus of the advanced countrieson price stability being the main objective of their central banks.

The case of developing countries, including India, has been somewhat different in as much as the central banks have been viewed as responsible not only for price stability but also as facilitators of economic growth. In retrospect, it seems that it has been a job well performed. However, in view of the recent price rise, concerns are being expressed as to why inflation in India is so high. And why is it, that in the case of India, stabilising inflation does not lead to stability in the output gap? Why can't the Reserve Bank of India (RBI) focus on the single objective of inflation control?

The aforesaid questions triggered the present research. To answer these questions, we need to know the empirical relationship between inflation and the output gap - in other words, the Phillips curve. Older Keynesians define the output gap as arising primarily due to inflationary pressures, though the New Keynesian Dynamic Stochastic General Equilibrium theory posits that the output gap arises primarily due to nominal rigidities. The classical model[1]by Lucas (1973) concludes that the output gap-inflation association is entirely contemporaneous. However, this paper points to the existence of lagged effects, which are difficult to explore in short-term time series. The study concludes that the simple structure of the relationship between inflation and the output gap captures the main phenomenon predicted by the natural rate theory very well.

The purpose of the present paper is toexamine the contemporaneous relationship betweeninflation and the output gap.We also estimate the open-economy Phillips curve as given by Ball (1998).

This paper is divided into eight sections, including the introductory section. We address the conceptual issues in section 2, which may be regarded as the basic building blocks of the study. In section 3, we discuss the relationship between inflation and the output gap by examining the trends in India's economic growth and inflation during 1997 and 2009. In section 4,we review and discuss the literature on the empirical estimation of the Phillips curve in the Indian context. Section 5 discusses the New Keynesian Phillips Curve (NKPC) and supply shocks. It also extends the model to the open-economy context. Section 6 provides a description of the data and methodology used in the paper. The findings of the empirical investigation are contained in section 7. Finally, we present our concluding observations and spell out the agenda for further research in section 8.

[1] The model follows that the quantity supplied in each market will be determined by a normal component and a cyclical component, which vary from market to market. The model considers index market z, and uses y_{nt} and y_{ct} to denote the logs of the two components. In the model, the supply in market z is given as $y_t(z) = y_{nt} + y_{ct}(z)$, *where* y_{nt} is the normal component which reflects capital accumulation and population change, and y_{ct} is the cyclical component, which varies with perceived relative prices and also with its own lagged value.

I thank Peter Ireland for his helpful comments.

2. Concepts and Their Measurement

The Phillips curve predicates the relationship between inflation and the output gap. Thus, it is critical to define these concepts, more so in terms of how these are measured.

Output Gap. In general, the output gap is measured on two scales – the deviation of the actual level of output from the potential output level, and the growth of output relative to potential growth (the latter is called 'speed limit policy'). In India, while designing the monetary policy, the RBI announces forecasts of GDP growth. Since the RBI does not announce the forecast of the level of GDP, it may possibly be following the speed limit policy.In studies about India, we observe that there is a greater reliance on the former scale to measure the output gap.To be consistent with earlier studies, we have chosen to do likewise.

However, this is not the maiden attempt to measure the output gap by the level of output method for the Indian economy.There have been several studies in this regard - the studies of Callen and Chang (1999), Ray and Chatterjee (2001),Kundan (2009) and Paul (2009). These studies have used the Index of Industrial Production (IIP) as a proxy for output to measure the output gap. However, the IIP is not a good proxy for overall economic activity. For instance, in 2008-09, industries covered in IIP accounted for only about 18 percent of GDP (Central Statistical Organisation, India – National Accounts Statistics, 2009).

A number of other studies have used the Hodrick-Prescott (HP) method to estimate the output gap for India - Callen and Chang (1999), Ray and Chatterjee (2001), Srinivasan(2009),Dua and Gaur (2009),Kundan (2009), and Paul (2009). It is interesting to note that even though they use the HP approach, Callen and Chang (1999) list several drawbacks to this approach.Ozbekand Ozlale (2005) point out that the HP filter cannot capture the excessive boom-and-bust cycle along with volatile output, which is a well-known characteristic of many emerging markets. Another serious problem with the HP method is that it defines the estimated smoothed series of GDP as the potential output. Basu and Fernald (2009) argue that, so far, no macro economic theory has proven that potential GDP is a smoothed series. Our paperalso establishes why the HP method is a spurious method in the context of the Indian economy.

Virmani (2004) estimated the output gap using an unobserved components model for the Indian economy. This model is an extended version of the Kalman model. Though in the original estimation of the model, Kuttner (1994) used the Consumer Price Index (CPI)as the measure of inflation to estimate the forward-looking Phillips curve,Virmani chose the Wholesale Price Index (WPI).

Inflation. Inflation is the rate of increase ofthe index of general price level. It is the other variable in the Phillips curve. In economic literature, we come across the consumer price index and the wholesale price index as the measures of inflation. It is important to account for the limitations of both the CPI and the WPI as measures of inflation while estimating the Phillips curve. Srinivasan T.N. (2008) describes the shortcomings of using the WPI as a measure of general inflation in India. The WPI is constructed for a given basket of goods in the economy. Data on prices comes from various sources – the farm gates, the factory gates, primary markets, secondary markets, wholesale markets and retail markets. So the WPI captures neither the supply side (producer price) nor the demand side (market price). On the other hand, Shapiro and Wilcox (1996) found that the CPI tends to overestimate inflation by 0.6 to 1.5 percentage points per year. This raises some serious doubts about the appropriateness of using the CPI as a measure of inflation. The Boskin Commission Report (1996) also found similar levels of an upward bias in CPI estimation, ranging between 0.8 to

1.6 percentage points per year. Shapiro and Wilcox (1996) finally concluded that the inaccurate measurement of the CPI has no implication on the output gap or on naturalemployment. Technically, the CPI captures both demand side factors as well as agents' expectations.

