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Opinion paper

Reforming fossil fuel prices in India: Dilemma of a developing economy

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HIGHLIGHTS

- Fossil fuels' contribution in primary energy supply has risen from 55 to 75 per cent.
- Energy intensity halved for aggregate GDP, but doubled for agricultural GDP.
- Impact of fossil fuel price increase on farming costs mimics a widening spiral.
- Total cost of farming may increase 6.7 times the increase in direct fuel input cost.

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ABSTRACT

Over the period between 1990–1 and 2012–3, fossil fuel use on farms has risen and its indirect use in farming, particularly for non-energy purposes, is also growing. Consequently, both *energy intensity* and *fossil fuel intensity* are rising for Indian agriculture. But, these are declining for the aggregate Indian economy. Thus, revision of fossil fuel prices acquires greater significance for Indian agriculture than for rest of the economy. There are significant differences across crops. The crop-level analysis is supplemented by an alternative approach that utilizes a three-sector input–output (I–O) model for the Indian economy representing *farming*, *fossil fuels*, and *rest of economy*. Fossil fuels sector is assessed to portray, in general, strong forward linkages. The increase in *total* cost of farming, for a given change in fossil fuel prices, is estimated as a multiple of increase in *direct* input cost of fossil fuels in farming. From the three-sector aggregated economy this multiple was estimated at 3.99 for 1998–9. But it grew to 6.7 in 2007–8. The findings have stronger ramifications than commonly recognized, for inflation and cost of implementing the policy on food security.

1. Introduction

Revision of fossil fuel prices in India continues to be a political *hot potato*. This paper is motivated by the often repeated conjecture that, increase in fossil fuel prices have a strong influence on prices in general and food prices in particular. Further, the indirect or later-round impact is significantly large relative to the direct or first-round impact.[1] RBI (2011a, pp 641) reports that,

> *"Empirical estimates show that every 10 per cent increase in global crude prices, if fully passed-through to domestic prices, could have a direct impact of 1 percentage point increase in overall WPI inflation and the total impact could be about 2 percentage points over time as input cost increases translate to higher output prices across sectors".*

We focus sharply on interaction between fossil fuels and farming in India, to capture *total intensity* of fossils in farming and

Abbreviations: AC, All Commodities; ATF, Aviation Turbine Fuel; CACP, Commission for Agricultural Costs and Prices; CSO, Central Statistics Office; FA, Food Articles; FAI, Fertiliser Association of India; FO, Furnace Oil; F&P, Fuel and Power; GDP, Gross Domestic Product; GoI, Government of India; HSD, High Speed Diesel; HYV, High Yielding Variety; IEA, International Energy Agency; INR, Indian Rupee; I–O, Input–Output; IP&NG, Indian Petroleum and Natural Gas; kgoe, kilograms of oil equivalent; ktoe, kilo tonnes of oil equivalent; LNG, Liquefied Natural Gas; LPG, Liquefied Petroleum Gas; LSHS, Low Sulfur Heavy Stock; MP, Manufactured Products; MSP, Minimum Support Price; NF, Non-Food Articles; NG, Natural Gas; NIPFP, National Institute of Public Finance and Policy; PA, Primary Articles; RBI, Reserve Bank of India; RFO, Residual Fuel Oil; SKO, Superior Kerosene Oil; VFC, Virginia Flue Cured; WPI, Wholesale Price Index

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[1] As per a newspaper report in August 2012, then governor of Reserve Bank of India (RBI) D. Subbarao conjectured that, elimination of fuel subsidy could cause a 2.6 per cent spike in inflation (http://articles.economictimes.indiatimes.com/2012-08-07/news/33083665_1_food-inflation-fuel-subsidy-governor-d-subbarao).

offer some evidence on inflationary impact due to fossil fuel price increase in India.

Anand (2012) in a report on pricing diesel in India, among other things discussed the input cost of diesel/petroleum products for broad economic activities. However, it made only a passing reference to Indian agriculture with a couple of crop-specific examples. Importantly, Anand (*op. cit.*) concerned itself with direct use of only *diesel* in farming, but indirect use of fossil-fuels for farming appears to be significant.

Two important indirect linkages of fossil-fuels and farming are through use of (a) fertilizers and (b) power or electricity (see *Table 51* in Government of India (GoI, 2012a, pp 48). Natural gas (NG) and naphtha, apart from furnace oil and other heavy distillates, are commonly used as feedstock (raw material) in production of fertilizers. Coal, diesel, and liquefied NG (LNG) are used as fuel for electricity (thermal-power) generation for supply to (b1) consumers, including farmers to power their irrigation pump-sets and other farm-equipment and (b2) industry, as input to produce those pump-sets, farm-equipment, fertilizers, pesticides, and other inputs or raw-materials used on farms.

In the next section, we first discuss some issues to contextualize this research. This is followed by a description of the approach to organize relevant data and the analytical framework to derive certain macro-aggregate conclusions that may facilitate debate on fossil fuel price policy reforms.

2. Issues, methods, and sources

Food price inflation in India, over the last few years, has remained at an elevated level (RBI, 2014). The dominant reason accorded to this persistent increase in prices, especially of fruits and vegetables, is a *demand pull* factor due to growth in incomes (Bandara, 2013). Others have argued that income increase has also raised the demand for fine-cereals and protein-rich food (Ganguly and Gulati, 2013; RBI, 2011b, 2011c).[2]

On supply side, increase in farming costs could be an outcome of certain domestic policies. The declared intent of certain policies on, say, (a) wage and employment, (b) procurement and buffer-stock, and (c) subsidy, to name a few, could appear virtuous in isolation. However, these may not be incontrovertible as the interactions in their implementation may generate incentives that could dampen the expected outcome, and at worst could accentuate macroeconomic imbalances.

For example, an upward revision in minimum wages and implementation of employment guarantee program, that may help raise income of rural workers and / or reduce distress migration, may also cause an increase in input cost of farm labor (Gulati et al., 2014; Channaveer et al., 2011). Next, the minimum support price (MSP) policy periodically ratchets-up prices garnered by farmers / producers. Essentially geared to account for input costs incurred by farmers, the MSP policy could be a conduit for *cost-push* inflation (Nair and Eapen, 2012; Gulati et al., *op. cit*).

Subsidy policies also impact in several profound ways. Some subsidies could lower net revenue realization on account of tax expenditures or, constitute foregone revenue implied in the investment incentives. Further, farming costs are often influenced by controls on price of (a) fossil fuels that are used directly on farms and (b) important farm inputs like water, power and fertilizers. The last two in turn use fossil fuel inputs. These controls, on the face of it, should enable keeping a lid on farm-output prices. But such input price subsidy may compromise on effort towards fuel-conservation and even distort technological choices (Aw-Hassan et al., 2014; Roy et al., 2009).

The design of subsidy policy may be such that it lowers incentives to ramp-up output and/or to minimize cost of production. Thus, policies to directly control prices, practiced over a prolonged period, may have yielded in a perverse outcome of insufficient and inefficient (high cost) power and fertilizer industries (Dorward, 2009). Ironically, while government appears to be pre-occupied with "managing growth of subsidy", industry appears focused on "garnering subsidy".

In the context of a developing economy like India, a limited scope to circumscribe public expenditures and / or compulsions to raise public investment could then result in revenue and fiscal deficits. Despite legislation to contain deficits, both at the federal and provincial levels, inadequate credible action to contain subsidies could also be a trigger for inflation. Certain subsidies are in the nature of 'tax expenditures' and often designed as concessions. In a different setting, Swift (2006) discusses that "[T]ax expenditure programs are comparable to entitlement programs", and "[a]ffect (1) the budget balance, (2) budget prioritization in allocation, (3) the effectiveness and efficiency of fiscal resources, and (4) the scope for abuse by taxpayers, government officials and legislators".

Analytical research suggests that reduction in fossil fuel subsidies should improve prospects for price stabilization and growth (Bhattacharya and Bhattacharyya, 2001; Bhattacharya and Batra, 2009; Bhanumurthy et al., 2012). Recommendations contained in several committee reports drawn over years (see, GoI, 2006, 2010, 2013a), have also concluded that it is desirable to decontrol fossil fuel prices. These studies tend to emphasize favorable long-run outcomes, although acknowledging that in the short-run this could cause inflation and dampen growth.

