Do global food commodity prices determine inflation in India?

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Abstract

The purpose of this paper is to investigate the impact of global food commodity prices and the exchange rate on the domestic food commodity prices and aggregate consumer price index (CPI) inflation in India. We employ Johansen (1991) cointegration method in conjunction with a single equation error correction model. We find that inflation in India is highly dependent on international food commodity prices and exchange rates. High international food commodity prices contributed about 2 percentage points of the 3.7 percentage point increase in inflation observed during the global food crisis (2007-2008). Global food commodity prices are an important factor for explaining inflation in all countries where food is a major component of consumption, as is the case in most developing countries.

JEL Codes: C22; E31; E41

Keywords: Inflation; Food Commodity Prices; India; Error Correction Model

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1. Introduction

After growing slowly in the early 2000s, world food commodity prices dramatically increased, hitting a peak in 2008. This period has become known as the global food crisis. Following the onset of the financial crisis, food commodity prices briefly subsided before climbing again in 2010-11. The World Bank (2011) has argued that the high food commodity prices increased the number of people living in poverty, decreased the level and quality of nutrition, and decreased consumption of other essential services such as health and education.

The connection between global and local food commodity prices is not always clear. As Durevall, Loening, and Birru (2013) state, "the mechanisms that link world food prices to domestic food prices are not well understood". Whatever the potential linkages, the fact is that India had persistently high food commodity prices and high overall inflation during the global food crisis.

As measured by the Consumer Price Index (CPI), both food commodity price inflation and total inflation averaged between 3 and 4 percent per year from 2000 to 2005. But they increased to 10.2 and 7 percent, respectively, during 2006-08, and they further increased to 10.6 and 10.4 percent during 2010-12. The manifestation of high food commodity prices despite favourable harvests is puzzling.[1] Past episodes of high inflation often coincided with adverse supply shocks in agricultural production.

Explanations for the high food commodity inflation in India include those proposed by Sthanumoorthy (2008), Chand (2010), Kumar, Vashisht, and Kalita, (2010), Nair and Eapen (2012), Sonna, Joshi, Sebastian, and Sharma (2014), and Rajan (2014), all of which focus on domestic factors.

However, the increase in international trade makes it likely that global forces play an important role. Bernanke (2007) and Trichet (2008) have emphasized that even the US central bank needs to monitor international price developments and analyse their implications for the domestic economy. Ito and Sato (2008) document the importance of exchange rates for importer, producer, and consumer prices in East Asian countries. Kapur (2013), Mohanty and John (2015), Sarmah and Bal (2021) show that global prices of crude oil have significant effect on inflation in India. Joshi and Acharya (2011a) argue that the link between international commodity price and domestic price in India has strengthened since 2000. In another study, Joshi and Acharya (2011b) have shown that the inclusion of foreign indicators improves the

[1] Agricultural and allied activities grew at 5 percent per annum during 2006-08, compared to a 3 percent average from 1996 to 2015.

forecast of inflation in India. There exists little evidence regarding the importance of global food commodity prices for inflation in India, other than Holtemöller and Mallick (2016).

To help fill this gap, we examine whether the rise in global food commodity prices and the depreciation of the rupee-US dollar exchange rate caused domestic food commodity prices to increase in India using a single equation error correction model in conjunction with the Johansen (1991) cointegration method. We also investigate whether these global factors led to an increase in aggregate CPI inflation. Our empirical approach builds off of Durevall, Loening, and Birru (2013), but we focus on India rather than Africa. We first separately measure the deviations from the long run equilibrium in the external food, non-food, and domestic money markets using quarterly data from 1996 to 2015. We also calculate the deviations from trend in the domestic agricultural and non-agricultural markets. We then combine these five long-run deviations with various short-run variables and estimate separate single equation error correction models for food, non-food, and overall consumer price inflation, using a general-to-specific approach in order to estimate their effect on inflation in India.

We find that a one percent increase in global food commodity prices raises domestic food commodity prices by about one percent, in the long-run. Similarly, a one percent increase in the rupee-US dollar exchange rate increases domestic food commodity prices by just over one percent. In the short-run, if there is 'disequilibrium' in the global food commodity market (i.e. if domestic food commodity prices deviate from their equilibrium level as determined by global food commodity prices and the rupee-US dollar exchange rate), then domestic food commodity prices change by five percent each quarter to correct the disequilibrium. A half-way correction toward the long-run equilibrium occurs in about 2 years. We also find that *total* inflation changes by about five percent per quarter when there is disequilibrium in the global food commodity market. Our model estimates indicate that about 2 percentage points of the observed 3.7 percentage point increase in inflation in India during the global food crisis was the result of high international food commodity prices. However, according to our estimates, inflation does not respond to disequilibrium in the external non-food and domestic monetary sectors.

The rest of the article is structured as follows. Section 2 presents data on the evolution of inflation and food prices in India. Section 3 details the methodology. It discusses the long-run equilibrium relationships (or trends) in the five markets (the external food and non-food markets, and the domestic money, agricultural, and non-agricultural markets), their deviations and develops single equation error correction models for inflation incorporating these deviations. Section 4 presents the empirical results. It estimates and discusses the deviations

from the long-run equilibrium relationship in five markets. It also estimates and discusses the single equation error correction models for food, non-food, and overall CPI inflation incorporating these deviations It also discusses robustness of the main results by (i) specifying an alternative long-run model for food inflation and (ii) estimating single equation models without dummy variables. Section 5 concludes.

2. Inflation and Domestic Food Commodity Prices in India

Table I lists the major components of the Consumer Price Index (CPI) for India. Food makes up almost half of the index, with cereals, milk, and fruits and vegetables accounting for over 25 percent.

Table I: Main Components of the CPI (Industrial Workers) (Base: 2001=100)

Components	Weight
a. Food Total	46.20
(i) Cereals	13.48
(ii) Pulses	2.91
(iii) Oil and fats	3.23
(iv) Meat, fish, and eggs	3.97
(v) Milk	7.31
(vi) Condiments and spices	2.57
(vii) Vegetables and fruits	6.05
(viii) Other food	6.68
b. Pan, supari, tobacco and intoxicants	2.27
c. Fuel and Light	6.43
d. Housing	15.27
e. Clothing, bedding and footwear	6.57
f. Miscellaneous	23.26
Total	100

Source: The Indian Ministry of Labour and Employment.

Figure 1 shows that the fluctuations in overall inflation are correlated with changes in domestic food commodity prices in India. The rapid increase in the CPI during 1997-98 followed from the 1997-98 droughts. Subsequently, there were good harvests in 1998-99 and disinflation. The early 2000's was a period of calm for both domestic food commodity prices and overall inflation. Beginning in 2005, however, food prices and total inflation both began to increase. Inflation went from 3.1 percent in August 2005 to 9.5 percent in May 2006, and as high as 21 percent in December 2009. The price increases were massive, bigger than in any other G-20 country (Karat 2010). A September 20, 2013 article in the *Times of India* stated, "if you were to ask any random aam admi [common man] anywhere in India what is the single biggest failing of UPA [United Progressive Alliance], the answer would be -price rise. This is so because the most important items of family spending- food items- have relentlessly risen for

the past several years despite repeated promises to bring them down by the economic mandarins and policy wonks that run the country".

