Modelling Food and Nonfood Production in India: The Effects of Oil Price using Bayer-Hanck Combined Cointegration Approach

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Abstract

This study investigates the role of oil price in agricultural productivity for India by incorporating land, employment, gross capital formation and inflation using annual time series data for the period 1985 to 2017. Having applied the recently developed cointegration technique by Bayer and Hanck (2013), which combines four major cointegration tests, significant long-run relationships are confirmed among the investigated variables. The long-run results show that the effect of oil price on both food and non-food agricultural production is insignificant but there is a short-run and long-run positive effect of gross capital formation on agricultural production. The inflation has a negative effect on agricultural production only in the short-run. Our finding suggests that capital formation drives the agricultural sector in India, and not oil input. The VECM Granger causality result shows that there is no causal relationship between oil price and agricultural production but bi-directional causality runs between gross capital formation and agricultural production. In addition, oil price has causal effect on capital formation. The study, therefore, implies that agricultural sector will cope in the case of oil price crises because its productivity is independent of oil price changes.

Keywords: Cointegration; Food production; Non-food production; Oil price; Real sector; VECM Granger causality.

JEL Codes: C32, O13, Q10, Q18,

1. Introduction

The real sector economy has always had to adjust to significant oil price changes, this is especially true of productive activities that are energy intensive. The effects of these changes on agriculture is noteworthy because agriculture tends to shift from labour intensive to energy intensive as economies pace towards development. While conventional methods of production in agriculture are energy intensive, most of the inputs employed cannot easily be substituted for less energy-intensive inputs when oil price rises. Where energy substitution is possible, there is bound to be a rise in the price of alternative energy resources due to shift in energy demand. It is therefore expected that the net impact of sharp increase in crude oil price and gasoline price will include increased cost of production, slowed-down production process and reduced income for farmers. However, the overall impact of oil price changes on agriculture depends on whether the country is a net oil importer or net oil exporter, the intensity of oil price change at the particular time and the measures taken by policy makers to prevent the transmission into the domestic economy. While the impact is mild for net exporters of oil, the impact is high for net oil importers. Furthermore, among the heavy importers, countries with low import elasticity of demand for oil are at higher disadvantage when price rises since they cannot swerve to alternatives. In fact, both net oil importers and net exporters tend to experience significant changes in real sector activities during oil price fluctuations, but as high oil price tends to favour net exporters, the reverse brings adverse effects on the economy of net oil importers.

The effects of crude oil price change can be significantly transmitted through demand and supply channels into real economy. On the supply side, where crude oil is a basic energy input employed in production, oil price changes have a positive relationship with production cost. The impact of crude oil prices on real sector productivity is transferred from spot prices, refining and production costs from the oil market. In agriculture, the conventional systems require the use of heavy equipment, which mostly depend on oil, being the most exclusively viable commercial energy. Preservation, distribution and transportation in agricultural production process are also significantly influenced by oil prices because they are oil intensive. As oil price increases, an increase in the cost of using farm machineries for large scale farming could discourage the most efficient method of mechanized farming, thereby resulting in delayed processing and supply shortage. In addition, the rising cost of other inputs which are produced from energy-intensive technologies, such as chemicals and manufactured fertilizers, also contribute to rise in final agricultural commodity prices. These, altogether, account for inefficiency and higher cost in distribution of agricultural products to final consumers when oil price rises.

On the demand side, oil price change is theoretically supposed to have a negative relationship with disposable income and real investment. Since disposable income positively determines the level of consumption, thus, oil price change has negative relationship with aggregate demand through its negative effects on consumption and investment spending. As part of the consequences on net-income, industries are forced to lower production. Since raw materials from agriculture mostly feed the industry, if industries, especially agro-based industries are forced to cut production due to the rising cost of raw materials in the agricultural sector and lower aggregate demand, there will be low demand for primary and intermediate inputs in the agricultural sector. Finally, when prices of agricultural commodities rise, the country's agricultural products become less competitive in international market, causing export of agricultural goods to shrink. These might lead to sectoral reallocation of factors of production, causing mobility of resources from areas of low demand to areas of higher demand, and from oil energy intensive production to less oil intensive production.

The world oil price has often been characterized by fluctuations and uncertainty due to Iraq crisis, supply imbalances and decline in global oil inventories. For example, from the recorded highs of the year 2008 oil price shocks, when crude oil sold for as high as $143 per barrel in global market, oil price dropped sharply before the end that year to $42.94 per barrel in December, 2008. In 2014, the spot price of the Brent crude oil increased again and it was $101.12 per barrel on August 25, 2014 and dropped continuously to $36.42 per barrel on April 1, 2016. Oil prices picked up in that same month and the price of Brent oil has risen steadily through the year 2017. It was $60.42 per barrel on October 30, 2017, by January 26, 2018, it reached $70.08 per barrel, and as at October 1, 2018, price was $85.12 per barrel. Although, the price volatilities in recent years seems to have been moderate, but as an engine of economic growth, oil price has often been transmitted into many aspects of the economy.

Macroeconomic behavior following oil price shocks in the past has triggered research interest on the interaction between oil prices and the macro-economy (Brown & Yücel, 2002; Hamilton, 1983; Mork, 1989; Balcilar and Usman, 2018). Research on the relationship between oil price and economic activities has taken several dimensions, such as its effects on the GDP, national income and reserves, inflation, exchange rates and stock markets returns (Hamilton, 2011; Kilian & Vigfusson; 2011; Olanipekun, et al, 2017; Balcilar et al. 2017). For instance, Hamilton (1983) found negative correlation between the GNP of the US and oil price changes, the US recession that followed an oil price increase was also linked to the extraordinary rise in oil price. Generally, the decline in aggregate economic activity has been associated with oil price increase (Balke, Brown & Yücel, 2002; Hooker, 1996; Mork, 1989; Mory, 1993; Mork, Olsen, & Mysen, 1994; Rasche & Tatom, 1977).

Few have examined the impact of oil price change on agriculture, showing that oil price increase has negative effects on food production (Esmaeili & Shokoohi, 2011) and prices of produce (Chen, Kuo & Chen, 2010; Nazlioglu, 2011; Nazlioglu & Soytas, 2012; Wang, Wu & Yang, 2014; Zhang & Chen, 2014; Zhang & Qu, 2015). Nazlioglu and Soytas (2011) and Fowowe (2016) did not find any linkage between oil price and agricultural commodity prices in Turkey and South Africa respectively. Gohin and Chantret (2010) found that real income effect and cost push effect are the linkages through which energy price impact negatively on agriculture. Real income effect causes reduction in demand for the sector's produce when oil price goes up, while the cost push effect comes via the rise in agricultural input cost. Wang and McPhail (2014) showed that the short-run impact of oil price increase on agricultural productivity growth is negative and this retards the contribution made by agriculture to the economy in the long-run. Hanson, Robinson, and Schluter (1993) established that there is a general loss in agriculture sector during oil price increase. Recently, Alola and Alola (2019) apparently found a positive relationship between crop production and house price index for South Africa.

The general loss in agriculture as oil price hikes implies a significant loss in real sector productivity. This is because the role of agriculture in the real sector goes beyond basic food supply to the population and it gets more complex during the transition period of a developing economy into a developed economy. It is a major facilitator of economic growth especially for less developed countries. According to Kuznets (1961) and Johnston and Mellor (1961), the direct contributions of agriculture to the real sector involves increasing total productivity which is essential for aggregate economic growth. Others include: increasing national income, aiding the growth of other sectors through exchange of products and resources as well as contributing directly to foreign trade through exports. Agriculture contributes significantly to real sector growth and economic growth indirectly by its direct contributions to both domestic and external sectors. Thus, it is theoretically right to assume that if oil price change will impact on the real sector and aggregate economic growth, it comes indirectly through its effects on the real sector productivity, of which agriculture is key.

