Direct and Indirect use of Fossil Fuels in Farming: Cost of Fuel-price Rise for Indian Agriculture

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Abstract

A hornet's nest could be an apt simile for fossil fuel prices in India. Over years a policy maze has evolved around it, with sharply diverging influence on disparate constituencies.[1] We estimate the increase in total cost of farming as a multiple of direct input costs of fossil fuels in farming. Over the period between 1990-1 and 2010-1, direct use of fossil fuels on farms has risen and there is also increasing indirect use of fossil fuels for non-energy purposes. Consequently, for Indian agriculture both energy intensity and fossil fuel intensity are rising. But, these are declining for the aggregate Indian economy. Thus, revision of fossil fuel prices has acquired greater significance for Indian agriculture than for the remainder of the economy. We validate these findings by utilising an input-output table for the Indian economy to assess the impact of fossil fuel price increase. We assess that fossil fuels sector has strong forward linkages and increase in its price has a steep inflationary impact. Using a three-sector I-O model for Indian economy, we estimate that a 10 per cent increase in fossil fuel price could cause, *mutatis mutandis*, the wholesale price index (WPI) to rise about 4.3 percentage points with 0.7 percentage points being contributed by the farm sector alone.

Keywords: Agriculture, Fossil-fuel intensity, Inflation, Input-Output analysis

JEL Classification: C67, E31, Q12, Q43

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[1] Formed along differing dimensions these constituencies may or may not overlap, like agriculture, industry or services, upstream or downstream companies, public or private sector, households or commercial consumers etc.

1. Introduction

This paper focusses on the interaction between fossil fuels and farming in India, to capture *total intensity* of fossils in farming and offer some evidence on *inflationary impact of fossil fuel price increase in India*.

Revision of fossil fuel[2] prices in India continues to be a political *hot potato*. This paper is motivated by the often repeated conjecture that, the increase in prices of fossil fuels could have a significantly large indirect or later-round impact than direct or first-round impact, on prices in general and food prices in particular.[3]

A recent report on pricing diesel (Anand, 2012)[4] in India, among other things discussed very briefly the input cost of diesel / petroleum products. However, it made only a passing reference to Indian agriculture with a couple of crop-specific examples. Anand (*op. cit.*) concerned itself with direct use[5] of only *diesel* in farming,[6] but indirect use of fossil-fuels for farming appears to be significant.[7]

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[2] While *fossil* is a generic term signifying *remains*, the term *fossil-fuels* is often used to denote products and by-products derived from coal, lignite, crude petroleum, and natural gas. However, the term *fuel* is pertinent only when used for deriving energy from their combustion.

[3] As per a newspaper report in August 2012, the 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). RBI (2011, 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".*

[4] Titled *Diesel Pricing in India: Entangled in a Policy Maze*, this report may be downloaded from http://www.nipfp.org.in/newweb/sites/default/files/Diesel%20Price%20Reform.pdf; Working Paper version at http://www.nipfp.org.in/newweb/sites/default/files/WP_2012_108.pdf

[5] *Direct use* (of fossil fuels) essentially concerns *direct purchase* of diesel by farmers.

[6] See in particular, *section 7.5* in Anand (2012).

[7] The distinction between fuel and non-fuel (respectively, energy and non-energy) use of fossils, while important, is not a core concern. Table 51, GoI (2012), pp 48, lists the major end-uses of petroleum products. The ones relevant for farming and agriculture are (a) Naphtha / NGL (natural gas liquid): Feedstock / fuel for fertiliser units, feedstock for petrochemical sector, and fuel for power plants; (b) HSD (high speed diesel): Fuel for transport sector (railways / road), agriculture (tractor, pump sets, threshers, etc.), and captive power generation; (c) LDO (light diesel oil): Fuel for agricultural pump sets, small industrial units, start-up fuel for power generation; (d) FO / LSHS (fuel oil / low sulphur heavy stock): Secondary fuel for thermal power plants, fuel / feedstock for fertilizer plants, industrial units.

Two important indirect linkages of fossil-fuels and farming are through use of (a) fertilisers and (b) power or electricity. Natural gas (NG) and naphtha, apart from furnace oil and other heavy distillates, are commonly used as feedstock (raw material) in production of fertilisers.[8] Coal, diesel, and liquefied NG (LNG) are used as fuel for electricity (thermal-power) generation for supply to (a) consumers including farmers, to power their irrigation pump-sets and other farm-equipment and (b) industry, as input to produce those pump-sets, farm-equipment, fertilisers, pesticides, and other inputs or raw-materials used on farms.

In the next section, we briefly recapitulate fossil fuel use at the aggregate economy level highlighting the proportion of final consumption in agriculture sector.[9] In section 3 we explore some rudimentary evidence on the (direct) input cost of fossil fuels (essentially diesel) in farming. The available evidence with some supporting assumptions are then used in section 4 to estimate the direct impact of an increase in diesel prices on farming operations for differing crops. The use of fossil-fuels as raw material for manufacture of fertilisers, almost exclusively used on farms, is discussed in section 5. Use of fossils to derive thermal energy that is consumed on farms, while energising irrigation pump-sets and certain farm equipment, is estimated in section 6.[10] The disparate components from sections 3 to 6 are pieced together in section 7. Next, the deep linkages between fossil fuels and farming are explored using an alternative approach that employs an input-output (I-O)[11] table for the Indian economy. This is conducted at two levels.[12] *First*, in section 8, a 130-sector

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In the approach adopted in this paper direct use constitutes of *b* and *c,* while *a* and *d* constitute indirect use.

[8] This constitutes one of the non-energy or non-fuel uses of fossils. The euphemistically called fossil-fuels may be put to non-energy (non-fuel) uses in several other processes. For example, coal is used as feedstock in making steel as well as in some other industries.

[9] There is almost total overlap between final consumption of fossil fuel in agriculture and direct use of diesel on farms.

[10] However, note that thermal power to energise the production processes in industries for manufacture of fertilisers, pesticides, farm equipment or other such inputs used on farms, is not estimated here. Although important, the complexity rises sharply with every level of detail or, as one we go further back in value chain. In any case, this can only add to the total intensity (of fossil fuels in agriculture) that we seek to estimate.

[11] I-O tables for the Indian economy are prepared by the National Accounts Division (NAD) of the Central Statistics Office (CSO) of the Ministry of Statistics and Programme Implementation (MoSPI) of the Government of India (GoI). Starting with the publication of the first I-O tables for 1968-9, the NAD has published a detailed I-O table almost every five years. The latest in the series pertains to 2007-8 and was published in October, 2012. Until 1998-9 the detailed tables were constructed for 115 sectors classification, but the level of detail was raised to 130 sectors in 2003-4.

[12] It may be a useful exercise to decipher use of fossil fuels through input of power (electricity) on farms to run farming equipment, or when used in industrial-production of

I-O table for Indian economy is aggregated into three sectors representing (i) *farming*, (ii) *fossil fuels*, and (iii) *rest of the economy*. And *second*, in section 9, the *farming* sector is again disaggregated into 15 sectors to decipher the varying impact of fossil fuel price change on differing crops. Finally, section 10 summarises the paper.

2. Aggregate energy consumption in India and direct use (final consumption) of fossil-fuels (diesel) on Farms

Energy intensity, estimated as available commercial energy in kilogram of oil equivalent (kgoe) per thousand Indian rupees (INR) of gross domestic product (GDP),[13] increased from 12.3 in 1980-1 to 14.9 in 1991-2. But since then, has secularly declined to reach 10.9 in 2009-10.[14] Such a situation may transpire from a combination of the following, (a) the use of fossil fuels may be displacing use of non-fossil fuels (like firewood, dung-cake), (b) heat energy from burning of fossil-fuels may be easier to harness and redirect, and (c) technological developments may raise the efficacy of energy derived from fossil-fuels.

Data collated from the international energy agency (IEA) on energy balance corroborates that energy intensity of GDP has declined to almost half its level in 1990-1 (*Column 4*, *Table 1*). Estimates on total primary energy supply (*Column 2, Table 1*) also depict a declining trend at the aggregate level. But the proportion of fossil fuels in total primary energy supply has risen from close to 50 per cent to above 75 per cent (*cf. columns 2 and 3*). In 1990-1, energy intensity of agricultural GDP (*cf. columns 4 & 5*, *Table 1*) was only 7 per cent of that for the economy as a whole. But, in 2011-2, this ratio had risen to 28 per cent and in absolute terms energy intensity of agricultural GDP is

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those equipment as well as farm inputs like fertilisers, pesticides. However, this is not attempted here as unlike in case of fertilisers that are almost exclusively used on farms, power is an input into a much wider range of economic activities.