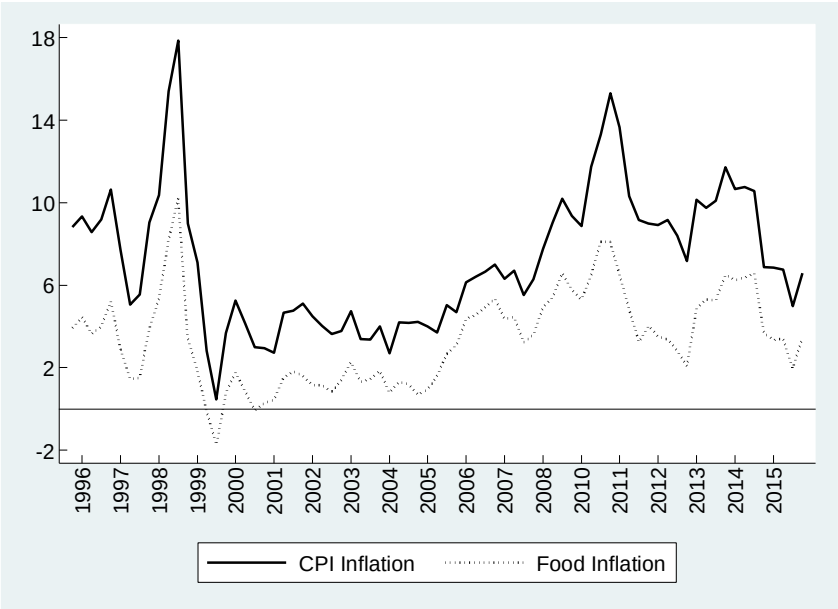

Figure 1. Annual CPI and Food Inflation in India (%) 1996-2015

Notes: The CPI inflation is measured by the annual percentage change in consumer price index (Base:2001=100). Food inflation is measured by the annual percentage change in domestic food consumer price index for Industrial workers. The consumer price index and the food consumer price index for industrial workers come from the Handbook of Statistics on Indian Economy, 2015-16, Reserve Bank of India.

What caused the food commodity price to increase so rapidly? In her February 22, 2010 address to Parliament, India's President Patil said, "While we were able to avert any threat to our food security, there has been unhappy pressure on the prices of food grains and food products. Higher prices were inevitable given the shortfall in domestic production and prevailing high prices of rice, cereals, and edible oils globally."

Figure 2 depicts the positive correlation between domestic food commodity prices in India and the world food commodity prices (the product of the world food commodity price index and rupee-US dollar exchange rate). They are very highly correlated (the correlation coefficient equals 0.96). This tells a provocative story in which the inflation rate in India depends on domestic food commodity prices, and domestic food commodity prices are, at least partially, determined globally. The next section develops a model of inflation to test this hypothesis.

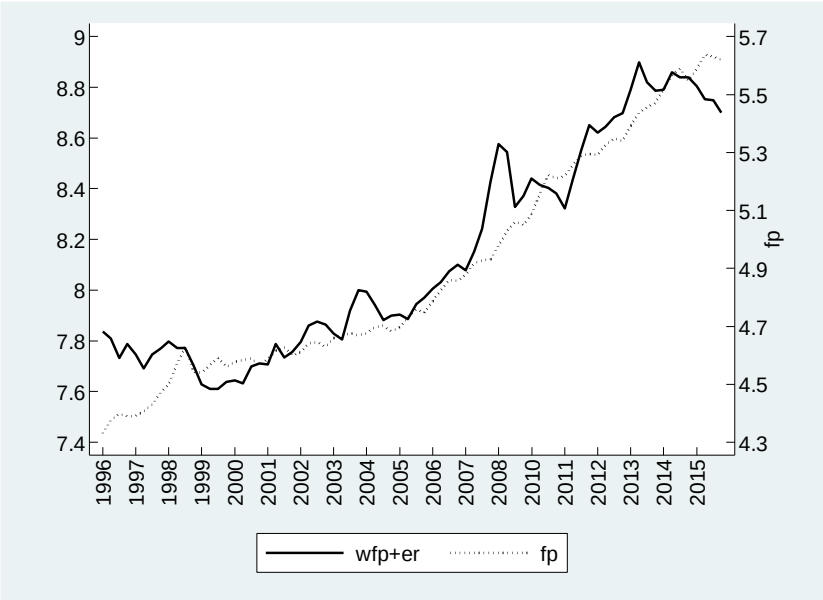

Figure 2. Log of world food commodity price plus exchange rate (wfp+er) and domestic commodity prices, (dfp), 1996 to 2015.
Notes: World food commodity price is measured by the world food price index. Domestic food commodity price is measured by the domestic food consumer price index for industrial workers. Exchange rate is measured by the rupee-US dollar exchange rate. World food price index comes from the World Bank's Development Prospects Group (WBDPG). Also see notes of Figure 1.

3. Methodology

This section discusses the long-run equilibrium conditions in each sector and then explains how we estimate the deviations from the long-run relationships. It also explains how we develop a single-equation Error Correction Model for inflation.

3.1 Long-run Equilibrium Conditions for the Component Sectors

We consider five sectors:

1. the external food sector,
2. the external non-food sector,
3. the domestic money market,
4. the domestic non-agricultural sector,
5. and the domestic agricultural sector.

We explain each sector below.

As per the theory of purchasing power parity (PPP), the long run equilibrium relationship in the external food and non-food sectors can be written as

$$dfp_t = er_t + wfp_t \qquad (1)$$

$$dnfp_t = er_t + wnfp_t \quad (2)$$

where dfp_t is the log of the domestic food commodity price, er_t is the log of the exchange rate, wfp_t is the log of the world food commodity price, $dnfp_t$ is the log of the domestic non-food price and $wnfp_t$ is the log of the world non-food price level. As food items are traded in the international market, domestic food commodity prices in India is expected to depend on world food commodity prices. Further, international food commodity prices might be transmitted to overall consumer prices, as food makes up nearly half of household expenditures (see Table I). We also assume that the price level for domestic non-food items is determined globally.

We write the long-run equilibrium relationship in the domestic money market as

$$m_t - p_t = \rho_0 + \rho_1 y_t + \rho_2 i_t + \rho_3 neer_t \quad (3)$$

where m_t-p_t is the log of the real broad money supply (M3), y_t is the log of real gross domestic product, i_t is the interest rate, neer is the nominal effective exchange rate. The demand for real money balances depends on the number of transactions (measured by real output) and the opportunity cost of holding money (measured by returns on other assets such as treasury bills and foreign currency). An increase in money supply above its equilibrium level is expected to affect domestic food inflation.

We assume that the domestic agricultural and non-agricultural sectors balance in the long-run. Thus,

$$ag_t = agp_t \quad (4)$$

$$non\text{-}ag_t = non\text{-}agp_t, \quad (5)$$

where ag_t and $non\text{-}ag_t$ are the log of actual agricultural and non-agricultural production, and agp_t and $non\text{-}agp_t$ are the log of potential agricultural and non-agricultural production. A decrease in domestic agricultural output relative to the trend output is assumed to increase food and overall inflation in the short run. Similarly, an increase in the domestic non-agricultural output relative to trend is expected to increase food and overall inflation.

