PRICE CO-MOVEMENTS, COMMONALITIES AND RESPONSIVENESS TO MONETARY POLICY: EMPIRICAL ANALYSIS UNDER INDIAN CONDITIONS

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This study aims to empirically establish the co-movement of price indices of seemingly unrelated commodities, suggesting that the Central Bank should not decouple fluctuation in the national price index into volatile and core components. An attempt is also made to understand whether monetary policy can influence the factors responsible for price fluctuations in the states of India. The study becomes especially relevant under Indian conditions where flexible inflation targeting has been adopted by the Reserve Bank of India (Central Bank of India) and achieving the targeted inflation is a primary concern of the Indian government. The results of the empirical analysis clearly reveal that unrelated price indices co-move in India, and that monetary policy initiatives fail to influence the common factors of the states of India. The empirical results have crucial implications for the Reserve Bank of India and, as such, a conscious effort is needed to enable policy to influence the price indices of the states of India.

JEL classification: C50, E31, E50

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I. INTRODUCTION

Analysis of price behaviour has attracted the attention of economists and policymakers for more than a hundred years (Sraffa, 1926; Chamberlin, 1933; Robinson, 1969; Taylor, 1980; Calvo, 1983; Rotemberg, 1982). Research on prices has attempted to address a number of issues such as: comparing trends between unrelated commodity prices (Prebisch, 1950), studying the time series properties of prices (Deaton, 1999), testing for convergence in prices (Cecchetti, Nelson, and Sonora, 2002) and the impact of staggered price setting on policy effectiveness (Taylor, 1980; Calvo, 1983; Rotemberg, 1982).

Dixit and Stiglitz (1977) were among early macroeconomists to explain pricing behaviour in monopolistically competitive markets using the Dynamic Stochastic General Equilibrium framework. Using the technique of dynamic optimization, they showed that for a given economy, the aggregate price is a weighted average of individual (disaggregate) prices. This implies: 1) Disaggregate prices play a critical role in the determination of aggregate prices; and 2) If disaggregate prices co-move, then fluctuations in one of the disaggregate prices would pull other non-related disaggregate prices along with it, causing the aggregate price to fluctuate much more than the initial fluctuation in the disaggregate price. However, contrary to these findings, most central banks believe that fluctuations in price indices (which are a weighted average of disaggregate prices) can be decoupled into volatile fluctuations (usually fluctuations in food prices) and core fluctuations, and therefore should respond only to core fluctuations (Sprinkel, 1975; Tobin, 1981; Eckstein, 1981; Blinder, 1982; Rich and Steindel, 2005).

The Reserve Bank of India has recently adopted flexible inflation targeting as the new monetary policy framework. Under this new framework, the official measure of inflation is the rate of change in the new consumer price index (CPI), constructed by the Ministry of Statistics and Programme Implementation of India (MOSPI). This is constructed as a weighted average of prices for six broad categories of commodities and services (see table 1) collected from 79 different centres spread across the country, and reported at three different levels – rural, urban and combined (rural + urban). The successful implementation of flexible inflation targeting in India thus warrants a further understanding of the push and pull factors influencing the new CPI. It is against this backdrop – the theoretical contribution of Dixit and Stiglitz (1977) on aggregate and disaggregate prices, as opposed to the belief in volatile and core price movements (Sprinkel, 1975; Tobin, 1981; Eckstein, 1981; Blinder, 1982; Rich and Steindel, 2005) and the changing contours of monetary policy in India – that the present study attempts to answer the following research questions:

1. Do disaggregate price indices (state level food and state level non-food prices) co-move in India? If yes, then any positive or negative shock to disaggregate prices, would eventually percolate through to other prices and create upward or downward movements in the average prices.

2. Are unrelated disaggregate price indices (e.g. food price indices and non-food price indices) influenced by non-stationary common factors?

3. Do the common factors of the disaggregate prices respond to monetary policy?

To elaborate further, the present research undertakes the task of identifying co-movements across unrelated price indices of Indian states, analysing the microbehaviour of the price indices, filtering out the common factors affecting these indices, and eventually testing the policy-responsiveness of these common factors. The paper is structured as follows: section II reviews the literature; section III briefly discusses the trends in the new CPI; section IV discusses data and methodology; section V discusses empirical results and Section VI concludes.

II. REVIEW OF LITERATURE

The behaviour of prices has been studied by researchers from various perspectives, ranging from their behaviour in different markets, to their trends and convergence to responsiveness to policy.

Although they tended to be treated as being fully flexible in perfectly competitive markets by classical macroeconomists, Sraffa (1926), Chamberlin (1933) and Robinson (1969) began to question the analysis of prices in perfectly competitive markets against imperfect or monopolistic competition. Hall and Hitch (1939) went further into other market forms, shedding light on the system of “full-cost pricing” practised by firms or producers. The new classical economists severely criticized Keynes for arbitrarily assuming price stickiness and thus proving policy to be effective. Keynes (1936) assumed (without substantiation) that prices are not flexible – contrary to the belief of the classical economists – and as such policy becomes effective on that basis. The works of Lucas (1972) clearly showed how unanticipated policy shocks are effective due to staggered price adjustments that occur as a result of incomplete information, even when perfect competition prevails in the markets. The new Keynesians (Taylor, 1980; Calvo, 1983; Rotemberg, 1982; Blanchard and Kiyotaki, 1987; Dixit and Stiglitz, 1977) rekindled the Keynesian belief in policy effectiveness due to the prevalence of nominal and real rigidities that occur in markets as a result of imperfect competition in the factor or product markets, by providing microfoundations to the entire Keynesian theory.