[13] GDP at constant 2004-5 prices from http://mospi.nic.in/Mospi_New/upload/NAS13.htm.

[14] As per GoI (2013, pp 42), energy intensity measured as amount of energy for generating one unit of GDP (at 1999-2000 prices) increased from 0.128 KWh in 1970-1 to 0.165 KWh in 1985-6. This came down to 0.148 KWh (at 2004-5 prices) in 2011-2. It may however be noted that because of differing base years for reporting GDP, energy intensity figures for 2011-2 are not strictly comparable over the entire period as presented in GoI (2013). In another context, energy intensity of GDP is also expressed as *available commercial energy per unit of real GDP* (see, CMIE (2013), TERI (2012)). This is estimated using data on *available commercial energy* in million tonnes of oil equivalent (MTOE) and *GDP at factor cost at 2004-5 prices* in crore INR. Analogous interpretation is adopted while referring to diesel or petroleum-products intensities of GDP.

almost double its value in 1990-1. *In India thus, energy intensity for aggregate GDP is declining but energy intensity of agricultural GDP is rising*.

Table 1: Energy Consumption and GDP in India

Year	Primary Energy Supply in kgoOE per 1000 INR of GDP		Final Consumption of Energy in kgoOE per 1000 INR of GDP of		GDP at Constant 2004-5 Prices at Factor Cost (crore INR)	Share of Agriculture in GDP at 2004-5 Prices, (%)
	Total	**Fossil Fuels**	**Economy**	**Agriculture**		
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
1990-1	23.50	13.01	18.67	1.40	1347889	29.5
1998-9	20.22	12.81	14.49	2.37	2087828	24.4
2001-2	18.79	12.21	12.85	2.01	2472052	22.4
2007-8	15.52	10.75	10.29	2.40	3896636	16.8
2010-1	14.66	10.62	9.61	2.65	4937006	14.5
2011-2	14.29	10.33	9.39	2.64	5243582	14.1

Source: GDP data from http://mospi.nic.in/Mospi_New/upload/NAS13.htm;
Energy balance data from International Energy Agency
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=2011

Notes: kgoOE 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 fertilisers, and energy utilised in production of fertiliser, pesticides, farm equipment, and other farm inputs that are likely accounted for under *industry*.

Data collated from alternative sources and presented in *table 2* confirm the above observation. *Row 5*, *table 2* shows that GDP growth (6.72) is relatively steeper than growth in consumption of fossil fuels, either as a group (5.12) or individually. [15] Therefore, energy efficiency at the macro-aggregate level and fossil-fuel intensity of GDP has improved.[16]

A sharply divergent assessment however, may be concluded if one were to consider a relatively longer period starting from 1974-5.[17] Between 1974-5

[15] The decline in fossil fuel intensity is corroborated, but there are differences with respect to the magnitudes. For example, the 1990-1 estimate for fossil fuels is 16.09 kgoOE per 1000 INR of GDP (against 13.01 as per IEA) and 13.25 for 2007-8 (against 10.75 as per IEA).

[16] However, decline in energy-intensity or enhancement of thermal efficiency at the aggregate level should not be an excuse for complacency in efforts to reduce fossil fuel consumption.

[17] There is no ostensible reason for the choice of these initial years, except the ease of availability of data in the case of former, and in the latter to allow a comparison with publicly

and 2010-1, real GDP (at constant 2004-5 prices) has grown at 5.71 per cent per annum (*Row 3*, *Column 8*, *Table 2*). Over that period, fossil fuel consumption consisting of coal, lignite, petroleum products and natural gas grew at 5.78 per cent per annum (*Row 3*, *Column 6*, *Table 2*). It thus appears that fossil fuel intensity of GDP may have risen or remained unchanged between 1974-5 and the present.[18]

Table 2: Trend growth rates, in consumption of fuels and of GDP, 1970-1 to latest available

Period	**Coal Offtake**	**Lignite Despatch**	**Petroleum Products**	**Natural Gas**	**Total Fossil Fuel**	**Diesel**	**GDP at constant 2004-5 prices**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
1970-1 to Latest	5.50	7.44	5.47	11.86	5.75	-	5.52
1974-5 to Latest	5.50	7.68	5.51	11.32	5.78	6.19	5.78
1974-5 to 2010-1	5.50	7.57	5.63	11.56	5.78	6.25	5.71
1990-1 to Latest	5.00	4.49	5.02	5.93	5.12	4.64	6.80
1990-1 to 2010-1	5.00	4.41	5.26	5.96	5.12	4.38	6.72

Source: CMIE, MoSPI, MoPNG

Notes: One million tonne of coal equals 0.67 mtoe. One million tonne of lignite equals 0.33 mtoe. 1 billion cubic metres of natural gas equals 0.9 mtoe. One million tonne of all refined petroleum products equals one mtoe. Data on 'latest' year pertains to (a) 2010-1 for coal and total fossil fuels; (b) 2011-2 for lignite, natural gas, and GDP; (c) 2012-3 for petroleum products, diesel, and GDP.

Further, while relative intensity of lignite and natural gas with respect to GDP had risen, it declined on account of coal and petroleum products. However, within the class of petroleum products diesel consumption grew at 6.25 per cent per annum (*Row 3*, *Column 7*, *Table 2*). Consequently, diesel-intensity of GDP appears to have risen significantly.[19] This has found resonance elsewhere

available IEA data (as in *table 1*). Fortuitously, though 1990-1 and 1991-2 are often considered as watershed years in Indian economic policy orientation.

[18] This is not surprising, but often causes sharp differences in perception when assessing policy outcome, especially in developing economies with evolving institutions. Over relatively longer intervals, abrupt changes arise merely from differences in understanding, definition or scope of variables. Often these changes are not systematically documented or adequately evaluated. It thus appears that, *the choice of terminal years, in turn determining the length of the period, considered for analysis makes a significant difference to the conclusion on direction of estimated trend on energy intensity*. However, we believe that to adopt appropriate policy response, it may be justifiable to accord higher significance to signals that derive from relatively recent changes.

[19] Consumption of middle-distillates and all petroleum products grew respectively at 5.21 and 5.58 per cent per annum over 1974-5 and 2011-2.

expressing concern over *dieselisation* (http://www.cseindia.org/dte-supplement/air20040331/dieselised.htm).[20]

The introductory section noted that direct use of fossils on farms pertains to use of diesel to run agricultural machinery (including tractors, harvesters, combines etc.), water pumps, and generators. *Table 3* presents the share of diesel consumption (columns 3 to 7), juxtaposed to the changing structure of GDP (*columns 8 to 12*).

Table 3: Sector-Wise Share of Total Diesel Consumed and GDP (per cent)

Sector	**Mode**	**Diesel Consumed**					**GDP**				
		1998-9	**2000-1**	**2008-9**	**2010-1**	**2011-2**	**1998-9**	**2000-1**	**2008-9**	**2010-11**	**2011-2**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Transportation	Railways	3.8	3.8	4.2	4.0		1.0	1.0	1.0	1.0	1.0
	Water	0.6	0.7	1.4	0.9						
	Aviation	0.1	0.1	Negligible			4.9	5.0	5.6	5.4	5.6
	Road	53.0	53.9	59.6	60.4						
Industry		10.4	9.9	8.3	8.2		15.4 (9.5)	15.5 (9.5)	15.8 (10.6)	16.2 (11.3)	15.7 (10.9)
Power Generation		6.9	6.8	8.4	8.2		2.3	2.2	2.0	1.9	1.9
Agriculture		19.2	19.8	11.9	12.2		24.4 (20.7)	22.3 (18.7)	15.8 (13.4)	14.5 (12.3)	14.1 (12.0)
Miscellaneous		6.1	6.7	4.3	3.8						

Source: GDP by Economic Activity at Constant 2004-5 prices accessed at http://mospi.nic.in/Mospi_New/upload/NAS_2012_25july12/statements(pdf)/S11.1.pdf on September 20, 2012. Diesel consumption from http://petroleum.nic.in/pngstat.pdf, GoI, 2012b.
http://mospi.nic.in/Mospi_New/upload/NAS13.htm
http://economicoutlook.cmie.com/kommon/bin/sr.php?kall=wshreport&&repcode=0160170150100100100000000000000000000000000&repnum=12932&prs=000-999-999-00012930

Notes: GDP data in transportation services is available for 'railways' and 'other transport services' the latter includes air and water transport; Share of Industry in GDP pertains to 'manufacturing' (registered (shown in parenthesis) plus unregistered); Share of Power in GDP relates to 'electricity, gas and water supply'; Share of agriculture in GDP includes 'agriculture (shown in parenthesis), forestry and fishing'.