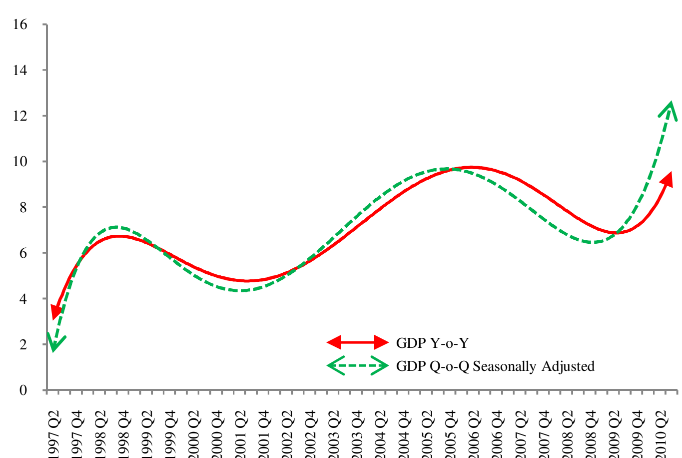
In the Indian context, however, the CPI is subject to extreme problems. For instance,becausethe base year of agricultural and rural labourers is still 1986-87, it provides a very poor account of new entries into the consumption basket for the two income groups. Given that the structure of the Indian economy has been changing rapidly, such a strong assumption underlying the consumption basket for the last two decades raises serious questions about the reliability of the statistics. In this paper, we assume that continuing to use the old basket of products does not lead to time-varying biases, i.e. over or under estimation of inflation due to the usage of the old basket is assumed to be a constant bias for every year, and that this may not change substantially from one year to another. Also, since there is no better alternative to measure inflation, this paper uses the CPI as a measure of overall prices in the economy.

With this background, in this paper we attempt to check the existence of an open-economy Phillips curve in the Indian scenario. We estimate the output gap series for the time periods between the first quarter of 1997 to the third quarter of 2010, using the non-linear Kalman filter approach. We find that during that period, the output gap captured the important events in the economy. We also prove that the HP filter approach is a spurious method to estimate the output gap in the case of India. The supply shocks coefficient suggests that India's inflation is very sensitive to such shocks. After accounting for supply side factors, we find that the Phillips curve relation holds true for recent time periods.

3. A Review of India's Economic Growth and Inflation

An examination of the economic growth and inflation is the first step towards estimating the Phillips curve. Figure 1 presents India's economic growth in the last ten years. We have used quarterly data that describes India's growth cycle.

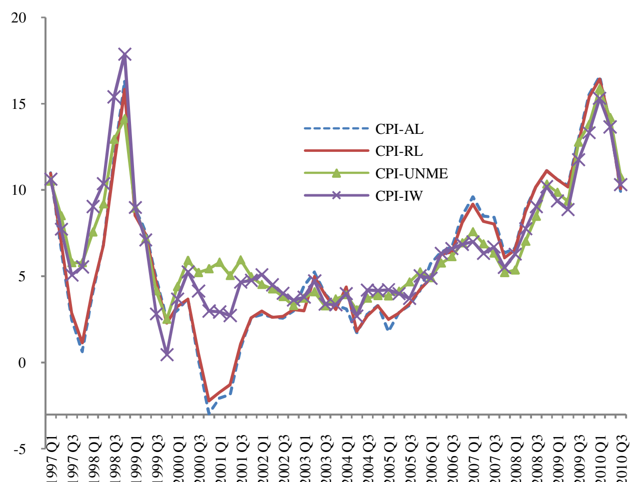
Figure 1. India's Growth Cycle (percent)



Source: Authors' own calculations using the Online Database on the Indian Economy, Reserve Bank of India.

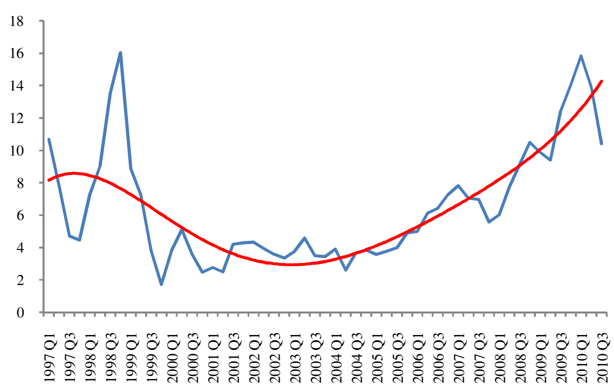
In figure 1, we have plotted the growth of seasonally adjusted annualised GDP over the last quarter and GDP growth quarter-over-quarter in the polynomial functions of order 5. We have chosen the polynomial order of 5 because when we raise the polynomial order, the R-Square continues to rise and reaches itsmaximum at the order of 5. The two lines are quite similar to each other; however, the seasonally adjusted growth rate has a clear advantage in its ability to predict the inflection of growth points in advance. From the trend of seasonally adjusted GDP growth since the fourth quarter of 2008, it is clear that that the Indian economy has entered a new growth cycle. The planners, researchers and the RBI, therefore, need to assess whether this cycle will have the same momentumas the cycle during 2003 and 2008. It is pertinent to mention here that, according to Bhalla (2007),the Indian economy has entered a new growth trajectory, which is above 9 percent per annum. It is even more pertinent to note that many studies have estimated that the Indian economy is still growing below its potential, and that the estimated output gap (actual growth relative to potential growth) is close to 2 percent. As a result,the RBI has been criticized for not having played enough of a role in pushing the growth cycle even further. However, economic theory tells us that the output gap is not independent of inflation. In Figures 2 and 3, we review the inflation scenario in the Indian economy.