Some strands of literature decouple price movements into the volatile components of price indices (such as food and fuel) from prices of non-volatile components (such as core commodities of price indices), arguing that policy should respond only to movements in the core items. Other strands of literature however show that co-movements in commodity prices exist very strongly, and highlight a "herd behaviour" in prices (Pindyck and Rotemberg, 1990).

The decoupling of core from volatile components of the prices emerged in the 1970s during the glory years of the Organization of the Petroleum Exporting Countries (OPEC), when it was realized that the underlying trend in inflation had to be tracked for policy purposes, rather than the headline or aggregate inflation. Since then, several studies on the relevance of core price movement from the point of view of policy started pouring in (Sprinkel, 1975; Tobin, 1981; Eckstein, 1981; Blinder, 1982; Rich and Steindel, 2005). These studies looked at prices from the perspective of their inflationary impact, and therefore subsequent policy response. Eckstein (1981) was among the pioneers to propose that measured inflation could be split into three parts: core inflation; demand inflation; and shock inflation. Since demand shocks are short term in nature, policy should respond only to inflation which is due to core inflation or non-food prices. The last decade marked a watershed on this point for developing nations, where food comprises a major component in the consumption basket and food prices have been disproportionately rising. To some extent, this strand of literature connects to that of co-movement in prices.

The second strand of literature, however, highlights the fact that co-movements are a central and distinctive feature of commodity prices (West and Wong, 2014). These co-movements may be due to common factors influencing those prices, or to herd behaviour. Studies on co-movements in prices have concentrated on economic aspects, such as their impact on aggregate inflation, impact of fuel prices on food prices (Baffes, 2007; Baumeister and Geert, 2011), impact of financialization on co-movement of prices (Pradhananga, 2016). Many studies concluded that there are various common factors influencing these prices. For example, if these prices are I (1) (integrated of order one, i.e. become stationary on first differencing), then a cointegrating relationship between the prices and common factors should exist. In short, these prices hover around the common factor (West and Wong, 2014). While some studies concentrate on co-movements in prices of similar commodities (Chow, Huang and Niu, 2013; Baffes, 2007), others have found co-movements among different groups of prices (West and Wong, 2014).

In the process, a myriad of methodologies have been used by researchers. Some techniques used in the literature are: time varying correlations to study the co-movements in volatility of prices (Chow, Huang and Niu, 2013); vector autoregressions and their impulse response functions to study the impact of changes in one type of commodity price on the other; variants of structural VARS and their impulse response functions (Baumeister and Kilian, 2012); factor-augmented VARS; principal component analysis (West and Wong, 2014; Alquist and Coibion, 2013).

From a review of the foregoing literature one can appreciate the importance of understanding whether some price movements (food items) are temporary, while others (core items) are permanent, or if a movement in any price leads to a ripple effect across prices, (i.e. whether there are co-movements among unrelated commodity prices). Also, if prices do co-move, there are probably some common factors influencing all prices. Very few studies delve into the question as to whether the common factors of prices respond to policy. To the best of our knowledge, no such study has been conducted in the context of India. Such a study is an essential prerequisite to policy implementation for an accurate understanding of price movements, the factors influencing them and the response of those factors to policy decisions. Further to the work of Bryne, Fazio, and Fiess (2010), this paper studies co-movements among prices and the response of these co-movements to policy. However, it differs from Bryne, Fazio and Fiess (2010), in terms of the methodology used for identifying co-movement among price indices and the nature of prices used. The panel cointegration methodology of Pedroni (1999) has been used in this paper to identify co-movements among the unrelated disaggregate price indices which, to the best of the author's knowledge, has not been attempted until now. Additionally, the co-movements in this study are taken up from states of India for both food and non-food price indices, whereas Bryne, Fazio and Fiess (2010) studied co-movement among prices of 24 commodities. An attempt is also made to split the factors responsible for the co-movements in prices into idiosyncratic and common factors, using panel analysis of idiosyncratic and common component – PANIC analysis – of Bai and Ng (2004). The response of the common factors – as derived from the price indices of Indian states using PANIC analysis – to monetary policy at the aggregate (national) level is then tested in a factor augmented vector autoregression – FAVAR framework.

