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Inflation dynamics in India: A hybrid New Keynesian Phillips Curve approach

Jagadish Prasad Sahu
Institute of Economic Growth, University of Delhi Enclave, Delhi-110007, India

Abstract

This paper examines the short run inflation dynamics in India over the period 1996-97 to 2009-10 using quarterly data. I estimate an open-economy version of the hybrid New Keynesian Phillips curve (NKPC) and find that the hybrid NKPC provides a robust explanation of the dynamics of both wholesale price index (all commodities) inflation and manufacturing sector inflation over the sample period after considering supply shocks. Specifically, the price setting agents in the economy are guided by both backward-looking and forward-looking behaviours. The agricultural and the industrial output gaps (used separately to account for the role of sectoral characteristics), fuel inflation, exchange rate and foreign inflation are significant determinants of the wholesale price index inflation. All the variables except exchange rate are found to be significant in determining the manufacturing sector inflation in India.

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Contact: Jagadish Prasad Sahu - sahujagadish@gmail.com.
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1. Introduction

Understanding the dynamics of inflation is critical to an efficient monetary policy formulation. In recent years, the New Keynesian Phillips Curve (NKPC) has become the benchmark model for the short run analysis of inflation dynamics. Unlike the traditional Phillips curves, the NKPC is derived from the micro-foundations where monopolistically competitive firms set prices to maximize their discounted stream of expected future profits, subject to the constraints on price adjustment. In this framework, inflation is a function of real marginal cost and expected future inflation. The distinctive features of NKPC are the introduction of rational expectations and nominal rigidity in prices in modeling inflation.

Although the NKPC is theoretically appealing, its empirical estimation has not been entirely successful in explaining the inflation dynamics (Gali and Gertler 1999, and Dufour et al. 2006). In order to capture the persistence in inflation, Gali and Gertler (1999) extend the model to allow for a fraction of the firms to follow the backward looking rule of thumb so as to set prices and derive the so-called hybrid New Keynesian Phillips Curve. The hybrid NKPC implies that current inflation is a function of real marginal cost, expected future inflation as well as past inflation.

The present study examines the short run dynamics of inflation in India over the period 1996-97 to 2009-10 using quarterly data in an open-economy hybrid NKPC framework. With a view to taking into account the role of sectoral characteristics in the determination of inflation in India, I use the agricultural output gap and the industrial output gap separately in the model. The fuel inflation has been included in the model to represent a supply shock (i.e. a cost of production shock) to the economy. Given the open economy nature of the Indian economy, the model also includes the exchange rate and the foreign price level to measure the impact of external factors on domestic price level. In order to solve the problem of endogeneity of the expected future inflation in the model, I have used the Generalized Method of Moments (GMM) technique to estimate the model.

The paper is structured as follows. Section- 2 contains the review of the extant literature. Section- 3 analyses the empirical model and Section- 4 describes the dataset and methodology. Estimation results are discussed in Section- 5. Section- 6 concludes with a summary.

2. Review of Literature

Most of the literature on inflation in India follows either of the two approaches in modeling inflation: the Monetarist approach and the Structuralist approach. While the basic contention of the Monetarist approach is that inflation is the result of excess growth of money supply over real output growth, the Structuralist approach sees inflation as a result of structural disequilibrium in the economy. Among the earlier studies on inflation, Pradhan and Subramanian (1998) and Callen and Chang (1999) follow the Monetarist approach to model inflation in India. Finding that the structural factors like agricultural output have a significant influence on the price level, Pradhan and Subramanian (1998) concede that the inflationary process in Indian economy is not purely a monetary phenomenon. Callen and Chang (1999) find that the growth of money supply is an important indicator of future inflation in India, and the exchange rate and import prices are significant determinants of manufacturing sector inflation.

On the other hand, the Structuralist approach deems inflation as a result of sectoral disequilibrium in the economy. It holds that the price behaviour is not uniform across the economy; the agricultural prices adjust to clear excess demand in the agricultural sector whereas industrial prices are cost determined. The Structuralist explanation of inflation is that the excess demand raises the price of agricultural products, leading to an increase in the industrial prices as agricultural products are used as inputs into industrial production (Balakrishnan 1994). Balakrishnan (1994) finds that the Structuralist model performs better than the Monetarist model in explaining inflation in India.