We use quarterly data from q2 1996 to q1 2015 for two reasons. First, quarterly data on agricultural and non-agricultural output are not available prior to q2 1996. Second, there was a change in monetary policy regime after q1 2015, as the Reserve Bank of India (RBI) officially adopted inflation targeting as the monetary policy framework for the Indian economy in March

2015[2]. All variables are expressed in logarithmic form. The data sources and variable definitions are given in Table A1 in Appendix A in Supplementary Material.

3.2 Deviations from the Long-Run Equilibrium Relationships

We first test for stationarity in the above-mentioned variables using the Augmented Dickey Fuller (ADF) unit root test. All the variables, except devag and devnon-ag, are non-stationary in levels but are stationary in their first difference (see Table A2 in Appendix A in Supplementary Material). Then, we estimate the long-run equilibrium relationship in the external food, non-food, and domestic monetary sectors (Equations 1-3) using the Johansen (1991) cointegration method. We also estimate the trend agricultural and non-agricultural output (Equations 4 and 5) using the Hodrick-Prescott filter method.

After estimating the long-run equilibrium relationships, we obtain the deviations in the markets from Equations 1 - 3 by subtracting the equilibrium values of dfp, dnfp, and m-p from their actual values. The deviations for the external food (ECextfood), non-food (ECextnon-food), and domestic monetary (ECmoney) sectors are calculated quarterly as (suppressing the time subscripts) ECextfood = dfp - λ_0 - $\lambda_1$er - $\lambda_2$wfp; ECextnon-food = dnfp - μ_0 - $\mu_1 er_t$ - $\mu_2$wnfp; and ECmoney = m-p - ρ_0 - $\rho_1 y_t$ - ρ_2i - $\rho_3$neer - ρ_4t. Similarly, after estimating trend agricultural (agp) and non-agricultural (non-agp) output, the deviations for agricultural (devag) and non-agricultural (devnon-ag) sectors are calculated as devag = ag - agp and devnon-ag = non-ag – non-agp.

3.3 Single Equation Error Correction Model for Inflation

Then we combine these five long-run deviations (based on Eqs.1-5 in Section 3.1) along with the first differences of the variables used in Equations 1-3 and estimate separate single equation Error Correction Models (ECMs) for food, non-food, and overall consumer price inflation following Durevall et al. (2013), Durevall and Njuguna (2001), Juselius (1992), and Kinda 2013). It allows us to consider different sources of inflation. The general single-equation ECM for inflation is

[2] Th RBI and the Government of India (GOI) signed an agreement on the Monetary Policy Framework on February 20, 2015. As per the framework, it was specified that: (a) the Reserve Bank will aim to bring inflation below 6 per cent by January 2016; and (b) that the inflation target for India for 2016-17 and all subsequent years shall be 4 per cent with a band of (+/-) 2 per cent.

$$\Delta p_t = \alpha + \beta_1(ECextfood)_{t-1} + \beta_2(ECextnon\text{-}food)_{t-1} + \beta_3(ECmoney)_{t-1} + \beta_4 devag_{t-1} + \beta_5 devnon\text{-}ag_{t-1} + \sum_{i=0}^{k-1} \Delta x'_{t-i}\gamma_{1i} + \sum_{i=1}^{k-1} \Delta p'_{t-i}\gamma_{2i} + \sum_{i=0}^{q} D'_{t-i}\gamma_{3i} + u_t \qquad (6)$$

where, Δ is the first difference operator. The variable Δp_t is the first difference of the logarithm of the price levels in quarter t. The exact specification of the ECM is allowed to differ across the three inflation measures, as we explain below. $ECextfood_{t-1}$, $ECextnon\text{-}food_{t-1}$, and $ECmoney_{t-1}$ are estimates of the deviations (error corrections lagged one period) in the external food, non-food, and domestic money markets, and $devag_{t-1}$ and $devnon\text{-}ag_{t-1}$ are the agricultural and non-agricultural output gaps (lagged one period). The vector of variables Δx_{t-i} includes the lags of the first differences of the log-level of the control variables: er, wfp, wnfp, m-p, y, i, neer and lagged Δp. It also includes a few other factors specific to India that might have affected inflation: the minimum support price for rice and wheat (msp), and the fiscal deficit(fd) and global factors such as world energy prices (wenergy) and world fertilizer prices (wferti). Vector D_t contains a set of seasonal dummies, and a dummy to capture the implementation of Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS),[3] We also include impulse dummies, as detailed below (so q varies across models). The model includes 3 lags of the differenced variables (k=4). However, the contemporaneous values of variables which are potentially endogenous are not included to avoid simultaneity bias. All other variables are treated as exogenous and enter the equation in contemporaneous and lagged form.

We first estimate a separate general model for each measure of inflation using Ordinary Least Squares (OLS) method. We next reparametrized each model by dropping the most insignificant regressor, i.e., which has the highest P-values (while retaining the key variables of interest such as $ECextfood_{t-1}$, $ECextnon\text{-}food_{t-1}$, and $ECmoney_{t-1}$ $devag_{t-1}$ and $devnon\text{-}ag_{t-1}$) and re-estimate the model.

4. Empirical Results

This section presents the main estimation results. Sections 4.1, 4.2, and 4.3 estimate the ECextfood, ECextnon-food, ECmoney, using Equations 1, 2, and 3, respectively. Section 4.4 estimates devag, and devnon-ag using Equations 4 and 5, respectively. Sections 4.5.1, 4.5.2, and 4.5.3 incorporate these deviations along with the first differences of variables used in

[3] The MGNREGS guarantees at least 100 days of employment per year to each rural household if its adult members are willing to do unskilled manual work at a fixed minimum wage rate. It was first implemented in 200 districts in 2006 and then extended to an additional 130 districts in 2007. The remaining 285 districts gained coverage in 2008. The program may have increased the demand for food (Rakshit 2011).

Equation 1-3 and msp, fd, wenergy and wferti and estimate 3 separate single equation ECMs based on Equation 6. Sections 4.5.4 and 4.5.5 describe robustness checks and discussion.

4.1 The External Food Sector

If there is a long-run equilibrium relationship between global and domestic food commodity prices, then the relative food commodity price should revert to its mean level after a shock. In Figure 3, the relative food commodity price appears to be stationary even though the fluctuations around the mean are large, particularly from 2006 to 2010.

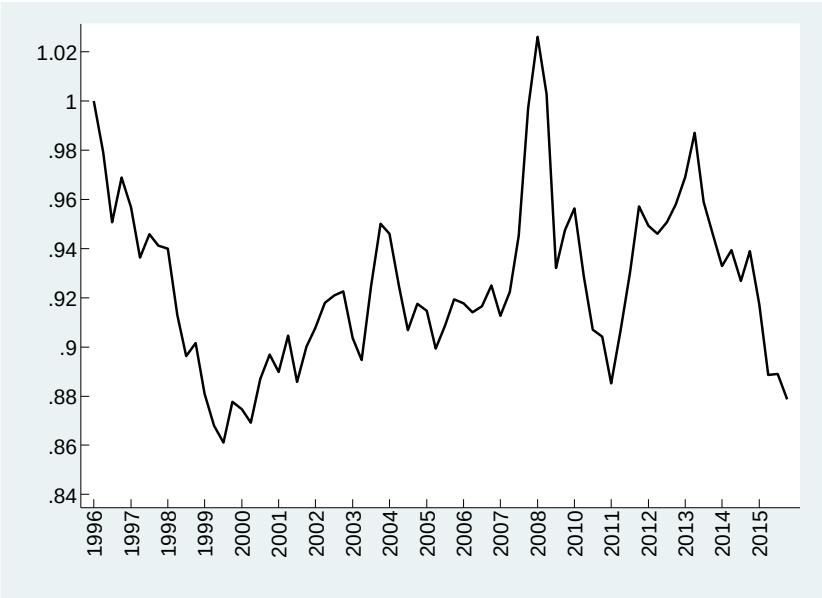

Figure 3. Relative Price of Food Commodity, 1996-2015

Note: The relative price of food commodity is calculated as the ratio of the world food commodity price measured in rupees (the sum of wfp and er) to the domestic food commodity price (dfp). Also see notes of Figures 1 and 2.