III. COMPOSITION AND TRENDS IN THE NEW CONSUMER PRICE INDEX OF INDIA

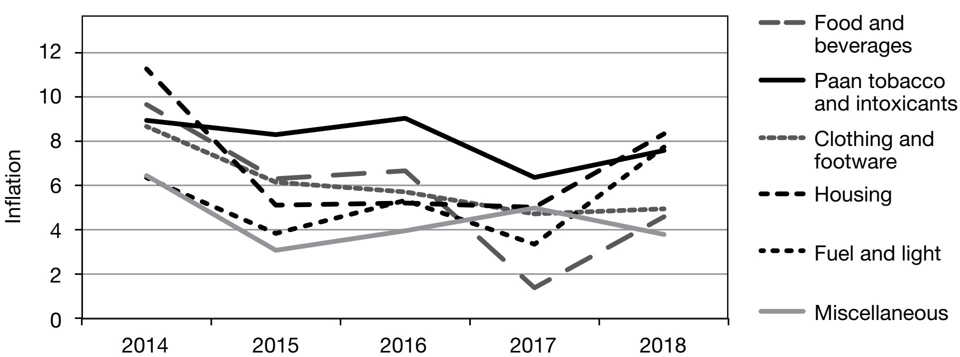
The empirical exercise of the present study employs the new consumer price index of Indian states to study co-movements among unrelated prices. The new CPI (combined) of India is the weighted average of prices collected from 79 centres across India, and the growth rate of the new CPI is used to estimate the official measure of inflation. This index is constructed and published by the Ministry of Statistics and Programme Implementation of India, for the individual states and union territories of India as well as for the entire country. There are some variations in the weighting of different items included in this index across the states and across rural and urban areas, thereby highlighting the difference in their consumption baskets and demand conditions. The weight given to each of the six broad categories of items included in the new CPI (combined) for the entire country has been reported in table 1 below. It is apparent that, of the six broad categories of commodities used to construct the new CPI, food items occupy the maximum weight across different levels.

Table 1. Itemized weightings in the new consumer price index (CPI) (all India)

Item	Weight of items in the rural CPI	Weight of items in the urban CPI	Weight of items in the CPI combined
Food and beverages	54.18	36.29	45.86
Paan, tobacco and intoxicants	3.26	1.36	2.38
Clothing and footwear	7.36	5.57	6.53
Housing	..	21.67	10.07
Fuel and light	7.94	5.58	6.84
Miscellaneous	27.26	29.53	28.32

Food items are followed by miscellaneous items and housing in urban areas. The weight given to the rest of the items is less than 10. The rate of change for each component index of the new CPI of India (i.e. inflation) has been plotted for the period 2014 to 2018 in the figure 1 below.

Figure 1. All-India inflation rate by component



While there is a remarkable decline in the rate of inflation across all components of the new CPI, most of them are moving together. Food inflation was significant in 2014, and thereafter gradually declined, reaching its lowest levels in 2017. With a decline in food prices, all other prices, except the miscellaneous items, also declined. The movement almost in sync of the components of the new CPI of India thus sets the background for the empirical work taken up in the rest of this paper.

IV. DATA AND OUTLINE OF METHODOLOGY

The empirical design

The empirical analysis is accomplished in the following three steps:

Step I: To empirically test whether unrelated price indices in the states of India (food prices and non-food prices) co-move, using the technique of panel cointegration analysis (Pedroni, 1999). Presence of a significant cointegrating relationship between a set of variables in a panel dataset establishes that the variables co-move over a period of time. Application of a cointegration test for testing of co-movements is a standard technique used in the literature (Manes, Schneider and Tchetchik, 2016).

Step II: To empirically explore the source of non-stationarity in the panel of prices using the panel analysis of idiosyncratic and common component - PANIC analysis of Bai and Ng (2004). The PANIC analysis decomposes the panel into idiosyncratic and common components, and allows the common component to be non-stationary. From the perspective of the present study, if the common components of the panel of prices are found to be non-stationary it implies cross-unit cointegration. To clarify further, our panel is composed of food price data and non-food price data from 25 states of India. The PANIC of the Bai and Ng (2004) test helps us to show that prices of the same set of commodities, (e.g. food prices, are cointegrated across the states of India) in addition to the prevalent cointegration between food and non-food prices as discussed in step one.

Step III: To empirically evaluate whether the common factors derived in Step 2 (see above) respond to monetary policy impulse. Impulse response functions derived from the vector autoregression are commonly-used techniques for understanding the response of variables to shocks. Since we are attempting to study the behaviour of the common factor of prices in response to a shock to monetary policy, the conventional vector autoregression model is augmented by the inclusion of a common factor. This is derived from prices using the method of principal component analysis, hence the name factor augmented vector autoregression – FAVAR model, following Bernanke, Boivin, and Eliasz (2005). If the impulse response functions of the common factor of prices respond to policy shocks, then it can be concluded that policy is effective and vice versa.

Definition of variables used in the empirical analysis and data sources

The food and beverages price index (food prices hereafter) and fuel price index are readily available for all the states of India. However, the non-food price indices for each state had to be derived, following the exclusion-based measure (of food and fuel prices) of Bhattacharya and others (2014), which is as given in equation (1):

$$Nonfoodpriceindex = \frac{CPI\text{-}w(fa)CPI(fa)\text{-}w(fu)CPI(fu)}{1\text{-}w(fa)\text{-}w(fu)} \qquad (1)$$

Where, w(fa) is weight of food articles in CPI, w(fu) is weight of fuel in CPI, CPI(fa) is consumer price index of food articles and CPI(fu) is consumer price index fuel articles.