Among the leading agricultural countries in the world is India, with large proportion of agro-based industries responsible for its rapid economic growth. For example, India is the largest producer of millet and milk, second largest producer of rice, wheat, potato, sugarcane, tea and tobacco, to mention a few. India now ranks as the third-largest oil-consuming country in the world, ranking behind U.S. and China in the first and second positions respectively. It is expected that India will overtake China in its position as the second largest net-oil importing country by the year since 2035. India’s growing dependence on oil imports reflects its rapid economic growth which can no longer be sustained by domestic oil supply alone. India's oil consumption increased by about 10.04 percent between 2017 and 2018 only, oil consumption was about 15 million tons in 2017 and rose to about 17 million tons in 2018. Within the same period, diesel consumption increased by 14.5 percent while gasoline consumption increased by 15.6 percent. Meanwhile, India's crude oil imports has been increasing, rising from about 111.50 million tons in 2007 to about 213.93 million tons in 2017 to 220.4 million tons in 2018. Over 80 percent of India’s oil requirement are met from external sources and their diesel and gasoline retail prices of are connected to world oil prices.

Due to an extraordinary dependence of India on oil imports, changes in crude oil price in the global oil market will affect production, especially in oil intensive industries and this poses a challenge to their real sector productivity, and thus, economic growth. As long as India continues to rely heavily on oil import, rising oil prices are expected to hit its economy through the price transmission mechanisms.

This paper forms an extension of the existing literature by looking directly into the effects of oil price on value added to agriculture rather than on agricultural commodity prices or specific food production. This is because value added to agriculture is important for economic growth. This study is unique in two ways: First, it tests the long-run relationship between food production and oil price change on one hand, and also tests the long-run relationship between nonfood production and oil price on the other hand, through the recently developed Bayer and Hanck cointegration procedure. Second, it shows the effects of oil price change on food and nonfood productivity separately, and compares this with the effects on aggregate agricultural production.

Since oil price change disrupts agricultural activities which accounts for a significant percentage of real sector productivity, the effects of oil price change on agriculture is better assessed through its contribution to real economic growth. Understanding how the changing prices affects agriculture, whether through food production or through nonfood production, provides remarkable signals for policy making on the channels through which oil price changes get to decline real economic activity. This also offers useful information to policy makers on the specific energy policy and macroeconomic policy that might improve general economic welfare. This research, therefore, seeks to find if India's agricultural productivity is subject to world oil price, and which aspect of such production is more affected, because it shows the extent to which the attainment of general economic progress is bound to waver with oil price.

The rest of this paper is organized as follows: Section 2 explains the data and methodology, Section 3 discusses the results, and Section 4 presents the conclusion and policy implication.

2. Data and methodology

2.1 Data

In our paper, we use annual data from 1985 to 2017. Data on food and nonfood production are value of gross production for various food and nonfood agriculture aggregates as obtained from Food and Agriculture Organization (FAO) of the United Nations Statistics via http://www.fao.org/faostat/en/#data/. Total agricultural production is the addition of food and nonfood production for each year. The data on agricultural land area measured in hectare were also sourced from FAO statistics. The annual average of Brent crude oil spot price is derived from the U.S. Energy Information Administration (EIA). Our choice for Brent crude oil for this research is because India's oil imports are mostly from Iran and the benchmark for Iranian crude oil price is the Brent. Data on total employment in agriculture, gross capital formation, measured in constant 2010 US dollar, and inflation as measured by the consumer price index in were obtained from World Development Indicators (WDI).

2.2 *Model specification*

In order to achieve the study objective, the empirical model for this study follows the Cob-Douglas production function in which aggregate production is a function of three conventional inputs: land labour and capital proxied by gross capital formation. Due to the multi-input nature of agricultural production, the production function is extended by two other variables, oil price (OIL) and inflation which shows the effects of changing general prices. As we intend to find out the various effects of the determinants on the food and nonfood production separately, three models emerged which are expressed in Eqs. 1 – 3 as:

Model 1: $FOOD = \alpha_0 + \phi_1 OIL + \phi_2 LAND + \phi_3 EMP + \phi_4 GCF + \phi_5 INF + \mu_t$ (1)

Model 2: $NFOOD = \beta_0 + \delta_1 OIL + \delta_2 LAND + \delta_3 EMP + \delta_4 GCF + \phi\delta_5 INF + \mu_t$ (2)

Model 3: AGRIC= $\gamma_0 + \theta_1 OIL + \theta_2 LAND + \theta_3 EMP + \delta\theta_4 GCF + \theta\delta_5 INF + \mu_t$ (3)

where α_0, β_0 and γ_0 are the constant coefficients, μ_t is the stochastic term in each model which are independently and identically distributed. *FOOD* is agricultural food production, *NFOOD* is nonfood agricultural production while *AGRIC* is the total agricultural production. *OIL* indicates oil price, *LAND* indicates land, *EMP* is total labour in agriculture, while *GCF* is gross capital formation and *INF* represents inflation rate.

The transformed version of the models in their log form, is as follows:

$$lFOOD = \alpha_0 + \phi_1 lOIL + \phi_2 LAND + \phi_3 lEMP + \phi_4 lGCF + \phi_5 INF + \varepsilon_t \quad (4)$$

$$lNFOOD = \beta_0 + \delta_1 lOIL + \delta_2 LAND + \delta_3 lEMP + \delta_4 lGCF + \delta_5 INF + \varepsilon_t \quad (5)$$

$$lAGRIC = \gamma_0 + \theta_1 lOIL + \phi\theta_2 LAND + \theta_3 lEMP + \theta_4 lGCF + \theta_5 INF + \varepsilon_t \quad (6)$$

The models in Autoregressive Distributed Lag (ARDL) approach are as follow:

$$\Delta lFOOD = \alpha_0 + \phi_1 lFOOD_{t-1} + \phi_2 lOIL_{t-1} + \phi_3 LAND_{t-1} + \phi_4 lEMP_{t-1} + \phi_5 lGCF_{t-1} + \phi_6 INF_{t-1} + \sum_{i=0}^{q} \phi_{7,i}\, \Delta lFOOD_{t-i} + \sum_{i=0}^{P} \phi_{8,i}\, \Delta lOIL_{t-i} + \sum_{i=0}^{P} \phi_{9,i}\, \Delta LAND_{t-i} + \sum_{i=0}^{P} \phi_{10,i}\, \Delta i + \sum_{i=0}^{P} \phi_{11,i}\, \Delta lGCF_{t-i} + \sum_{i=0}^{P} \phi_{12,i}\, \Delta INF_{t-i} + \varepsilon_t \qquad (7)$$

$$\Delta lNFOOD = \beta_0 + \delta_1 lNFOOD_{t-1} + \delta_2 lOIL_{t-1} + \delta_3 LAND_{t-1} + \delta_4 lEMP_{t-1} + \delta_5 lGCF_{t-1} + \delta_6 INF + \sum_{i=0}^{q} \delta_{7,i}\, \Delta lFOOD_{t-i} + \sum_{i=0}^{P} \delta_{8,i}\, \Delta lOIL_{t-i} + \sum_{i=0}^{P} \delta_{9,i}\, \Delta LAND_{t-i} + \sum_{i=0}^{P} \delta_{10,i}\, \Delta lEMP_{t-i} + \sum_{i=0}^{P} \delta_{11,i}\, \Delta lGCF_{t-i} + \sum_{i=0}^{P} \delta_{12,i}\, \Delta INF_{t-i} + \varepsilon_t \qquad (8)$$

$$\Delta lAGRIC = \gamma_0 + \theta_1 lAGRIC_{t-1} + \theta_2 lOIL_{t-1} + \theta_3 LAND_{t-1} + \theta_4 lEMP_{t-1} + \theta_5 lGCF_{t-1} + \theta_{6,i} INF_{t-1} + \sum_{i=0}^{q} \theta_{7,i}\, \Delta lARIC_{t-i} + \sum_{i=0}^{P} \theta_{8,i}\, \Delta lOIL_{t-i} + \sum_{i=0}^{P} \theta_{9,i}\, \Delta LAND_{t-i} + \sum_{i=0}^{P} \theta_{10,i}\, \Delta lEMP_{t-i} + \sum_{i=0}^{P} \theta_{11,i}\, \Delta lGCF_{t-i} + \sum_{i=0}^{P} \theta_{12,i}\, \Delta INF_{t-i} + \varepsilon_t \qquad (9)$$