As per the Johansen method (1991), we find strong evidence of one cointegrating vector, as we cannot reject the null hypothesis of no cointegrating relationship (i.e. r=0). The long run estimates for dfp are reported in Table II.

Table II: Cointegration Analysis of the External Food Sector, 1996-2015

Rank test				
Null Hypothesis	r=0	r ≤ 1	r ≤ 2	
Eigen Values	0.32	0.18	0.04	
Trace:	47.69**	18.37	3.20	
	[34.87]	[20.18]	[9.16]	
Cointegrating vector				
	dfp	wfp	er	Constant
β_i	1.00	-0.99	-1.16	3.64
	-1.00	(-7.01)	(-4.73)	(5.39)
Adjustment coefficients				
α_i	-0.082***	-0.044	0.087	
	(-4.75)	(-1.65)	(1.46)	
		Weakly exogenous	Weakly Exogenous	

Notes: The numbers in square brackets are 95% critical values. The figures in parentheses are t-ratios. ***, **, and * indicate significance at 1%, 5% and 10% level. The VAR includes 2 lags (optimum lag length chosen by AIC) on each variable, three centered seasonal dummy variables, and one impulse dummy for 2008q2.

The coefficients for both wfp and er have positive signs. The dfp, on average, increases by 0.99 and 1.16 percent due to 1 percent increase in wfp and er, respectively.[4]

The error correction term, representing the deviations in dfp, for food sector is ECextfood = dfp - 1.16er - 0.99dwfp + 3.64. Figure 4 plots the deviations and provides evidence that the linear combination of dfp, er, and dwfp is stationary.

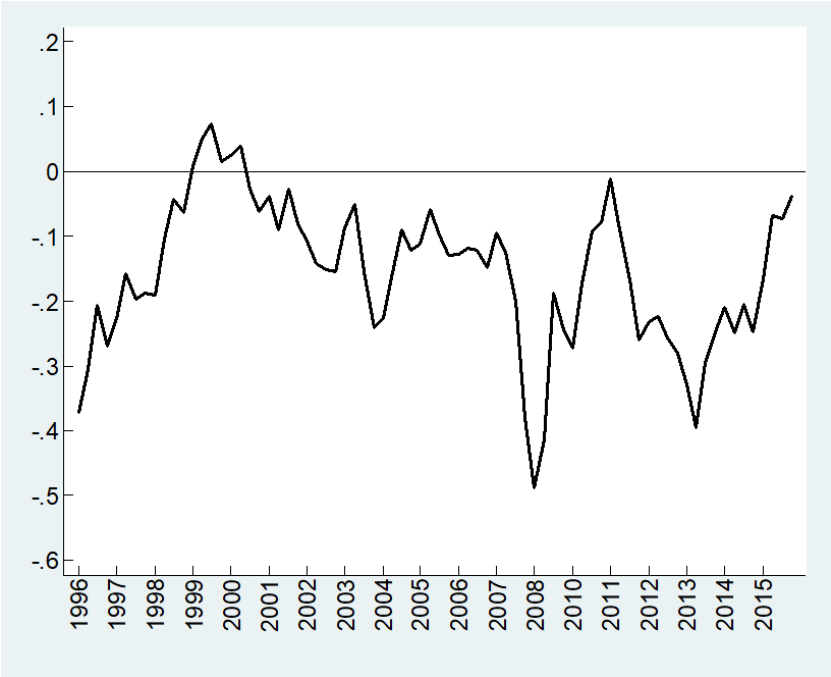

Figure. 4 External Food Sector Cointegrating Vector, dfp-1.16er-0.99wfp+3.64, 1996-2015

The adjustment parameter in the dfp equation equals -0.08 and is statistically significant at the 1% level (see Table II). This suggests that the dfp is endogenously determined, and the long-run food PPP function is represented by the cointegrating vector. The adjustment coefficients in the er, and wfp equations are not significant. Hence, they are weakly exogenous. India, being a developing economy, is unlikely to impact global food commodity prices. Similarly, the supply and demand for currency due to food trade is unlikely to impact the er, which is largely determined by capital flows.

[4] As the long run coefficients are close to one (0.99 and 1.16), we examine whether the PPP holds for the food prices. To this end, we test whether the coefficients of world food price and exchange rate both be equal to 1. The likelihood ratio statistic for imposing -1 and -1 for the word food price and the exchange rate on the cointegrating vector is insignificant. The $\chi 2$ statistic with 2 degrees of freedom is found to be 0.65 with 0.72 p-values. This provides evidence in favour of the validity of PPP for the domestic food prices during the sample period.

4.2 The External Non-Food Sector

Figure 5 plots the log of relative non-food price index. It appears that the ratio of non-food prices is not stationary[5].

Figure 5. **Relative Non-Food Prices 1996-2015**

Notes: The relative price of non-food items is calculated as the ratio of the world non-food price (the sum of wnfp and er) to the domestic non-food price (dnfp). Wnfp is measured by the producer price index in the US. Dnfp is measured by domestic non-food consumer price index for industrial workers. er is measured by the rupee-US dollar exchange rate. Domestic non-food consumer price index for industrial workers and exchange rate come from the Handbook of Statistics on Indian Economy, 2015-16, Reserve Bank of India and producer price index in the US come from Federal Reserve Bank of St. Louis database

Thus, we assume that the trend relative non-food price equals the long-run equilibrium non-food price following Durevall et al. (2013). The deviations in the ECextnon-food appears to be stationary (see Figure 6).

[5] Relatedly, the Johansen method indicates that there is no co-integrating relationship between dnfp, wnfp, and er.

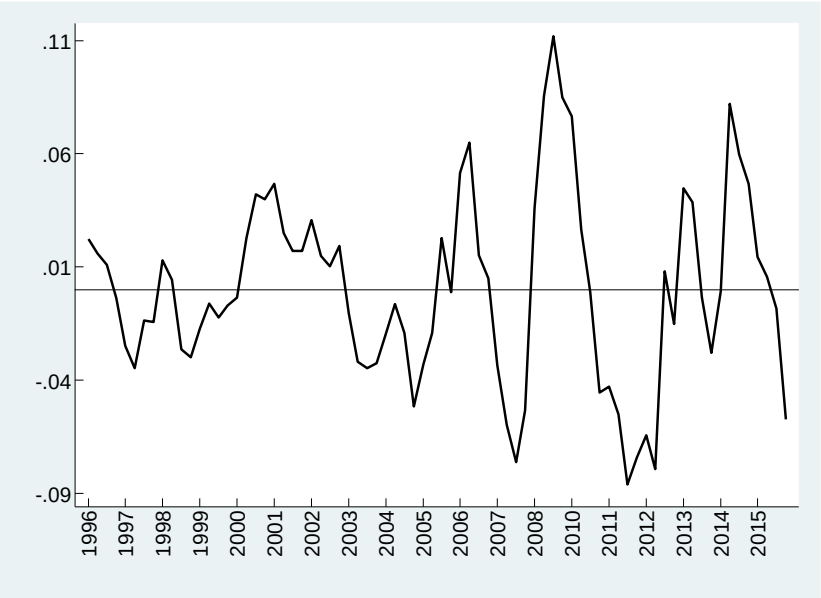

Figure 6. Deviations in the Equilibrium Relative Non-Food Price, 1996-2015

Note: The deviations in the external non-food sector are calculated as the difference between the actual relative non-food price and the equilibrium relative non-food price. The equilibrium relative non-food relative price is calculated using Hodrick-Prescott filter method. Also see Notes to Figure 5.