Table 2. List of variables used in the empirical exercise and their data sources

Name of the variable	Level	Period	Data source	Calculation method
New CPI (food)	25 states of India (rural, urban and combined)	2011 Jan to 2018 Jan	MOSPI (2019) website	Readily available
New CPI (non-food)	25 states of India (rural, urban and combined)	2011 Jan to 2018 Jan	MOSPI (2019) website	According to equation 1 given below
Common factor of prices	25 states of India (rural, urban and combined)	2011 Jan to 2018 Jan	MOSPI (2019) website	Principal component of price indices used
Call money rate	All India	2011 Jan to 2018 Jan	Reserve Bank of India (2017) Handbook of Statistics on Indian Economy	Readily available
Demand shock	All India	2011 Jan to 2018 Jan	-	Standard deviation of prices of the States
Supply shock	All India	2011 Jan to 2018 Jan	MOSPI (2019) website	Actual rainfall for a given month – average rainfall in that month in the last century

Note: India, Ministry of Statistics and Programme Implementation (MOSPI).

V. RESULTS OF EMPIRICAL ANALYSIS

Step I: To test if the unrelated price indices co-move

Given that the panel of price indices comprise a lengthy time dimension, they may possess time series properties (i.e. the panel data set comprises 84 monthly (time dimension) observations for each of the 25 states of India). Therefore, as a first step, the panel data is tested for stationarity using the cross sectional augmented Im, Pesaran and Shin (CIPS) test and the results are reported in table 3 below. At this point, it is important to mention that the state-level prices were tested for cross-sectional dependence using the Breusch and Pagan (1980) test and the Pesaran (2007) test, and were found to be cross-sectionally dependent (results not reported here).

Table 3. Panel unit root tests of the price indices for states of India (January 2012 to September 2016)

Variable name	CIPS statistic (level)	CIPS statistic (1^{st} Diff)
Food prices (rural)	-2.2918	-3.7871***
Non-food prices (rural)	-2.4714	-3.7319***
Food prices (urban)	-2.1536	-4.1682***
Non-food prices (urban)	-2.2484	-4.1255***
Food prices (rural+urban)	-2.2576	-3.7601***
Non-food prices (rural+urban)	-2.1791	-3.7457***

Note: Implied p-value is 0.0001.

These tests were carried out for rural, urban and combined price indices separately. It can be seen from table 3 (see above) that price indices are non-stationary in level as per the CIPS test and become stationary on first differencing, implying that their order of integration is (1). Since the order of integration of the variables is the same, they can be tested for a cointegrating relationship. Presence of cointegration between food and non-food price indices, at different levels (rural, urban and combined) will establish co-movements among them.

Table 4. Bivariate cointegration test between different price indices

Cointegrating relationship between	Null of no cointegration
Food prices and non-food prices (rural)	Rejected
Food prices and non-food prices (urban)	Rejected
Food prices and non-food prices (rural+urban)	Rejected

A summary of panel cointegration test results based on the Pedroni (1999) methodology for the food and non-food price indices is reported in table 3 above, with detailed results reported in the appendix. It is evident that the food and non-food price indices are cointegrated in rural, urban and combined areas. A cointegrating relationship among price indices implies that these indices share a common trend and therefore co-move. This serves the main objective of the present exercise, which is to empirically establish that unrelated price indices do indeed co-move.

Step II: Studying the source of non-stationarity in the panel of prices

Table 5. Bai and Ng (2004) panel analysis of idiosyncratic and common components – PANIC test results

Component of prices	t-value	Null of non-Stationarity
Demeaned	4.677***	Rejected
Idiosyncratic	11.0963***	Rejected
Common	-1.989	Fail to reject

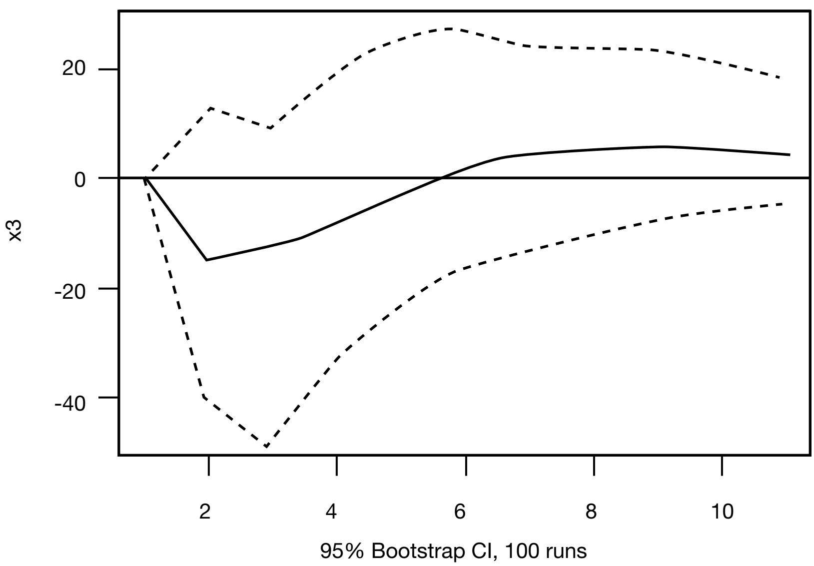
Having established the cointegrating relationship between the price indices, the next step is to filter out the common factors affecting them and to test their response to the monetary policy variable. It is equally important to establish whether these common factors are the reason for non-stationarity in the price data. Accordingly, the Bai and Ng (2004) PANIC test was applied to the prices. Table 5 (see above) shows the test results. The total number of common factors was found to be one, using the Bayesian Information Criteria (BIC) 3 criteria (results not reported here), and using principal components analysis, the common factor which was the first principal component found to be I(1), with a t value equal to -1.989. Since this value is less than the critical value at 5 per cent significance level, we fail to reject the null of non-stationarity. It is thus clear that the common factor governing the price indices is non-mean reverting, and this is the reason for non-stationarity in the data. It is important to note that the idiosyncratic component is stationary (see table 5), and as such the impact of local fluctuations on the price indices has temporary memory.