[20] There is rising rhetoric against risks from single-fuel predominance due to policy induced technological choices or from dithering energy-price reforms. The number of units of petroleum products to satisfy a unit increase in average final demand for all sectors, increased by almost one-third, from 2.991 to 4.0461, between 1983-4 and 2003-4. Anand (*op. cit*, pp. 37) discussed the strong and intensifying forward linkage of petroleum products / diesel with rest of the economy, endorsing the steep increase in weight on diesel in the wholesale price index (WPI). The weight on diesel changed from 2.02034 in 1993-4 series to 4.67020 in 2004-5 series. The weight on fuels as a group changed from 8.74254 to 11.45858. The weight on power declined from 5.48369 to 3.45163 (see also *table 12* in *section 7*).

Between 1998-9 and 2010-1, the proportion of diesel consumed had risen significantly in *transportation*, along with an equi-proportionate rise in its contribution to GDP. In *industry* the proportion of diesel consumed has declined but contribution to GDP has somewhat risen. In case of *power* the proportion of diesel consumed has risen but contribution to GDP has somewhat declined. But, in *agriculture* the proportion of diesel consumed has declined and so has the contribution to GDP.

A sharper focus on only recent data indicates a reversal of above trends. Between 2008-9 and 2010-1, *agriculture* is the only sector to portray a rise in share of diesel consumed (from 11.9 to 12.2 per cent) and also a perceptible decline in share of GDP (from 15.8 to 14.5 per cent). It appears that diesel-intensity of GDP contributed by different sectors, may have grown differently. *Table 4* presents the relative diesel intensity, and it is observed that, between 1998-9 and 2000-1, relative diesel intensity of GDP increased for both *power* and *agriculture*, but declined for *industry* and remained almost unchanged for *transportation* sectors. In more recent years again, since 2008-9, while relative diesel intensity of GDP has risen for all sectors, it has grown fastest for agriculture sector GDP.

Table 4: Relative Diesel Intensity of Sectoral GDP

Year	Transportation	Industry	Power	Agriculture
1998-9	9.75	0.68	3.00	0.79
2000-1	9.75	0.64	3.09	0.89
2008-9	10.00	0.65	4.15	0.75
2010-1	10.20	0.65	4.32	0.84
Change During Period (per cent)				
1998-9 to 2000-1	0.04	-5.42	3.03	12.84
2000-1 to 2008-9	2.56	1.07	34.26	-15.17
2008-9 to 2010-1	2.03	0.40	3.99	11.71

Source: Author's own computation

Notes: Industry includes registered and unregistered manufacturing; Agriculture includes forestry and fishing. Relative intensity is calculated using shares instead of actual quantity / value and expressed as a ratio of the share of diesel consumed in the sector to share of GDP contributed by the sector.

Acceleration in relative diesel-intensity of agriculture in comparison to non-agriculture (including transportation), in part, is indicative of continual mechanisation of farm labour. But more importantly, it perhaps signals widespread disappointment with the power sector to satisfactorily address the rising energy-demand from this sector.[21] One may surmise that, *in recent years Indian agriculture is experiencing faster dieselisation than rest of the*

[21] This issue is revisited in section 6.

economy.[22] Note the congruence with observations on agricultural sector from *table 1*. Further, *if correctives are not introduced earnestly, fossil-fuelisation of Indian agriculture may rise alarmingly*.

3. Cost of Agricultural Production

Over the last few years, food price inflation in India has continued to remain 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). Further, income increase has also raised the demand for finer cereals and protein-rich food (Ganguly and Gulati, 2013; RBI, 2011a; RBI 2011b). There could hardly be a case to dispute these arguments.[23]

On *supply side*, the minimum support price (MSP) policy periodically ratchets-up prices garnered by farmers / producers. However, the MSP policy is necessarily geared to account for input costs incurred by farmers. In that sense it could be a conduit for cost-push inflation. But, retail prices of several farm inputs including power, fertilisers, and diesel are also administered (fixed or influenced) by government policy. In the event of an increase in international price of crude petroleum or other fossil fuels, the government is faced with a choice to either allow their passage onto domestic retail prices or continue to subsidise farm inputs, while compensating the (input) producers of power, fertilisers, and diesel.

Several government of India (GoI) committees (GoI (2006, Rangarajan), GoI (2010, Parikh), GoI (2013, Parikh)) constituted over years, have concluded that in the long run it is desirable to decontrol fossil fuel prices.[24] These committee reports however, have neither indicated the timing for decontrol nor spelt out the pre-conditions that warrant it. On the contrary, they cemented the belief that the time (for decontrol) may not be ripe as yet.[25] It is believed

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[22] However, this observation needs to be tempered considering the possibility of abrupt changes in categorisation of data. The most recent example is the sweeping categorisation of more than 85 per cent consumption of HSD under *Miscellaneous Services* for the year 2011-2 (see pg. 73, http://petroleum.nic.in/pngstat.pdf, January 2013).

[23] Both, finer cereals and protein-rich food are *normal* goods at extant average income and consumption level.

[24] This author however opines that full 'decontrol' is a myth when the tax component in the price is significant and in the case of some fossil fuels constitutes close to half of the prevalent price.

[25] This is also reflected in the hesitation of the empowered committee of state finance secretaries to include all fossil fuels under the ambit of the proposed GST.

that while decontrol would lead to immediate increase in prices of essential items (and hence general inflation), it may have a salubrious influence on long term growth prospects and price stabilisation (RBI, Bhanumurthy et al (2012), Bhattacharya and Batra (2009), Bhattacharya and Bhattacharya (2001).

Political constituency for decontrol is however weak, perhaps due to inadequate mapping of (and therefore estimates for) economy-wide impact of fossil fuel price revision. In particular, there is paucity of studies in the Indian context, relating to impact of fossil fuel prices on agriculture. However, reports of Commission for Agricultural Costs and Prices (CACP) collate costs of production of several commodities. And, appendix II of GoI (2000) describes the approaches adopted for estimating various costs under a comprehensive scheme for studying the cost of cultivation of principal crops.

In one approach, cost data categorised into operational and fixed costs (per hectare) is collated for specific crops. The operational cost is grouped into labour (human, animal and machine), material (seeds, fertiliser, manure, insecticides), and service (irrigation, interest) categories. But, a quick scan reveals that expenditure incurred on direct purchase of fuels or on purchase of power, is not shown separately.[26] Apparently, operational cost of machine labour includes costs incurred on fuel and lubricants for mechanised agricultural implements and equipment including water-pumps. Although entailing further assumptions, this structure appears convenient for our purpose to estimate input cost of diesel for differing crops over years.

Cost incurred on purchase of fertilisers and insecticides are also presented, but again these are retailed to farmers at subsidised rates. Consequently, the transmission of fossil fuel price revision may not be reflected in farming costs. The paper attempts to address this gap. It deciphers the direct (as diesel) and indirect (as in production of fertilisers and power) use of fossil fuels on farms and then focuses on the likely impact of change in fossil fuel prices on costs of agricultural production.

[26] There is an element of *irrigation charges* that essentially relates to payment to the irrigation department for consumption of water on farms.

4. Operational cost of machine labour and cost of diesel in total cost of production

Fortuitously, a one-off table (partly reproduced here as *table 5*), gives a rough estimate of diesel cost as a proportion of operational cost of machine labour.[27] One observes that diesel cost per hectare varies significantly among crops and across provinces. This variation is on account of differences in (a) technology, including adoption of high-yielding variety (HYV) of seeds, degree of mechanisation, (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).[28] On an average, however for the crops and provinces shown in *table 5*, diesel accounted for about 62 per cent of operational cost of machine labour.