Figure 2. India's CPI Inflation (percent)



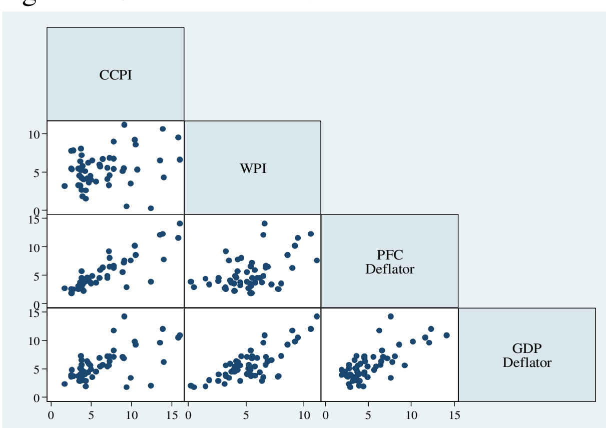
Source: Authors' own calculations using the Online Database on the Indian Economy, Reserve Bank of India.

Figure 3. India's Composite CPI Inflation (percent)



Source: Authors' own calculations using the Online Database on the Indian Economy, Reserve Bank of India and the methods proposed by Singh, B.K. and Joseph M., (2009) in 'Monetary Policy: Inflation the Major Concern?'(Macro Perspectives and Updates. ICRIER, New Delhi, India)
For an economically diverse country like India, a single measure of inflation does not suffice. Therefore, in Figure 2, we have plotted four consumer price indices that account for four diverse income groups, viz., agricultural labourers, rural labourers, industrial workers, and, urban non-manual employees. Besides these, the Wholesale Price Index is also used to measure inflation. An issue of concern is, out of the five indices, which index should the RBI use while formulating monetary policy. In the beginning of the nineties, the central banks used the WPI as a measure of inflation. In more recent years, however, many central banks have given up using the WPI,asit is not deemed as an accurate measure to reflect general inflation levels.Khatkhate (2006) presents a case for an aggregate measure based on the CPI for the country as a whole, which could then be used to design monetary policy. In this study, we have used a Composite CPI (CCPI), which has been used earlier by Singh and Joseph (2009). The CCPI weights are based on the proportion of households in each employment category (NSSO, 2004-05). As shown in Figure 3, inflation is likely to be high for the year 2011. We have carried out a number of checks to see if the constructed CCPI explains the overall inflation, i.e.we have correlated the four measures of inflation - CCPI, WPI, the GDP deflator, and the Private Final Consumption (PFC) deflator[2]. Figure 4 presents the correlation graph of different measures of inflation.

Figure 4. Correlation between Different Measures of Inflation from Q1 1997 to Q32010



Source: Authors' own calculations using the Online Database on the Indian Economy, Reserve Bank of India.

Figure 4 shows that the CCPI and the PCF deflators are highly correlated and that the correlation line falls close to the 45-degreeangle. Inconsistencies within the other measures of inflation can be seen by looking at the dispersion in the correlation. Since the PFC deflator is released with huge lags as compared to the CCPI, throughout this paper, we continue to use the CCPI as a measure of inflation. We then look at the trend lines of the CCPI and GDP growth. It seems that growth has fallen whilst inflation has risen – this would appear counter-intuitive in normal circumstances. The latter section of the paper investigates this further.

4. Literature Review in the Indian Context

The theory of the Phillips curve was recently proposed in the context of the Indian monetary policy. The report by Rajan (2009) on financial sector reforms recommended that the RBI should focus on

[2] The authors are grateful to Shankar Acharya for pointing out the usefulness of the PFC deflator.

the single objective of inflation control, i.e. to stay close to a low inflation rate or to stay within a given range. The report concludes that by doing so, the RBI can achieve stability in growth and inflation. Contradicting the report, Acharya (2009) argued that, given the frequent occurrence of supply shocks in the Indian economy, the single objective of inflation control is not the right choice for the RBI at this stage of development. A monetary response to contain inflation, which is driven by supply-side factors, is ineffective, and in such cases, the RBI has a trade-off between inflation and growth. Singh and Kalirajan (2003) concluded that the ability of central banks in controlling inflation in developing countries is not any better than that of central banks in developed countries. Paul (2009) found empirical evidence for the existence of the Phillips curve for the industrial sector for the longest time period (1956 - 2007). After controlling for agricultural, oil and liberalisation shocks, the research proved that the Phillips curve does exist in India, as it does in developed countries. We suspect that the study may perhaps be subject to three major limitations, (a) it accounts only for the industrial sector, which is not a proxy for overall economic activity; (b)it estimates the output gap using the HP method, which is not accurate in the case of developing countries like India; and (c), the authoruses the WPI as a measure of inflation which, as discussed above,not capture the demand-side response.

Another study,Dua and Guar (2009), used quarterly GDP between1996 and 2005, and after controlling for agricultural shocks and imported inflation through exchange rates, also found a positive relation between the output gap and inflation. In general, a review of the literature on inflation in India suggests that supply shocks were the most prominent issues in India's inflation dynamics. Therefore, it becomes imperative to appropriately incorporate supply shocks in the estimation of the existence of the Phillips curve in India.