Where l indicates the natural logarithm of the variables, Δ is the difference operator for the variables. The first parts of Eqs. (7) to (9) show the long-run coefficients of food, nonfood and total agricultural production respectively, while the second parts indicate the short-run coefficients. Given that the economy of India is significantly associated with massive agriculture, and the fact that India is a leading net oil importer, oil price is envisaged have negative impact on agricultural production, we expect $\emptyset_2 > 0, \emptyset_3 > 0, \emptyset_4 > 0, and\ \emptyset_5 > 0$ from Eq. (4), on the other hand we expect $\emptyset_1 < 0,\ and\ \emptyset_6 > 0$. From Eq. (5) we expect $\delta_2 > 0, \delta_3 > 0, \delta_4 > 0, and\ \delta_5 > 0,$ on the other hand we expect $\delta_1 < 0,\ and\ \delta_6 > 0$ and from Eq. (6), we expect $\theta_2 > 0, \theta_3 > 0, \theta_4 > 0, and\ \theta_5 > 0,$ while we expect $\theta_1 < 0,\ and\ \theta_6 > 0$

Therefore, based on Eqs. (7) to (9), whenever any of the explanatory variables changes, agricultural productivity may not immediately change to its long-run equilibrium state, hence there will be short-run disequilibrium in the system. The adjustment of the short-run to its long-run equilibrium will take place through the error correction mechanism (ECM). The ECM equation is expressed as:

$$\Delta lnFOOD = \alpha_0 + \sum_{i=0}^{q} \phi_{7,i}\, \Delta lnFOOD_{t-i} + \sum_{i=0}^{P} \phi_{8,i}\, \Delta lnOIL_{t-i} + \sum_{i=0}^{P} \phi_{9,i}\, \Delta LAND_{t-i} + \sum_{i=0}^{P} \phi_{10,i}\, \Delta lnEMP_{t-i} + \sum_{i=0}^{P} \phi_{11,i}\, \Delta lnGCF_{t-i} + \sum_{i=0}^{P} \phi_{12,i}\, \Delta INF_{t-i} + \partial ECM_{t-1} + \varepsilon_t \qquad (10)$$

$$\Delta lnNFOOD = \beta_0 + \sum_{i=0}^{q} \delta_{7,i}\, \Delta lnNFOOD_{t-i} + \sum_{i=0}^{P} \delta_{8,i}\, \Delta lnOIL_{t-i} + \sum_{i=0}^{P} \delta_{9,i}\, \Delta LAND_{t-i} + \sum_{i=0}^{P} \delta_{10,i}\, \Delta lnEMP_{t-i} + \sum_{i=0}^{P} \delta_{11,i}\, \Delta lnGCF_{t-i} + \sum_{i=0}^{P} \delta_{12,i}\, \Delta INF_{t-i} + \gamma ECM_{t-1} + \varepsilon_t \qquad (11)$$

$$\Delta lnAGRIC = \gamma_0 + \sum_{i=0}^{q} \theta_{7,i}\, \Delta lnAGRIC_{t-i} + \sum_{i=0}^{P} \theta_{8,i}\, \Delta lnOIL_{t-i} + \sum_{i=0}^{P} \theta_{9,i}\, \Delta LAND_{t-i} + \sum_{i=0}^{P} \theta_{10,i}\, \Delta lnEMP_{t-i} + \sum_{i=0}^{P} \theta_{11,i}\, \Delta lnGCF_{t-i} + \sum_{i=0}^{P} \theta_{12,i}\, \Delta INF_{t-i} + \partial ECM_{t-1} + \varepsilon_t \qquad (12)$$

The pace of adjustment to the long-run equilibrium level in Eqs. (10) to (12) is captured byECM_{t-1}, which is defined in the long-run equation, as one period lag of residuals.

2.3 Unit Root Tests

Ascertaining the stationarity of the underlying data series requires that we apply unit root test, the unit root test proposed by Zivot and Andrews (1992) is preferred to the conventional unit root tests such as the Augmented Dickey-Fuller (ADF), the Phillips–Perron (PP) and KPSS because it accounts for information about structural breaks which may exist in the series. The conventional unit root tests fail to accommodate this, hence we are not likely to reject the null hypothesis of no unit root when it should otherwise be rejected. This makes the conventional unit root tests have lower predictive power, hence, reliance on their unit root test results alone tends to lead us to producing spurious results in our estimation, which are not reliable for drawing inferences. Judgment based on the Zivot-Andrew unit root test will help us to be fair enough so as not to reject or fail to reject the null hypothesis when we should have decided otherwise.

The null hypothesis for Zivot-Andrew unit root test is $H_0 : \theta = 0$, and the alternative hypothesis is $H_1 : \theta < 0$. The Zivot-Andrews unit root tests performed in this study include two models: first, model with break in intercept (Model A), second, a model with break in intercept and trend (Model B).

Model A: $$\Delta x_t = \alpha_0 + \alpha_1 + \lambda x_{t-1} + \phi DU_t + \sum_{j=1}^{k} \theta_j \Delta x_{t-j} + \nu_t \qquad (13)$$

Model B: $$\Delta x_t = \varphi_0 + \varphi_1 + \lambda x_{t-1} + \phi DU_t + \Phi DT_t + \sum_{j=1}^{k} \theta_j D x_{t-j} + \nu_t \qquad (14)$$

$DU_t = 1$ if t > T_j^b, and 0 if otherwise. Similarly, $\Phi DT_t = t - T_j^b$ if t > T_j^b, and 0 if otherwise.

In Eqs. (13) and (14) DU_t represents the dummy variable which indicates the shift in the mean of the data series that occurs at a possible breakpoint (T_j^b), while the trend variable represented by DT_t corresponds to the mean shift and T_j^b denotes the possible break point that may appear in the series. The null hypothesis of the Z-A single breakpoint test states that $H_0 : \theta = 0$. If we cannot reject this, then a unit root exists in the presence of single breakpoint, if otherwise, we go with the alternative hypothesis stated as $H_1 : \theta < 0$, then, we are able to reject the null hypothesis implying that no unit root is found in the presence of a single breakpoint.

2.4 Bayer and Hanck Cointegration Test

To examine cointegration among the variables, a cointegration test proposed by Bayer and Hanck (2013) is explored in this study. B-H cointegration test has an advantage over most of the cointegration tests applied by previous studies on the relationship between agricultural productivity and oil price. The B-H cointegration test combines four major cointegration tests - Engle and Granger (1987), Johansen (1995), Boswijk (1994) and Bannergee (1998) to give robust results (Shahbaz, Khan, Ali & Bhattacharya, 2017). This method by Bayer and Hanck (2013) overcomes the challenge of possible conflicts in results that may arise while using different types of cointegration tests, and it prevents random and inconsistent decision taking. The B-H test applies the formula proposed by Fisher (1932) to combine the statistical level of significance for the separate cointegration tests. The separate cointegration tests are written in the following form:

$$EG-JOH=-2[ln(P_{EG})+ln(P_{JOH})] \qquad (15)$$

$$EG-JOH-BO-BDM=-2[ln(P_{EG})+ln(P_{JOH})+ln(P_{BO})+ln(P_{BDM})] \qquad (16)$$

In Eqs. (15) and (16), EG indicates the Engle and Granger (1987) cointegration test with (P_{EG}) representing the corresponding p-value, and JOH indicates Johansen (1995) cointegration test with (P_{JOH}) representing the corresponding p-value. BO indicates the Boswijk (1994) cointegration test with its corresonding p-value as (P_{BO}), while BDM indicates the cointegration test proposed by Banerjee (1998) with the corresponding p-value as (P_{BDM}).