Table 5: Diesel Cost in Operational Cost of Machine Labour, INR per Hectare, 1998-9

Crop	Province	Diesel Cost	Op. Cost of Mach. Lab.	col. 3 / col. 4 (per cent)
1	2	3	4	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

Source:Directorate of Economics and Statistics, Ministry of Agriculture, http://cacp.dacnet.nic.in/ Reports on Price Policy, Compendium Reports, 2000-1. Annexure 1, pp. 543.

As described, cost of diesel and petroleum products are imbedded in the operational cost of machine labour. We collate this information for 23 crops namely, sugarcane, jute, six rabi,[29] and 15 kharif[30] crops, for which details are

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

[28] 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.

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

available in the reports of the Commission for Agricultural Costs and Prices (CACP).

Table 6 gives the operational cost of machine labour as per cent of total cost of production for two years[31] for each of these crops. In the year 1998-9,[32] 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 differing years between 2008-9 and 2010-1)[33] for which information is available *jute* reported the lowest fraction of 1.9 per cent while *tobacco* continues to report the highest at 19.1 per cent.

In 1998-9, the average operational cost of machine labour was 5.9 per cent of total cost of production (averaged across all crops, in turn averaged across reporting states). This average had risen to 8.1 per cent as per the latest data. Note further 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*, and *cotton*) the proportion for operational cost of machine labour has also increased in the later year (see *column 4*).

Table 6: Operational Cost of Machine Labour for Different Crops as Per Cent of Total Cost of Production per Hectare

Crop	Year	No. of Pro.	Op. Cost (%)	Crop	Year	No. of Pro.	Op. Cost (%)
1	2	3	4	1	2	3	4
Sugarcane	2010-1	7	3.0	**Ragi**	2009-10	4	2.2
	1998-9	5	7.1		1998-9	3	1.9
Wheat	2010-1	13	13.5	**Tur (Arhar)**	2009-10	9	7.0
	1998-9	6	10.5		1998-9	6	3.5
Barley	2010-1	2	12.8	**Moong**	2009-10	5	10.5
	1998-9	2	10.6		1998-9	3	3.2
Gram	2010-1	10	11.0	**Urad**	2009-10	8	10.7
	1999-00	4	9.1		1998-9	3	4.6
Lentil	2010-1	5	10.9	**Groundnut**	2009-10	6	4.6
	1998-9	2	8.7		1998-9	3	2.0
Rapeseed &	2010-1	8	10.4	**Soyabean**	2009-10	3	11.8

[30] 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.

[31] The estimates pertain to 1998-9 and the latest year for which data is available at http://cacp.dacnet.nic.in/ (last updated on Friday, July 05, 2013) when accessed on July 15, 2013.

[32] Only the data on *gram* refers to 1999-2000.

[33] *Rabi* crops for 2010-1 and VFC Tobacco for 2008-9, while all others for 2009-10.

Crop	Year	No. of Pro.	Op. Cost (%)	Crop	Year	No. of Pro.	Op. Cost (%)
1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Mustard	1998-9	6	11.1		1998-9	3	8.8
Safflower	2010-1	2	3.5	**Sunflower**	2009-10	3	7.4
	1998-9	1	1.1		1998-9	3	4.9
Paddy	2009-10	18	8.5	**Sesamum**	2009-10	5	6.3
	1998-9	9	5.1		1998-9	5	3.9
Cotton	2009-10	10	4.6	**Nigerseed**	2009-10	1	3.7
	1998-9	4	6.6		1998-9	1	0.0
Jowar	2009-10	6	9.8	**Jute**	2009-10	3	2.2
	1998-9	4	5.4		1998-9	3	2.0
Bajra	2009-10	6	10.9	**VFC Tobacco**	2008-9	1	19.1
	1998-9	4	7.4		1998-9	1	18.8
Maize	2009-10	10	7.7	**ALL-CROPS AVERAGE**	**2009-10**		**8.1**
	1998-9	5	3.4		**1998-9**		**5.9**

Source: Author's computation; Basic Data: Directorate of Economics and Statistics, Ministry of Agriculture, http://cacp.dacnet.nic.in/ Reports on Price Policy.

Notes: Op. Cost: Operational cost shown in column 4 is maximum out of average and median for the reporting provinces. For a large majority of crops, average (operational cost) across provinces is more than the median. No. of Pro.: number of reporting provinces. See also appendix table for more details on each crop; VFC Tobacco: Virginia Flue Cured Tobacco.

The product of (a) the estimated proportion of operational cost of machine labour in total cost of production, and (b) the estimated proportion of diesel cost in operational cost of machine labour, gives an estimate of the proportion of diesel cost in total cost of production. In 1998-9, the former averaged 5.9 per cent and the latter averaged 62 per cent (*section 3*). *On average therefore, diesel or direct use of fossils constituted 3.7 per cent of total cost of production. An upward revision in diesel price by 10 per cent*[34] *in 1998-9 then would have raised the cost of agricultural production, on an average, by about 0.37 per cent.*

In 2009-10, the average operational cost of machine labour was estimated at 8.1 per cent of total cost of production. Next, if the proportion of diesel cost in operational costs is assumed as unchanged at 62 per cent even in 2009-10, then a 10 per cent increase in price of diesel would have raised average cost of farm production by about 0.5 per cent.

[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.

However, if one assumes that diesel price inflation may have exceeded inflation in other input prices (see *Table 11*, *Section 7*), then diesel could constitute about two-thirds of operational cost of machine labour.[35] For such a scenario, *table 7* presents the likely impact of a 10 per cent increase in price of diesel on cost of agricultural production. As expected, there is significant variation across different crops, but on average, cost of farming could increase by about 0.56 per cent.[36]

Table 7: Effect of 10 per Cent Increase in Cost of Diesel on Percentage Increase in Cost Per Hectare (2009-10)

Crop	Rise in Total Cost	Crop	Rise in Total Cost
(1)	(2)	(1)	(2)
Sugarcane	0.20	**Ragi**	0.14
Wheat	0.90	**Tur (Arhar)**	0.47
Barley	0.85	**Moong**	0.70
Gram	0.73	**Urad**	0.71
Lentil	0.73	**Groundnut**	0.31
Rapeseed & Mustard	0.69	**Soyabean**	0.79
Safflower	0.23	**Sunflower**	0.49
Paddy	0.57	**Sesamum**	0.42
Cotton	0.31	**Nigerseed**	0.25
Jowar	0.65	**Jute**	0.15
Bajra	0.73	**VFC Tobacco**	1.27
Maize	0.51	**ALL-CROPS AVERAGE**	**0.56**

Source: Basic data from Reports of the CACP, GoI, 2010b.
Notes: It is assumed that diesel constitutes 67 per cent of operational cost of machine labour.

Purchase of diesel constitutes direct use of fossil fuels on farms. An increase in price of fossil fuels in general, and diesel in particular, thus has an immediate or first round impact on cost of farm production (as estimated in this section). But, to assess total impact of fossil-fuel price increase on farming, its indirect use should also be accounted. We investigate this next, and the following section focuses on use of fossil fuels as feedstock in production of fertilisers.

[35] That is, 67 per cent in 2009-10, as compared to an average of 62 per cent in 1998-9, see *Table 4*.
[36] As a pessimistic scenario, if the whole of operational cost of machine labour 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 0.83 per cent in total cost of cultivation.

5. Fossil fuels as feedstock for fertilisers used in farming

Consumption of fertilisers (N, P_2O_5, K_2O) grew almost 11 times, from 2.6 to 28.1 million tonnes between 1974-5 and 2011-2 (*column 6*, *Table 8*). But, this was accompanied by a mere 20 per cent increase in total cropped area. Consequently, per hectare fertiliser consumption in India has risen from 15.67 to 144.59 kilograms (*column 7*, *Table 8*). Per hectare fertiliser consumption thus grew at 5.32 per cent per annum, portraying more than nine-fold rise in average fertiliser-intensity[37] of agricultural practice in India.

