Energy Input Use and CO_2 Emissions in the Major Wheat Growing Regions of India*

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ABSTRACT

The structural and technological changes that have taken place over the past several decades have resulted in an increased use of direct and indirect energy inputs in Indian agriculture. In particular, the substitution of capital for labour has increased the reliance of agriculture on non-renewable energy use.

Increased wheat production in India has been achieved through the expanded use of increasingly sophisticated inputs, such as farm machinery, fertilizers, herbicides, and irrigation. All these involve the use of commercial energy. The use of fossil fuel in the agriculture industry contributes to the overall Greenhouse emissions.

This study estimates the impact on CO_2 emissions from two policy options: (i) the increase in price of direct energy inputs, and (ii) the increase in price of indirect energy inputs. These impacts, in the short run, largely depend upon the elasticities of substitution between energy and other farm inputs, which, in turn, are determined by the current production technology.

The results indicate that substantial reductions in CO_2 emissions cannot be achieved. The increase in fertilizer prices has a larger overall emission reduction than increase in the price of direct energy inputs. The non price measures like Resource Conservation Technologies and direct restrictions on input use could be the effective options.

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Agricultural production and input use in agriculture has recorded remarkable growth in the post Green Revolution period. Wheat production, in particular, has had a dramatic increase in the use of fertilizers and mechanical power. There has been a substantial increase in the use of diesel and electric power for irrigation and other agricultural operations.

The cost of energy inputs and environmental concerns from use of these inputs are of concern in Indian agriculture. Increased wheat production in India has been achieved through the expanded use of increasingly sophisticated inputs, such as farm machinery, fertilizers, herbicides, and irrigation. All these involve the use of commercial energy. Although there has been a relatively small decline in labour use in wheat production[1], the increased use of capital and to some extent the substitution of capital for labour has increased the reliance of agriculture on non-renewable energy resources.

The concentration of CO_2 and other green house gases (GHG) in the atmosphere has been rising from historical levels, primarily due to fossil-fuel burning and land-use changes. These gases have the potential to trap energy from the sun, which may result in global warming, and this has sparked a world-wide concern that emissions of these gases should be reduced below the 1990 levels by the year 2012 (Kyoto Protocol). The international community has recognized the need to stabilize/reduce CO_2 and other Greenhouse gases emission. All are aware of the fact that something needs to be done to protect the environment. Developed and developing countries, however, have differing views on the approach to be taken.

It is generally accepted that voluntary measures, to address environmental concerns, should be given priority but could also involve the use of economic instruments, such as energy taxes, carbon taxes, and the removal or redirection of subsidies. These measures can be used as tools to change the current incentive structure and, hence, the energy-use patterns.

[1]Bhatia, M. S. “Input Use Efficiency in Wheat Production In India”, Agricultural Situation in India, August, 1992 pp. 339-344.

Any change in taxes or subsidies that targets energy use is expected to alter the consumption patterns via their impact on relative prices. This, in turn, would affect production costs and input allocation decisions in agriculture. The magnitude of these impacts depends upon the substitution possibilities between energy, energy-based, and non-energy inputs that are employed in agricultural production. An analysis of the impacts of price changes on agricultural energy use requires information on substitution possibilities amongst the factors of production and on own- and cross-price elasticities of demand for each input.

In India, research on substitution of energy and non-energy inputs in agriculture has been rather limited. Paul and Mehta (1991), used time series data from 1960-83 and estimated the substitution elasticity for four inputs, land, labour, capital, and fertilizer and other inputs. These elasticities were calculated for the entire country and are useful to study the impacts of various policies that change relative prices of inputs used in agriculture.

This study assessed the impact on CO_2 emission from two policy options: (i) the increase in price of direct energy inputs, and (ii) the increase in price of indirect energy inputs.

In order to fulfill these objectives, the estimates have been made for: (i) the current levels of CO_2 emissions associated with agricultural production, and use the own and cross-price elasticities of input demands, and the elasticities of substitution for inputs reported in the paper by Paul and Mehta (1991) to analyze the two policy options.