Our decision on the existence of cointegration among our varables of interest is based Fisher's statistic. The null hypothesis of no cointegration is rejected if the B-H critical values are greater than the calculated Fisher statistics. If the otherwise, then we will fail to reject the null hypothesis of no cointegration. This implies that there exists a long-run relationship among the variables of interest

2.5 VECM Granger causality test

In the presence of cointegrating relationship among the variables, we seek to estimate both short and long-run causal relationships among the variables. Under the framework for vector error correction mechanism *(ECM),* we performed the Granger causality tests for each of the three models earlier specified. The framework for VECM Granger causality model takes the following form:

Model 1

$$\begin{pmatrix} \Delta lFOOD_t \\ \Delta lOIL_t \\ \Delta LAND_t \\ \Delta lEMP_t \\ \Delta lGCF_t \\ \Delta INF_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{pmatrix} + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lFOOD_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lFOOD_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{pmatrix} \quad (17)$$

Model 2

$$\begin{pmatrix} \Delta lNFOOD_t \\ \Delta lOIL_t \\ \Delta LAND_t \\ \Delta lEMP_t \\ \Delta lGCF_t \\ \Delta INF_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{pmatrix} + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lNFOOD_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lNFOOD_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{pmatrix} \quad (18)$$

Model 3

$$\begin{pmatrix} \Delta lAGRIC_t \\ \Delta lOIL_t \\ \Delta LAND_t \\ \Delta lEMP_t \\ \Delta lGCF_t \\ \Delta INF_t \end{pmatrix} = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{pmatrix} + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lAGRIC_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \beta_{11}\beta_{12}\beta_{13}\beta_{14}\beta_{15}\beta_{16} \\ \beta_{21}\beta_{22}\beta_{33}\beta_{24}\beta_{25}\beta_{26} \\ \beta_{31}\beta_{32}\beta_{33}\beta_{34}\beta_{35}\beta_{36} \\ \beta_{41}\beta_{42}\beta_{43}\beta_{44}\beta_{45}\beta_{46} \\ \beta_{51}\beta_{52}\beta_{53}\beta_{54}\beta_{55}\beta_{56} \\ \beta_{61}\beta_{62}\beta_{63}\beta_{64}\beta_{65}\beta_{66} \end{pmatrix} \times \begin{pmatrix} \Delta lAGRIC_{t-1} \\ \Delta lOIL_{t-1} \\ \Delta LAND_{t-1} \\ \Delta lEMP_{t-1} \\ \Delta lGCF_{t-1} \\ \Delta INF_{t-1} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \end{pmatrix} ECT_{t-1} + \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \\ \mu_6 \end{pmatrix} \quad (19)$$

In Eqs. (17) to (19), Δ represents the difference operator. ECT_{t-1} is the lag of the error correction term obtained from the long-run equations. The error terms assumed to have zero mean and finite covariance matrices are represented by $\mu_1, \mu_2, \mu_3, \mu_4, \mu_5$ and μ_6. If the value of ECT_{t-1} is statistically significant, then long-run causal relationship exists among the variables. If F-statistic for first difference of variables is statistically significant, then short-run causal relationship exists between the variables.

3. Empirical findings and discussions

The descriptive statistics of the variables is presented in Table 1. Land has the highest mean value of 180534.7, followed by gross capital formation with 36.257. The standard deviation values show that all series, except land, are less volatile, as their standard deviation values range from 0.133 for employment in agriculture to 4.314 for gross capital formation. The statistics suggest that labour in agriculture has the least variation among the series in the study, while land is the most volatile with a standard deviation of about 710.764. Furthermore, the values of skewness are closed to zero for most of the variables, but gross capital formation tends to be negatively skewed with a value of -2.102 suggesting asymmetry. The series have positive kurtosis values, gross capital formation is not normally distributed as the kurtosis figure exceeds 5. Consequently, the null hypothesis for the Jarque-Bera normality test can only be rejected for gross capital formation at 1% significance level, because it is not normally distributed. The time plots of the variables are presented in Figure 1 in the appendix (A). It is revealed that the food, nonfood, total agriculture, and capital formation are positively trending while employment and land are negatively trending. The oil price variable shows no clear evidence of trend. However, most of the variables are characterized by fluctuations.

Table 1: Descriptive statistics

	*l*FOOD	*l*NFOOD	*l*AGRIC	*l*OIL	LAND	*l*EMP	*l*GCF	INFLATION
Mean	18.935	15.941	18.984	8.123	180534.7	4.034	36.257	7.508
Median	18.910	15.820	18.954	7.824	180560.0	4.088	37.590	7.164
Maximum	19.360	16.515	19.416	9.320	181586.0	4.183	39.041	13.870
Minimum	18.475	15.311	18.521	7.152	179573.0	3.755	25.001	3.263
Std. Dev.	0.278	0.385	0.283	0.705	710.764	0.133	4.314	3.097
Skewness	0.040	0.291	0.061	0.437	-0.002	-0.800	-2.102	0.288
Kurtosis	1.901	1.800	1.893	1.726	1.439	2.317	5.783	1.970
Jarque-Bera	1.669	2.445	1.707	3.285	3.352	4.158	34.946	1.916
Probability	0.434	0.295	0.426	0.195	0.187	0.125	0.000	0.384

The Z-A test results in Table 2 shows that all our variables are not stationary at level but Table 3 shows that they are stationary at first difference. The Z-A test identified breaks in each of the variables which vary depending on the intercept or intercept and trend tests. However, it is observed that these series are found stationary in their first differences – an indication that the variables are integrated of order one, 1(1)[1].

Table 2: Zivolt Andrew unit root tests at level

	Intercept		Intercept and Trend	
Variables	Statistics	Break date	Statistics	Break date
Ln FOOD	-3.797 (0)	2000	-3.757 (0)	2002
Ln NONFOOD	-3.635 (0)	1997	-3.446 (0)	1997
Ln AGRIC TOTAL	-3.693 (0)	2000	-3.639 (0)	2000
Ln OIL	-3.203 (1)	2004	-2.517 (1)	2005
LAND	-4.288 (0)	2001	-4.364 (0)	2005
ln EMP	-2.855 (0)	2011	-4.340 (0)	2001
Ln GCF	-2.645 (0)	2000	-6.041 (0)	1992
INFLATION	-4.243 (2)	1999	-4.420 (2)	1999
1 Percent	-5.57		-5.34	
5 Percent	-5.08		-4.93	
10 Percent	-4.82		-4.58	

Note: The chosen lag length is presented in the parenthesis

Table 3: Zivolt Andrew unit root tests in first difference.

	Intercept		Intercept and Trend	
Variables	Statistics	Break date	Statistics	Break date
Ln FOOD	-8.115 (0)***	2003	-8.174 (0)***	2006
Ln NONFOOD	-6.495 (0)***	2003	-6.415 (0)***	2003
Ln AGRIC TOTAL	-7.986 (0)***	2003	-7.827 (0)***	2003
Ln OIL	-5.510 (1)***	1999	-5.914 (1)***	2004

[1] The results of the ADF and KPSS tests are also provided in the Appendix (C) for robustness check on the unit root tests.

LAND	-9.557 (0)***	2008	-9.465 (0)***	2008
ln EMP	-5.659 (0)***	2004	-6.828 (0)***	2011
Ln GCF	-7.923 (4)***	2004	-7.466 (4)***	2004
INFLATION	-6.516 (1)***	2002	-6.665(1)***	2006
1 Percent	-5.57		-5.34	
5 Percent	-5.08		-4.93	
10 Percent	-4.82		-4.58	

Note: The chosen lag length is presented in the parenthesis

*** denotes 1% significance level

Table 4: Cointegration test results.