Table 8: Fossil Fuels Used as Feedstock in Fertiliser Production

Year	Thousand Tonnes of Oil Equivalent				Total Fertiliser Consumption '000 Tonnes	Fertiliser Consumption Kgs. Per Hectare	Fertiliser 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		8211.0	47.48	37
1990-1	5051	1980	2208	9239	11568.2	67.55	23
1995-6	6842	2869	2834	12545	13563.6	74.02	27
2000-1	7632	3889	2581	14102	18068.9	90.12	13
2005-6	6986	2418	1817	11221	18398.4	105.52	25
2009-10	11851	907	1611	14370	24909.3	137.81	37
2010-1	12086	959	1670	14715	26486.4	146.32	42
2011-2	10197	1034	1721	12952	28122.2	144.59	43

Source: Basic data from Fertiliser Statistics, FAI (2012)

Notes: FO includes furnace oil (FO), low sulphur heavy stock (LSHS), residual fuel oil (RFO); *****: Availability refers to the sum of opening stock, production and net imports during the year.

Over years, consumption of fertilisers has significantly exceeded domestic production. Imported fertilisers constituted close to half of all domestic consumption in 1980-1 and about 43 per cent in 2011-2 (*column 8*, *Table 8*). On average however, between 1984-5 and 2011-2, domestically produced fertilisers constituted close to three-fourths of total fertiliser nutrients available to Indian farmers.[38] In particular, all potash fertilisers are imported, but

[37] Intensity of fertiliser use varies significantly across crops and regions.

[38] The figures range between 57 and 88 per cent for differing years between 1984-5 and 2011-2. With the exception of a few years, total availability (domestic production plus imports) of fertilisers in India has exceeded consumption by about five per cent during the period. The share of imports fluctuated between 11 and 46 percent of consumption between 1990-1 and 2011-2, but the period average worked out to 27 per cent.

proportion of imports in total consumption of nitrogenous and phosphatic fertilisers is relatively small.

Starting from 1980-1, only the first few years saw a rapid increase in use of naphtha and heavier-distillates as feedstock for domestic production of fertilisers. However, this trend was retarded very soon. There appears to be significant variation in the composition of feedstock for fertiliser production between 1990-1 and 2011-2, and use of naphtha and heavy-distillates declined respectively at about 3 and 2.4 per cent per annum. But, use of natural gas as feedstock grew steadily at about 3 per cent per annum almost doubling by the end of the period.[39]

Columns 2, 3, and 4 in *table 8* show the use of fossil fuels as feedstock for fertiliser production. Converted into oil equivalent units, the composition of aggregate feedstock in 1980-1 was in the ratio of 16:53:31 respectively for gas: light distillate (naphtha): heavy distillates (FO, LSHS, RFO). However, this composition had changed to 79:8:13, in 2011-2. Thus, not only was there a sharp increase in intensity of fertiliser use in farming, but also a drastic change in feedstock composition for fertiliser production, in favour of natural gas. A larger proportion of gas in feedstock significantly raised the efficiency of fertiliser production. In turn, this could have affected substantial savings in total use of fossil fuels. But, the benefits were eroded by increase in intensity of fertiliser use (*column 7*, *Table 8*).

Direct use of fossil fuels, chiefly diesel, in agriculture constituted only 1.3 per cent of all diesel consumed in India in 1980-1 (about 0.14 out of 10.7 million tonnes of oil equivalent (mtoe) (CMIE, 2013)). But indirect use, in that year, of petroleum and natural gas based fossil fuels consumed as feedstock, in domestic production of fertilisers, amounted close to 3.5 mtoe (*column 5*, *Table 8*). Thus indirect fossil fuel use for agriculture, on account of domestically produced fertilisers alone, was almost 25 times the direct use.

Rapid increase in use of machine labour and simultaneous reduction in use of animal labour on farms raised the direct use of diesel in Indian agriculture. Thus by 2010-1, consumption of diesel in agriculture grew to about 7.6 mtoe and constituted more than 12.2 per cent of total diesel consumption (see

[39] The analysis was undertaken after applying the appropriate conversion factors to denote all fuel types in oil-equivalent terms. The conversion factors utilised are the following: (a) one billion cubic meters of natural gas equals 0.9 million tonnes of oil equivalent; (b) one tonne of diesel equals 1.035 tonnes of oil equivalent; (c) one tonne of naphtha equals 1.075 tonnes of oil equivalent; and (d) one tonne of heavy distillates (furnace oil, LSHS / RFO) equals 0.985 tonnes of oil equivalent.

column 6, Table 3).[40] Indirect use of fossil fuels has also grown, and in 2010-1 this amounted to about 14.7 mtoe on account of domestic production of fertilisers (see *column 5*, *Table 8*). Thus the multiple for indirect to direct use of fossil fuels may have fallen to less than two (from 25 in 1980-1). Adjusting indirect use, from fossil fuels consumed in imported fertilisers could raise this multiple to 2.6.[41] But, the multiple could be yet higher if one includes fossil fuels in grid-supplied power[42] used on Indian farms.

6. Fossil fuels in power supplied to farms

The discussion in *section 2* alluded to rise in relative diesel intensity, of Indian agriculture especially in recent years, from direct use on farms to energise irrigation pump-sets and mechanised farm equipment including tractors, harvesters, threshers, combines. *Tables 3 & 4* there related to use of only diesel in Indian agriculture. But, diesel constitutes about two-fifths of all petroleum products consumed in India (Anand, 2012, table 4, pg 10). We therefore utilise information contained in the energy balance tables of International Energy Agency (IEA) to decipher the direct use (final consumption) of all petroleum products in agriculture (*column 6* of *table 9*). It is observed that, even on this metric, the proportion of petroleum products consumed in agriculture (that includes forestry and fishing) has risen sharply, and more than doubled between 1990 and 2011.[43]

[40] Total diesel consumption amounted to about 67 mtoe in 2011-2. However, the fraction of diesel used in agriculture is not reported. There is sharp change in fraction of diesel consumption attributed to different sectors between 1996-7 and 1997-8. It appears that in 1997-8 there may have been some reclassification of diesel consumption into broad economic sectors. Caution needs to be exercised that the proportion of diesel attributed to similarly named sectors may not be strictly comparable over time.

[41] Imported fertilisers constituted, on an average, one-quarter of consumption. In other words, imported fertilisers amounted to one-third of domestic production. Assuming similar efficiency in feedstock use for domestically produced and imported fertiliser, accounting for the latter in domestic consumption is likely to raise the multiple, for indirect to direct use of fossil fuels (in agriculture), by one-third.

[42] Chiefly coal, but may also include diesel and natural gas used for generation of power for grid-based electricity supply on farms.

[43] Further, the magnitudes reported in *tables 3 & 9* broadly corroborate the assumption relating to diesel as the principal petroleum product used directly on farms. As per the IEA energy balance tables, final consumption of natural gas in agriculture constituted less than six per cent of all petroleum products in 1990 and by 2011 this had declined to less than two per cent. Final consumption however does not include the non-energy use of natural gas and other petroleum products (especially naphtha and furnace oil) as feedstock for production of fertilisers which for the purpose of this paper constitutes an indirect use.

Table 9: Consumption of Power and Fossil-Fuels in Indian Agriculture

Year	Final Consumption of Electricity (ktoe)			Thermal Power out of Total Electricity	Proportion of Final Consumption of Oil Products and Natural Gas in Agriculture (%)
	Total	Agriculture	Proportion in Agriculture (%)		
(1)	(2)	(3)	(4)	(5)	(6)
1990	18209	4328	23.8	89	2.1
1998	30180	8359	27.7	92	4.1
2001	32129	7024	21.9	92	4.0
2007	49775	8960	18.0	90	5.0
2009	56663	10276	18.1	91	4.8
2010	61193	11098	18.1	89	4.8
2011	66526	11495	17.3	87	4.8

Source: IEA, Energy Balances.
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

While the situation has improved significantly over years, several rural areas with agricultural farms are still characterised by little or erratic power [give reference]. The energy balance tables for India suggest that the proportion of electricity consumed in agriculture has declined while the proportion of oil products and natural gas may have increased between 1990 and 2011 (*Table 9*). This is in consonance with the remarks in *section 2* between energy demand of Indian agriculture and perceived disappointment with the power sector.

The proportion of thermal power (*column 5, table 9*), essentially derived from fossil-fuels, is also assumed to hold for the fraction of power consumed in agriculture (*columns 3 & 4*, *table 9*). This is utilised to assess the element of fossil-fuels in agriculture (all forms combined, that is solid, liquid, and gas), due to use of power or electricity on farms. These estimates are collated in the next section and presented along with the estimates for direct use and use as feedstock in fertiliser production.