Some studies like Chand (1996) and Coe and McDermott (1997) focus on the role of the output gap in modeling inflation in India. Chand (1996) examines the behaviour of the GDP deflator and finds that excess demand is an important determinant of inflation in India. On the other hand, Coe and McDermott (1997) find that the output gap model does not explain the Indian inflationary experience possibly since India has a large agriculture sector which is often subject to supply shocks.[1]

The more recent studies on inflation in India include Srinivasan et al. (2006), Srinivasan et al. (2009), Paul (2009), Dua and Gaur (2010) Singh et al. (2011) and Mazumder (2011). Srinivasan et al. (2006) estimate an augmented Phillips curve to examine the effects of supply shocks on inflation in India and find that supply shocks only have a transitory effect on both headline and core measures of inflation. They conclude that supply shock per se is not crucial in determination of inflation; it is the policy makers' response to these shocks that are important. Srinivasan et al. (2009) argue that the initial rise and subsequent fall in inflation in India during the 1960s to early 1990s are due to the lack of institutional commitment towards price stability and the low inflation in the later period is the result of positive supply-side developments. Considering supply and policy shocks and reconstructing the data series on output gap and inflation in crop year, Paul (2009) finds out the Phillips curve in the Indian manufacturing sector. Dua and Gaur (2010) examine the determinants of inflation for eight Asian countries including India in an open economy forward-looking as well as backward-looking Phillips curve framework and find that the output gap, import inflation and exchange rate are important determinants of inflation in these economies. They also find that for all countries, the forward-looking Phillips curve provides a better fit compared to the backward-looking Phillips curve. Taking supply shocks into account, Singh et al. (2011) find a clear evidence of the empirical existence of the Phillips curve in India for the recent years. Mazumder (2011) demonstrates that the Phillips curve exists for India, and the Lucas critique does not apply empirically to it.

[1] A positive demand shock causes output to rise above its potential level (i.e. a positive output gap develops) and this leads to an increase in inflationary pressure. However, a positive supply shock due to favourable monsoon is likely to result in lower inflation in agricultural sector and a decline in the general price level through its impact on industrial sector prices. Callen and Chang (1999) estimate an output gap model for India and find that while the agricultural output above its potential level reduces the WPI inflation, industrial output above its potential level is inflationary, although only the agricultural output gap is statistically significant.

3. The Empirical Model: A hybrid New Keynesian Phillips Curve for India

Following Gali and Gertler (1999) and Gali et al. (2001), the hybrid NKPC can be formulated as:

$$\pi_t = \alpha + \gamma_f \mathrm{E}_t\{\pi_{t+1}\} + \gamma_b \pi_{t-1} + \lambda' x_t + u_t \quad (1)$$

where π_t is the rate of inflation at time t, x_t represents the explanatory variable(s), $\mathrm{E}_t\{\pi_{t+1}\}$ is the expected value at time t of the inflation rate prevailing at time $t+1$, π_{t-1} represents lagged inflation and u_t is a disturbance term. In the NKPC specification x_t includes variables that capture demand pressure, proxied by the output gap or the unemployment rate or a measure of firms' real marginal cost. In the open economy versions of the NKPC, x_t also includes the exchange rate and the price of imported intermediate goods (Batini et al. 2005).

The theory of NKPC is suitable for the analysis of inflation dynamics in developed economies where the agriculture sector is very small (i.e. a low share of agriculture in GDP). The use of hybrid NKPC in explaining the inflation dynamics in India requires some modifications as the economy has a large agriculture sector which is often subject to supply shocks. Given the sector specific characteristics of the Indian economy, I use the agricultural and industrial output gaps separately in the model. I also incorporate the fuel inflation into the model in order to proxy the supply shocks to the economy. In an open economy, the exchange rate and the foreign price level have a direct impact on domestic price level through imports. In recent years, India has become increasingly integrated with the rest of the world through trade and finance.[2] Considering the open economy nature of the Indian economy, the model also includes the exchange rate and the foreign price level. Thus, the open economy hybrid NKPC for India can be written as:

$$\pi_t = \alpha + \gamma^f \mathrm{E}_t\{\pi_{t+1}\} + \gamma^b \pi_{t-1} + \beta y_t^a + \delta y_t^i + \lambda \pi_t^{fuel} + \phi \Delta e_t + \kappa \pi_t^f + u_t \quad (2)$$

where π_t and π_{t-1} represent current and lagged inflation respectively. $\mathrm{E}_t\{\pi_{t+1}\}$ is one period ahead expected inflation, y_t^a is the agricultural output gap, y_t^i denotes the industrial output gap. π_t^{fuel}, Δe_t and π_t^f represent the fuel inflation, the change in exchange rate and the foreign inflation respectively.