Panel A: The results of Bayer and Hanck Cointegration Analysis

Estimated Model	EG–JOH	EG–JOH–BO–BDM	Cointegration
$lnFOOD_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t$	13.120	19.942	Yes
$lnNFOOD_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t$	18.593	24.643	Yes
$lAGRIC_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t$	66.630	177.154	Yes
5% Critical values	10.419	19.888	

Panel B: Robustness check through ARDL Bounds Testing Approach

Estimated Model	F-Statistics	T-Statistics	Cointegration
$lnFOOD_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t$	6.887	-4.714	Yes
$lnNFOOD_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t$	9.213	-5.954	Yes

$lAGRIC_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t$	8.495		-4.707		Yes
Critical Value	Lower Bound	Upper Bound	Lower Bound	Upper Bound	
1 Percent	2.26	4.68	-3.13	-3.86	
5 Percent	2.62	3.79	-2.86	-4.19	
10 Percent	3.41	3.35	-2.57	-4.46	

Table 4 shows the evidence of cointegration among the variables in all three models using the Bayer and Hanck cointegration (2013) procedure and the robustness check for cointegration using ARDL bounds test procedure. Lag length was selected using the Akaike Information Criteria (AIC). Considering the Bayer and Hanck cointegration test, we found that all F-statistics are significantly greater than the critical values in the three equations. All F-statistics and T-statistics are also greater than the upper bound of the ARDL bounds tests for cointegration in all three models. This agreement between Bayer and Hanck cointegration and ARDL test for cointegration results indicates there is at least one cointegrating vector among the variables in each model. Therefore, from the first model, a valid long-run relationship exists between food production, oil price, land used in agriculture, labour in agriculture, gross capital formation and inflation. From the second model, it is also evident that long-run relationship exists between oil price, nonfood agricultural production, inflation and the three factors of production. Finally, we also established that long-run relationship exists between total value added to agriculture, oil price, inflation, land labour and used in agriculture as well as capital formation. We also established that Bayer and Hanck cointegration procedure is valid for establishing this relationship. This finding is different from Fowowe (2016) who, with the use of structural breaks cointegration tests, could not establish any long-run relationship between oil prices and agricultural commodity prices.

Tables 5, 6 and 7 present the results of the long-run and short-run ARDL estimations for the three models in Eqs. 7, 8, 9 respectively.

Table 5: Long- and Short-run ARDL Coefficients for Model 1

Dependent Variable: Δ*l*FOOD (2, 0, 0, 0, 0, 2)

Short-run Parameters				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	26.9717***	5.573	4.840	0.000
Δ*l*FOOD	-0.4779***	0.101	-4.714	0.000
Δ(*l*FOOD(-1))	-0.3780**	0.147	-2.582	0.017
Δ*l*OIL	0.0073	0.016	0.454	0.654
ΔLAND	-0.0001***	0.000	-4.246	0.000
Δ*l*EMP	-0.3305**	0.148	-2.232	0.037
Δ*l*GCF	0.0068***	0.002	2.907	0.008
ΔINFLATION(-1)	0.0054**	0.002	2.740	0.012
Δ(INFLATION(-2))	-0.0031**	0.002	-1.821	0.083
ECM_{t-1}	-0.4779***	0.067	-7.153	0.000
Long-run Parameters				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
*l*OIL	0.0152	0.034	0.447	0.659
LAND	-0.0002***	0.000	-4.498	0.000
*l*EMP	-0.6916***	0.197	-3.514	0.002
*l*GCF	0.0142***	0.003	4.118	0.001
INFLATION	0.0114**	0.005	2.469	0.022
Diagnostic Tests	Statistic	P-value		
$\chi^2 SERIAL$	1.142076	0.3401		
$\chi^2 ARCH$	0.159217	0.8536		
$\chi^2 RESET$	0.419653	0.6792		
$\chi^2 NORMAL$	6.853702	0.032489		

*** and ** indicate significance level at 1% and 5% levels respectively.

In Table 5, having food production as the dependent variable. The impact of oil price on food production is not significant both in the short-run and in the long-run. However, the short-run and long-run impact of land, labour and capital on food production are highly significant. Specifically, in the short-run, an increase in land by one hectare causes a decrease in food production by less than 0.001% while it also decreases food production by about 0.019% in the long-run. A percentage increase in labour in agriculture causes a decrease in food production by 0.33% in the short-run and 0.69% in the long-run. However, an increase in gross capital formation by 1% will increase food production by 0.068% in the short-run and 0.014% in the long-run. A unit increase in the rate of inflation will negatively affect food production by 0.31% in the short-run but in the long-run food production will increase by 1.1% even as inflation rate increases by 1 unit.

Table 6: Long- and Short-run ARDL Coefficients for Model 2

Dependent Variable: D(*l*NFOOD) (2, 0, 2, 0, 1, 1)

Short-run Parameters

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	59.6843***	9.414	6.340	0.000
Δ*l*NFOOD	-1.0641***	0.179	-5.954	0.000
Δ(*l*NFOOD(-1))	0.3433**	0.122	2.826	0.011
Δ*l*OIL	-0.0040	0.031	-0.128	0.899
Δ(LAND)	-0.0002***	0.000	-4.531	0.000
ΔLAND(-1)	-0.0002***	0.000	-4.685	0.000
Δ*l*EMP	-1.7962***	0.387	-4.637	0.000
Δ(*l*GCF)	0.0238***	0.005	4.590	0.000
Δ*l*GCF(-1)	0.0174***	0.005	3.586	0.002
Δ(INFLATION)	0.0096**	0.004	2.733	0.013
ΔINFLATION(-1)	0.0222***	0.004	5.906	0.000

Long-run Parameters

Variable	Coefficient	Std. Error	t-Statistic	Prob.
*l*OIL	-0.0037	0.029144	-0.127327	0.900
LAND	-0.0002***	4.48E-05	-4.211575	0.000

*l*EMP	-1.6880***	0.156127	-10.81194	0.000
*l*GCF	0.0163***	0.002945	5.547960	0.000
INFLATION	0.0208***	0.003217	6.479534	0.000
ECM	-1.0641***	0.127341	-8.356258	0.000
Diagnostic Tests	Statistic	P-value		
$\chi^2 SERIAL$	0.5137	0.607		
$\chi^2 ARCH$	0.3566	0.703		
$\chi^2 RESET$	0.2016	0.843		
$\chi^2 NORMAL$	0.6406	0.726		

*** and ** indicate significance level at 1% and 5% levels respectively.

Table 6 presents the results of equation 8 estimated, in which nonfood agricultural production is the dependent variable. Again, oil price change has no significant impact on value of nonfood agriculture both in the short- and long-run. An expansion of land by one more hectare will increase nonfood production by 0.02% in the short-run but decrease it in the long-run by about 0.02%. In the short-run, a percentage increase in agricultural labour will reduce productivity by 1.796% and by 1.688% in the long-run. However, if gross capital formation is increased by 1%, nonfood agriculture will increase by 0.238% and in the 0.016% in the short- and long-run respectively. A unit rise in inflation rate will increase value added to nonfood agriculture in the short-run by 0.96% and about 2.08% in the long-run.