4.3 The Domestic Monetary Sector

As per the Johansen method (1991), we find evidence of one cointegrating vector (i.e. r=1) in the domestic monetary sector, as we cannot reject the null hypothesis of no cointegrating relationship (i.e. r=0). Table III reports the long run estimation results.

Table III: Cointegration Analysis for the Monetary Sector, 1996-2015

Rank test					
Null Hypothesis	r=0	r ≤ 1	r ≤ 2	r ≤ 3	
Eigen Values	0.48	0.28	0.12	0.03	
Trace:	48.51**	25.30	9.76	2.56	
	[31.79]	[25.42]	[19.22]	[12, .39]	
Cointegrating vector					
	m-p	y	i	neer	trend
β_i	1.00	-0.71	0.08	-0.93	-0.014
	-1.00	(-3.74)	(3.17)	(-8.99)	(-4.44)
Adjustment Coefficients					
α_i	-0.10*	0.04	-1.98***	0.20*	
	(-1.73)	(0.76)	(-5.33)	(1.98)	
		Weakly exogenous			

Notes: See notes of Table II.

As one might expect, the demand for broad real balances is positively related to real GDP and neer and negatively related to i.[6] Our estimated long-run income elasticity for money

[6] A decrease in neer implies depreciation in the rupee's value whereas an increase reflects appreciation. So, an increase in neer is expected to increase the demand for broad money (M3).

demand is about 0.71 percent, exchange rate elasticity is 0.93 and the interest rate elasticity equals -0.08.

The error correction term representing the deviations in the domestic money market is ECmoney = (m-p)-0.71y+0.08i-0.93neer-0.014trend. The deviations appear to be stationary (see Figure 7).

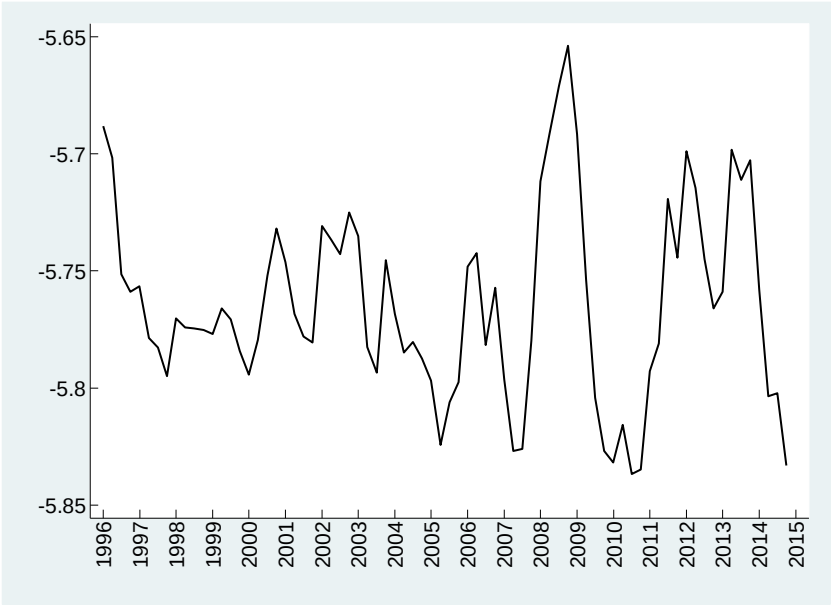

Figure 7. Money Demand Cointegrating Vector, (m-p)-0.71y+0.08i-0.93neer-0.014trend, 1996-2015

The coefficient on the error correction term equals 0.10 and is statistically significant at the 10% level (see Table III). As the adjustment parameter is significant, the real money stock is likely endogenously determined, and the long-run money demand function is represented by the cointegrating vector. The adjustment coefficients for i, and neer, are also statistically significant. These findings imply a possible feedback effect. The adjustment parameters for y is not highly statistically significant. It might be weakly exogenous, as actual GDP is primarily determined by potential GDP in the long-run.

4.4 The Domestic Non-Agricultural and Agricultural Sectors

Inflation and devnon-ag are positively related (see Figure B1 in Appendix B in Supplementary Material). In contrast, devag and inflation are generally negatively related (see Figure B2 in Appendix B in Supplementary Material).

4.5 Estimates of the Single Equation ECM for Inflation

Table IV reports the estimated coefficients for the parsimonious representation of the of the single equation ECM for different measures of inflation.

Table IV: Parsimonious Inflation Models for India

		Column (1)	Column (2)	Column (3)
		Model 1: Food (Δdfp)	Model 2: Non-food (Δdnfp)	Model 3: CPI (Δp)
$ECextfood_{t-1}$	β_1	-0.049** (0.019)	---	-0.054*** (0.013)
$ECextnon\text{-}food_{t-1}$	β_2	---	-0.084** (0.040)	-0.004 (0.049)
$ECmoney_{t-1}$	β_3	0.004 (0.056)	-0.053(0.047)	0.005 (0.066)
$Devnon\text{-}ag_{t-1}$	β_4	0.036 (0.155)	0.224*** (0.078)	0.173* (0.100)
$Devag_{t-1}$	β_5	-0.134** (0.062)	-0.024 (0.029)	-0.050 (0.038)
Change in rupee-US dollar exchange rate	Δer_{t-2}		0.135*** (0.035)	
Change in rupee-US dollar exchange rate	Δer_{t-3}		0.119*** (0.035)	
World food commodity inflation	Δwfp_{t-2}			-0.058** (0.019)
World non-food inflation	Δwnf_{t-1}		0.134** (0.057)	
World non-food inflation	Δwnf_{t-3}			
Growth rate of money supply	Δm_{t-3}			0.172** (0.079)
Growth rate of GDP	Δy_{t-1}	0.066*** (0.011)	---	
Growth rate of GDP	Δy_{t-2}	---	-0.207*** (0.069)	
Change in interest rate	Δi_{t-1}			0.025** (0.011)
Change in interest rate	Δi_{t-2}	-0.045***(0.015)	-0.019** (0.008)	
Change in interest rate	Δi_{t-3}		-0.016** (0.008)	
Change in nominal effective exchange rate	$\Delta neer_{t-1}$		-0.094** (0.041)	
Lagged domestic food commodity inflation	Δdfp_{t-2}	-0.450*** (0.099)	0.105** (0.047)	
Lagged Domestic non-food inflation	$\Delta dnfp_{t-1}$		-0.235** (0.097)	
Lagged Domestic non-food inflation	$\Delta dnfp_{t-2}$		0.431*** (0.101)	
World energy inflation	$\Delta wenergy_{t-3}$		-0.019** (0.007)	-0.036*** (0.009)
MGNREGS		0.020*** (0.004)		
1998 dummy		0.066*** (0.011)		0.0251*** (0.006)
1999 dummy			-0.352 *** (0.007)	-0.050*** (0.009)
Quarter 1		-0.024*** (0.005)	-0.003 (0.003)	-0.006** (0.003)
Quarter 2		0.004 (0.005)	-0.004 (0.002)	0.008* (0.004)
Quarter 3		-0.002 (0.006)	0.010*** (0.003)	0.018*** (0.003)
Constant	β_0	0.023 (0.328)	-0.295 (0.271)	0.037 (0.382)