4.1 New Keynesian Phillips Curve (NKPC) and Supply Shocks

We have taken equations (1), (2) and (3) mentioned below from Woodford (2003) which state the theoretical relationship between inflation and the output gap.

$$\pi_t = \kappa(\hat{Y}_t - \hat{Y}_t^n) + \beta E_t \pi_{t+1} \quad (1)$$

Where

π_t = Inflation at time t,

$\hat{Y}_t$ = Actual output at time t,

$\hat{Y}_t^n$ = Potential or natural output at time t,

$E_t \pi_{t+1}$ = Expected inflation for the time period t+1 at the time t.

Reduced form of the New Keynesian Phillips Curve

$$\pi_t = \kappa x_t + \beta E_t \pi_{t+1} \quad (2)$$

Where

$x_t = \hat{Y}_t - \hat{Y}_t^n$ = Output gap.

Woodford(2003) argued that in special circumstances, an economy is likely to face exogenous shocks[3]. However, equation (2) does not account for this. So equation (2) is transformed into Equation (3), taking into account exogenous shocks occurring in the economy by adding an additional variable μ_t.

$$\pi_t = \kappa(\hat{Y}_t - \hat{Y}_t^n) + \beta E_t \pi_{t+1} + \mu_t \qquad (3)$$

Where
μ_t = Exogenous shock at time t.

In early literature, Poole (1970) argued that the monetary policy objective of stabilisation should focus on both inflation and output. According to Woodford (2003), the recent literature has arrived at a consensus that the objectives of central banks should be to move away from output stabilisation and towards the output gap. From an efficiency point of view, and in normal circumstances, the role of output stabilisation means that the central bankintervenes tolimit only the output gap. Because the output gap is temporary or short-term deviation from the natural output, themore important role of monetary policy is to focus on the fall or rise in the temporal component of output.

On the one hand,this may lead to the conclusion that the output gap should be targeted at zero at all points in time.On the other hand, in theory, according to equation(2), complete stabilisation of the output gap and future expected inflation should lead to lower inflation. But Woodford (2003) argued that equation(2) does not hold true in all circumstances. In special circumstances, the residual term μ_t added in equation(2), might become critical due to exogenous shocks faced by the economy. As a result,equation(3) would be the appropriate model to explain the structure of the economy, in the presence of random shocks such as cost-pushed shocks and a zero lower bound on nominal interest rates. This is why, in practice, central banks have discretionary policies to decide the tradeoffs between inflation stabilisation and output stabilisation. In the Indian context,it would be interesting to examine whether there is an empirical relationship between inflation and the output gap as stated by equation(2). Goyal and Pujari(2004) have found that the Indian economy is subject to large supply shocks. Inflation in India may be high due to negative supply shocks or because of the residual term. These negative shocks come from two main sources - 1) the failure of the monsoons and2) very high fluctuation in the global price of crude oil and basic metals.

Demand-side induced shocks would result in a positive relation between inflation and the output gap. On the other hand, supply-side shocks would result in a negative relation. As a result, the central banks' job is easy whenever there is a demand shock. The central banks can stabilise the economy and bring it to a more efficient equilibrium with low inflation and an optimal level of output. This can be done by targeting the level of output gap as zero. But in the case of supply shocks, monetary policy can only target non-zero level of output gap.It is here that a trade-off between inflation and the output gapmanifests itself for the consideration of the monetary policy. The optimality condition in choosing between the two goals depends upon the relative weights of the goals. In theory, the weights of the two variables are derived from a loss function (Woodford, 2003).

[3] Exogenous shocks arise from supply channels. Fall and rise in supply are called negative supply shocks and positive supply shocks, respectively.

4.1 Open-Economy Phillips Curve

$$\pi_t = \kappa(\hat{Y}_t - \hat{Y}_t^n) + \beta E_t \pi_{t+1} - \gamma X_t + \mu_t \qquad (4)$$

Where
X_t = Change in real effective exchange rate.

Kumar et al. (2007) argue that the Indian economy has now integrated with the global economy - its currentaccount transactions surpassed 50 percent of GDP in 2005-06. Thus, we consider extending our model to an open-economy Phillips curve. Equation(4) is the open-economy Philips curve, taken from Ball (1998).

5. Data and Methodology

Data on the consumer price indices for agricultural labourers, rural labourers, industrial workers and urban non-manual employees, as well as data on wholesale price index, real GDP and private final consumption expenditurehas been taken from the Online Database on the Indian Economy, Reserve Bank of India. To construct the composite CPI, we have used methods outlined by Singh and Joseph (2009). To measure the exchange rate variables we use 36 currency trade-weighted real effective exchange rates as give by the RBI. However, the RBI's estimation of the real effective exchange rate has a limitation as it uses the WPI as a measure of inflation for India. In 2009, there was a discrepancy between the WPI and the CPI – the WPI recorded much lower inflation as compared to the inflation recorded by the CPI. Therefore, in this paper, we have also used the real effective exchange rate constructed by Karan Singh, B. and Mathew, Joseph (2010)[4],which uses the CPI as a measure of inflation for India.

Throughout this paper, we have measured inflation and the change in the real exchange rate i.e. year-over-year percentage change. To estimate the output gap at quarterly intervals, real GDP data has been seasonally adjusted by using X-12-ARIMA methods (Findley et al., 1998). We estimate the output gap using the State Space model, described below. We measure the supply shocks by looking at the outlier point in the contemporaneous relationship between inflation and the output gap. Finally, we estimate the open-economy Phillips curve using OLS and Instrumental Variables Two-stage Least Squares Regression (IV Reg 2SLS).