Between the practitioners in political and economic domains, often there are perceptible differences on (i) duration of short- / long-run, (ii) adversity of inflation, and importantly (iii) adequacy of macro-aggregate growth indicators as basis for policy implementation. With respect to the last, inadequate evidence on distributional outcomes from macro-aggregate analysis of sector specific programs fosters inertia in policy. Despite weakening/ stagnating contribution to economic output, farming constitutes a strong political constituency in India. Faced with this reality, the government appears inclined to continue subsidizing farm inputs, while compensating producers of these inputs, namely, fuel, power, and fertilizers (Dansie et. al., 2010).

There ostensibly has been a shift away from what was popularly termed 'administered price mechanism'.[3] Thus, pricing of motor spirit (MS / petrol / gasoline), high speed diesel (HSD / gasoil),[4] aviation turbine fuel (ATF) and all industrial fuels follow a 'market mechanism'.[5] However, the *de jure* position on pricing of fuels is quite at variance from the *de facto* situation. And, the retail price of certain farm inputs are administered (controlled, fixed, or influenced) as government policy.

The (relevant) 'desired' producer prices for fossil fuels are often benchmarked to some notion of international prices. An increase in international prices of raw materials (say, petroleum crude) may then immediately impact domestic producer prices. In addition,

[2] Both, fine-cereals and protein-rich food are *normal* goods at current average income and consumption level.

[3] Full 'decontrol' however, appears a myth when the tax component in price is large and in case of some fossil fuels constitutes almost half the prevalent retail price.

[4] Pricing of diesel was deregulated in October 2014.

[5] Currently, however, 'price control' is exercised only on two 'sensitive' products namely, kerosene (superior kerosene oil (SKO) rationed to households below the poverty line through the public distribution system (PDS)), and liquefied petroleum gas (LPG, to a prescribed limit and for household use only). In 2012–3, the two together constituted less than 15 per cent (by weight) of all consumption of petroleum products. The figure for 2013–4 is estimated to be of similar order.

domestic producer prices may be affected by increase in costs of any or all of the following, namely, (a) inputs (like, labor), (b) foreign exchange (that is, depreciation of INR), and (c) governance (like, taxes). In the event of a change in international price of crude petroleum or other fossil fuels, the government faces a choice to allow the change to be either fully or partially, passed onto domestic consumer prices.

An important issue in subsidy reduction then concerns an upward revision in fossil fuel prices. There however, appears to be paucity of studies, in particular relating to impact of fossil fuel price increase on cost of farming. The cost or expenditure incurred on purchase of an input (say, fossil fuel) is a product of (a) number of units of fuel purchased and (b) price per unit of the fuel. Change in (output) cost therefore, is a function of changes in (input) quantity and (input) price, and positively co-related to both. This paper attempts to measure the full extent of an increase in cost of farming from changes in prices of fossil fuel.

2.1. Quantity use of fossil fuels in agriculture[6]

We trace the use of fossil fuels, both direct (in agriculture) and indirect (as in production of fertilizers and power). Data from the *energy balance* tables of the International Energy Agency (IEA) are collated for selected years. The IEA presents such data in oil-equivalent units, [7] presumably following a consistent approach, that facilitates comparison and aggregation across differing fossil fuels.

Quantity of fossil-fuels used directly on farms are presented as final consumption by the sector, and may be read-off from the *energy balance* tables. But, indirect use of fossil fuels for farming could be construed in multiple stages. In *one-stage-removed* (from farming) this relates to inputs that, in turn, directly use fossil fuels. For example, power and fertilizer are direct inputs in farming but fossil fuels are used as fuel to produce power and as feedstock to produce fertilizers.[8]

Fossil fuels, used to produce power that is consumed in the production of fertilizers or in manufacturing farm equipment, constitute an example of *two-stage-removed* use of fossil fuels in farming. More-distantly-removed stages could be analogously construed, and fossil fuel use in such distant stages from farms could also be significant. But, deriving stage-wise estimates could quickly grow in complexity. We present estimates for one-stage-removed use of fossil fuels in farming (Sections 2.1.1 and 2.1.2) but subsequently utilize a simple input–output structure (see Section 2.3) to assess the full extent of fossil fuel use in farming.

2.1.1. Fossil fuels in fertilizers

The energy balance tables of IEA present data on fossil fuels used as feedstock, but not separately for what is utilized to manufacture fertilizers. Further, a significant proportion of domestic consumption of fertilizers is met from imports. We utilize data collated by The Fertiliser Association of India (FAI), and presented in its annual publication named *fertiliser statistics* (FAI, 2014). Note that fossil fuels used as feedstock pertain only to the fraction of consumption of fertilizers that is manufactured domestically. We apply the input rate of fossil fuels in domestic fertilizer production on the quantity of fertilizer imports, to estimate fossil fuels used in imported fertilizers.[9] The sum of domestic and imported components gives the total quantity of fossil fuels used to produce fertilizers consumed in India.

2.1.2. Fossil fuels in power consumed on farms

Use of fossil fuels pertains to thermal power generation and the proportion consumed on farms. This is assessed in two steps. We estimate the proportion of thermal power in total power produced and this may be derived from input of fossil fuels as a proportion of gross output of power (both expressed in identical units). The product of this proportion and the quantity of final consumption of power on farms, then gives the quantity of fossil fuel based power consumed on farms.

2.2. Price of fossil fuels

The economic impact on the cost of a product (good or service) that uses fossil fuels as input also depends on the relative price of all inputs. If all prices increase at the same rate, then the relative price structure remains unchanged and the proportion of fuel cost in the total cost of a product remains unchanged. But, in case the price of some inputs (say, fossil-fuels) rises faster than the average price of output (farm produce) then cost of that input (fossil fuel) increases as a proportion of total cost of a product. Conversely, if price of input (fossil fuels) rises but relatively slower than the price of output, then it constitutes a lower proportion of total cost.

Note that fossil fuels constitute a complex bundle of hydrocarbons in solid, liquid, and gaseous forms. Thus, prices of the constituents are quoted along differing metrics. To assess change in farming cost due to a change in price of fossil fuels, one may need to track the movement in prices. However, information on nominal prices is not germane to illustrate the impact, and it may suffice to consider relative movement of price indices.

Observe from Table 1 that, with 1993–4 as the base year, in 1998–9 WPI for fuel and power (*column 6*) was lower than that for food articles (*column 4*), while, in all the subsequent years the index for fuel and power is significantly higher than that for food articles. Thus, if quantity of fuel input remains unchanged, then in 1998–9 fuel and power costs as proportion of total cost of food articles, would have been lower as compared to 1993–4. But, in 2004–5 (or 2007–8 and subsequent years), fuel and power would have constituted a larger proportion of total costs of food articles.

In other words, in a comparative static exercise, change in price of input (fuel and power) relative to price of output (food articles) could either depress or reinforce the impact of changes in technical / quantity use of an input.

As an example, Fig. 1 illustrates the movement of crude prices over last 25 years. It can be seen that crude prices in nominal terms were at their lowest in 1998–9 and at their peak in 2007–8. For most of that period however, nominal prices for fossil fuels in India have only ratcheted-up slowly under a controlled regime.[10]

2.3. Cost of fossil fuels directly used on farms

The approach to estimate various elements of cost of cultivation of principal crops is described in GoI, 2000 (see, Appendix II,

[6] Farming is used interchangeably with agriculture that includes *forestry* and *fisheries*.

[7] Unfortunately, GoI, 2013b adopts differing approach for different petroleum products to classify end-use sectors. This renders inter fuel comparison (or aggregation) infructuous. Preliminary analysis further revealed significant volatility in sectoral consumption. Closer scrutiny however, suggested high likelihood of error from misclassification. This is likely to yield in inconsistency in reporting.

[8] Note that, the latter constitutes a non-energy use of fossil fuels. The distinction however, between energy and non-energy (respectively, fuel and non-fuel) use of fossils, while important, is not a core concern here.

[9] We make at least two implicit assumptions that, (a) domestic and foreign technology of fertilizer production are similar and (b) increase in fossil fuel prices triggered by an increase in their international prices would have similar influence on price of both domestically produced and imported fertilizers.

[10] Consumer prices for fossil fuels vary significantly across provinces in India on account of significant differences in sales taxes (GoI, 2013, pp 94-5, IP&NG Statistics). And for some fuels, say diesel, prices could also vary across consumer categories within a province (Anand, 2012, footnote 16, pp 21).