Step III: Testing for response of common factors to policy impulses in a factor augmented vector autoregressive approach – FAVAR framework

In this step, the common factors of price indices derived in the previous step were modelled in a FAVAR framework. In addition to the common factors (which serve as a proxy for the average prices across the country) and the policy rate, the demand shocks (proxied by the standard deviation of prices) and the supply shocks (proxied by rainfall shocks as defined in table 2) were also added to the FAVAR model. The demand and supply shocks were added to the FAVAR model because prices cannot be modelled in isolation from demand and supply. It is important to note that a number of demand and supply shocks influenced prices: not all of them can be measured nor can we include all of them into the FAVAR model. As a result, proxies have been used following Bryne, Fazio, and Fiess (2010).

Lastly, the repo rate is the policy variable of the Reserve Bank of India. However, due to the difficulties in making it stationary – as the sample is relatively small and the repo rate remained constant for long periods of time – the call rate, which is the operating target of monetary policy in India and which has a very high correlation with the repo rate, was used.

Figure 2. Orthogonal impulse response of the common factor (x3) due to shock to call rate (x5)



Since the FAVAR model is comprised of four variables, sixteen impulse response functions were derived. However, because the aim of the FAVAR analysis is to study the response of the common factor of prices to monetary policy impulse, we only report the impulse response function of that common factor in figure 2 above. The dotted lines in the impulse response function represent 95 per cent confidence interval bands, and it can be clearly seen that the confidence interval bands include the zero-horizontal axis at all time horizons, which implies the impulse response function is statistically insignificant throughout the time horizon. This clearly suggests that monetary policy is not able to affect the common factors influencing the price indices of the states of India.

VI. DISCUSSION OF EMPIRICAL RESULTS AND CONCLUSION

The stationarity test clearly reveals that the food price index and the non-food price index for states under consideration is non-stationary in level, and becomes stationary on first differencing, which implies that these price indices are not mean. Since the non-stationary series with the same order of integration can be cointegrated, the food price and non-food price indices of Indian states were tested for Pedroni's (1999) panel cointegration. Significant cointegrating relations between food and non-food price indices were observed at all levels (rural, urban and combined). This result authenticates the viewpoint of West and Wong (2014), that co-movements are a central feature of commodity prices, and therefore Central Banks should not decouple price movements into volatile and core components. This part of the empirical result reaffirms the fact that prices follow a form of herd behaviour, and that food price inflation is not temporary, as it breeds into the prices of non-food commodities and vice versa. As a result, every movement in the price index, which is used to estimate the official measure of inflation, warrants policy response.

Second, the Bai and Ng (2004) panel analysis of idiosyncratic and common component analysis further demonstrates that non-stationarity among price indices is due to the common factors influencing them. From this it can be inferred that common factors influencing prices, (which may be demand or supply shocks) might not be of a temporary nature and would thus require structural changes at the micro level.

Third, the impulse response functions derived from the factor augmented vector autoregression analysis throws light on some important aspects of monetary policy and its effectiveness. The insignificant impulse response function, showing the impact of shocks to policy rate among common factors in Indian states, clearly highlight the fact that monetary policy in India is unable to address those factors responsible for fluctuations of prices across the country. This is perhaps one of the reasons behind the differential rates of inflation existing across India.

It can thus be concluded that co-movements among prices of unrelated goods do exist in India. These co-movements are mainly due to the common factors such as political, economic, international or social factors, affecting prices. As a result of these co-movements among unrelated prices, no movement in any price should be ignored by policymakers. Since these common factors among Indian states do not respond to policy, the Reserve Bank of India should seek to identify the sources of fluctuations within states, so that the flexible inflation targeting of India becomes successful in the long run.

REFERENCES

Alquist, R., and O. Coibion (2013). The comovement in commodity prices: sources and implications. IMF Working Paper, No.13/140. Washington, D.C.: International Monetary Fund. Available from www.imf.org/en/Publications/WP/Issues/2016/12/31/The-Comovement-in-Commodity-Prices-Sources-and-Implications-40633.

Bai J., and S. Ng (2004). A PANIC attack on unit roots and cointegration. *Econometrica*, vol. 72, No. 4, pp. 1127-1177.

Baffes, J. (2007). Oil spills on other commodities. *Resource Policy*, vol. 32, No. 3, pp. 126-134.

Baumeister, C., and P. Geert (2011). The role of time-varying price elasticities in accounting for volatility changes in the crude oil market. *Journal of Applied Econometrics*, vol. 28, No. 7, pp. 1087-1109.

Baumeister, C., and L. Kilian (2012). Real-time forecasts of the real price of oil. *Journal of Business and Economic Statistics*, vol. 30, No. 2, pp. 326-336.