Table 7 Long- and Short-run ARDL Coefficients for Model 3

Dependent variable = *lAGRIC* (1, 0, 0, 1, 0, 2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Short-run Parameters				
Constant	31.5038***	5.437	5.794	0.000
Δ*l*AGRIC(-1)	-0.9389***	0.200	-4.707	0.000
Δ*l*OIL	0.0028	0.015	0.179	0.859
ΔLAND	-0.0001**	0.000	-2.489	0.022
Δ*l*EMP(-1)	-0.4089**	0.154	-2.648	0.015
Δ*l*GCF	0.0069***	0.002	2.980	0.007
ΔINFLATION	0.0101***	0.003	3.809	0.001
Δ(INFLATION(-1))	-0.0045**	0.002	-2.340	0.030
Long-run Parameters				
*l*OIL	0.0029	0.016206	0.180587	0.859
LAND	-0.0001*	0.000	-1.925	0.069
*l*EMP	-0.4355***	0.153	-2.843	0.010
*l*GCF	0.0074***	0.002	3.277	0.004
INFLATION	0.0107***	0.002	4.739	0.000
ECM	-0.9389***	0.118	-7.982	0.000
Diagnostic Tests	Statistic	P-value		
$\chi^2 SERIAL$	1.1485	0.339		
$\chi^2 ARCH$	0.1165	0.891		
$\chi^2 RESET$	0.5622	0.580		
$\chi^2 NORMAL$	2.0726	0.355		

***, ** and * indicate significance level at 1%, 5% , and 10% levels respectively.

Table 7 presents the results of equation 9, having the aggregate of agricultural production as dependent variable. Once more, the effect of oil price change is insignificant neither in the long-run nor in the short-run, and the impact of land and labour in agriculture is negative. As one more hectare of land is used in agriculture, total productivity will fall by 0. 01% in the long-run and less in the short-run. A percentage increase in labour employed in agriculture will reduce production by 0.409% in the short-run and by 0.436%in the long-run. Gross capital formation increases production by 0.007% both in the short- and long-run when increased by 1%. Inflation rate will reduce total production by 0.45% in the short-run when increased by 1 unit, but will cause an increase in value added to agricultural production by 1.07% in the long-run.

Our findings imply that agricultural production in India is independent of international spot price of crude oil, hence there are agricultural inputs other than oil products which are being used as an input in agricultural production in India. The general finding is consistent with the neutrality hypothesis already established in the study of relationship between agricultural commodity prices and global oil prices by Zhang, Lohr, Escalante and Wetzstein (2010), Nazlioglu (2011) and Fowowe (2016). Nazlioglu and Soytas (2011), with impulse response analysis also confirmed that agricultural commodity prices do not respond to both direct and indirect effects of oil prices changes in the long- and short-run. This is also buttressed by the findings of Hanson, et al. (1993) that the effects of global oil prices on energy costs in agriculture are dependent on the exchange rate policy adjustments and adjustments of government finance to higher oil import costs.

Contrary to the a-priori expectation, the coefficients of employment and land in agriculture are negative. This inverse relationship between employment in agriculture and agricultural productivity implies that agricultural productivity continues to grow even as the sector loses more of its labour to secondary and tertiary sectors. As a large emerging market economy, it is also expected that India will have a shift in factors of production from primary sector to manufacturing and tertiary sectors as it paces towards development. This is clearly depicted in appendix, Figure 1, where all the variables on agriculture maintain an upward trend even though employment in agriculture takes a downward trend for over three decades. This is an indication of development, and technological advancement in the real sector. This can also explain why there is an inverse relationship between agricultural land area and value of agricultural production. It is synonymous to the findings of Yotopoulos and Lau (1973) and Yotopoulos, Lau, and Somel (1970) who for India, also found negative relationship between farm size and agricultural productivity while testing for relative economic efficiency of land in agricultural productivity (see also, Ahmad, et al., 1999). The empirical results proved that the relationship between gross capital formation and agriculture is positive both in the short-run and long-run, emphasizing the impact of capital inputs in production. Thus, increasing capital input supply and more conventional technology in production will stimulate the growth of agricultural production. We also show that the negative effects of inflation on production is only a short-run phenomenon, the impact of inflation becomes positive in the long-run.

The coefficient of the ECM is negative and statistically significant at 1% in all three models. This indicates that the yearly adjustment of the deviations occurring in the short-run will be corrected by and 47%, 106% and 94% towards the long-run equilibrium path in the first, second and third models respectively. The speed of adjustment is highest in the model of nonfood production and lowest in the model of food production. This implies that nonfood production will adjust back to long-run equilibrium provided there is any distortion in the equilibrium. These adjustments mechanisms will be through the huge contribution of gross capital formation and inflation.

Going further, the diagnostic tests conducted on the models show that neither the null hypothesis of no heteroscedasticity nor the null hypothesis of no serial correction can be rejected. The ARCH test statistics for the existence conditional heteroscedasticity are above 5% and the Breusch–Godfrey LM test statistics for serial correction are above 5% in all. Thus, the problem of serial correlation and heteroscedasticity are not valid in the models. Additionally, the Ramsay RESET test statistics are above 5% in all three models, and the Jarque-Bera Normality test statistics, also show that the models are correctly specified in their functional forms, and the error terms are normally distributed in each model. Finally, we conducted the stability tests for the models and the pictorial results are presented in Figures 2-7 in the Appendix (B). Both the cumulative sum (CUSUM) and cumulative sum of squared CUSUM-squared stability tests indicate the proper stability of the models at 5% level of significance each.

VECM Granger Causality Tests

Tables 8 – 10 show both long-run and short-run directions of causality for each model estimated separately. In the short-run, it can be observed that the neutrality hypothesis is common to the relationship of oil price with food production, non-food production and the aggregate agricultural production. However, in the model of non-food production, one-way causality runs from oil price to gross capital formation in the short-run.

In Tables 8 and 10, bi-directional short-run causal relationships exist between gross capital formation and food production, and between gross capital formation and total agricultural production. This mutual interaction is an indication that agriculture, especially food production, is one of the major sources of India's economic wealth. There is no short-run causality from gross capital formation to non-food production in the second model as shown in Table 9. As expected, short-run causality runs from land and labour in agriculture to agricultural production. Also observed, is the short-run bi-directional relationship between inflation and gross capital formation, notable in all the three models. The implication of this result is that the mutual interaction between capital formation and inflation are the most crucial in the Indian agricultural sector and should receive proper policy attention provided there is any disequilibrium in the system. In the long-run, causality runs from all the exogenous variables to food production, non-food production as well as total agriculture. Furthermore, there is long-run joint causality from other variables in the 3 models to gross capital formation.

In Table 11, there are long run causal effects from oil price, land. Labour and capital formation on food, nonfood and total agricultural production, and from other variables to labour in agriculture. The long run causality also run from other variables to oil price only in the model of nonfood production.

Table 8: Granger Causality test for Model 1: $lFOOD, lOIL, LAND, lEMP, lGCF, INF$

Dependent variable	**Short-run Causality**					
	*l*FOOD	*l*OIL	*l*LAND	*l*EMP	*l*GCF	INFLATION
*l*FOOD	–	1.915 (0.384)	4.574 (0.102)	5.821* (0.055)	4.760* (0.093)	1.306 (0.521)
*l*OIL	2.043 (0.360)	–	4.272 (0.118)	5.428* (0.066)	10.417*** (0.006)	6.243** (0.044)
*l*LAND	7.715** (0.021)	3.846 (0.146)	–	3.579 (0.167)	3.439 (0.179)	1.545 (0.462)
*l*EMP	3.413 (0.182)	0.444 (0.801)	0.093 (0.954)	–	0.314 (0.855)	0.622586 (0.7325)
*l*GCF	6.363** (0.042)	1.360 (0.507)	6.517** (0.038)	7.833** (0.020)	–	7.132** (0.028)
INFLATION	1.494 (0.474)	3.000 0.223	12.059 (0.002)	0.523 (0.770)	7.371** (0.025)	-

Notes: The p-values are in parenthesis ( ). *** and ** indicate significance level at 1% and 5% levels respectively.