Energy Use in the Major Wheat Producing States

Background

The structure of agriculture in India has changed dramatically in the post green revolution period. The major wheat growing regions, Haryana, Madhya Pradesh, Punjab and Uttar Pradesh account for nearly 78 percent of total wheat production in India. These states have adopted high yielding varieties and mechanical technologies in agricultural production.

Energy use in agriculture can be divided into two categories: direct energy and indirect energy. Direct energy, the energy required to power machinery, includes refined petroleum products and electricity. Indirect energy is the energy embodied in other inputs of production, such as fertilizers, pesticides and herbicides.

The increased level of mechanization and changing production techniques have resulted in an increased use of both direct and indirect energy inputs. For the year 1981-82, the estimated energy use in India for production of six major crops; paddy, wheat, oilseeds, cotton, pulses, and sugarcane was 501,946 TeraJoules. Haryana, Madhya Pradesh, Punjab, and Uttar Pradesh accounted for nearly 50 percent of the energy use[2].

Moulik et al, 1988 used the 1981-82 estimates of energy use to project the demand for energy in the year 1999-2000. The demand for energy for the year 1999-2000, for the country, in the production of the six major crops was 928,792 GJ, 85 percent increase over the 1981-82 year. The demand for energy in Haryana was 74,970 TeraJoules, for Madhya Pradesh it was 25,862 TeraJoules, for Punjab it was 157,231 TeraJoules, and for Uttar Pradesh it was 211,278 TeraJoules in the year 1999-2000.

Direct Energy Use

Petroleum products and electricity constitute the bulk of direct energy use in the four states. Table1 shows the direct energy used (in TeraJoules) in the four states. Conversions from energy quantities to standard energy measures were made based on the following assumptions:

[2]Moulik, T. K., B. H. Dholakia, and P.R. Shukla, "Energy Demand for Agriculture in India in the Year 2000", Indian Institute of Management, Ahmedabad, 1988.

the energy content of all refined petroleum products is 38,680 KJ per litre and electricity contains 3.6 TeraJoules per GWH (Statistics Canada, *Energy Statistics Handbook, 1994*).

Table 1: Energy Content of Direct Energy Used in the Major Wheat Growing Regions in India, in TeraJoules

Refined Petroleum (A)	**1981-82**	**1989-90**	**1994-95**	**1999-2000**
Haryana	3,414	3,596	4,340	5,243
Madhya Pradesh	1,981	2,332	2,573	2,843
Punjab	8,847	9,494	11,272	13,469
Uttar Pradesh	20,406	26,409	32,994	41,192
Sub-total (A)	34,649	41,831	51,179	62,747
% of Total Direct Energy	**65.82**	**63.70**	**64.01**	**64.27**
Electricity (B)				
Haryana	3,339	4,652	5,698	7,004
Madhya Pradesh	1,134	1,422	1,629	1,865
Punjab	5,357	6,549	7,368	8,306
Uttar Pradesh	8,160	11,211	14,076	17,708
Sub-total (B)	17,990	23,834	28,771	34,883
% of Total Direct Energy	**34.18**	**36.30**	**35.99**	**35.73**
Total (A+B)				
Haryana	6,753	8,248	10,038	12,247
Madhya Pradesh	3,115	3,754	4,202	4,708
Punjab	14,204	16,043	18,640	21,775
Uttar Pradesh	28,566	37,620	47,070	58,900
Total Direct Energy	**52,638**	**65,665**	**79,950**	**97,630**

Source: Calculations based on data obtained from, "Energy Demand for Agriculture in India in the Year 2000", by T.K. Moulik, B.H. Dholakia, and P.R. Shukla, IIM, Ahmedabad, 1988.

Diesel fuel is primarily used for farm machinery operations, transportation, and irrigation. Electricity is mostly used for irrigation. There has been a 50 percent increase in the demand for direct energy inputs for the period 1981-82 to 1999-2000. Sixty four percent of the total direct energy use as in the form of refined petroleum product. Punjab and Uttar Pradesh account for a major share of direct energy use.