Bhattacharya, Rudrani, Narhari Rao, and Abhijit Sen Gupta (2014). Understanding food inflation in India. ADB South Asia Working Paper, No. 26. Asian Development Bank. Available from https://www.adb.org/publications/understanding-food-inflation-india.

Bernanke, B.S., J. Boivin, and P. Eliasz (2005). Measuring the effects of monetary policy: a factor-augmented vector autoregressive (FAVAR) approach. *Quarterly Journal of Economics*, vol. 120, No. 1, pp. 387-422.

Blanchard, O. J., and N. Kiyotaki. (1987). Monopolistic competition and the effects of aggregate demand. *American Economic Review*, vol. 77, No. 4, pp. 647-666.

Blinder, A. S. (1982). Review of core inflation by Otto Eckstein. *Journal of Political Economy*, vol. 90, pp. 1306-1309.

Breusch, T. S., and A. R. Pagan (1980). The Lagrange multiplier test and its application to model specifications in econometrics. *Review of Economic Studies*, vol. 47, No. 1, pp. 239-253.

Bryne, J.P., G. Fazio, and N. Fiess (2010). Primary commodity prices: co-movements, common factors and fundamentals. *Journal of Development Economics*, vol. 101, pp 16-26.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, vol. 12, No. 3, pp. 383-398.

Chamberlin, E. (1933). *The Theory of Monopolistic Competition*. Cambridge: Harvard University Press.

Chow, G. C., S. Huang, and L. Niu (2013). Econometric analysis of stock price co-movement in the economic integration of East Asia. Working Papers, Wang Yanan Institute for Studies in Economics (WISE), Xiamen University. Available from www.princeton.edu/~gchow/Econometric%20Analysis%20of%20Stock%20Price%2020111004.pdf.

Cecchetti, S.G., C. M. Nelson, and R. Sonora (2002). Price index convergence among United States cities. *International Economic Review*, vol. 43, No. 4, pp. 1081-1099.

Deaton, A. (1999). Commodity prices and growth in Africa. *Journal of Economic Perspectives*, vol. 13, No. 3, pp. 23-40.

Dixit, A., and J. Stiglitz (1977). Monopolistic competition and optimum product diversity. *The American Economic Review*, vol, 67, No. 3, pp. 297-308.

Eckstein, Otto (1981). *Core Inflation*. Englewood Cliffs: Prentice-Hall.

Hadri, K. (2000). Testing for stationarity in heterogeneous panel data. *Econometrics Journal*, vol. 3, No. 2, pp. 148-161.

Hall, R. L., and C. J. Hitch (1939). Price theory and business behaviour. *Oxford Economic Papers*, vol. 2, No. 1, pp. 12-45.

Im, K. S., M. H. Pesaran, and Y. Shin (1997). Testing for unit roots in heterogeneous panels. Mimeo.

Im, K. S., M. H. Pesaran, and Y. Shin (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, Vol. 115, pp. 53-74.

India, Ministry of Statistics and Programme Implementation (MOSPI) (2019). Consumer Price Index (CPI) Database. Available from www.mospi.gov.in. Accessed 23 April 2019.

Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*. London: Macmillan.

Lucas Robert Jr. (1972). Expectations and the neutrality of money. *Journal of Economic Theory*, vol. 4, No. 2, pp. 103-124.

Levin, A., C. F. Lin, and C. S. J. Chu (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, vol. 108, No. 1, pp. 1-24.

Manes. E., F. Schneider, and A. Tchetchik (2016). On the boundaries of shadow economy: an empirical investigation. IZA Discussion Paper No. 10067. Bonn: IZA Institute of Labor Economics. Available from www.iza.org/publications/dp/10067/on-the-boundaries-of-the-shadow-economy-an-empirical-investigation.

Moon, H. R., and B. Perron (2004). Testing for a unit root in panels with dynamic factors. *Journal of Econometrics*, vol. 122, No. 1, pp. 81-126.

Patnaik, A. (2016). Inflation differential and inflation targeting in India. *Prajnan*, vol. 45, No. 1, pp. 9-24.

Pedroni, P. (1999). Critical values for cointegration tests in heterogenous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, Special Issue, 0305-9049, pp. 653-670. Oxford, United Kingdom: Blackwell. Available from https://pdfs.semanticscholar.org/305e/3d41bb89d64cad1662532952f980a169f3f5.pdf.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross section dependence. *Journal of Applied Econometrics - Special Issue*, vol. 22, No. 2, pp. 265-312.

Pindyck, R. S., and J. J. Rotemberg (1990). The excess co-movement of commodity prices. *The Economic Journal*, vol. 100, No. 403, pp. 1173-1187.

Pradhananga, M. (2016). Financialization and the rise in co-movement of commodity prices. I*nternational Review of Applied Economics*, vol. 30, No. 5, pp. 547-566.

Prebisch, R. (1950). *The Economic Development of Latin America and its Principal Problems*. New York: United Nations. Available from https://repositorio.cepal.org/bitstream/handle/11362/30088/S4900192_en.pdf?sequence=1&isAllowed=y.