Table 1
Annual average wholesale price index (WPI, 1993-94 = 100).
Source: Adjusted by the author to a common base year. Basic data from https://www.rbi.org.in/Scripts/PublicationsView.aspx?id=16481, accessed on January 13, 2016, RBI (2015).

Year (1)	AC (2)	PA (3)	FA (4)	NF (5)	F&P (6)	MP (7)
1993–4	100.0	100.0	100.0	100.0	100.0	100.0
1998–9	140.7	156.2	159.4	151.8	148.5	133.6
2004–5	187.3	188.1	186.3	187.6	280.2	166.3
2007–8	218.4	233.0	230.2	214.6	338.9	188.6
2012–3	313.9	413.8	394.6	378.8	522.6	244.6
2013–4	332.6	454.4	445.1	400.0	575.5	251.9
2014–5	339.4	468.0	472.1	397.9	570.2	257.9

Notes: AC: all commodities; PA: primary articles; FA: food articles; NF: non-food articles; F&P: fuel and power; MP: manufactured products.

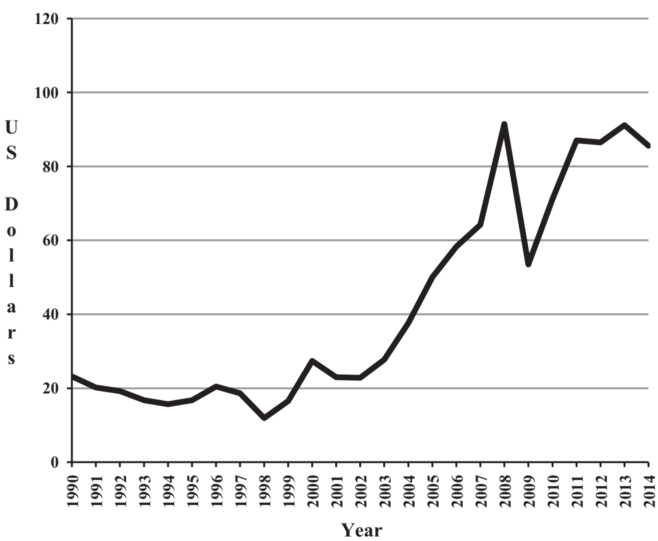

Fig. 1. Annual average (nominal) price per barrel of crude.
Source: http://inflationdata.com/inflation/inflation_rate/historical_oil_prices_table.asp; accessed on January13, 2016.

pp 253-6). In one particular form of representation, the cost components are categorized into (a) operational and (b) fixed costs, on per hectare basis. Although entailing further assumptions, this specific structure is convenient for our purpose.

Operational cost is grouped into labor (human, animal and machine), material (seeds, fertilizer, manure, insecticides), and service (irrigation, interest) categories. But, expenditure incurred on purchase of fuels is not shown separately.[11] This is apparently imbedded in the operational cost of machine labor as it includes cost incurred on fuel and lubricants for mechanized agricultural implements and equipment including water-pumps.

As discussed in the introductory section, perhaps diesel is the only fossil fuel directly used on farms. An estimate of the proportion of diesel cost in total cost of production can then be derived as a product of (a) the estimated proportion of operational cost of machine labor in total cost of production (presented in Section 3.2), and (b) the estimated proportion of diesel cost in operational cost of machine labor (discussed in Section 3.2.1).

2.4. Analysis of I–O transactions in India

Economy-wide I–O tables are a representation of intermediate value transactions $\{c_{ij}\}$ among sectors, where i and j are indices representing sectors. The national currency serves as the numeraire or unit of measurement to facilitate comparability across differing sectors. In particular, the I–O tables are suitable for short-term analysis at an aggregated level when rigidities in production techniques may be a fair assumption and the underlying fixed-coefficient technology serves as a convenient representation of production relations (Bulmer-Thomas, 1982).[12]

In this exercise, the commodity * commodity I–O tables, balanced under the industry technology assumption,[13] are utilized to assess the system-wide impact of an increase in price of fossil fuels. The system of quantity (output) and price (input) equations (relations) for different sectors is represented in the form of a matrix. But, such representation often encounters less than ideal conditions of full (perfect) information. In particular, data requirements could be overwhelming if required to satisfy strict homogeneity of sector classification. In practice therefore, the sector classification accommodates for wide divergence in prices and quality of apparently similar products (or services that collectively constitute a sector).

The technical coefficients $\{a_{ij}\}$ in the Indian I–O transactions table are derived by dividing the respective cell values $\{c_{ij}\}$ with the corresponding column total, that is,

$$a_{ij}=\frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}}, \forall i, j: 1, \ldots, n$$

Where, c_{ij} is the rupee value of i^{th} commodity that goes into producing the j^{th} commodity. The a_{ij}'s then represent the proportion of each input in every rupee worth of given output. That is, a_{ij} is the fractional rupee worth of i^{th} commodity that goes into every rupee worth of j^{th} commodity.

Let, $A=\{a_{ij}\}$, where a_{ij} is the $(i, j)^{th}$ element of the input–output co-efficient matrix, when i is the row index and j is the column index (for all i, j: 1, 2, 3, …., n), and a_{ij} is the input co-efficient of i^{th} commodity in the production of j^{th} commodity.[14]

Then, the output relations are denoted by,

$$x = Ax + f$$

where, x is the output vector, Ax represents intermediate use, and f is the vector of final demand. Rearranging the terms for x on LHS, and pre-multiplying with $[I - A]^{-1}$, one gets,

$$x = [I-A]^{-1} f \quad (1)$$

where, I is an identity matrix of order n.

Similarly, let p and ν respectively be vectors of producer prices and coefficients of value added for sectors of the Indian economy.

[11] *Irrigation charges* relate to consumption of water on farms. Input cost of fertilizers and pesticides are reported distinctively, but that for purchase of power are not. However, fertilizers, pesticides, and power are supplied to farmers at subsidised prices. While some provinces supply power free of charge to the farmers, others may levy only a low / flat rate. Consequently, revision in price of fossil fuels may not reflect completely in retail prices of fertilizers, pesticides and power used on farms.

[12] In the long-term though, technological flexibility or availability of substitutes cannot be ignored.

[13] Stated simply, 'industry technology' assumption relates to the situation when a commodity that could be a produce from different industries, is produced with the same technology as the principal product in that industry. See Appendix 2, at http://mospi.nic.in/Mospi_New/upload/iott-07-08_6nov12.htm for a detailed description of the steps involved in creating such a table. Also see the description for alternative 'commodity technology' assumption. In the remainder of the paper, in the context of I–O tables, the words 'commodity', 'industry', and 'sector' are used interchangeably.

[14] Upper case letters denote matrices, while small case letters denote column-vectors and indices, ' denotes a row vector.

Further, let ν include the vector of indirect taxes.[15] In particular, under a system of tax on value-added with full forward shifting of taxes then, the input relations may be denoted by

$$p' = p'A + \nu'$$

After rearrangement of terms containing p' on the LHS and post-multiplication with $[I - A]^{-1}$, we have,

$$p' = \nu'[I-A]^{-1} \quad (2)$$

In Eqs. (1) and (2), both, note the matrix $[I - A]^{-1}$. This is the Leontief inverse matrix and changes in exogenous vectors f and ν (respectively, final demand and value-added) work through its elements to capture the total (direct and indirect) effect respectively on output and prices.

Let $[I - A]^{-1}=R=\{r_{ij}\}$, where r_{ij} is the $(i, j)^{th}$ element of the matrix.

If ν_i increases by one unit – say, on account of increase in tax on i^{th} commodity, while taxes and value added in all other commodities remains unchanged – then, from equation (ii), because of strict linearity in price equations, $\delta p_j / \delta \nu_i = r_{ij}$, that is the $(i, j)^{th}$ element of the Leontief inverse matrix is the partial derivative of p_j with respect to ν_i.[16] The total effect on the production system, or increase in price for all commodities, is captured by the expression $\Sigma_j r_{ij}$.[17] Thus the sum of row-elements of the Leontief inverse matrix shows the total effect on the economy of a unit change in value-addition for the commodity shown at the head of row. Similarly, $\Sigma_i r_{ij}$, the sum of column elements of the Leontief inverse matrix shows the total effect on j^{th} commodity when value added in each sector rises by unity.