5.1 State Space Model (SSM)

Structural time series, in most cases, have unobservable information, which iscaptured through several statistical techniques. The most common methods of estimation are smoothing and filtering. Filtering is widely accepted to be a better technique since it allows one to track the information available in real time. In the following model, the predictive error is decomposed to estimate the

[4]Karan Singh, B. and Mathew, Joseph, *Why Are Trade Deficits Worsening in the Case of India?* (Unpublished)

likelihood function. Thus, in order to estimate the potential GDP series, we have constructed our model in a state-space form and then applied the Kalman filter method.

The Kalman filter is a recursive estimator (e.g. Kalman (1960), Nelson and Plosser (1982), Harvey (1989), and De Jong (1991)) and it requires onlythe previous time step and current measurement to compute the estimate of the current state. The model does not include the current observation information and hence, during the update phase,theestimate of the current state is combined with the current observation information and called the posterior state estimate. Given that our primary objective is to identify a model that is adaptive and time-varying due to inherent properties of the time series such as non-stationary, shifts, breaks, benchmark revision and so on, the SSM provides a powerful framework. Furthermore, distinguishing outliers, changes or shifts becomes crucial when it comes to time series forecasting. In other words, whether the effect is transitory or permanent can be well addressed through the State Space Model (SSM). In our model, the GDP series is decomposed as a trend component and white noise error. In the model, the trend component can be assumed to be derived from the stochastic equations (5) and (6).

$$y_t = \mu_t + \varepsilon_t \quad (5)$$

Where

μ_t = Trend component,

ε_t = White noise error with ε_t ~(0, σ_ε^2).

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta 1_t \quad (6)$$

$$\beta_t = \beta_{t-1} + \eta 2_t \quad (7)$$

Where

$\eta 1_t$ and $\eta 2_t$ are independent white noise disturbances with $\eta 1_t$ ~(0, $\sigma_{\eta 1}^2$) and $\eta 2_t$ ~(0, $\sigma_{\eta 2}^2$).

To begin with, the state space model emphasises that a time series can be decomposed as follows:

$$y_t = H Z_t + u_t \quad (8)$$

$$X_t = F X_{t-1} + v_t \quad (9)$$

Where

u_t and v_t are with mean zero, serially and mutually uncorrelated random vectors with covariance matrices U_t and V_t (t=1,2,3,…n). Hence,F,H,U_t and/or V_t contain unknown parameters to be estimated from the observed series y_t = (y_1 , y_2, … y_n). We can further take one step to explain each of the parameter as follows -

$$H = (1,0)$$

$$F = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$$

$$X_t = (\mu_t \beta_t) \qquad (10)$$

$$V_t = (\eta 1_t \eta 2_t) \qquad (11)$$

$$VaR\begin{bmatrix} \eta_t \\ \varepsilon_T \end{bmatrix} = \begin{bmatrix} \sigma\eta 1_t^{\ 2} & 0 & 0 \\ 0 & \sigma\eta 2_t^{\ 2} & 0 \\ 0 & 0 & \sigma\varepsilon^2 \end{bmatrix}$$

When y_t noise ε_t is normally distributed, the average likelihood function for the state space model can be derived as follows -

$$L = \frac{1}{T}\sum_{t=1}^{T} L_t$$

Where

$$L_t = -\frac{Ny}{2}(Log\,2\Pi) - \frac{1}{2}Log(|C_t|) - \frac{1}{2}\hat{\varepsilon}' C_t^{-1}\hat{\varepsilon}_t$$

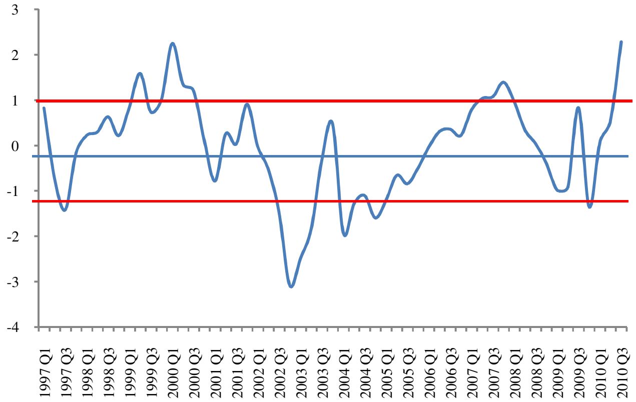
Where

C_t is the mean square error matrix of the prediction error ε_t .

6. Empirical Results

A number of studies have estimated the output gap for India by using theHP method. We argue that the HP method does not yield reliable output gap estimates. In Figure 5,we have plotted the estimates; we find evidence for the proposition that the HP method has severe limitations due to its smoothing assumptions. As a result, betweenQ1 2004 andQ1 2006, the HP method overestimates the potential GDP growth, while it underestimates the potential growth for the periods between Q22006 and Q32008.

Fig 5:Output Gap – HP Method(percent)

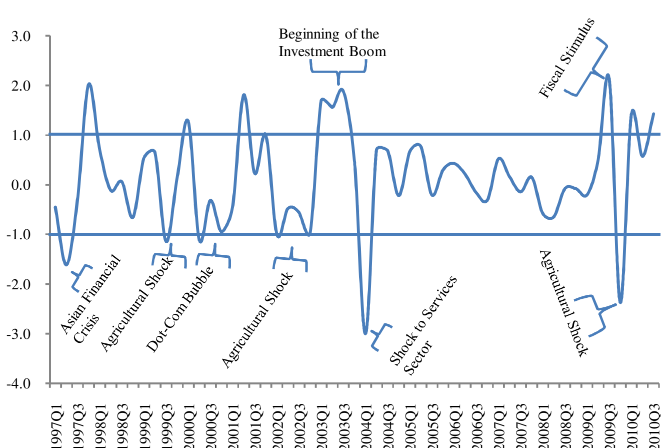


Source: Authors' own calculations.