The one period ahead expected inflation $\mathrm{E}_t\{\pi_{t+1}\}$ is not directly observable. In order to estimate the equation, we need a suitable proxy for it. One option is to use survey data on expected inflation. Though it can be treated as an exogenous variable in the model, it may not

[2] India's total external trade (exports plus imports) in goods and services as percentage of gross domestic product (both measured in current prices) has increased from 20.4 per cent in 1996-97 to 44.9 per cent in 2008-09. (Data source: RBI Handbook of Statistics on Indian Economy).

be consistent with rational expectations (Scheibe and Vines 2005). In the absence of survey data on expected inflation in India over the sample period, I follow the technique proposed by McCallum (1976) of using the actual future value of inflation as a proxy for the one period ahead expected inflation. With this formulation the model can be rewritten as:

$$\pi_t = \alpha + \gamma^f \pi_{t+1} + \gamma^b \pi_{t-1} + \beta y_t^a + \delta y_t^i + \lambda \pi_t^{fuel} + \phi \Delta e_t + \kappa \pi_t^f + u_t \qquad (3)$$

where π_{t+1} is the actual (realized) inflation at time $t+1$. In the above specification, the disturbance term u_t includes the expectational error. Under rational expectations, this error must be uncorrelated with the information set dated *t*. So γ^f can be consistently estimated by using variables dated *t* or earlier as instruments for π_{t+1}.

I use the following equation for estimation:

$$\pi_t = \alpha + \gamma^f \pi_{t+1} + \gamma^b (L) \pi_{t-1} + \beta(L) y_t^a + \delta(L) y_t^i + \lambda(L) \pi_t^{fuel} + \phi(L) \Delta e_t + \kappa(L) \pi_t^f + u_t \qquad (4)$$

where (L) represents polynomials in the lag operator.

In the above model, π_{t+1} is expected to be correlated with the error term u_t since the disturbance term includes the expectational error. This is due to the fact that the actual future value of inflation is used as a proxy for the one period ahead expected inflation. However, in a rational expectations framework, this expectational error is uncorrelated with the information set at time period t. Thus, γ^f can be consistently estimated by using variables dated *t* or earlier as instruments for π_{t+1}. The instruments satisfy two conditions: instrument exogeneity and instrument relevance. That is, the instruments are uncorrelated with the model error term but are correlated with the endogenous regressor.

The agricultural and the industrial output gaps have been used separately in the model so as to represent the sectoral characteristics of both the sectors of the Indian economy. Although there were administered fuel prices in India over the sample period, the economy had experienced inflationary pressures over different periods due to the fuel price liberalisation. Hence, the fuel inflation has been included into the model to represent a supply shock (i.e. a cost of production shock) to the economy.

The lagged inflation captures the persistence in inflation. Both lagged and expected inflation show the backward and forward looking behaviour of the price setting agents in the economy respectively. Given the inertia in inflation as observed in the empirical literature, high inflation in the previous period leads to high current inflation. Similarly, high inflation expectations increase inflation in the current period due to higher wage bargaining by the workers. So the sign of the coefficient of lagged inflation and the inflation expectation one period ahead are expected to be positive.

It is worth mentioning that the appropriateness of the output gap model depends on whether demand or supply shocks dominate the economy (Callen and Chang 1999). The output gap is a good indicator of demand pressure in a sector (or economy) which is relatively less prone to supply shocks.

It is widely accepted that the agricultural output in India is largely supply determined. Following the Structuralist explanation, agricultural prices can be seen as adjusting to clear excess demand in the agricultural sector. Given that the Indian agriculture is still heavily rain dependent, a positive supply shock due to a favourable monsoon can cause agricultural output to exceed its potential (trend) level of production. Higher agricultural output compared to its trend level is likely to reduce the overall price level in the economy. As agricultural products are used as raw materials in industrial production, low agricultural prices reduce the cost of production in industrial sector and consequently reduce the price level in industrial sector. So the agricultural output above its potential level is likely to result in a decline in inflation at least in the first round. But the second round effects due to the rise in income in the agricultural sector may lead to higher demand for manufactured products and a rise in inflation (Callen and Chang 1999). Similarly, adverse supply shocks such as crop failures owing to droughts and floods have economy-wide inflationary ramifications.