In this exercise we concern ourselves with only the price equations. Note that, the direct (or first round) impact of change in price of commodity i on price of j is measured by the input coefficient a_{ij} itself, and the total effect is measured by r_{ij}. The ratio $r_{ij} / a_{ij,}$ then denotes the *technical multiple* that we use to estimate the total effect in relation to the direct impact.

Further, for the limited purpose that this paper focuses on, the I–O tables published by the Central Statistics Office (CSO) are collapsed onto three sectors representing (a) farming,[18] (b) fossil fuels,[19] and (c) rest of economy.[20] The sectors are indexed by the numerals 1, 2, and 3 respectively. Thus, the indices i and j run over the set {1, 2, 3}. And, we utilize the I–O transaction tables and its derivative matrices for 1998–9 and 2007–8, to analyze some relevant comparative statics.[21] These are presented in Table 8 in *Section 3.3*.

[15] This could be alternatively, interpreted as the proportion of value added from government factor.

[16] An analogous interpretation may be offered for final demand and output analysis. Similarly, from (i), because of strict linearity in quantity relations, $\delta x_i / \delta f_j = r_{ij}$, that is the $(i, j)^{th}$ element of the Leontief inverse matrix is the partial derivative of x_i with respect to f_j.

[17] In this design of representation, any change in tax is fully shifted forward. Alternatively, in case of commodities with administered prices, this may be interpreted as increase in administered price, in turn affected by an increase in taxation of an equivalent magnitude.

[18] 'n' equaled 115 and 130 respectively in 1998–9 and 2007–8. For the 2007–8 I–O tables, 26 (out of 130) sectors from 001 (paddy) to 026 (fishing) are grouped as *farming*.

[19] There are five sectors in this group coal and lignite (027), natural gas (028), crude petroleum (029), petroleum products including LPG (063), and coal tar products (064).

[20] There are 99 sectors in *rest of economy*.

[21] The 1998–9 I–O tables were compiled for 115 sector classification. The 2007–8 I–O tables are available for a 130-sector classification. On concordance between sectors of the I–O transaction tables for 1998–9 and 2007–8, please see Appendix 5 at http://mospi.nic.in/Mospi_New/upload/iott-07-08_6nov12.htm

Table 2
Fossil fuel used directly on agricultural farms.
Source: Basic data from IEA, Energy Balances; Author's estimates.

Year (1)	Final consumption / Direct use on farms (IEA), ktoe (2)	Proportion out of total final consumption of: Oil and natural gas (3)	All fossil fuels (4)
1990	4296	7.7	4.4
1998	7845	8.7	6.2
2001	7897	7.8	5.8
2007	7937	5.8	4.2
2009	7952	5.2	3.5
2010	8525	5.4	3.5
2011	9210	5.5	3.6
2012	9812	5.6	3.7

http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=balances&year=1990 http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=balances&year=1998 http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=balances&year=2001 http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=balances&year=2007 http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=balances&year=2009 http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=balances&year=2010 http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=balances&year=2011 http://www.iea.org/statistics/statisticssearch/report/?country=INDIA&product=balances&year=2012

3. Data and estimates

3.1. Quantity use of fossil fuels in Indian agriculture

We discussed in *Section 1* that use of fossil fuels directly on agricultural farms consisted in diesel consumption to run farm equipment and machinery. Further, it is likely that over years there has been a decline in use of animal and human labor on farms, and simultaneous increase in mechanization. Consequently, fossil fuel consumption on farms may have grown.

As discussed in *Section 2.1*, data on quantity of fossil fuels directly used in agriculture are collated from the energy balance tables of IEA.[22] Table 2 suggests that between 1990–1 and 2012–3, such use grew 2.3 times.[23] However, the share of agriculture in total final consumption of fossil fuels registered a decline since the second half of the nineties (*column 3 and 4*). In recent years though, since 2009-10 this share appears to be slowly inching-up.

3.1.1. Use of fossils in fertilizers

In the nascent years of domestic fertilizer industry, there was rapid increase in use of naphtha and heavier-distillates as feedstock. However, this trend was retarded very soon, and eventually reversed. Columns 2, 3, and 4 in Table 3 show the quantity of fossil fuels used as feedstock for production of fertilizers in oil equivalent units.

[22] GoI (2014) presents the sector-wise consumption of important petroleum products. However, the presentation there puts serious limitations for any meaningful analysis. Different consumption categories are defined for differing products. This may sometimes be desirable. But, take for example, diesel (see GoI, 2014, pp. 72), where the sector classification includes (1) transport, (2) agriculture, (3) power generation, (4) mining and quarrying, (5) manufacturing industries, (6) resellers / retail, (7) miscellaneous, and (8) private imports. Total diesel consumption in 2013–4 is estimated at 68.4 million tonnes – with nearly 89.9 per cent attributed to reseller / retail category. However, by definition reseller / retail can hardly be categorised into a consuming sector.

[23] Almost all of it consists of petroleum products, specifically diesel with only around 1.6 per cent constituted by natural gas.

Table 3
Fossil fuels used as feedstock in fertilizer production.
Source: Basic data from Fertiliser Statistics, FAI (2014).

Year	Thousand tons of oil equivalent				Total fertilizer consumption '000 t	Fertilizer consumption kgs. per hectare	Fertilizer imports in availability* (share %)
	Natural gas	Naphtha	FO#	Total feedstock			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1974–5	161				2573.3	15.67	
1980–1	550	1847	1062	3459	5515.6	31.95	48
1985–6	2250		1509		8474.1	47.48	37
1990–1	5051	1980	2208	9239	12546.2	67.55	23
1995–6	6842	2869	2834	12545	13876.2	74.02	27
2000–1	7632	3889	2581	14102	16702.3	90.12	13
2005–6	6986	2418	1817	11221	20340.3	105.53	25
2009–10	11851	907	1611	14370	26486.4	140.15	37
2010–1	12086	959	1670	14715	28122.2	142.52	42
2011–2	10197	1034	1721	12952	27790.0	142.33	43
2012–3	10346	965	1143	12454	25536.2	130.79	36
2013–4	9954	555	417	10925	24484.4	125.39	31

Notes
FO includes furnace oil (FO), low sulfur heavy stock (LSHS), residual fuel oil (RFO).
* Availability refers to the sum of opening stock, production and net imports during the year. Basic data on fossil fuels is converted into oil equivalent units using the following conversion factors: (a) one million cubic meters of natural gas equals 0.9 ktoe; (b) one kt of diesel equals 1.035 ktoe; (c) one kt of naphtha equals 1.075 ktoe; and (d) one kt of heavy distillates (furnace oil, LSHS / RFO) equals 0.985 ktoe.

Between 1990–1 and 2013–4, the use of naphtha and heavy-distillates as feedstock for domestic fertilizer production declined at about 4.5 per cent per annum. But, use of natural gas grew steadily at about 2.8 per cent per annum. Consequently, quantity of natural gas use almost doubled since 1990–1, while use of naphtha and heavy-distillates stands at less than one-fourth of its 1990–1 level.

The composition of aggregate feedstock for fertilizer production, in 1980–1 was in the ratio of 16:53:31 respectively for gas: light distillate (naphtha): heavy distillates (FO, LSHS, RFO). The ratio was transformed to 55:21:24 in 1990–1, and in 2013–4 stood at 91:5:4. A drastic change in feedstock composition, in favor of natural gas, significantly raised the efficiency of feedstock utilization. In turn, this could have affected substantial savings in total use of fossil fuels.

However, there was a sharp increase in intensity of fertilizer use on Indian farms (*column 7*, Table 3). Total cropped area increased by only 20 per cent, from 169.9 million hectares in 1974-5 to 195.3 million hectares in 2013–4. But, consumption of fertilizers grew almost 9.4 times, from 2.6 to 24.5 million tons (after peaking at 28.1 million tons in 2010-1, *column 6*, Table 3). Thus, fertilizer consumption in India shot-up from 15.67 to 125.39 kg per hectare (after peaking at 142.52 kg per hectare in 2010-1, *column 7*, Table 3). Per hectare fertilizer consumption therefore grew at 5.08 per cent per annum and portrayed an eight-fold rise in average fertilizer-intensity [24] of agricultural practice in India.

Further, consumption of fertilizers significantly exceeded domestic production. On average, between 1984-5 and 2013–4, domestically produced fertilizers constituted almost three-fourths of total fertilizers available to Indian farmers. In particular, all potash fertilizers are imported, as against relatively smaller proportions of total consumption of nitrogenous and phosphatic fertilizers. Figures in *column 5* pertain to fossil fuels used as feedstock in domestic fertilizer production. But, to estimate the input of fossil fuels in fertilizers consumed domestically, one must also include the quantity of fossil fuels used as feedstock in imported fertilizers.