Table 9: Granger Causality test for Model 2: $lNFOOD, lOIL, LAND, lEMP, lGCF, INF$

Dependent variable	**Short-run Causality**					
	*l*NFOOD	*l*OIL	*l*LAND	*l*EMP	*l*GCF	INFLATION
*l*NFOOD	–	1.505 (0.471)	1.450 (0.484)	2.612 (0.271)	0.414 (0.813)	0.981 (0.612)
*l*OIL	1.574 (0.455)	–	0.830 (0.660)	0.386 (0.825)	0.857 (0.652)	1.414 (0.493)
*l*LAND	10.190*** (0.006)	3.206 (0.201)	–	8.813** (0.012)	1.202 (0.548)	2.668 (0.264)
*l*EMP	3.220 (0.200)	0.451 (0.798)	0.067 (0.967)	–	1.098 (0.578)	0.000 (1.000)
*l*GCF	25.223*** (0.000)	8.303** (0.016)	9.343*** (0.009)	15.939*** (0.000)	–	23.861*** (0.000)
INFLATION	0.063 (0.969)	1.421 (0.492)	6.763** (0.034)	1.476 (0.478)	4.618* (0.099)	-

Notes: The p-values are in parenthesis ( ). ***, ** and * indicate significance level at 1%, 5% and 10% levels respectively.

Table 10: Granger Causality test for Model 3: $lAGRIC, lOIL, LAND, lEMP, lGCF, INF$

Dependent variable	**Short-run Causality**					
	*l*AGRIC	*l*OIL	*l*LAND	*l*EMP	*l*GCF	INFLATION
*l*AGRIC	–	2.614	5.614**	7.599**	5.517*	1.550
		(0.271)	(0.060)	(0.022)	(0.063)	(0.461)
	1.829	–	4.277	5.283**	9.564***	6.147**
*l*OIL	(0.401)		(0.119)	(0.071)	(0.008)	(0.046)
	8.444**	3.921	–	4.590	4.009	1.743
*l*LAND	(0.015)	(0.141)		(0.101)	(0.135)	(0.418)
	3.466	0.476	0.144	–	0.221	0.701
*l*EMP	(0.177)	(0.788)	(0.931)		(0.895)	(0.705)
	6.864**	0.032	6.845**	7.870**	–	7.910**
*l*GCF	(0.032)	(0.475)	(0.033)	(0.020)		(0.019)
	1.258	2.924	11.298***	0.545	7.374**	-
INFLATION	(0.533)	(0.231)	(0.004)	(0.762)	(0.025)	

Notes: The p-values are in parenthesis ( ). *** and ** indicate significance level at 1% and 5% levels respectively.

Table 11: Long-run causality tests

Dependent variable	**Long-run causality** ECM_{t-1}	**Dependent variable**	**Long-run causality** ECM_{t-1}	**Dependent variable**	**Long-run causality** ECM_{t-1}
*l*FOOD	-0.632***	*l*NFOOD	-0.469**	*l*AGRIC	-0.710***
	[3.504]		[-2.301]		[-3.741]
	2.594*		0.856		2.842*
*l*OIL	[1.743]	*l*OIL	[1.219]	*l*OIL	[1.755]
	-0.007		0.008**		-0.007
*l*LAND	[-0.890]	*l*LAND	[-2.390]	*l*LAND	[-0.916]
	-0.006		-0.016		-0.019
*l*EMP	[-0.072]	*l*EMP	[-0.449]	*l*EMP	[-0.222]
	-30.602***		-22.988***		-33.725***
*l*GCF	[2.684]	*l*GCF	[6.920]	*l*GCF	[-2.752]
	-8.070		2.501		-8.156
INFLATION	[-0.554]	INFLATION	[0.369]	INFLATION	[-0.513]

Notes: The T-statistics are in parenthesis []. *** and ** indicate significance level at 1% and 5% levels respectively.

4. Conclusion and policy implications

The study examines the relationships between oil price changes and real sector growth with specific reference to agricultural productivity. Within the context of oil as an energy input in production, we considered India's agricultural sector between the year 1985 and 2017. The recently developed test by Bayer and Hanck cointegration test was used in our three models featuring food production, nonfood production and total agricultural production as dependent variables. Having taken a non-arbitrary decision on their long-run relationship status, through judgement based on the combined cointegration procedure of Bayer and Hanck (2013), we confirmed the existence of long-run relationships among the variables in each model with supporting evidence from ARDL bounds test for cointegration. This implies that both food and non-food production will not drift too far away from a combination of oil price change, inflation and other factors of production combined in the long-run.

Going further, the short-run and long-run coefficients of ARDL estimations showed that the effect of oil price on agricultural productivity is not significant, the effects of land and labour are both negative and statistically significant while the effects of gross capital formation is positive and also statistically significant. The effects of inflation in our models are positive in the long-run but negative in the short-run. We also confirmed mutual causal interactions between gross capital formation and inflation, and between gross capital formation and agriculture. Therefore, how oil price affects the agriculture in the real sector economy is partly through its effects on inflation in the short run, and most importantly, through its effects on gross capital formation both in the long-run and in the short-run. However, the error correction coefficient shows that nonfood production will adjust faster than food production from short-run to long-run equilibrium whenever there is a shock in the model. This study also shows that the real sector variables, labour, capital and inflation, have influence on oil prices, this is a slight indication of the role India plays in global oil demand which in turn influences price.

On the basis on these findings, we recommend having a policy that focus on capital formation because it is at the center of this relationships in the real sector. The real sector growth through India's agriculture is hinged on its level of technological development and not oil energy consumption. The first implication is that the conventional methods of production in agriculture may not be oil intensive, or there are other sources of commercial energy which are more important to India's agriculture than oil, hence, global oil price is not a direct input cost in production. Second, as far as India is concerned, exchange rate policy adjustments to international spot price of oil and government policy on oil imports are efficient to quiet the effects of international price of oil on energy input costs in agriculture. Therefore, economic policy on the finance of oil import costs when price changes is adequate to shield the system from the effects of changing oil prices. Lastly, if agriculture plays a key role in India's real sector growth, oil price change cannot constrain this development process. Therefore, if oil price change will have any effect on India's real sector, it will not be through the agricultural sector.