These results are inconsistentbecause the Indian economy is subject to transitions and its growth is not a smooth series like that of a developed country. Hence, the application of theHP method, in the context of developing countries like India,does not reveal the true picture.

Figure 6 shows the Kalman filter estimates; we find that it is able to accurately capture the important events in the Indian economy.

Fig 6: Output Gap – KalmanMethod(percent)



Source: Authors' own calculations.

As shown in the figure, the trend of the output gapduring Q1 1997 and Q12004was dynamic, and recorded very high levels of deviation. The prime factors behind this instability were the Asian financial crisis, the dotcom bubble burst, monsoon failures, a structural break due to the investment boom and a shock in the services sector. From Q1 2003 toQ3 2003, the output gap wasrecorded atan average of above 1.7 percent because the investment rates rose by about 4 percent of the GDP, which was a significant structural break in India's growth history - ithas been clearly captured bythe

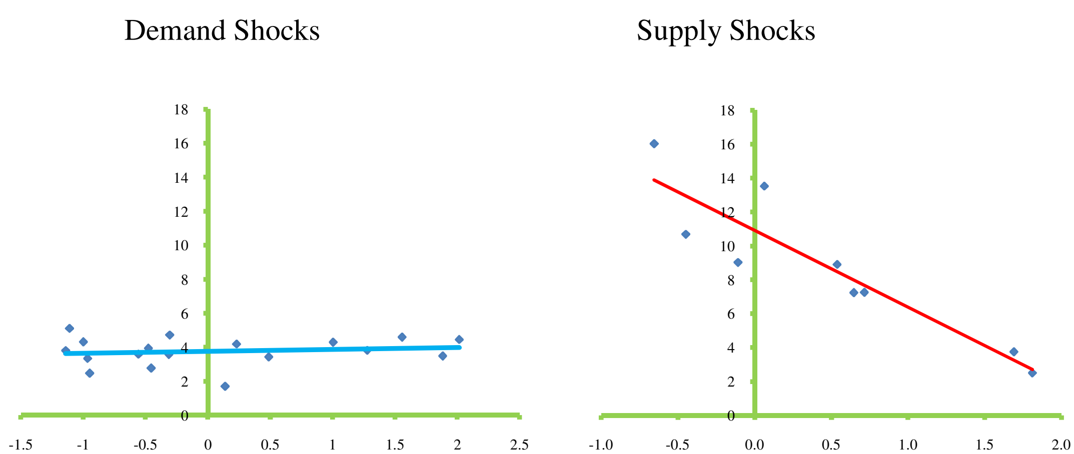
Kalmanmethod. The HP method, however,fails to capture this, because of which the estimates for the following periodsare inconsistent. After the structural break, the Indian economy entered a historical period in which the country achieved the highest consecutive five-year average growth since its independence, i.e. 8.8 percent between 2003-04 and2007-08. Surprisingly, when we look at the output gaps for the period after the structural break, we find that the deviation was substantially reduced. From Q22004to Q2 2009, the output gap fell between the range of –1 and+1 percent. In Q3 2009,the output gap reached 2 percent due to the second round of fiscal stimulus to counter the economic slowdown, one of the main components of which wasthe Sixth Pay Commission, where the salaries of the central government employees were substantially revised upwards.

Since the range of the output gaps is narrow in the period after the structural break,one would expect no inflationary pressure in the economy. However, the period after the structural break did experience a rise in inflation. The question then arises as to what thenwas the cause of the high inflation.

In line with earlier studies, we find that negative supply shocks are the prime factor behind the high level of inflation. Firstly, supply shocks nullify the Philips curve relation in the Indian context. Secondly, the shape of the Philips curve changes within a short period of time. Based on our period of research, there is evidence to support instability in the Philips curve relation. Since our reference period is very small, we have beenunable to prove statistically the causes of the instability. However, to get a clearer picture, we've broken the entire time period of the study into two periods, namely,period 1 – Q11997 to Q12004, andperiod 2 – Q22004 to Q42009[5].

The classification of the periods is based on the Kalman method estimates of output gaps. In period 1 we observe high volatility in output gaps as compared to period 2. Period 2 follows the time period after one quarter of the structural break. For period 1 and period 2, we detect the supply shocks by fitting the linear relation between the output gap and inflation. We label the outliers of the linear relation as supply shocks. For each shock, we have also crosschecked the cause of inflation from various monthly publications of the RBI Bulletin (1997 - 2009), and we find that our methods are able to predict the supply shocks accurately.