Notes: The dependent variable for each of the three models is listed in row 1. The table reports the coefficient estimates from the specific inflation models based on Equation 6. The error correction terms and output gaps are based on Equations 1-5. The impact of MGNREGS captured by a dummy variable that takes the value 0 prior to 2006 and 1 after 2006. Quarter 1, Quarter 2, and Quarter 3 are seasonal dummy variables. Quarter 4 is not included as it is the reference quarter. 1998 dummy takes the value of 1 in quarters 3 and 4 of 1998, otherwise 0 in food and CPI inflation equation for the sharp increase in food and CPI inflation in those two quarters (see Figure 1). 1999 dummy takes the value of 1 in quarter 2 of 1999, otherwise 0 in nonfood and CPI inflation equation for the sharp decrease in non-food and CPI inflation in that quarter (see Fig.1). Values in parentheses are standard errors and ***, **, and * denote significance at the 1, 5, and 10% level, respectively.

Table V reports the model diagnostic tests for each model. Across, the three models, we note the high R^2 values (around 0.78) despite the relatively low number of explanatory variables. The F-statistic, which measures the joint significance of all the controls, is also relatively high, especially for the food and CPI inflation models. The remaining diagnostic statistics show that the specifications pass the usual battery of tests (serial correlation, functional form, heteroscedasticity, and normality).

Table V: Model Diagnostic Tests

	Model 1: Food (Δdfp)	Model 2: Non-food (Δdnfp)	Model 3: CPI (Δp)
R Square=	0.78	0.78	0.77
F Statistic=	F(12, 60)=18.30 [0.00]	F(19, 52)=9.64 [0.00]	F(14, 57)=14.03 [0.00]
Serial Correlation =	F(4, 56)=1. 32 [0.35]	F(4, 48)= 1.31 [0.28]	F(4, 53)=0.72 [0.58]
Functional Form=	F(1, 59)= 5.35 [0.03]	F(1, 55)= 11.93 [0.001]	F(1, 56)=3.28 [0.075]
Normality =	$\chi^2(2)$=12.44 [0.002]	$\chi^2(2)$=0.25 [0.87]	$\chi^2(2)$=2.08 [0.35]
Heteroscedasticity=	F(1, 71)=0.08 [0.77]	F(1, 70)=1.16 [0.28]	F(1, 70)=0.09 [0.76]

Notes: Serial correlation test is the LaGrange multiplier test of residual serial correlation using four lags. Functional form is the Ramsey's RESET test using the square of the fitted values. Normality is based on a test of skewness and kurtosis of the residuals. Heteroscedasticity is based on the regression of squared residuals on squared fitted values.

4.5.1 Food Inflation

The general model for food inflation (Δdfp=first difference of log dfp) includes ECextfood, ECmoney, devag, enon-ag lagged one period.[7] The variables in first differences are lags of er, wfp, m-p, y, i, neer, dfp, dnfp, wenergy, wferti, msp and the fd. The contemporaneous values of m-p, i, and neer are not included to avoid simultaneity bias. The results are reported in column 1 of Table IV.

The plot of the Cumulative Sum of Squares (CUSUM) and Cumulative Sum of Squares (CUMSUMSQ) of our food inflation specification show that the specification is stable over time, as there is no evidence of a structural break (see Figures C1 and C2 in Appendix C in Supplementary Material).[8] The recursive estimates of the ECextfood, and devag show that the parameter estimates are also remarkably stable over time (see Figure C3 in Appendix C in Supplementary Material).

The estimated coefficient for the ECextfood term (β_1=-0.049) is negative and highly statistically significant (P-ratio=0.019). When the actual dfp deviates from the equilibrium dfp, which is determined by the er and wfp, the dfp responds to the deviation. Our estimates imply that 5% of the disequilibrium is corrected each quarter by changes in dfp. In other words, it takes about 2.5 years for changes in dfp to halve the disequilibrium.

Our model indicates that about 1.8 percentage points of the 5.2 percentage increase in observed domestic food inflation during the global food crisis was the result of the high international food commodity prices. We arrive at this estimate by multiplying the coefficient on the ECextfood (-0.0498) by the change in the deviation (-0.3662) occurred during the global food crisis.

[7] We do not report the general models for the sake of brevity.

[8] The CUSUM and CUSUM statistics are based on the one step ahead prediction errors, i.e., the differences between Δdfp and its predicted value based on the parameters estimated at time t-1.

The coefficients of devag have a significant effect on dfp. A 10% decrease in the devag leads to an increase in dfp of about 1.3% a quarter later. This estimate is consistent with the idea that a decrease in agricultural activities below trend leads to an increase in shortage of food items, which, in turn, increases dfp.

The estimated coefficient on the ECmoney term (β_3) and devnon-ag have correct signs (positive) but they are statistically insignificant. This does not mean that they are unimportant. They might have affected indirectly through y.

The other variables that enter the model are lagged Δy, Δi, Δdfp, and MGNREGS. Δy and MGNREGS have positive signs and Δi has negative sign. This suggests that an increase in Δy and implementation of MGNREGS lead to an increase in income and an increase demand for food items (i.e., food is a normal good), which, in turn, increases Δdfp. An increase in Δi decreases Δdfp. This implies that contractionary monetary policy is effective in reducing Δdfp. Lagged Δdfp is also statistically significant, implying that there exists inertia in food inflation. Wenergy does not enter the model, possibly because energy related inputs used in agricultural production are often subsidized.[9] Similarly, wferti does not affect Δdfp significantly, as fertilizer prices are subsidized in India.[10] The sign on the seasonal dummy variables suggests that, on average, Δdfp is the lowest during the first quarter (January- March).

The msp does not appear as a significant variable in the Δdfp regression. Possibly, this is because the msp and world food commodity prices are related; the Commission for Agricultural Costs and Prices, which recommends the msp, takes the international prices of rice and wheat into account (see Acharya et al. (2012) for more on this relationship).[11] fd also does not appear to affect Δdfp significantly. It might have affected Δdfp indirectly by increasing the Δy.

4.5.2 Non-Food Inflation

The general model for non-food inflation (Δdnfp= first difference of log dnfp) includes ECextnon-food, ECmoney, devag, and devnon-ag lagged one period. The variables in first differences are er, wnfp, m-p, y, i, neer, lagged dfp, lagged dnfp, wenergy and the fd. The contemporaneous values of m-p, i, and neer are not included to avoid simultaneity bias.

[9] The price of diesel, for example, was subsidized for most of our study period, as it was deregulated in October 2014.

[10] In 2015-16, the government of India budgeted about 0.5 percent of GDP for fertilizer subsidies. Nearly 70 percent of this amount was allocated to urea, the most commonly used fertilizer. It is the largest subsidy after food.