Imported fertilizers constituted close to half of all domestic consumption in 1980–1 and about 31 per cent in 2013–4 (*column 8*, Table 3). The share of imports fluctuated between 11 and 45 per cent of consumption between 1990–1 and 2013–4, but simple average works out to 27 per cent.[25] With the exception of a few years, total availability (domestic production plus imports) of fertilizers in India has exceeded consumption by about five per cent during this period.

Table 4
Electricity consumed in Indian agriculture.
Source: Same as for Table 2.

Year	Final consumption of electricity			Thermal electricity	
	Total (ktoe)	Agriculture (ktoe)	(3) / (2) in (%)	Out of total (%)	In agriculture (ktoe)
(1)	(2)	(3)	(4)	(5)	(6)
1990	18493	4328	23.4	89	3852
1998	30765	8359	27.2	92	7690
2001	32844	7024	21.4	92	6462
2007	50605	8960	17.7	91	8064
2009	57542	10276	17.9	91	9302
2010	62533	10868	17.4	90	9877
2011	69049	12123	17.6	89	10001
2012	74713	13168	17.6	89	11720

To arrive at the estimate for fossil fuels in imported fertilizers, we assume that, (a) feedstock mix for the imported fertilizers is identical to the mix of feedstock for domestic fertilizer production, and (b) efficiency in feedstock use for imported fertilizers is identical to that for domestically produced fertilizers.

The proportion of imported fertilizers in total fertilizers available (*column 8*, Table 3), multiplied by the quantity of fossil fuel used as feedstock in domestic production (*column 5*, Table 3), then yields the quantity of fossil fuels used as feedstock in imported fertilizers. For brevity these are reported in *column 4* of Table 5 in *Section 3.1.3*.

3.1.2. Use of fossil fuels for electricity generation

Over years, electricity generation capacity has increased significantly. *Column 1,* Table 4 gives the final consumption of electricity. However, several rural areas with agricultural farms are still

[24] This pertains to average for the nation as a whole, but intensity of fertilizer use varies widely across crops and regions.

[25] Expressed differently, fertilizer imports on average were one-third of domestic production.

Table 5
Direct and indirect use of fossil-fuel on farms (in ktoe).
Source: Same as for Table 2.

Year	Direct use / Final consumption, (IEA)	Indirect use in (one-stage-removed only)			Total to Direct multiple (2+3+4+5)/2
		Fertilizers		Electricity	
		Domestic	Imported		
(1)	(2)	(3)	(4)	(5)	(6)
1990	4296	9239	2813	3852	4.7
1998	7845	14713	3441	7690	4.3
2001	7897	13119	2235	6462	3.8
2007	7937	12290	6530	8064	4.4
2009	7952	14341	8384	9302	5.0
2010	8525	12556	9262	9877	4.7
2011	9210	12559	9351	10001	4.6
2012	9812	12454	7111	11720	4.2

Notes: Indirect use in electricity estimated from data collated from IEA; Indirect use in imported fertilizer estimated from data collated from *Fertiliser Statistics*;

Table 6
Operational cost of machine labor for different crops as per cent of total cost of production per hectare.
Source: Author's computation; Basic Data from various archived reports on Price Policy, accessed from http://cacp.dacnet.nic.in/.

Crop	Year	No. of Pro.	Op. Cost (%)	Crop	Year	No. of Pro.	Op. Cost (%)
1	2	3	4	1	2	3	4
Sugarcane	2012–3	7	3.5	**Ragi (Finger Millet)**	2011–2	5	7.3
	1998–9	5	7.1		1998–9	3	1.9
Wheat	2012–3	13	13.7	**Tur (Arhar) (Pigeon Pea)**	2011–2	8	6.5
	1998–9	6	10.5		1998–9	6	3.5
Barley	2012–3	2	10.9	**Moong (Green Gram)**	2011–2	6	8.2
	1998–9	2	10.6		1998–9	3	3.2
Gram	2012–3	9	12.1	**Urad (Black Gram)**	2011–2	8	10.6
	1999–00	4	9.1		1998–9	3	4.6
Lentil	2012–3	4	12.3	**Groundnut**	2011–2	6	5.8
	1998–9	2	8.7		1998–9	3	2.0
Rapeseed & Mustard	2012–3	8	10.9	**Soyabean**	2011–2	4	13.5
	1998–9	6	11.1		1998–9	3	8.8
Safflower	2012–3	1	1.0	**Sunflower**	2011–2	2	10.1
	1998–9	1	1.1		1998–9	3	4.9
Paddy	2011–2	18	8.2	**Sesamum**	2011–2	7	9.0
	1998–9	9	5.1		1998–9	5	3.9
Cotton	2011–2	10	4.6	**Nigerseed**	2011–2	1	0.0
	1998–9	4	6.6		1998–9	1	0.0
Jowar (Sorghum)	2011–2	5	10.1	**Jute**	2012–3	3	3.3
	1998–9	4	5.4		1998–9	3	2.0
Bajra (Pearl Millet)	2011–2	7	13.7	**Copra**	2012–3	2	1.7
	1998–9	4	7.4	**VFC Tobacco**	1998–9	1	18.8
Maize	2011–2	10	8.4	**ALL-CROPS**	**2011–2**		**8.2**
	1998–9	5	3.4	**AVERAGE**	**1998–9**		**5.9**

Notes: Op. Cost: Operational cost shown in column 4 is the maximum between average and median for the reporting provinces. No. of Pro.: number of reporting provinces. VFC Tobacco: Virginia Flue Cured Tobacco.

characterized by little or erratic power. Data collated from (IEA) *energy balance* tables for India suggest that, between 1990–1 and 2012–3, the proportion of electricity consumed in agriculture has declined (*column 4*, Table 4).

The proportion of thermal electricity, that is electricity produced from fossil-fuels, is shown in *column 5* of Table 4. We assume this proportion to hold for the fraction of thermal electricity (out of total electricity) consumed in agriculture. This is utilized to assess the element of fossil-fuels in agriculture due to use of electricity on farms (*column 6*, Table 4). Such use has more than tripled between 1990–1 and 2012–3.

3.1.3. Piecing together the direct and indirect components of fossil fuel inputs in farming

Table 5 summarizes the direct use of fossil fuels on farms (column 2) and the estimates for their indirect use in fertilizers, both domestically produced and imported, respectively in *columns 3 and 4*, and in electricity (*column 5*) consumed on farms.

Between 1990–1 and 2012–3, direct use of fossil fuels more than doubled. Despite a near doubling in intensity of fertilizer use, growth in indirect use of fossils fuels through fertilizers was subdued (about 1.6 times). This fructified from a sharp change in composition of feedstock for production of fertilizers and the consequent (significant) gains in efficiency.

It is observed that, one-stage-removed indirect use exceeds final consumption of fossil fuels on farms. In fact the direct use of fossil fuels on farms constituted less than a quarter of total use. The multiple for total to direct use is estimated to exceed 4.7 and 4.2 respectively for 1990–1 and 2012–3. It may be fair to conclude that despite some reduction in magnitude of the (total to direct use) multiple over years, fossil fuel use in farming is significantly higher than what may meet the eye. In the next sub-section, we decipher the cost of direct use of fossil fuels on farms.

3.2. Operational cost of machine labor

It was mentioned in Section 2.3 that, cost of fossil fuels used directly on farms, is contained in'operational cost of machine labour' in reports of the *Commission for Agricultural Costs and Prices* (CACP). We collate this data for 24 crops that include sugarcane, jute, copra, six *rabi*,[26] and 15 *kharif*[27] products. Table 6 gives the operational cost of machine labor as per cent of total cost of production for two years[28] for each of these crops.

In the year 1998–9,[29] the lowest fraction for operational cost was reported as nil for *nigerseed* and highest at 18.8 per cent for *tobacco*. For the latest year (pertaining to years 2011–2 / 2012–3)[30] for which information is available, the lowest fraction was

[26] These are sown during winter for harvest during spring and include wheat, barley, gram, *masur* (lentil), rapeseed & mustard, and safflower.