Fig 7: Relationship between Inflation and theOutput Gap during Period 1 (Q11997 to Q12004)



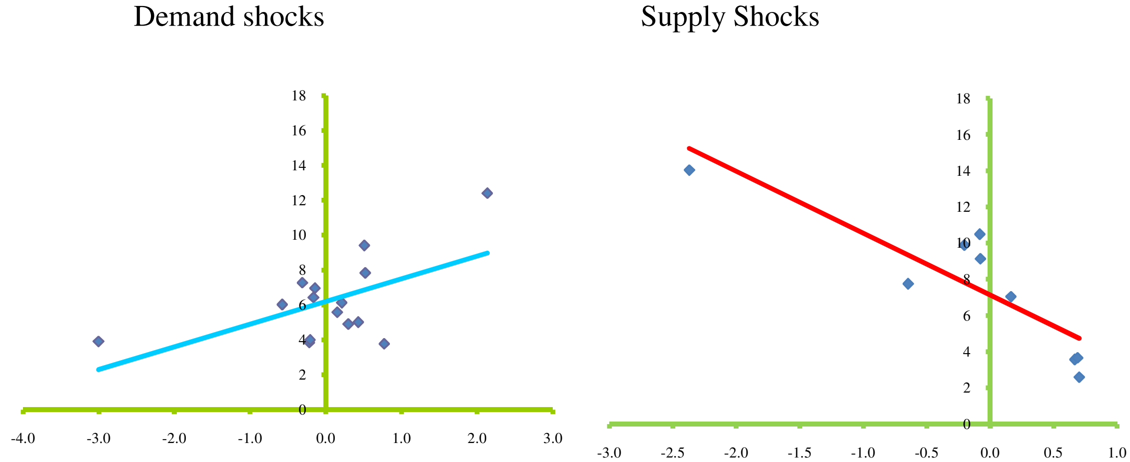
[5] Though output gap estimation data is available up to Q3 2010, we haven't used it because it is subject to revision.

Source: Authors' own calculations.

Figure 7 shows that in period 1, after controlling for supply shocks, there was no evidence to support the relationship betweeninflation and the output gap. However,the positive supply shocks were the prime factors in bringing inflationdownin this period.

Figure 8 captures the evidence of the emerged Phillips curve in period 2. After accounting for supply shocks, there is a very positive and significant relationship between inflation and the output gap.

Fig 8: Relationship between Inflation and the Output Gap in Period 2 (Q22004 to Q42009)



Source: Authors' own calculations.

These results show that India does have a Phillips curve like that within a developed country. However, the supply shocks during period 2 are also significant. Unlike in period1, we find a high incidence of negative supply shocks in period 2. According to our estimates, the following are the negative shock periods within period 2 – Q22004, Q32004, Q12005, Q22007, Q22008, Q3 2008, Q42008, Q1 2009and Q42009. When we look at the existing literature relating to these particular time periods, we find evidence of cost-push factors behind the shocks. The intercept for the Phillips curve is 6 percent in period 2; according to our model, we refer to this as the threshold level of inflation in the Indian context. Our estimate of the threshold level of inflation is quite high as compared to the 4 percent recommended by Chakravarty et al. (1985). The difference arises because of the structure of the economy wherein the present Indian economy looks quite different from what it did almost two decades ago. Significantly, our estimate is still higher than the estimates of other studies on inflation since the onset of structural reforms. For example, Rangarajan (2001) argued that 5 to 6 percent may be acceptable. This leads to the question as to whythethreshold level of inflation for India should be so high.At present, the RBI does not follow a single objective of inflation targeting. Instead, it follows multiple objectives. Acharya (2009) argued that at our stage of development, the RBI is quite right to weigh and pursue several objectives, including inflation, economic activity, financial stability and institutional development.

Mishkin (2008) argued that the role of the central bank in anchoring inflation expectations is essential. If the central bank fails to anchor inflation expectations, then supply shocks lead to volatility in both inflation and the output. However, in India, in period 2, although there is evidence of supply shocks, we do not find much deviation in the output gap. This shows that given the multiple objectives, the RBI's assigned weightage to inflation stabilisation may be at the optimal level. Clarida et al. (1999) pointed out that extreme inflation targeting in the presence of a cost-push shock might not be the most optimal policy. Perhaps in period 2, the presence of frequent and high-magnitude exogenous supply shocks could account for the high level of inflation.

Our next task is to estimate the empirical estimation of equation4. We modify equation4 to equation12 where we define the shock variable as a slope dummy interacting with the output gap.

The empirical model follows.

$$\pi_t = c + \kappa(\hat{Y}_t - \hat{Y}_t^n) + \beta E_t \pi_{t+1} - \gamma X_t - \alpha((\hat{Y}_t - \hat{Y}_t^n) * sdum) + \varepsilon_t \qquad (12)$$

Where
c = Constant,
sdum = 1 for the period of supply shocks; otherwise it is equal to 0,
ε_t = Error term.

First, we have estimatedequation12 using the OLS (ordinary least squares) method. The OLS results for period 2 provide the expected signs for the coefficients for all the independent variables. But this estimation is problematic because the dependent variable, inflation, and the independent variable, the output gap, are dated to the same time. This leads to an endogeneity problem in estimating equation12 via the OLS method. To overcome this, we apply the Instrumental Variables two-stage least-squares (2SLS)regression.The instrumented variable is $\hat{Y}_t - \hat{Y}_t^n$ and the instruments are $\pi_{t-1}, (\hat{Y}_t - \hat{Y}_t^n) * sdum, X_t, \pi_{t-2}$ and $(\hat{Y}_{t-1} - \hat{Y}_{t-1}^n)$. In tables 1 and 2, we present the results of both OLS and IV 2SLS regressions for each period respectively. Since OLS estimation is spurious due to endogeneity problems, we use only the IV 2SLS estimation results. Whereas for period 1, as we expected, the estimated coefficients are insignificant in all cases, except π_{t-1}, indicating that the Phillips Curve does not exist in period 1. For period 2, the estimated coefficients yield the expected signs with statistical significance at the 5 percent level and above, and thus prove the existence of the open-economy Phillips curve. As we expected, the discrepancies between the CPI and the WPI in 2009 have also been captured in our results. Using the CPI as a measure of inflation in constructing the real effective exchange rate yields a right measure, which is statistically significant at the 1 percent level, whereas the use of WPI-based real effective exchange rate is insignificant at the 5 percent level.