The Structuralist approach postulates that the industrial prices are cost driven. The Industrial output above its potential level is inflationary. The potential output of the industrial sector depends on the constraints on factors of production in an economy. Attempts to produce more output than capacity would generate production bottlenecks and increase the cost of production in the industrial sector. This in turn results in higher industrial prices. An increase in fuel prices directly raises the cost of production. So the fuel inflation is expected to contribute to the overall inflation. An increase in the nominal exchange rate implies depreciation of the domestic currency which makes imports costly. Similarly, the foreign price level enters directly into import prices. Increase in the cost of the imported raw materials leads to higher prices of the manufactured products. From the above theoretical considerations, it is expected that the industrial output gap (a measure of excess demand in the industrial sector), fuel inflation, exchange rate and foreign inflation have a positive effect on domestic inflation.

4. Data and Methodology

4.1 Data sources and definition of the variables

Seasonally adjusted quarterly data from the first quarter of 1996-97 to the last quarter of 2009-10 are used for estimation.[3] Since the quarterly sectoral GDP data for India are available only for the first quarter of 1996-97 onwards, the sample period starts from thereon. The source of the data on the Wholesale Price Index (WPI) is the Office of the Economic Adviser, Ministry of Commerce and Industry, Government of India. The agricultural and the industrial output data are obtained from the Central Statistical Organisation. Data on nominal

[3] The X-12 ARIMA procedure is used for seasonal adjustment.

exchange rate and Wholesale Price Index of the top twenty import partners of India have been taken from the International Financial Statistics (IFS) database of the International Monetary Fund.

Inflation (π_t) is defined as the year-on-year percentage change in the wholesale price index (WPI-all commodities).[4] Both manufacturing sector inflation (π_t^m) and fuel inflation (π^{fuel}) are defined as the year-on-year percentage change in the manufactured products sub group of WPI and the fuel group of WPI respectively. The agricultural output gap (y_t^a) is measured as percentage deviation of agricultural output from its trend (proxy for potential output), where the trend computation is explained below. Similarly, the industrial output gap (y_t^i) is measured as percentage deviation of industrial output from its Hodrick-Prescott trend. Foreign inflation (π_t^f) is defined as the year-on-year percentage change in the index of foreign price level where the index of foreign price level has been constructed as a weighted average of the WPI of the top twenty import partners of India.[5] The nominal exchange rate (Rs/$) is defined as the number of Indian rupees per US dollar. An increase in the nominal exchange rate implies depreciation of Indian rupee against US dollar. The change in exchange rate (Δe_t) is measured as the year-on-year percentage change in the nominal exchange rate series. 364-day Treasury bill rate (r_t^{364}) is measured as the yield on 364- day Treasury bills issued by the Government of India.

[4] In the Indian context, inflation is usually measured as the year-on-year percentage change in the price index (Srinivasan et al. 2006, and Singh et al. 2011). Moreover, defining the inflation in terms of the year-on-year percentage change in the price index removes the seasonality effect in the data.

[5] The weights are determined by the period average import shares of the respective countries. The present study includes the following top 20 import partners (during the sample period) of India: Saudi Arabia, USA, Germany, Switzerland, Australia, South Korea, Japan, Singapore, Malaysia, Indonesia, Hong Kong, UK, Belgium, Italy, Thailand, Canada, Egypt, Netherlands, South Africa, Sri Lanka. Although countries like China, U.A.E, Kuwait, Iran, France and Russia have figured in the list of top 20 import partners of India for the sample period, they have been excluded because of the unavailability of the quarterly data on their Wholesale Price Index for the whole period.

Table-1

Descriptive statistics of the variables used in the empirical estimation:

Variable	Mean	Std. Dev.	Minimum	Maximum
π_t	4.975	2.162	-0.195	11.682
π_t^m	4.014	2.853	-5.870	14.366
π_t^f	2.226	3.330	-7.794	11.337
π_t^{fuel}	7.688	7.450	-9.840	27.477
y_t^a	-0.138	2.766	-11.629	5.573
y_t^i	-0.089	1.596	-3.057	2.968
Δe_t	2.399	7.575	-13.491	22.202
r_t^{364}	7.229	2.111	3.854	11.741

Note: All the variables are measured in terms of percentage.