[11] The annual average growth rate in the minimum support price (of both paddy common rice and wheat) increased by 20% during 2007-2010.

Column 2 of Table IV reports the estimated coefficients of the specific model.

The estimated coefficient for the ECextnon-food term (β_2=-0.084) is negative and statistically significant (P-values=0.04). This estimate implies that a disequilibrium in the external non-food sector is corrected by 8 percent each quarter. The coefficient of the devnon-ag has a positive sign (0.22) and it is significant (P-Values=0.078). This estimate implies that a 10 percent increase in devnon-ag leads to an increase in dnfp about 2.2%.

The other variables that enter the model are lagged Δer, Δdwnfp, Δy, Δi, Δneer, Δdnfp, and Δwenergy. As expected, an increase in Δer and Δwnfp affect Δdnfp positively and Δneer and Δi affect it negatively. The effect of lagged Δdnfp is also significant. It captures the persistence in dnfp. The Δy and Δwenergy also affect dnfp, but they are difficult to interpret, as the estimated coefficients are negative.

4.5.3 CPI Inflation

The final model for CPI inflation (Δp= first difference of log CPI) includes ECextfood, ECextnon-food, ECmoney, devag, and devnon-ag lagged one period. It also includes lagged Δp, but not lagged Δdfp and Δdnfp. The contemporaneous values of m-p, i, and neer are not included to avoid simultaneity bias. Column 3 in Table IV reports the results for the specific model.

The estimated coefficient for ECextfood term (β_1=-0.054) is negative and highly statistically significant (P-values=0.013). This implies that when the actual dfp deviates from the equilibrium dfp (there is disequilibrium), the CPI responds to the deviation. For example, on average, about 5 percent of a disequilibrium in the external food sector is corrected each quarter. Further, the magnitude of the coefficient on ECextfood term in the CPI inflation model (see Column 3) is close to the magnitude of the coefficient of ECextfood in the food model (See Column 1), suggesting that in India CPI inflation is very closely related to food inflation. Our model indicates that about 2 percentage points of 3.7 percentage increase in CPI inflation observed during the global food crisis was the result of high international food commodity prices. We arrive at this estimate by multiplying the coefficient on the ECextfood term (-0.0543) by the change in the deviation occurred during the global food crisis (-0.3662).

The coefficient on the ECextnon-food term is negative (as one might expect) although not statistically significant.

The coefficient on the ECmoney term is positive, but it is insignificant. This implies that CPI inflation does not respond to the disequilibrium in the domestic monetary sector.

Ajmair (2015) and Anantha Ramu (2014) also find that money supply does not affect inflation in India.

The coefficient on devnon-ag is positive and statistically significant. According to this estimate, a 10 percent increase in the devnon-ag leads to an increase in CPI inflation of 1.73 percent. This finding is consistent with the notion that an increase in non-agricultural activities above trend increases wages, which, in turn, leads to an increase in CPI inflation.[12]

The other variables that enter the model are lagged Δwfp, Δm-p, Δi, and Δwenergy. An increase in Δm-p affects inflation positively. Lagged Δwfp and Δwenery have negative signs, which we find difficult to explain. The signs of the seasonal dummy variables suggest that, on average, CPI inflation is the lowest during the first quarter (January- March) and the highest during the third quarter (July-September). So, the third quarter is the highest inflationary period.

As with the other inflation measures, the CUSUM and CUMSUMSQ plots for the CPI model suggest model stability over time. The recursive estimates for the coefficients on the ECextfood terms and the devnon-ag (the key coefficients) are also remarkably stable over time. There is no evidence of structural breaks.[13]

4.5.4 Robustness Checks

We performed robustness checks in two ways. First, we test whether our main result for food inflation (i.e., food inflation is endogenously determined) is sensitive to an alternative model specification. To this end, we conduct weak exogeneity test for food inflation by modelling dfp, er, y, and i alternatively. The Johansen (1991) procedure provide strong evidence of one cointegrating vector, as we cannot reject the null hypothesis of no cointegrating relationship (i.e. r=0). The long run estimates for dfp are reported in Table D1 in Appendix D in Supplementary Material. The adjustment parameter in the dfp equation equals -0.07 and is statistically significant. This suggests the dfp is endogenously determined and it is not sensitive to alternative model specification.

Second, we also check if the impact of wfp on dfp and CPI inflation are sensitive to the exclusion of impulse dummy variables. In order to test this, we estimate the models of dfp, dnfp, and CPI inflation excluding the impulse dummy variables and instead using

[12] We have alternatively included the real GDP gap lagged one period instead of ag_{t-1} and non-ag_{t-1} in the food, non-food, and overall inflation equations. The GDP gap is not statistically significant in any of the three. The GDP gap coefficients (and corresponding t-statistics) are 0.033 (0.229), 0.011 (0.181), and 0.073 (0.672), respectively. We calculated the GDP gap using the same method as for the agricultural and non-agricultural output gaps.
[13] The figures are not shown here for brevity, but they are available on request.

heteroscedastic and autocorrelation consistent (HAC) standard errors. The results remain largely unchanged (see Table D2 in Appendix D in Supplementary Material).

4.5.5 Discussions

How can high global food commodity prices be transmitted to domestic food commodity prices and overall inflation? First, the world food commodity price could be transmitted through arbitrage. In 2006-08, the increase in relative food commodity price (see Figure 3) increased competitiveness of domestic food items. As a result, the net export of food from India increased, which might have created a domestic shortage and contributed to the increase in overall food prices despite a favourable harvest.[14] This is consistent with Joshi and Acharya (2010), who have shown that trade openness and foreign inflation are significant determinants of Inflation in India. Second, domestic food commodity prices might have increased due to the rise in imports of select food items. India is heavily dependent on the foreign market for some products such as pulses and edible oils. The net imports of these items (and wheat) increased significantly during 2006-08, which might have been passed on to the consumers by increasing retail prices.[15] Third, the world food commodity price might have transmitted to the domestic food commodity price through the minimum support price of rice and wheat. The Commission for Agricultural Costs and Prices recommends the minimum support price based on various factors, including international prices of rice and wheat[16]. Acharya et al. (2012) show that the minimum support price for rice and wheat are highly correlated with international prices.

Global food commodity prices can affect domestic CPI inflation in at least two ways. First, food accounts for a significant share of household expenditures. In India, cereals and other globally traded agricultural commodities make up a large component of food consumption. Therefore, global food commodity prices impact overall CPI directly through domestic food commodity prices. Second, global food commodity prices might affect overall domestic CPI indirectly through non-food prices. Persistent domestic food inflation can spill over to wages, which can then affect the prices for non-food items. Our empirical estimates

[14] The net export of rice and sugar increased from 4.1 and 1 million tonnes in 2005-06 to 6.4 and 5.8 million tonnes in 2007-08. The net export of spices also increased from 0.29 million tonnes in 2005-06 to 0.55 tonnes in 2008-09. Rice production for the first time exceeded 90 million tonnes continually from 2005-06 to 2008-09 (while the government's procurement was closer to the minimum norm of 39 million tonnes).

[15] The net imports of edible oils and pulses increased from 4.1 and 1.24 million tonnes in 2005-06 to 7.6 and 3.3 million tonnes in 2009-10, respectively. The net export of sugar was reduced from 5.8 million tonnes in 2007-08 to -3.68 million tonnes in 2009-10.