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

Table 10 summarises the relevant estimates on direct and indirect use of fossil-fuel on farms. There are two estimates on direct use. The *first* (*column 2*) uses data from Indian petroleum and natural gas statistics (GoI, 2013) and is also reported by CMIE (Economic Outlook). The *second* (*column 3*) uses data from energy balance tables of IEA.[44]

Table 10: Direct and Indirect Use of Fossil-fuel on Farms (in ktoe)

Year	Direct Use		Indirect Use in (one stage removed only)			Total to Direct Multiple (3+4+5+6)/3
			Power	Fertilisers		
	Only Diesel (CMIE)	(IEA)		Domestic	Imported	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1990	329	1244	3852	9239	2813	13.8
1998	7400	3719	7690	14713	3441	7.9
2001	7480	4128	6462	13119	2235	6.3
2007	9657	6747	8064	12273	6521	5.0
2009	7068	7356	9302	14370	8401	4.4
2010	7594	7786	9877	14715	10854	5.6
2011		8022	10001	12952	9644	5.1

Source: http://economicoutlook.cmie.com/kommon/bin/sr.php?kall=wshreport&repcode=01601701501001001000000000000000000000000&repnum=12930; IEA (same as in Table 9)

Notes: Indirect use in power estimated from data collated from IEA; Indirect use in imported fertiliser estimated from data collated from Fertiliser Statistics;

In the introductory section (*section 1*) we described an assumption that diesel is the only (or predominant) fossil fuel used directly on farms. This is corroborated by GoI (2013, table V.2, pp 72-6) that provides estimates of consumption of different petroleum products by type of user / sector. But, reported data on consumption of high speed diesel by user (sector) classification (see, *section 2, table 3, columns 3-6*), appears inconsistent over years, as reflected from changes in some years for the proportion across sectors.[45] In turn this raises doubts relating to quality of data put forth by the MoPNG. But, data sourced from energy balance tables of IEA appear consistent and these are presented in *column 3* of *table 10*. This includes both petroleum products and natural gas. However, in 1990-1 natural gas

[44] Note that, it is intended to assess use of fossil fuels in comparable units and not per se on the type of product, although this may be critical to derive the full policy import.
[45] In case of agriculture, the change is striking at two points between (a) 1996-7 and 1997-8 (from 1.66 to 19.1 per cent), and (b) 2007-8 and 2008-9 (from 19.57 to 11.9 per cent).

constituted less than six per cent of final consumption of fossil fuels in agriculture and this proportion further declined to less than two per cent in 2011-2.[46]

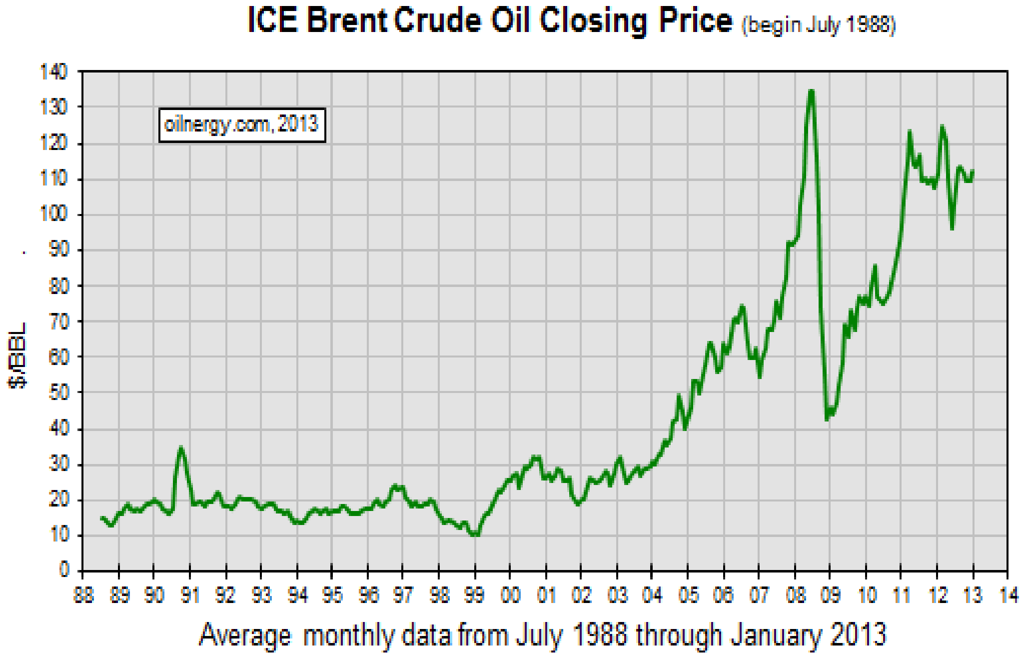
Table 10 also reveals that indirect use of fossil fuels (to generate power (*column 4*) and as feedstock in fertilisers (*columns 5 and 6*)) exceeds their direct use on farms. In 1990-1, the multiple for total to direct use of fossils fuels on farms was estimated at 13.8 (including fossil fuel content in imported fertilisers). But, direct use of fossil fuels has been rising fast and the estimate for the multiple stood at 5.1 in 2011-2. However, it may be fair to conclude that *despite 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*.

The cost or expenditure incurred on purchase of fuel is a product of (a) number of units of fuel purchased and (b) price per unit of the fuel. The effect on value therefore, is a function of quantity- and price-effects, and positively co-related to both. The economic impact on the cost of a product or good or service that uses fossil fuels as an input would also depend on the relative price structure. 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 inputs (fossil-fuels) rises faster than the average price of output (farm produce), then the proportion of input (fossil fuel) cost in total costs of a product rises. And, in case the price of input (fossil fuels) rises but slower than the price of output, then its proportion gets reduced.*

Thus, in a comparative static exercise (for example, using input-output transactions), the change in price of input (fuel and power) relative to price of output (food articles) could depress or reinforce the impact of changes in technical / quantity use of an input. Figure 1 charts 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.

[46] This may not suffice to confirm that diesel is the only or predominant petroleum product directly used on farms. Fortuitously, more recent data reported by MoPNG (2010-1), appears to be significantly close to that presented by IEA.

Figure 1



Source: http://www.oilnergy.com/1obrent.htm; downloaded on December 10, 2013.

In India however, nominal prices for fossil fuels have slowly ratcheted-up under a controlled regime. Even so, one can observe from *Table 11* that, with 1993-4 as the base year, the wholesale price index in 1998-9 for fuel and power (*column 6*) group stood lower than that for food articles (*column 4*), while, in 2007-8 the index for fuel and power was significantly higher than that for food articles.[47] Thus, in 1998-9 relative price of fuel and power would have depressed the effect of the multiple for technical or quantity use of fossil fuels in farm produce. But, in 2007-8, the relevant multiple would have been significantly amplified.

Table 11: Annual Average Wholesale Price Index (1993-94 = 100)

Year	**AC**	**PA**	**FA**	**NF**	**F&P**	**MP**
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(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	522.5	244.6

Source: Office of the Economic Adviser, Ministry of Commerce and Industry, Government of India. Downloaded on December 12, 2013 from

[47] As a corollary, total to direct multiple for *price-effect of fossil fuels on farm prices may have aggravated* between 1998-9 and 2007-8. This also corroborates the view on extant relatively weak substitution possibilities and therefore relatively low price-elasticity of fossil fuels.

http://www.rbi.org.in/scripts/PublicationsView.aspx?id=15160; Handbook of Statistics on Indian Economy, 2012-3.

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

Consequently, in value terms in 1998-9, the total to direct multiple for fossil fuels used in farming would be lower than the quantity / technical multiple (7.9, column 7, table 10). While, in 2007-8 the value based multiple would be higher than the quantity multiple (5.0, column 7, table 10) (*cf.* with estimates for 1998-9 and 2007-8 using input-output transactions in *section 8*).

*Estimates presented for 2009-10 / 2010-1 (table 7, section 4) suggest that the direct or first-round impact of a 10 per cent increase in price of fossil fuels is likely to raise cost of farm production by 0.56 per cent. But, assuming full pass through of increase in costs of production from increase in input prices, the total (direct plus indirect) impact of a 10 per cent upward revision in fossil fuel prices could have led to at least (0.56 * 5.0=) 2.8 per cent increase in agricultural costs of production.*[48]

The piece-meal approach in sections 2 through 6 put together in this section, to estimate direct and indirect use of fossil fuels in agriculture can be useful to identify and assess the repercussion of an external stimulus namely, a perturbation in price. In practice, full assessment of the indirect impact for the later round effects could quickly grow in complexity.