4.2 Unit Root Tests

In order to determine the order of integration of the variables, I have used three types of unit root tests – the augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test. Table- 2 presents the unit root test results.

The ADF test results suggest that all the variables except foreign inflation and change in exchange rate are stationary, i.e. I(0) at conventional level of significance. Similarly, the PP test shows that all the variables except WPI inflation are stationary at conventional level of significance. According to the KPSS test results, the null hypothesis of stationarity of the series cannot be rejected for all the variables at 1 percent level of significance. However, given the low power of the unit root tests, if two of these tests indicate stationarity of any series at conventional level of significance, we conclude that the underlying series is stationary. Based on the unit root test results presented in Table- 2, all the variables are considered to be stationary in level. The GMM estimation is appropriate under this condition.

Table- 2: Unit Root Test results

	Unit Root Tests in Level		
Variable	ADF test statistic	PP test statistic	KPSS test statistic
π_t	-6.704***	-1.901	0.106
π_t^m	-4.002***	-4.002***	0.289
π_t^f	-1.646	-2.646*	0.163
π_t^{fuel}	-3.556**	-2.737*	0.376*
y_t^a	-4.739***	-3.616***	0.056
y_t^i	-3.216**	-2.778*	0.116
Δe_t	-1.643	-2.760*	0.196
r_t^{364}	-1.666*	-1.725*	0.664**

Note: ***, ** and * denote significance at 1%, 5% and 10% level respectively. All the test equations except for the 364-day Treasury bill rate in ADF and PP test include an intercept. The lag length selection for ADF test is based on Schwarz Information Criterion.

5. Empirical Results

In order to correct for the endogeneity problem in the model, the Generalized Method of Moments technique with heteroscedasticity and autocorrelation consistent (HAC) weighting matrix and iterating weights has been used for estimation. I have used maximum four lags of each variable except the one period ahead expected inflation in the estimation. During the estimation exercise the lags of some variables changed their sign and were not significant. Based on various model selection criteria, the following specification presented in Table- 3 is our preferred model. Table-3 also summarises the estimation results.

The J-test (Hansen test) of overidentifying restrictions indicates that the null hypothesis of the validity of the instruments cannot be rejected. To simply put, it shows that the instruments satisfy the orthogonality conditions (i.e. the instruments are uncorrelated with the error term of the regression model). To check for potential weakness of the instruments, we perform an F-test (the test of joint significance of the excluded instruments) in the first-stage regression. The F-statistic is significant at less than one percent level, although it does not exceed the rule of thumb value of 10 (Staiger and Stock 1997). Overall, these results mean that although the instruments are not highly correlated with the endogenous regressor, they are uncorrelated with the error term of the regression model. That is, most importantly, they satisfy the orthogonality conditions. In order to find relatively stronger instruments for the one period ahead expected inflation, I use four lags of r_t^{364} leading to an improved first-stage F-statistic.[6]

[6] I used additional instruments such as food inflation (the percentage change in the price level of food articles subgroup of WPI) and rainfall (percentage deviation of actual rainfall from the normal rainfall which is measured as 30 years moving average of the actual rainfall) in the estimation. But the results were similar. In order to be parsimonious in the use of instruments (Hahn and Hausman 2002), our preferred model excludes the additional instruments – food inflation and rainfall.

In case of the first specification in Table-3 i.e. for the WPI inflation as the dependent variable, I find that the coefficients on both lagged and expected inflation are positive and statistically significant. This suggests that the price setting agents in the Indian economy have both backward and forward-looking behaviour. The agricultural output above its trend level of production reduces inflation in the current period. The coefficient of lagged industrial output gap is positive which suggests that industrial output above its potential level increases inflation with one period lag. Overall, the results show that the industrial output gap (i.e. excess demand in the industrial sector) is inflationary whereas the agricultural output above its trend level reduces WPI inflation. This implies the significance of sectoral characteristics in determining Indian inflation. It also indicates the importance of considering both the agricultural and the industrial output gaps separately in explaining inflation in India.