Reserve Bank of India (2017). *Handbook of Statistics on the Indian Economy*. Mumbai. Available from https://rbidocs.rbi.org.in/rdocs/Publications/PDFs/0HANDBOOK2017C9CF31D4B78241C9843272E441CD7010.PDF.

Rich, R., and C. Steindel (2005). A review of core inflation and an evaluation of its measures. Staff Report No. 236. Federal Reserve Bank of New York. Available from www.newyorkfed.org/medialibrary/media/research/staff_reports/sr236.pdf.

Rotemberg, J. J. (1982). Monopolistic price adjustment and aggregate output. *Review of Economic Studies*, vol. 49, No. 4, pp. 517-531.

Robinson, J. (1969). The theory of value reconsidered. *Australian Economic Papers*, vol. 8, No. 12, pp. 13-19.

Said, S.E. and D.A Dickey (1984). Testing for unit roots in autoregressive-moving average models of unknown order. *Biometrika*, vol. 71, No. 3, pp. 599-607.

Sprinkel, B. W. (1975). 1975: A year of recession, recovery and decelerating inflation. *Journal of Business*, vol. 48, No. 1, pp. 1-4.

Sraffa, P. (1926). The laws of returns under competitive conditions. *The Economic Journal*, vol. 36, No. 144, pp. 535-551.

Taylor J. B. (1980). Aggregate dynamics and staggered contracts. *Journal of Political Economy*, vol. 88 , No. 1, pp. 1-23.

Tobin, J. (1981). The monetarist counter-revolution today - an appraisal. *Economic Journal*, vol. 91, No. 361, pp. 29-42.

West, K. D., and K. Wong (2014). A factor model for co-movements of commodity prices. *Journal of International Money and Finance*, vol. 42, pp. 289-309.

APPENDIX

Table A.1. Panel cointegration results for the 25 states under consideration

Pedroni residual cointegration test CPI (food) and CPI (non-food) *Rural*			
Within dimensions	**Statistic**	**Between dimensions**	**Statistic**
Panel v-statistic	2.8593		
Panel rho-statistic	-62.034	Group rho-statistic	-70.3814
Panel PP-statistic	-16.390	Group PP-statistic	-16.1742
Panel ADF-statistic	-227.390	Group ADF-statistic	-15.9607

Pedroni residual cointegration test CPI (food) and CPI (non-food) *Urban*			
Within dimensions	**Statistic**	**Between dimensions**	**Statistic**
Panel v-statistic	65.24134		
Panel rho-statistic	-57.4018	Group rho-statistic	-53.1677
Panel PP-statistic	-12.8914	Group PP-statistic	-11.8808
Panel ADF-statistic	-14.4973	Group ADF-statistic	-11.6376

Pedroni residual cointegration test CPI (food) and CPI (non-food) *Combined*			
Within dimensions	**Statistic**	**Between dimensions**	**Statistic**
Panel v-statistic	13.39335		
Panel rho-statistic	-107.342	Group rho-statistic	-108.045
Panel PP-statistic	-27.7450	Group PP-statistic	-23.92913
Panel ADF-statistic	-107.086	Group ADF-statistic	-23.5788

Table A.2. List of states used in the panel

1. Andhra Pradesh
2. Arunachal Pradesh
3. Assam
4. Bihar
5. Chattisgarh
6. Goa
7. Gujarat
8. Haryana
9. Himachal Pradesh
10. Jammu and Kashmir
11. Jharkhand
12. Karnataka
13. Kerala
14. Madhya Pradesh
15. Maharashtra
16. Mizoram
17. Nagaland
18. Odisha
19. Punjab
20. Rajasthan
21. Tamil Nadu
22. Tripura
23. Uttar Pradesh
24. Uttarakhand
25. West Bengal

Methodology

Coss-sectionally augmented Im, Pesaran and Shin test (2007)

Since, a panel of the price indices of the states of India have been used, cross sectional dependence is natural (which was also found using the Pesaran (2004) test and the Breusch and Pagan (1980) test) and so Pesaran's (2007), cross sectional augmented Im, Pesaran and Shin (CIPS) panel unit root test has been used to test for presence of non-stationarity in the price indices. Unlike the first generation panel unit root tests which were the extensions of Augmented Dickey Fuller Test (ADF) test for cross-sectionally independent panels, Pesaran's test is a single factor panel unit root test for cross-sectionally dependent panels. For a panel of N cross sections and T time periods the following cross sectional ADF model given in equation (5) below was used by Pesaran (2007).

$$\Delta Y_{it} = \alpha_i + b_i Y_{it-1} + c_i \acute{y}_{t-1} + d_i \Delta \acute{y}_t + \varepsilon_{it} \quad (2)$$

Where $\acute{y} = n^{-1} \sum^{n}_{i=1} Y_{it}$, $\Delta \acute{y} = n^{-1} \sum^{n}_{i=1} \Delta Y_{it}$ (3)

and ε_{it} is the regression error.

With the null hypothesis of a unit root, Pesaran (2007) proposed a test based on the t-ratio of the ordinary least squares (OLS) estimate of the estimated bi. The cross sectional averages given in equation (3) are used as proxy for the unobserved common factor. In line with the Im, Pesaran and Shin (IPS) (2003) test, Pesaran proposed the cross sectional augmented version of IPS test.

$$CIPS = 1/N \sum^{n}_{i=1} CADF_i \quad (4)$$

Using equation (3) the individual CADF statistics (b_i) are estimated and using equation (4), the CIPS statistic is obtained (Patnaik, 2016).