[27] These are sown during summer or monsoon for harvest during autumn and include paddy, cotton, *jowar*, *bajra*, maize, ragi, *tur* (*arhar*), *moong*, *urad*, groundnut, soyabean, sunflower, sesamum, nigerseed, and VFC tobacco.

[28] The estimates pertain to 1998–9 and the latest year for which data is available at http://cacp.dacnet.nic.in/ (last updated on November 14, 2014) when accessed on May 15, 2015. Choice of 1998–9 is purposive, as that is the year for which not only an older I–O table is available but also the year that witnessed a sharp decline in international crude-oil prices. This presented an opportunity to analyze the impact of changes in oil prices more pragmatically.

[29] Data, only for *gram* refers to 1999-2000.

[30] Data relates to 2012–3 for *rabi* crops and *copra*, and 2011–2 for others.

Table 7
Diesel cost in operational cost of machine labor, INR per hectare, 1998–9.
Source: GoI, 2001, Reports on Price Policy, Compendium Reports, 2000-1 Annexure 1, pp. 543, accessed at http://cacp.dacnet.nic.in/.

Crop 1	Province 2	Diesel cost 3	Op. cost of mach. lab. 4	col. 3 / col. 4 (per cent) 5
Wheat	Haryana	1044.8	1958.41	53
	Punjab	978.4	2067.73	47
	Madhya Pradesh	425.1	881.06	48
	Rajasthan	1350.3	1537.52	88
	Uttar Pradesh	1368.7	1571.99	87
Barley	Rajasthan	1120.6	1189.56	94
Gram	Madhya Pradesh	372.7	789.79	47
	Rajasthan	381.8	622.18	61
Rapeseed & Mustard	Haryana	551.6	1236.65	45
	Rajasthan	711.8	1308.46	54

reported as nil, again for *nigerseed*, while the highest fraction was for *bajra* (pearl millet) at 13.7 per cent.[31]

Note from *column 3* of Table 6 that, for most crops for which data is collected by CACP, a higher number of provinces are reporting data in the later year as compared to 1998–9. And, for a large majority of crops (except sugarcane, rapeseed & mustard, safflower, and cotton) the proportion for operational cost of machine labor has also increased in the later year (see *column 4*). In 1998–9, the average operational cost of machine labor was 5.9 per cent of total cost of production (average across all crops, in turn estimated as average across reporting states). This average had risen to 8.2 per cent as per the latest available data.

3.2.1. *Diesel cost in operational cost of machine labor*

Recall that diesel or fossil fuel alone may not exhaust the operational cost of machine labor. A one-off table (partly reproduced here as Table 7), gives a rough estimate of diesel cost as a proportion of operational cost of machine labor.[32] One observes that diesel cost per hectare varies significantly among crops and across provinces.

The variation in proportion of input cost is on account of differences in (a) technology, including adoption of high-yielding variety (HYV) of seeds, degree of mechanization, (b) extent of irrigation, (c) accessibility to alternative sources of energy (mainly electric power), and even (d) price of diesel, that varies significantly across provinces (mainly due to differences in provincial taxes on diesel).[33] On an average, however for the crops and provinces shown in Table 7, diesel accounted for about 62 per cent of operational cost of machine labor.

Assuming that this proportion is unchanged between 1998–9 and 2011–2, it is estimated that direct use of fossil fuels (diesel) on farms on average accounted for 3.7 and 5.1 per cent of total cost of farm produce, respectively in 1998–9 and 2011–2. *An upward revision in diesel price by 10 per cent*[34] *then would have raised average cost of agricultural production, by about 0.37 and 0.51 per cent respectively in 1998–9 and 2011–2.* Note however that, this corresponds only to a minimum increase in cost. This is discussed further in Section 4, but in the next sub-section results are presented from a more comprehensive approach based on I–O analysis.

3.3. *I–O analysis of direct and total fossil fuel use in farming*

Table 8 gives the matrix of coefficients for balanced 3-sector (commodity*commodity) transactions and the corresponding Leontief inverse matrix in 1998–9 (*Panel A* and *B*) and 2007–8 (*Panel C* and *D*) for the Indian economy. As discussed in Section 2.4, the element a_{21} (in the C * C co-efficient matrix) is the input of fossil fuel in a rupee of farm produce. In the year 1998–9, this constituted 0.52 per cent of the value of farm produce. It increased to nearly one (0.98) per cent in 2007–8 (trace the downward directing bold vertical arrow in Table 8).[35] Subject to the simplifying assumptions underlying such sectorial aggregation in I–O analysis, it implies that, intensity of fossil fuels used directly in farming may have grown almost 1.9 (= 0.009826 / 0.005173) times between 1998–9 and 2007–8.

Analysis of Leontief inverse matrix suggests that in 1998–9, the technical multiple[36] for total to direct (r_{ij} / a_{ij}) effect of fossil fuel on value in farming was about 3.99 (= 0.020639 / 0.005173, *cf. Panel A and B,* trace the upper horizontal dashed arrow in Table 8). But in 2007–8, the value of this multiple rose to 6.70 (= 0.065810 / 0.009826, *cf. Panel C & D*, trace the lower horizontal dashed arrow in Table 8). These results are in consonance with the proposition concerning impact of price changes in Section 2.2. We discuss them in greater detail in the following section.

4. Results and discussion

Real GDP has quadrupled (*column 2,* Table 9) between 1990–1 and 2012–3. However, the share of Agriculture (*column 3*) in 2012–3 has reduced to less than half its level in 1990–1. Total primary energy supply (*Column 4*) per 1000 INR of GDP also depicts a declining trend. But the proportion of fossil fuels in total primary energy supply has risen from 55 per cent to nearly 75 per cent (*cf. columns 4 and 5*).

Energy intensity of GDP in 2012–3 is half its level in 1990–1 (*Column 6*, Table 9). However, energy intensity of agricultural GDP (*cf. columns 6 & 7*) was only 7 per cent of that for the economy as a whole in 1990–1.[37] But, in 2012–3, this ratio had risen to 32 per cent. And, in absolute terms energy intensity of agricultural GDP is more than double its value in 1990–1. *In India thus, energy intensity for aggregate GDP is declining but energy intensity of agricultural GDP is rising*. These trends are likely to be maintained in the foreseeable future. It is in this context that change in energy prices, in particular of fossil fuels, assumes significance for (a) farming cost, and consequently, (b) food prices.

The introductory section noted that direct use (final consumption) of fossil fuels in farming pertains to use of diesel to run agricultural machinery (including tractors, harvesters, combines etc.), water pumps, and generators. Relative acceleration in fossil-fuel intensity of agriculture compared to the remainder of economy, in part is indicative of continual mechanization of farm labor.

[31] As yet, data on *tobacco* was not available publicly for either 2011–2 or 2012–3.

[32] A search of other CACP reports on the web offered little succor.

[33] Diesel price could differ for differing sets of consumers. For example, farmers in some provinces (like, Punjab) face a lower tax and lower price for diesel as compared to other users in the province, as well as farmers in certain other provinces.

[34] Anand (2012) concluded that pricing of diesel to eliminate all under-recovery would likely entail an upward revision of about 25 per cent in then prevalent price.This relates to depot price exclusive of dealer commission and taxes (union and provincial). For reasons elucidated in that report, the extent of under-recovery may vary significantly with change in (dollar denominated) international price of diesel and (INR-USD) exchange rate.

[35] The coefficients (a_{ij}'s) may be multiplied with 100 to convert into percentage terms.

[36] This is estimated as the ratio of element in the Leontief matrix and the corresponding element in the co-efficient matrix (that is, r_{21} / a_{21}).

[37] Intensity of use in farming could have alternative metrics, for example, kgoe per hectare, kgoe per tonne of farming output, kgoe per 1000 INR of output. Each of these may suggest differing trends. However, when there are sectors with differing units for input and output measures, only the last one may facilitate comparison.

Table 8
Input–output coefficients and Leontief inverse matrices.
Source: Basic I–O tables from GoI (2005, 2012b), accessed from http://www.mospi.nic.in/Mospi_New/upload/nad_iott_1998_99/mat6.pdf, http://www.mospi.nic.in/Mospi_New/upload/iott_2007-08/M6.xls; Author's own computations.