The fuel inflation, the exchange rate and the foreign inflation have positive and significant effect on the WPI inflation. While both the fuel and foreign inflation have contemporaneous effect, the change in exchange rate has lagged effect on inflation. Both the external factors – foreign price level and exchange rate – are statistically significant in determining the WPI inflation. This indicates that the external factors are critical to determining the domestic price level in India.

As a robustness check, we estimate the model by using the manufacturing sector inflation as the dependent variable. The results are summarised in the third column in Table- 3. The J-test (Hansen test) of overidentifying restrictions indicates that the instruments are uncorrelated with the error term of the regression model. The F-statistic in the first-stage regression is significant at less than five percent level.

Table-3: The estimated open-economy Phillips curve for India

Variables	WPI inflation	Manufacturing sector inflation
α	-1.006***	-0.163
	(-6.027)	(-0.651)
π_{t+1}	0.451***	
	(13.266)	
π_{t-1}	0.583***	
	(15.985)	
π_{t+1}^{m}		0.428***
		(10.994)
π_{t-1}^{m}		0.401***
		(12.487)
y_t^a	-0.033*	
	(-1.848)	
y_{t-1}^{a}		-0.079***
		(-3.765)
y_{t-1}^{i}	0.146***	0.114**
	(4.551)	(2.647)
π_t^{fuel}	0.070***	0.028***
	(11.338)	(1.832)
Δe_{t-1}	0.060***	0.007
	(6.455)	(0.711)
π_t^{f}	0.085***	0.153***
	(2.970)	(5.284)
Hansen J-stat	10.651	10.759
	[0.979]	[0.978]
F-stat	3.443	2.307
	[0.006]	[0.041]

Note: ***, ** and * indicate significance at 1%, 5% and 10% level respectively. The t-statistics are in ( ) and the p-values are in [ ] under the corresponding coefficients. The J-statistic corresponds to the Hansen test of overidentifying restrictions and the F-statistic refers to the test of joint significance of the excluded instruments in the first-stage regression. In case of the WPI inflation, instruments used are: a constant and four lags each of inflation, industrial output gap, changes in exchange rate, fuel inflation and 364-day Treasury bill rate and current as well as three lags each of agricultural output gap and foreign inflation. In case of the manufacturing sector inflation, the instruments used are: a constant and four lags each of manufacturing sector inflation, agricultural output gap, industrial output gap, changes in exchange rate, fuel inflation and 364-day Treasury bill rate and three lags of foreign inflation. The current period fuel inflation and foreign inflation are also included in the list of instruments in both the model specifications.

In case of the second specification in Table-3 i.e. for the manufacturing sector inflation as the dependent variable, I find the agricultural output gap affects manufacturing sector inflation negatively with one period lag. This suggests that transmission of agricultural prices to manufacturing sector prices is not instantaneous. The positive coefficient on lagged industrial output gap implies that excess demand for industrial output in the previous period increases the price level in the manufacturing sector in the current period. Although both the exchange rate and foreign inflation have positive effect on manufacturing sector inflation, exchange rate is not statistically significant. The fuel inflation has positive and statistically significant effect on manufacturing sector price level in India.

6. Conclusion

The present study finds that the open economy hybrid New Keynesian Phillips Curve provides a robust explanation of the short run inflation dynamics in India over the sample period 1996-97 to 2009-10. The empirical results show that the price setting agents in the Indian economy are guided by both backward and forward-looking behaviours. The agricultural and the industrial output gaps, the fuel inflation, the exchange rate and the foreign inflation are important determinants of the wholesale price index inflation in India. All the variables except exchange rate are found to be statistically significant in determining the Indian manufacturing sector inflation. At length, the coefficient on the one period ahead expected inflation should be interpreted with caution as it may be biased owing to a little weaker set of instruments.

The results suggest that the supply side factor such as low agricultural production is one of the important determinants of the current inflationary pressure in India. Moreover, supply shocks due to increase in fuel prices add to the price level. The domestic price level is also affected by the global commodity prices due to India's increasing integration with the world economy through trade. Finally, the surge in rural demand in recent years has put an upward pressure on the prices of both agricultural and manufacturing products. An efficient supply management mechanism through the public distribution system together with a clear focus to enhance productivity in the agriculture sector are required to maintain a reasonably stable price level in India in the long run.

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