Panel cointegration analysis: Pedroni (1999)

The present study uses the panel cointegration test proposed by Pedroni (1999). In this test, Pedroni (1999) has proposed a residual based test for the null of no cointegration for both homogenous and heterogeneous panels. In particular it covers both between dimension and within dimension residual based test statistic. He derived seven panel cointegration test statistics, of which four are based on within dimension and three are based on between dimension. For the within dimension statistic the null hypothesis of no cointegration test is H0: $\gamma i = 1$ for all i

H0: $\gamma i = \gamma < 1$ for all i

For between dimension statistic the null hypothesis of no cointegration for the panel is

H0: $\gamma i = 1$ for all i

H0: $\gamma i < 1$ for all i

The residuals of the hypothesized cointegrating relations, which may be of the form given in the equation (4) are derived first.

$$Y_{it} = \alpha_i + \beta x_{it} + e_{it} \qquad (5)$$

t i =1....T (is the number of observations in the panel) , and i=1....N (is the number of cross section units used in the panel) The seven test statistics of Pedroni (1999) are :-

The within dimension tests (also called panel cointegration statistics)

(1) Panel υ-statistic (a non-parametric variance ratio test)

(2) Panel ρ-statistic (a non-parametric statistic similar to Phillips and Perron rho-statistic)

(3) Panel t-statistic (a non-parametric statistic similar to Phillips and Perron t-statistic)

(4) Panel t-statistic (parametric statistic similar to ADF t-statistic)

Between dimension tests (also called group mean panel cointegration statistic)

(5) Group ρ-statistic (a non-parametric statistic similar to Phillips and Perron t-statistic)

(6) Group t-statistic (a non-parametric statistic similar to Phillips and Perron t-statistic)

(7) Group t-statistic (parametric statistic similar to ADF t-statistic) Pedroni (1999)

The panel variance ratio test, under the alternative hypothesis diverges to positive infinity. Since the right tail of normal is used to reject the null hypothesis, large positive values imply that the null is rejected. The other entire statistic diverges to negative infinity under the alternative hypothesis. Since the left tail of normal distribution is used to reject the null hypothesis, large negative values imply that the null of cointegration is rejected.

Panel analysis of idiosyncratic and common components (PANIC): Bai and Ng (2004)

Empirical testing of co-movements in prices requires them to be cointegrated, and cointegration requires the price indices to be non-stationary and integrated of the same order. In recent years, a number of investigators have developed panel based unit root testing (Im, Pesaran and Shin, 1997; Hadri, 2000; Levin, Lin, and Chu, 2002; etc). Most of these tests are based on the assumption of cross sectional independence of panels. Also, most of the panel unit root tests filter out the common factors before testing for unit roots in the data (Pesaran, 2007; Moon and Perron, 2004). However, these common factors may be responsible for the non-stationarity in the panels. Bai and Ng's (2004) PANIC analysis decomposes the panel data into common and idiosyncratic components and allows the common component to be non-stationary, i.e. it allows for cross-unit cointegration. The Bai and Ng's (2004), can be explained as follows:-

Let the factor analytic model for the price indices $P_{i,t}$ be

$$P_{i,t} = \alpha_{it} + \lambda_i' F_t + e_{it} \qquad i = 1,\ldots\ldots..N; \text{ and } t = 1,\ldots\ldots...T \qquad (6)$$

Where, α_{it} is a polynomial trend function, F_t is an r x1 vector of common factors, and λ_i is an r x 1 vector of factor loadings. The term $\lambda_i' F_t$ is the common component, while e_{it} are the idiosyncratic components, (the factors are extracted using the principal component method). While all price indices share the same r common factors, λ_i the factor loadings may differ across indices. The $P_{i,t}$ series is the sum of deterministic component α_{it}, a common component $\lambda_i' F_t$ and an error e_{it}. A factor model with N variables has N idiosyncratic components but a small number of common factors. It will be stationary only if both, the common factor(s) and idiosyncratic factors are stationary and the common factors can be consistently estimated only if the errors of equation 6 are stationary. For inference, depending on the number of factors PANIC will determine the number of stochastic trends in the common factors. This will be different from the tests on the idiosyncratic errors. The two univariate test are based on the t-test of Said and Dickey (1984), on an augmented regression with suitable lags.

The factor augmented vector autoregression

The FAVAR proposed by Bernanke, Boivin, and Eliasz (2005) modifies the vector autoregression equation involving the observed variables like the repo rate/ call rate with the addition of the set of latent dynamic (common) factors (extracted from the price indices of the states using the method of principal components). The FAVAR model so derived can be shown with the help of the equation (7) given below:-

$$\begin{bmatrix} f_t \\ r_t \end{bmatrix} = \Phi\,(L) \begin{bmatrix} f_{t-i} \\ r_{t-i} \end{bmatrix} + v_t \tag{7}$$

Where r_t is an m x 1 vector of observed variables including the monetary policy instrument variables the demand and supply shocks and f_t represents the k x 1 vector of common factors comprising of additional information not contained in r_t and derived from the price indices data of the states.