Panel A	C*C Coefficients (a_{ij}), 1998-9			Panel B	Leontief Inverse (r_{ij}), 1998-9		
I - O Sectors	Farming	Fossil fuels	Rest of economy	I - O Sectors	Farming	Fossil fuels	Rest of economy
Farming	0.116896	0.000174	0.053981	Farming	1.146896	0.031834	0.105578
Fossil fuels	0.005173	0.355099	0.031049	Fossil fuels	0.020639	1.575709	0.083990
Rest of economy	0.119950	0.192566	0.404241	Rest of economy	0.237587	0.515724	1.726936
Panel C	C*C Coefficients (a_{ij}), 2007-8			Panel D	Leontief Inverse (r_{ij}), 2007-8		
I - O Sectors	Farming	Fossil fuels	Rest of economy	I - O Sectors	Farming	Fossil fuels	Rest of economy
Farming	0.190784	0.000354	0.043611	Farming	1.253891	0.027539	0.098558
Fossil fuels	0.009826	0.591782	0.043310	Fossil fuels	0.065810	2.502391	0.196230
Rest of economy	0.146087	0.109558	0.433067	Rest of economy	0.335819	0.490674	1.827193

Table 9
GDP and energy consumption in India.
Source: GDP data from http://mospi.nic.in/Mospi_New/upload/NAS13.htm; Energy data from IEA, same as for Table 2.

Year	GDP at constant 2004–5 prices at factor cost (trn INR)	Share of agriculture in GDP at 2004–5 prices, (%)	Primary energy supply in kgoe per 1000 INR of GDP		Final consumption of energy in kgoe per 1000 INR of GDP of	
			Total	Fossil fuels	Economy	Agriculture
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1990–1	13.5	29.5	23.50	13.01	18.67	1.40
1998–9	20.9	24.4	20.22	12.81	14.49	2.37
2001–2	24.7	22.4	18.79	12.21	12.85	2.01
2007–8	39.0	16.8	15.52	10.75	10.29	2.40
2010–1	49.4	14.5	14.66	10.62	9.61	2.65
2011–2	52.4	14.1	14.29	10.33	9.39	2.64
2012–3	54.8	13.9	14.38	10.59	9.33	3.02

Notes: kgoe denotes kilogram of oil equivalent; INR denotes Indian rupee; One crore equals 10 million or 100 lakhs. *Column 5* does not include the non-energy use of fossil fuels, *say* as feedstock for production of fertilizers. Energy utilized in production of fertilizer, pesticides, farm equipment, and other farm inputs is included in *economy* and not in *agriculture*.

Table 10
Effect of 10 per cent increase in cost of diesel on percentage increase in cost per hectare (2011–2).
Source: Basic data: Same as for Table 6; Authors' own computations.

Crop (1)	Rise in total cost (2)	Crop (1)	Rise in total cost (2)
Sugarcane	0.23	**Ragi**	0.49
Wheat	0.92	**Tur (Arhar)**	0.44
Barley	0.73	**Moong**	0.55
Gram	0.81	**Urad**	0.71
Lentil	0.82	**Groundnut**	0.39
Rapeseed & Mustard	0.73	**Soyabean**	0.90
Safflower	0.07	**Sunflower**	0.68
Paddy	0.55	**Sesamum**	0.60
Cotton	0.31	**Nigerseed**	0.00
Jowar	0.68	**Jute**	0.22
Bajra	0.92	**Copra**	0.11
Maize	0.56	**ALL-CROPS AVERAGE**	**0.55**

Notes: It is assumed that diesel constitutes 67 per cent of operational cost of machine labor.

One may surmise that, in recent years Indian agriculture is experiencing faster dieselization than rest of the economy (see, a report by Centre for Science and Environment, at http://www.cseindia.org/dte-supplement/air20040331/dieselised.htm). But more importantly perhaps, it also signals widespread disappointment with the power sector to satisfactorily address rising energy-demand in farming. Further, if correctives are not introduced earnestly, fossil-fuelization of Indian agriculture may rise alarmingly, as it slowly creeps-up to the economy average.

4.1. Direct (first-round) effect of an increase in fossil-fuel prices

In Table 7, *Section 3.2.1*, it was seen that diesel constituted, on average, 62 per cent of operational cost of machine labor in 1998–9. From Table 1, *Section 2.2*, it is found that in recent years fossil fuel price inflation exceeded inflation in other input prices. Consequently, proportion for diesel cost in farming may have risen and, we assume that in 2011–2, it constitutes two-thirds (67 per cent) of operational cost of machine labor. With this assumption, Table 10 presents the direct impact of a 10 per cent increase in price of diesel on cost of farming.

As expected, the impact of fossil fuel price varies significantly across different crops ranging from nil for nigerseed to 0.92 per cent for wheat and *bajra*. On average in 2011–2, a 10 per cent increase in fossil fuel prices could raise direct (first-round) cost of farming by about 0.55 per cent.[38] In contrast in 1998–9, when on average diesel constituted 62 per cent of operational cost of machine labor, a 10 per cent increase in diesel prices would have raised direct cost of farming by 0.37 per cent.

4.1.1. Estimates from I–O analysis

The average proportion (across crops and provinces) of direct costs of fossil fuel in farming is estimated (from Tables 6 and 7*)* at 3.7 per cent in 1998–9. This increased almost 50 per cent to 5.5 per cent in 2011–2, over a period of 13 years. In comparison, analysis of I–O coefficients from *panels A and C in* Table 8 *of* Section 3.3 suggest that fossil fuels directly used as input into farming in 1998–9, constituted a significantly lower proportion of 0.52 per cent. And, this proportion increased to 0.98 per cent in 2007–8.

I–O coefficients thus signal a *steeper rise in fossil fuel intensity of farming*, of more than 90 per cent in a shorter period spanning nine years. At least two straight-forward reasons may be offered for divergence in estimates following from Sections 3.2 and 3.3 respectively, (a) the all-crop averages in Tables 6 and 7 is a *simple average* for differing (selected) crops,[39] (b) the selected crops mentioned in Tables 6 and 7 constitute less than 44 per cent of total farm output.[40]

4.2. Total effect of fossil fuel price increase on cost of farming

In Table 5, we have seen that the total (quantity) use of fossil fuels in farming is more than 4.4 times the direct use on farms in 2011–2. Consequently, a 10 per cent increase in fossil fuel prices could raise total costs of farming by at least 2.42 (=4.4 * 0.55) per cent.[41]

Given the extant weight of 11.45 for fossil fuels in WPI (Table 11), a 10 per cent increase in prices of all fossil fuels could translate to a first round increase of 1.14 percentage points in WPI inflation.

Table 11
Weight in WPI of major groups (per cent).
Source: http://eaindustry.nic.in/WPI_Manual.pdf.

Major group / commodities	Weight out of 100	
(a) Primary articles, *of which*	20.12	
(a1) Food articles		14.34
(a2) Non-food articles		4.26
(a3) Minerals		1.52
(b) Fuel and power, *of which*	14.91	
(b1) Coal		2.09
(b2) Mineral oils		9.36
(b3) Electricity		3.45
(c) Manufactured products	64.97	

Food articles carry a weight of 14.34 in the WPI. Then, a 10 per cent increase in fuel prices that could raise average cost of farming by about 2.42 per cent or more, could in turn raise the WPI by another 0.35 (=14.34 * 2.4/100) per cent or more, and so on. It is likely that cumulative impact on inflation for the economy could then resonate with the apprehension expressed by RBI (refer to the quote in Section 1, from RBI (2011a), pp 641).

4.2.1. Economy-wide impact from I–O analysis

The above approach accounts for the quantity effect only (derived in Section 3.1), and does not account for the effect due to change in relative prices. In *Section 2.2*, it was described how the quantity multiple could be depressed or reinforced depending on relative price of fossil fuels (inputs) as compared to say, food articles (output).

In Section 2.4, we discussed that economy-wide price and quantity relations could be depicted as technical coefficients in an I–O table. The relatively lower price index of fuel and power (see Table 1) in 1998–9, as compared to food and non-food articles, therefore should depress the quantity multiple estimated at 4.3 (see Table 5, Section 3.1.3) for 1998–9. As described in Section 3.3, this resultant technical multiple is represented by the ratio of the respective elements of the Leontief inverse- and input- coefficient matrices (*cf.* Table 8). For the year 1998–9, it is estimated at 3.99.

For the year 2007–8, the quantity multiple is estimated at 4.4 (see Table 5, Section 3.1.3). But, in contrast to 1998–9, price of fuel and power in 2007–8 had risen relatively more steeply than price of

Table 12
Coefficients for direct and total effects of price change of fossil fuels, 2007–8.
Source: Same as for Table 8.