[16] The annual average growth rate of minimum support price (of both paddy common rice and wheat) increased by 20% during 2007-2010.

provide evidence in favour of both these channels, demonstrating that domestic inflation in India has been shaped by global factors, particularly international food commodity prices.

5. Conclusions

In this paper, we show empirically that global food commodity prices have a large impact on domestic food commodity prices in India. The results are based on the Johansen (1991) cointegration method in conjunction with a single equation error correction model.

Our estimates indicate that a one percent increase in the global food commodity price leads to an increase in domestic food commodity prices by about one percent, in the long-run. Similarly, a one percent increase in the rupee-US dollar exchange rate leads to an increase in domestic food commodity prices by just over one percent. In the short-run, if there is 'disequilibrium' in the global food market, domestic food commodity prices change by about five percent each quarter to correct the disequilibrium. Further, our CPI single-equation error correction model indicates that *total* inflation in India changes by about five percent per quarter when there is disequilibrium in the global food market. Inflation does not respond to disequilibrium in the external non-food sector, monetary sector, and agricultural output gap.

Our model estimates indicate that about 2 percentage points of the observed 3.7 percentage point increase CPI inflation during the global food crisis were the result of the high international food prices. Besides these main findings, the agricultural output gap, growth rate of GDP, interest rate, MGNREGS affect food inflation. Money supply, non-agricultural output gap, and interest rate affect CPI inflation. Seasonal factors also affect food and overall CPI inflation in the short-run. Both food and overall CPI inflation are found to be the lowest during the first quarter (January-March) and CPI inflation is found to be the highest during the third quarter (July-September). Overall, our findings strongly suggest that the dynamics of overall CPI inflation in India closely follow food commodity prices.

Our results highlight the importance of global food commodity prices and exchange rates. These global factors should be included in the analysis of inflation in places where food is a major component of household expenditures, especially when food prices change rapidly. Future research should be aimed at understanding how to design monetary, exchange rate, trade, and other policies taking the relationship between local and global food commodity prices into account.

References

Acharya, S.S., Chand, R., Birthal, P.S., Kumar, S. and Negi, D. S. (2012) Market Integration and Price Transmission in India: A Case of Rice and Wheat with Special Reference to the World Food Crisis of 2007/08. FAO Report.

Ajmair, M. (2015). Determinants of inflation in India. *The Indian Economic Journal*, *63*(2), 248-254.

Anantha Ramu. M. R. (2014). Relationship between fiscal deficit and inflation in India: a long term empirical analysis. *The Indian Economic Journal*, *62*(3), 1099-1120.

Bernanke, B.S. (2007) Globalization and Monetary Policy. Speech presented at the Fourth Economic Summit, Stanford Institute for Economic Policy Research, 2 March. Downloaded from https://www.federalreserve.gov/newsevents/speech/bernanke20070302a.htm

Chand, R. (2010) Understanding the Nature and Causes of Food Inflation. *Economic and Political Weekly*, 45, Pages 10-21.

Durevall, D., Loening, J. L., and Birru, Y. A. (2013) Inflation Dynamics and Food Prices in Ethiopia. *Journal of Development Economics*, 104, Pages 89-106.

Durevall, D. and Njuguna, N. S. (2001) A Dynamic Model of Inflation for Kenya, 1974-1996. *Journal of African Economics*, 10, 91-124.

Holtemöller, O., & Mallick, S. (2016). Global Food Prices and Monetary Policy in an Emerging Market Economy: The Case of India. *Journal of Asian Economics*, *46*, 56-70.

Ito, T. and Sato, K. (2008) Exchange Rate Changes and Inflation in Post-Crisis Asian Economies: Vector Autoregression Analysis of the Exchange Rate Pass-Through. *Journal of Money, Credit and Banking*, Vol. 40, No. 7, Pages 1407-1438.

Johansen, S. (1991) Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian Vector Autoregressive Models. Econometrica, 59, Pages 1551-80.

Joshi, A. R., & Acharya, D. (2010). Inflation and Trade Openness: Empirical Investigation for India. *IUP Journal of Monetary Economics*, *8*.

Joshi, A. R., & Acharya, D. (2011a). Commodity prices and domestic inflation in India. *Global Journal of Emerging Market Economies*, *3*(2), 223-246.

Joshi, A. R., & Acharya, D. (2011b). Inflation model for India in the context of open economy. *South Asia Economic Journal*, *12*(1), 39-59.Juselius, K. (1992) Domestic and Foreign Effects on Prices in an Open Economy: The Case of Denmark. *Journal of Policy Modelling*, 14, Pages 401-28.

Kapur, M. (2013) Revisiting the Phillips Curve for India and Inflation Forecasting, *Journal of Asian Economics*, 25, Pages 17-27.

Karat, B. (2010, February 23) “Price Rise Inevitable - Adding Salt to the Wounds”. *The Hindu*, retrieved from http://www.thehindu.com/opinion/op-ed/lsquoPrice-rise-inevitable-ndash-adding-salt-to-the-wounds/article16475174.ece.

Kinda, T. (2013) Oil Windfall, Public Spending and Price Stability: Modelling Inflation in Chad. *Applied Economics*, 45, Pages 3122-3135.

Kumar, R., Vashisht, P., and Kalita, G. (2010) Food Inflation: Contingent and Structural Factors. *Economic and Political Weekly*, 43, Pages 16-19.

Mohanty, D. and John, J. (2015) Determinants of Inflation in India. *Journal of Asian Economics*, 36, Pages 86-96.

Nair, S.R. and Eapen, L. M. (2012) Food Price Inflation in India (2008 to 2010): A Commodity Wise Analysis of the Causal Factors. *Economic and Political Weekly*, 47, Pages 46-54.

Rakshit, M. (2011) Inflation and Relative Prices in India 2006-10: Some Analytical and Policy Issues. *Economic and Political Weekly*, 46, Pages 41-52.

Rajan, R. (2014) *Fighting inflation*. Inaugural speech delivered at FIMMDA-PDAI Annual conference: Mumbai.

Sarmah, A., & Bal, D. P. (2021). Does Crude Oil Price Affect the Inflation Rate and Economic Growth in India? A New Insight Based on Structural VAR Framework. *The Indian Economic Journal*, *69*(1), 123-139.

Sthanumoorthy, R. (2008) Nature of Current Inflation in Food Prices. *Economic and Political Weekly*, 45 (9) Pages 17-21.

Times of India (2013) Food Prices Rose 157% between 2004 and 2013, September 20. Retrieved from https://timesofindia.indiatimes.com/india/Food-prices-rose-157-between-2004-and-2013/articleshow/22777817.cms.

Trichet, J.-C. (2008) Globalisation, Inflation and the ECB Monetary Policy. Lecture at the Barcelona Graduate School of Economics, 14 February. Downloaded from https://www.ecb.europa.eu/press/key/date/2008/html/sp080214_1.en.html.

World Bank (2011) Responding to Global Food Price Volatility and its Impact on Food Security. In: Attached for the April 16, 2011 Development Committee Meeting is a document entitled “Responding to Global Food Price Volatility and Its Impact on Food Security,” prepared by the staff of the World Bank. Joint Ministerial Committee of the Boards of Governors of the Bank and the Fund on the Transfer of Real Resources to Developing Countries.