Table 1. Estimated Open-Economy Phillips Curve for Period 1 (Q1 1997 –Q1 2004)

	OLS	IV Reg 2SLS
Time period 1	Q1 1997 - Q4 2003	
π_{t-1}	0.6 (0.1)***	0.6 (0.3) ***
$(\hat{Y}_t - \hat{Y}_t^n)$	0.2 (0.5)	2.9 (2.9)
$(\hat{Y}_t - \hat{Y}_t^n) * sdum$	-1.0 (0.9)	-3.7 (3.0)

$X_t WPI$	-0.3 (0.1)**	-0.2 (-0.2)
C	2.4 (1.0)***	1.9 (1.6)
Number of Observations	27	25
Adj R-squared	0.61	0.18
Durbin-Watson Statistic	1.6	1.7

Table 2. Estimated Open-Economy Phillips Curve for Period 2 (Q2 2004 – Q4 2009)

	OLS		IV Reg 2SLS	
Time period 2	Q2 2004 –Q4 2009			
π_{t-1}	0.8 (0.1) ***	0.9 (0.4)***	0.8 (0.1)***	0.8 (0.1)***
$(\hat{Y}_t - \hat{Y}_t^n)$	0.7 (0.4) **	0.9 (0.09) ***	1.5 (0.7)**	2.0 (1.0)**
$(\hat{Y}_t - \hat{Y}_t^n) * sdum$	-1.7 (0.6)***	-2.2 (0.6) ***	-2.6 (0.95)***	-3.4 (1.3)***
$X_t WPI$	-0.08 (0.04) **		-0.05 (0.03)*	
$X_t CPI$		-0.04 (0.02) ***		-0.05 (0.02)***
C	1.4 (0.6)***	1.1 (0.59)**	1.5 (0.6)***	1.4 (0.7)***
Number of Observations	23	23	23	23
Adj R-squared	0.92	0.92	0.81	0.92
Durbin-Watson Statistic	2.3	2.6	2.0	2.3

Note:
1) Standard errors are reported in parentheses.
2) *, **, *** indicate significance at the 10 %, 5 %, and 1% level, respectively.
3) We use one quarter lag of inflation (π_{t-1}) as a proxy for expected inflation.

Table 2. Data Definitions and Sources

Variables Name	Definition	Data Source
π_t	*Year-over-year percentage change in the composite consumer price index (CCPI).*	*To construct the CCPI, we have followed the methods used by Singh, B.K. andJoseph, M. (2009). Data on consumer price indices of the four income groups (agricultural labourers, rural labourers, industrial workers and urban non-manual employees) has beentaken from theOnline Database on the Indian Economy, Reserve Bank of India.*

$\hat{Y}_t - \hat{Y}_t^n$	*Deviation of actual output ($\hat{Y}_t$) from potential output ($\hat{Y}_t^n$), derived using the Kalman filter method.*	*Authors' own calculations using quarterly real GDP data from theOnline Database on the Indian Economy, Reserve Bank of India.*
$sdum_t$	*Supply shock dummy, which takes the value 1 for the periods of supply shocks; otherwise it is equal to 0.*	*Authors' own calculations, crosschecked with monthly publications of the RBI Bulletin (1997 - 2009),*
$X_t CPI$	*Year-over-year percentage change in the trade-weighted real effective exchange rate, based on the CPI.*	*Karan Singh, B. and Mathew, Joseph, Why Are Trade Deficits Worsening in the Case of India? (Unpublished)*
$X_t WPI$	*Year-over-year percentage change in the trade-weighted real effective exchange rate, based on the WPI*	*Online Database on the Indian Economy, Reserve Bank of India.*

7. Conclusion

The major findings of the study can be stated as follows - (i) The relationship between inflation and the output gap, as predicated by Phillips curve, is relevant for India during the recent time period, i.e. between the first quarter of 2004 and the first quarter of 2009; (ii) The Phillips curve exists only after controlling for supply shocks; (iii) Thenon-linear Kalman filter approach yields accurate output gap estimates; (iv) The HP estimates of output gap are spurious in the Indian context since they do not account for the structural break whichthe Indian economy has experiencedrecently; and (v) The real effective exchange rate elasticity of inflation is 0.05. Thissuggests that the real effective exchange rate has a minimal role in influencing domestic inflation.

In view of the above findings, the evidence of the supplyshock-driven open economyPhillips curve has some significant policy implications. First, in normal times, i.e. in the absence of any supply shocks, the RBI may consider 6 percent as the threshold level of inflation.Second, we also argue that the WPI is a poor measure of inflation, and that the RBI must instead use the CCPI as a measure of inflation. Third, our study shows that the RBI must use the non-smoothed model to estimate the potential growth, since using the linear form of potential output estimation misguides the state of the economy and it results in inefficient policy actions.

Finally, we would like to suggest some questions for further research in this area. Sincethe existence of the Phillips curve co-exists with India's higher growth trajectory of 8 percent plus,does it imply that the demand channel is active only when the economy grows at 8 percent or more? Is there any minimum level of growth required forthe demand channel to be active? Also one could explore as to why, in the case of India, the role of real effective exchange rate pass-through to domestic inflation is very limited. Another interesting research question would be how long the impact of supply shocks last in the economy. This could be analysed in adynamic framework.

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