Sectors (1)	Direct (a_{ij}) (2)	Total (r_{ij}) (3)	Total / Direct (r_{ij} / a_{ij}) (4)=(3) / (2)
Paddy	0.014659	0.110664	7.5
Wheat	0.011218	0.081323	7.2
Jowar (Sorghum)	0.023347	0.113257	4.9
Bajra (Pearl Millet)	0.033681	0.118469	3.5
Maize	0.020472	0.098290	4.8
Gram	0.023635	0.097114	4.1
Pulses	0.010541	0.076624	7.3
Sugarcane	0.005676	0.045953	8.1
Groundnut	0.011292	0.056529	5.0
Coconut	0.008332	0.069694	8.4
Other Oilseeds	0.011314	0.067316	5.9
Jute	0.012390	0.062644	5.1
Cotton	0.011354	0.068068	6.0
Tobacco	0.007865	0.057358	7.3
Other agriculture	0.007325	0.052624	7.2
Fossil fuels	0.591782	2.502251	4.2
Rest of economy	0.043314	0.195735	4.5

[38] As a pessimistic scenario, if all of operational cost of machine labor is assumed as proxy for cost of fossil fuels (diesel), then a 10 per cent increase in price of diesel could cause an average increase of 0.82 per cent in direct cost of farming.

[39] One could use a weighted average with output proportions as assigned weights for the differing crops.

[40] In 1998–9 these constituted less than 40 per cent of farm output.

[41] In the year 1998–9, the corresponding increase in total costs of farming could have been at least 1.57 (=4.3 * 0.37) per cent.

food articles (see Table 1). The resultant technical multiple (*cf.* Table 8) was estimated at 6.7 (Section 3.3).

4.2.2. Crop-specific differences: implications for food and farm policies

The aggregate-level analysis is supplemented with a discussion to highlight crop-specific differences. The *farming* group is re-expanded into 15 sectors while retaining the aggregate *fossil fuel* sector and *rest of economy*. Table 12 presents the direct input (*column 2*) and Leontief inverse (*column 3*) coefficients for this 17-sector Indian economy. The technical multiple estimated as the ratio of the two coefficients is shown in *column 4*.

The average multiple[42] for the total to direct effect of a given change in fossil fuel prices, for the entire economy is estimated at 4.6. For the 15 farming sectors, the average for multiple is estimated as 5.5.[43] There is however, significant variation in value of multiple for the different farming sectors, ranging from 3.5 for *bajra* to 8.4 for *coconut*.

An upward revision in fossil fuel prices is therefore likely to have an amplified impact on input costs of farming and consequently have implications for minimum support prices of farming output. Note that the technical multiple is significantly higher than average for *staples* including *wheat*, *paddy*, *coconut*, and *pulses*. In turn, this may have strong public finance implications arising from rise in costs of implementing the policy on food security and food subsidy.

5. Conclusions and policy implications

Out of 40 major economies, Voigt et al. (2014) find that India (see *figure 6*, *exhibit b*, pp 56, *ibid.*) is the only country with (i) high initial energy intensity and (ii) low energy intensity reduction between 1995 and 2007. Decomposing the causal factors into two components, for India they infer (see, *figure 10*, *exhibit f*, pp. 60, *ibid.*) that (a) change, if any, in economic structure has made hardly any contribution to energy intensity reduction, but that there is (b) some general improvement from use of more efficient production technologies and / or perhaps newer vintage of capital.

In consonance with Voigt et al. (*op. cit.*), we find improvement (that is, decline) in both energy and fossil fuel intensity for the economy. But, the evidence from the empirical exercise in this paper shows that energy intensity and fossil fuel intensity of farming in India are on the rise.[44]

Fossil fuels like coal, naphtha, diesel, and natural gas constitute a major input into power and fertilizer sectors. Increase in their prices would therefore raise cost of power and fertilizer production. Unless power and fertilizer subsidies are correspondingly raised, with consequent stress on public resources, input cost for farmers will increase sharply. It follows then that the perception on strong (adverse) inflationary impact, particularly on farm output in the short-run, is indeed well-founded. This, calls for a gradual calibration of fossil fuel price policy.

An across the board rise in fossil fuel prices would manifest itself in inflation in farm-output prices, and at a rate higher than what is normally portrayed in the literature. The cost-push effect could be aggravated by the existence of demand-pull factors from growth in incomes. Evidence derived in this paper suggests that staple food (including *paddy*, *wheat*, *pulses*, and *coconut*) would face a steeper rise in production costs. This would raise the cost of implementing the policy on food subsidy and food security that envisages staple food provision.

Given the weight of fossil fuels in the WPI, a 10 per cent increase in fossil fuel prices would directly contribute to a 1.14 per cent increase in WPI (Table 11). But, fossil fuel price rise would also raise direct input cost of important crops, on an average, by 0.55 per cent (Table 10, *Section 4.1*). Evidence from I–O analysis, with disaggregated farming sector, suggests that on average total input of fossil fuels may be in excess of 5.5 times the direct input (*Section 4.2.2*). This could raise farming cost by about 3.03 (= 5.5 * 0.55) per cent. With a weight of 14.34 per cent for (primary) food articles, increase in farming costs could add another 0.43 (= 0.1434*3.03) percentage points to WPI. Further, including the impact on remaining production sectors (not discussed in this paper), it appears that economy-wide inflation in WPI could significantly exceed the estimate suggested by RBI.

It is likely, that energy intensity of Indian agriculture may continue to rise to catch-up with the national average. In a developing economy like India, fossil fuel sector carries strong forward linkages. An increase in price of fossil fuel has a spiraling effect on price of other goods and services. But, the speed and intensity of spiraling could be asymmetric between an increase and a decrease in prices. While an increase in fossil fuel prices may set in motion a rapidly widening inflation spiral, a decline in fossil fuel prices could have only a muted economic impact. This poses special challenges for benchmarking policy responses. In particular, the extant institutional mechanisms in India foster strong downward price-rigidity. This is reaffirmed by recent data that hardly reflect any respite in domestic prices, despite a sharp decline in international price of crude petroleum (*cf.* the small decline in WPI for F&P in 2014–5, *column 6*, Table 1).[45] Not surprising then, that the domestic price index for food articles continued its unabated rise (*cf.* the significant rise in WPI for FA in 2014–5, *column 4*, Table 1).

It is only appropriate to add a caveat that this is essentially a static exercise. An I–O table for a given year represents a fixed coefficient production relation among sectors. We find that between 1998–9 and 2007–8, the forward linkage of fossil fuels with the remainder of Indian economy has intensified. But, it could also weaken in future. Technology forecasting to enable such analysis is beyond the scope of this paper.

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[42] This is estimated as the sum of column 3 elements divided by sum of column 2 elements. This magnitude of the multiple is influenced by the level of (dis)aggregation. For example, in the three-sector I–O model discussed in *Section 3.3*, the multiple for economy as a whole works out to 4.3 both in 1998–9 and 2007–8. The average could however be measured in different ways. For example, it could be the simple (un-weighted) average of the multiples (as shown in *column 4* of Table 12) which turns out to be 5.9. This simple average is however inappropriate. Using output weights the average multiple works out to 4.8 in 2007–8, both for the three-sector and 17-sector models. The output-weighted multiple in 1998–9, for the three-sector case is estimated as 3.0.

[43] Using output as weights the average multiple works out to 7.1 (*cf.* with the estimate of 6.7 for the aggregate farming sector in *Section 3.3*).

[44] In contrast, in Voigt et. al. (*op. cit. figure 5*, pp 54), a decline in energy intensity (or an improvement) is observed across all sectors (they consider 34 sectors) of the Indian economy. However, India appeared to be the only large country where sectors with relatively larger share of gross output performed significantly worse than a majority of other sectors.

[45] In January 2016, international price of crude petroleum had tumbled to almost one-third its level in June 2014.

working paper of NIPFP and may be downloaded from http://www.nipfp.org.in/media/medialibrary/2014/02/WP_2014_132.pdf. Indira Rajaraman (member, Thirteenth Finance Commission) and Rathin Roy (Director, NIPFP) offered advice on that version. Rita Wadhwa and Samreen Badr (editors, NIPFP) offered useful suggestions. Comments and observations by two anonymous referees were helpful to improve the focus of policy recommendations. I am thankful to all of them.

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