For example, given the extant weight in WPI (*Table 11*), a 10 per cent increase in price of diesel could raise WPI by 0.47 percentage points (Anand, 2012). Analogously, a 10 per cent increase in prices of all mineral oils could translate to a first round increase of 0.94 percentage points in WPI inflation.

[48] The multiple 5.0 is the average of 4.4 and 5.6 respectively for 2009-10 and 2010-1. The direct or first round impact in 1998-9 was estimated as 0.37 per cent. Using the multiple for that year as 7.9 (column 7, table 10) the total impact would have been at least (0.37*7.9=) 2.9 per cent, close to the figure estimated for 2009-10 / 2010-1.

Table 12: Weight in WPI of Major Groups (per cent)

Major Group / Commodities	2004-5	
Primary Articles, *of which*	20.12	
Food Articles		14.34
Non-Food Articles		4.26
Minerals		1.52
Fuel and Power, *of which*	14.91	
Mineral Oils, *of which*		9.36
High Speed Diesel	4.67	
Manufactured Products	64.97	

Source: http://eaindustry.nic.in/WPI_Manual.pdf

Farm products (primary articles including food and non-food) carry a weight of 18.6 (out of 100) in the WPI (*Table 12*). Then, a 10 per cent increase in fuel prices that could raise average cost of farming by about 2.8 per cent or more, could in turn raise the WPI by another 0.52 (=18.6*2.8/100) per cent or more, and so on.

In the next section, we take a different approach and make use of input-output (I-O) tables for the Indian economy for two differing years to assess the total effect in an integrated system. This has an advantage in that it assesses the overall impact of changes, both in (a) technical use and (b) relative prices.

8. Analysis of I-O transactions in India

We analyse I-O tables for a systematic approach to decipher some relevant comparative statics for 1998-9 and 2007-8. The commodity * commodity I-O tables, balanced under the industry technology assumption,[49] are utilised to assess the system-wide impact of an increase in price of fossil fuels. This approach is relatively less inhibiting for short-term analysis, when rigidity of production technology may be a fair assumption.[50] In particular, the I-O tables may be convenient for such *mutatis mutandis* analysis at an aggregated level.

The systems of quantity (output) and price (input) equations (relations) for different sectors could be represented conveniently in a matrix form. However, 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

[49] 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

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

therefore, the sector classification accommodates for wide divergence in prices and quality of apparently similar products. Moreover, units of measurement should be identical for ease of comparability across sectors. Thus, economy-wide I-O tables are presented as value transactions $\{c_{ij}\}$ among sectors and the national currency is utilised as the numeraire or the comparative unit.

For example, the co-efficients $\{a_{ij}\}$ in the Indian I-O transactions table are derived by dividing the respective cell values $\{c_{ij}\}$ with the corresponding column total, that is,

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

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. Note that this representation is especially convenient for current analysis.

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.[51] Then, $x = Ax + f$ denotes the output relations, where, x is the output vector, Ax represents intermediate use, and f is the vector of final demand. Rearranging the terms including x on LHS, and pre-multiplying with $[I - A]^{-1}$, one gets, $x = [I - A]^{-1} f$ where, I is an identity matrix of order n.

Similarly, let p and v respectively be vectors of producer prices and co-efficients of value added for sectors of the Indian economy. Further, let v include the vector of indirect taxes.[52] In particular, under a system of tax on value-added with full forward shifting of taxes then, $p' = p'A + v'$ represent the input relations. After rearrangement of terms containing p' on the LHS and post-multiplication with $[I - A]^{-1}$, we have $p' = v'[I - A]^{-1}$.

The matrix $[I - A]^{-1}$ is the Leontief inverse matrix. Elements of the Leontief inverse matrix capture both the direct and indirect effects of any change in the exogenous vectors f and v. Let $[I - A]^{-1} = R = \{r_{ij}\}$, where r_{ij} is the i, j^{th} element of the Leontief inverse. Because of strict linearity in quantity relations, $r_{ij} = \delta x_i / \delta f_j$, that is the i, j^{th} element of the Leontief inverse is the

[51] Upper case letters denote matrices, while small case letters denote column-vectors and indices, ' denotes a row vector. 'n' equals 115 and 130 respectively in 1998-9 and 2007-8.
[52] This could be alternatively, interpreted as the proportion of value added from government factor.

partial derivative of x_i with respect to f_j. Similarly, because of strict linearity in price equations, $r_{ij} = \delta p_j / \delta v_i$, that is the i, j^{th} element of the Leontief inverse is the partial derivative of p_j with respect to v_i.

We utilise this mathematical construct in this exercise.[53] Therefore, if v_i increases by one unit – say, on account of increase in tax on i^{th} commodity, while taxes and value added in all other sectors remains unchanged – the total effect on the productive system, or the increase in the price of all sectors, is captured by the expression $\Sigma_j r_{ij}$.[54] Thus the row sum of the Leontief inverse shows the direct and indirect effects on the economy of a unit change in value addition for the sector shown at the head of row. Similarly, $\Sigma_i r_{ij}$, i.e. the column sum of the Leontief inverse, shows the total effect on the j^{th} sector when value added in each sector increases by unity.

The 2007-8 I-O tables are available for a 130-sector classification.[55] But, for our purpose, we collapse the 130 sectors onto three sectors representing (a) farming,[56] (b) fossil fuels,[57] and (c) rest of economy.[58] *Table 13* gives the matrices of coefficients for balanced 3-sector (commodity*commodity) transactions and its Leontief inverse in 1998-9 (Panel A and B) and 2007-8 (Panel C and D) for the Indian economy.

[53] An analogous interpretation may be offered for final demand and output analysis.
[54] Recall that there is full-forward shifting of taxes. Alternatively, in case of commodities with administered prices, this may be interpreted as a unit increase in administered price, in turn affected by an increase in taxation of an equivalent magnitude.
[55] The 1998-9 I-O tables were compiled for 115 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
[56] This consists of 26 (out of 130) sectors from 001 (paddy) to 026 (fishing).
[57] There are five sectors in this group coal and lignite (023), natural gas (024), crude petroleum (025), petroleum products including LPG (063), and coal tar products (064).
[58] There are 99 sectors in *rest of economy*.

Table 13: Input-Output Co-efficients and Leontief Inverse Matrices

Panel A	**1998-9 C*C Co-efficients (a_{ij})**			**Panel B**	**1998-9 Leontief Inverse (r_{ij})**		
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	**2007-8 C*C Co-efficients (a_{ij})**			**Panel D**	**2007-8 Leontief Inverse (r_{ij})**		
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

Source: Authors own computations

As described, the element a_{21} (in the C * C co-efficient matrix) is the input of fossil fuel in every rupee of farm produce. In the year 1998-9, this constituted 0.52 per cent of the total value of farm produce. This increased to nearly one (0.98) per cent in 2007-8 (trace the downward directing vertical arrow in *Table 13*).[59] This resonates with the contention in *section 4* that intensity of direct use of fossil fuels on farms has increased over years. Thus, subject to assumptions underlying sectoral aggregation, estimates from I-O analysis suggest that intensity of fossil fuels used directly on farms may have grown almost 1.9 (= 0.98 / 0.52) times between 1998-9 and 2007-8. Compare this with close to 1.5 times increase (from 3.7 to 5.6 per cent) between 1998-9 and 2009-10 (estimated from *Tables 6 & 7* in *section 4*).