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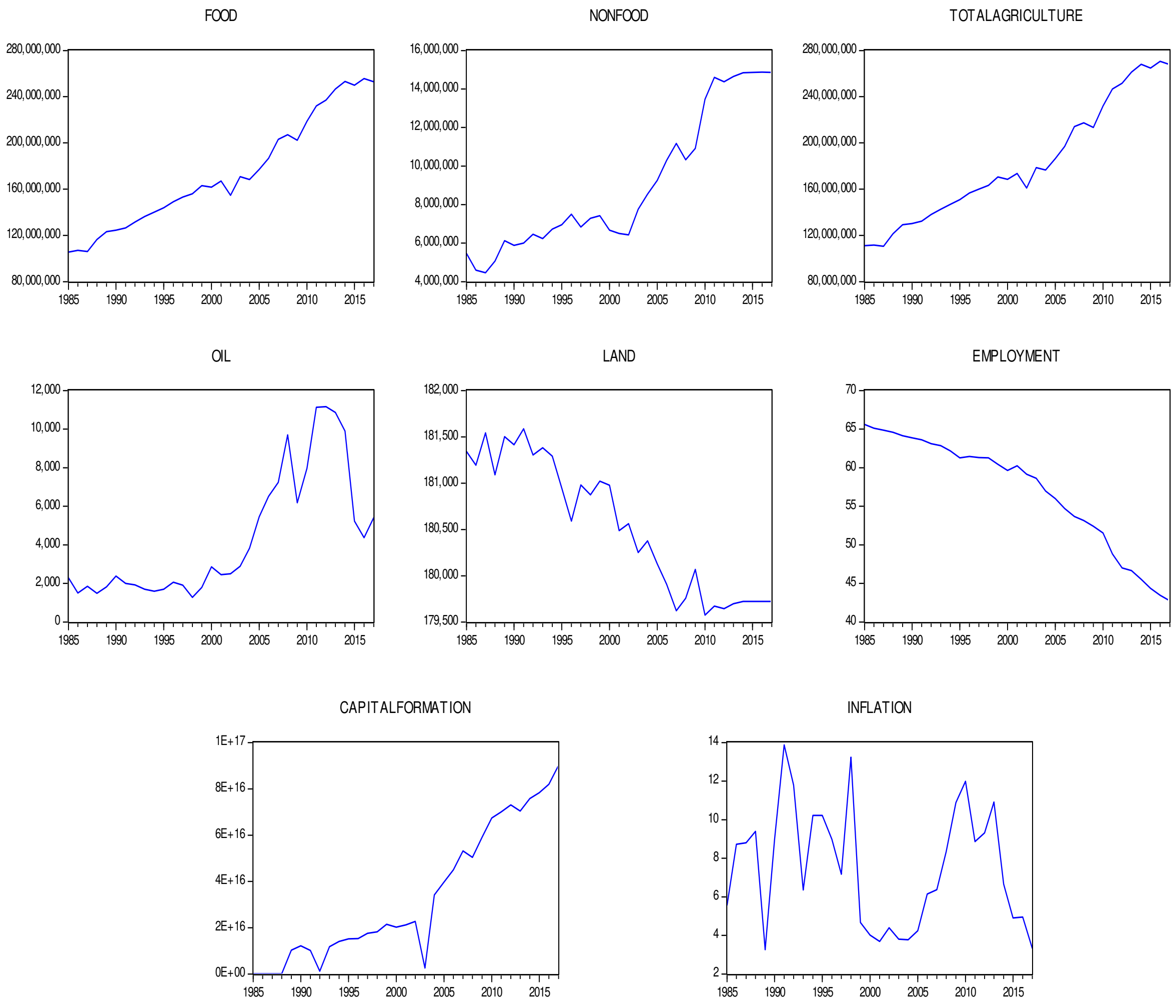
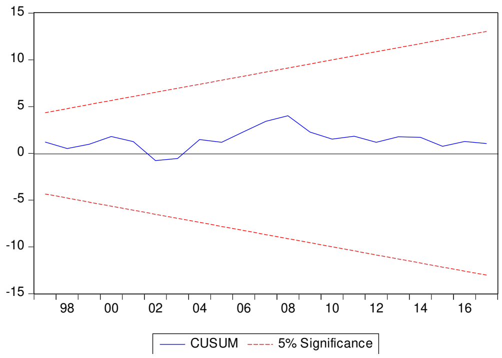
Appendix (A)

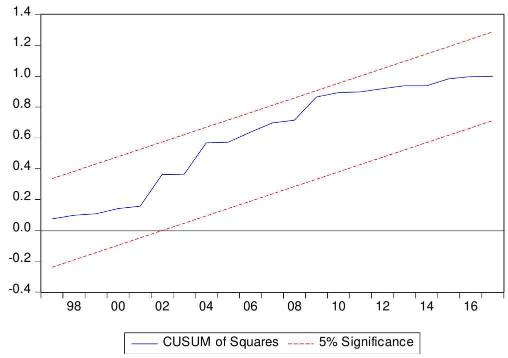
Figure 1: Time plots of variables



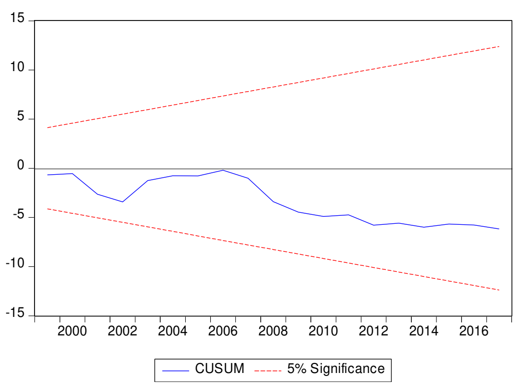
Appendix (B)

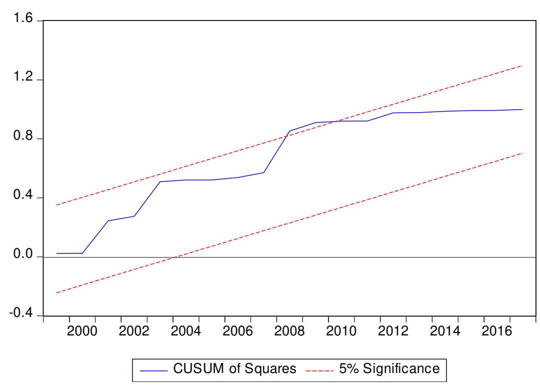
Figures 2 and 3: CUSUM and CUSUM Squares tests for Model 1: $lnFOOD_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t)$



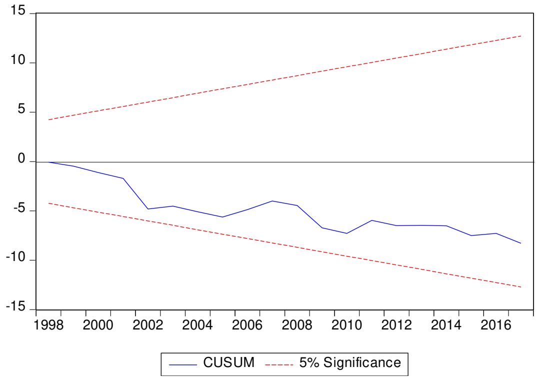


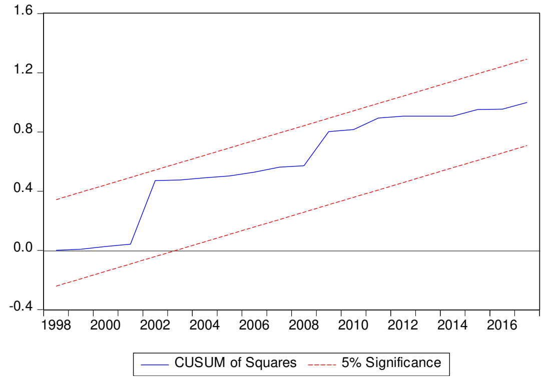
Figures 4 and 5: CUSUM and CUSUM Squares tests for Model 2: $lnNFOOD_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t)$





Figures 6 and 7: CUSUM and CUSUM Squares tests for Model 3: $lAGRIC_t = f(OIL_t, LAND_t,\ EMP_t,\ GCF_t, INF_t)$





Appendix (C)

Table 11. Unit root tests

Variable	Philip Perron Unit Root Test				ADF Unit Root Test			
	Level		First Difference		Level		First Difference	
	Intercept	Intercept and Trend	intercept	Intercept and Trend	Intercept	Intercept and Trend	Intercept	Intercept and Trend
lFOOD	-0.794179	-2.840842	-7.441628***	-7.378448***	-0.830562	-2.840482	-7.32119***	-7.244175***
lNONFOOD	-0.041159	-2.567444	-5.370239***	-5.188238***	-0.211787	-2.567444	-5.29309	-5.132154***
lAGRIC	-0.667022	-2.727119	-7.145161***	-7.016954***	-0.662059	-2.727119	-7.02568***	-6.938148***
lOIL	-1.007837	-2.260768	-5.532557***	-5.463122***	-1.007837	-2.143597	-5.53533***	-5.464698***
LAND	-0.714812	-3.267690*	-8.993704***	-8.833970***	-0.973526	-3.267690*	-8.62946***	-8.485975***
l EMP	4.015014	-0.169002	-3.537560**	-5.092413**	3.614532	-0.313936	-3.57751***	-5.044803***
l GCF	-4133***	-2.974745	-5.927***	-7.9550***	-2.831669*	-2.642520	-5.85485***	-6.142563***
INFLATION	-4.41330**	-2.974745	-5.912710***	-7.955010	-3.19569**	-4.800329***	-7.05323***	-6.964527***