From I-O analysis it appears that fossil fuels directly used as input into farming has a significantly lower proportion than the simple average utilised in the preceding sections. But, the rise in intensity over years is steeper. At least two straight-forward reasons may be offered for this divergence, (a) the all-crop averages in *table 6* and *7* is a simple average for differing (selected) crops,[60] (b) the selected crops mentioned in *tables 6* and *7* constitute less than 44 per cent of total farm output.[61]

There is also some resonance in results derived from I-O analysis depicted in *Table 13* and the discussion in *section 7*. Analysis of Leontief inverse matrix

[59] The coefficients (a_{ij}s) are multiplied with 100 to convert them into percentage terms.
[60] One could use a weighted average with output proportions as assigned weights for the differing crops.
[61] In 1998-9 these constituted less than 40 per cent of farm output.

in *Table 13* (*cf. Panel A and B*) suggests that the multiple[62] for total to direct (r_{ij} / a_{ij}) effect of fossil fuel on value in farming was about 3.99 (= 0.020639 / 0.005173) in 1998-9 (trace the upper horizontal dashed arrow in *Table 13*). This result is in consonance with the proposition in the preceding section that the relatively slower price increase of fuel and power (compared to food prices) should depress the technical or quantity multiple estimated at 7.9 for 1998-9.

In contrast, the price of fuel and power in 2007-8 had risen relatively more steeply than price of food articles. This was expected to aggravate the technical or quantity multiple of 5.0. As may be seen from *table 13* (*cf. Panel C & D*) the ratio for total to direct effect rose to 6.70 (= 0.065810 / 0.009826) in 2007-8 (trace the lower horizontal dashed arrow in *Table 13*). This also corroborates the assertion made in section 2 that, *intensity*[63] *of fossil fuels used in farming has risen*.

9. Crop-specific differences in total effects: Implications for farm policies

This section supplements the aggregate-level analysis with a discussion on crop-specific differences. The *farming* group is re-expanded into 15 sectors while retaining the aggregate *fossil fuel* sector and *rest of economy*. *Table 14* presents the direct input (*column 2*) and Leontief inverse (*column 3*) coefficients for this 17-sector Indian economy. The ratio of the two coefficients is shown as multiple in *column 4*.

[62] 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}).
[63] The proportion of value of a commodity contributed by the value of fossil fuels input.

Table 14: Co-efficients for Direct and Total Effects of Price Change of Fossil Fuels, 2007-8

Sectors	Direct (a_{ij})	Total (r_{ij})	Total / Direct (r_{ij} / a_{ij})
(1)	(2)	(3)	(4) = (3) / (2)
Paddy	0.014659	0.110664	7.5
Wheat	0.011218	0.081323	7.2
Jowar	0.023347	0.113257	4.9
Bajra	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

Source: Authors own computations

The average multiple[64] 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.[65] 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 the proposals relating to minimum support prices of farming output. In turn this

[64] 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 8, 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 (unweighted) average of the multiples (as shown in *column 4* of *table 14*) 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.

[65] 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 8).

would influence the costs relating to the policy on food security and food subsidy. This is however, beyond the scope of extant analysis.

10. Summary and conclusions

Inadequacy of extant evidence on the likely economic impact of an upward revision in fossil fuel prices has emboldened a strong political opposition (or fostered only a weak constituency). Utilising economy-wide linkages based on input-output tables for the Indian economy, this paper musters some evidence that the perception of strong adverse (inflationary) impact may not be unfounded.

Production technology choices are shaped by the macro and micro policies. It appears that the extant policy environment has intensified fossil fuel use, but relatively more sharply in case of agriculture. This is likely to have continued relevance for maintaining balance in the cross-subsidising scheme of pricing fossil fuels.

Fossil fuels have strong forward linkages with the power and fertiliser sectors. Increase in fossil fuel prices is likely to have strong implications for continuing with the extant policies on fertiliser and power subsidies. These are likely to aggravate the propagation of stress on public resources.

An increase of (say) 10 per cent in fossil fuel prices that may raise direct input cost of farming, on an average by 0.56 per cent (*table 7, section 4*), could impact total farming costs by about 3.75 (= 6.7 * 0.56) per cent. In turn, this alone could add 0.70 percentage points to WPI based inflation. Estimates from a three-sector model for the Indian economy suggest that the increase in WPI based inflation could exceed 4.3 percentage points (*cf.* footnote 64).

Thus, rise in fossil fuel prices could manifest in higher inflation in farm-output prices than what is normally portrayed in the literature. The cost-push effect may be aggravated by the existence of demand-pull factors from growth in incomes. It is likely to raise the cost of implementing the policy on food subsidy and food security.

It is only appropriate to add a caveat that this is essentially a static exercise based on input-output coefficients. Between 1998-9 and 2007-8, the forward linkage of fossil fuels with the remainder of Indian economy has aggravated. But, it could also weaken in future. Technological forecasting to enable such analysis is far beyond the scope of this paper.

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Appendix

Table A: Operational Cost of Machine Labour for Different Crops, Maximum of Average and Median for Reporting Provinces (in Per Cent of Total Cost of Production per Hectare)

Crop	Year	Number of States	Operational Cost of Machine Labour (per cent)				
			Min.	Max.	Avg.	Med.	Max. of 6 & 7
1	2	3	4	5	6	7	8
Sugarcane	2010-1	7	1.0	8.7	3.0	2.2	3.0
	1998-9	5	2.2	10.2	7.1	7.1	7.1
Wheat	2010-1	13	5.3	15.1	12.1	13.5	13.5
	1998-9	6	7.0	11.2	9.7	10.5	10.5
Barley	2010-1	2	12.5	13.0	12.8	12.8	12.8
	1998-9	2	10.3	10.8	10.6	10.6	10.6
Gram	2010-1	10	6.2	15.2	11.0	10.8	11.0
	1999-00	4	4.7	12.1	8.7	9.1	9.1
Lentil	2010-1	5	3.5	19.7	10.7	10.9	10.9
	1998-9	2	7.5	9.9	8.7	8.7	8.7
Rapeseed & Mustard	2010-1	8	2.6	13.4	9.3	10.4	10.4
	1998-9	6	0.2	14.8	10.1	11.1	11.1
Safflower	2010-1	2	0.2	6.8	3.5	3.5	3.5
	1998-9	1	1.1	1.1	1.1	1.1	1.1
Paddy	2009-10	18	2.8	15.8	8.4	8.5	8.5
	1998-9	9	1.0	11.3	5.1	5.1	5.1
Cotton	2009-10	10	1.5	8.4	4.6	4.6	4.6
	1998-9	4	4.6	9.4	6.6	6.2	6.6
Jowar	2009-10	6	6.0	15.8	9.8	8.5	9.8
	1998-9	4	2.4	11.8	5.4	3.7	5.4
Bajra	2009-10	6	7.8	13.0	10.9	10.9	10.9
	1998-9	4	3.2	12.7	7.4	6.9	7.4
Maize	2009-10	10	0.0	12.5	7.6	7.7	7.7
	1998-9	5	1.5	6.4	3.4	2.8	3.4
Ragi	2009-10	4	0.5	6.2	2.2	1.0	2.2
	1998-9	3	0.0	4.1	1.9	1.6	1.9
Tur (Arhar)	2009-10	9	0.9	10.5	7.0	7.0	7.0
	1998-9	6	0.0	5.0	3.0	3.5	3.5
Moong	2009-10	5	1.1	14.9	8.1	10.5	10.5
	1998-9	3	0.7	5.3	3.1	3.2	3.2
Urad	2009-10	8	1.0	21.1	10.7	9.8	10.7
	1998-9	3	0.0	6.3	3.6	4.6	4.6

Crop	Year	Number of States	Operational Cost of Machine Labour (per cent)				
			Min.	Max.	Avg.	Med.	Max. of 6 & 7
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Groundnut	2009-10	6	2.8	6.9	4.6	4.2	4.6
	1998-9	3	0.1	4.5	2.0	1.8	2.0
Soyabean	2009-10	3	9.8	13.5	11.7	11.8	11.8
	1998-9	3	4.9	11.1	8.3	8.8	8.8
Sunflower	2009-10	3	6.3	8.5	7.4	7.2	7.4
	1998-9	3	3.2	7.2	4.9	4.4	4.9
Sesamum	2009-10	5	1.8	8.5	5.7	6.3	6.3
	1998-9	5	0.0	7.2	3.7	3.9	3.9
Nigerseed	2009-10	1	3.7	3.7	3.7	3.7	3.7
	1998-9	1	0.0	0.0	0.0	0.0	0.0
Jute	2009-10	3	0.4	3.1	1.9	2.2	2.2
	1998-9	3	1.1	2.5	1.9	2.0	2.0
VFC Tobacco	2008-9	1	19.1	19.1	19.1	19.1	19.1
	1998-9	1	18.8	18.8	18.8	18.8	18.8