Estimates for 1999-2000 show that refined petroleum products constitute nearly 43 percent of direct energy use in Haryana. In absolute terms the use of direct energy has almost doubled, the composition of energy demand has remained fairly stable.

In Madhya Pradesh and Punjab, refined petroleum products constitute nearly 60 percent of direct energy use in agriculture. The direct energy use over the 1981-82 to 1999-2000 has increased by over 85 percent.

In absolute terms, the use of electricity in total direct energy use in Haryana and Uttar Pradesh has doubled. In Madhya Pradesh and Punjab, the use of both refined petroleum product and electricity had a significant increase. The total direct energy use for the year 1999-2000, in Uttar Pradesh was more than double the base year estimate of 1981-82. Refined petroleum product constitutes 70 percent of total direct energy use in Uttar Pradesh.

Carbon Emissions from Direct Energy Use in Agriculture

The calculation of carbon emissions from direct energy use in agriculture has to take into account two aspects. First, the burning of fossil fuels and natural gas release CO_2 directly into the atmosphere. Second, an input like electricity does not release CO_2 when it is used, but the inputs that are used to generate electrical energy release CO_2. Therefore, to calculate carbon emissions, the energy content of inputs must be broken down by the percentage of energy types embodied in each specific input. It is estimated that carbon emissions released into the atmosphere from burning liquid fuels, natural gas, and coal are 22.29 kg C per GJ, 13.78 kg C per GJ, and 24.65 kg C per GJ, respectively (Marland, 1990). These were used as conversion factors to calculate total CO_2 emissions in agriculture.

It is assumed that the electricity generation in each state uses 70 percent coal, 5 percent natural gas, and 25 percent hydro. The calculation of emissions from electricity use in agriculture is based on the ratio of coal and natural gas used in the generation process. It is assumed that hydro sources do not release CO_2 and they have, therefore, not been factored into the calculations. It is further assumed that there has been no change in these proportions over the reported period.

The carbon emission, in all the four states, from generating one gigajoule of electricity is, therefore 17.9440 kg C. These per unit emissions were then multiplied by the total electrical energy used in agriculture to arrive at the CO_2 emissions from farm electricity use.

Table 2 summarizes the results of the estimated CO_2 emissions from the direct energy use in agriculture. Refined petroleum is the greatest contributor to total CO_2 emissions (70 percent) whereas electrical energy use contributes 30 percent of total CO_2 from direct energy use. The Uttar Pradesh and Punjab contribute more than 80 percent of CO_2 emissions from Direct energy use.

Table 2: CO_2 Emissions from Direct Energy Use in the Major Wheat Growing Regions of India (tonnes of C)

Refined Petroleum (A)	**1981-82**	**1989-90**	**1994-95**	**1999-2000**
Haryana	76,088	80,155	96,738	116,861
Madhya Pradesh	44,152	51,987	57,361	63,375
Punjab	197,197	211,623	251,243	300,220
Uttar Pradesh	454,866	588,655	735,446	918,166
Sub-total (A)	772,303	932,420	1,140,788	1,398,622
% of Total	**70.52**	**68.56**	**68.84**	**69.08**
Electricity (B)				
Haryana	59,916	83,470	102,249	125,686
Madhya Pradesh	20,352	25,522	29,217	33,470
Punjab	96,126	117,509	132,218	149,040
Uttar Pradesh	146,419	201,176	252,580	317,755
Sub-total (B)	322,813	427,677	516,264	625,951
% of Total	**29.48**	**31.44**	**31.16**	**30.92**
Total (A+B)				
Haryana	136,004	163,625	198,987	242,547
Madhya Pradesh	64,504	77,509	86,578	96,845
Punjab	293,323	329,132	383,462	449,260
Uttar Pradesh	601,285	789,831	988,026	1,235,921
Total	**1,095,116**	**1,360,097**	**1,657,053**	**2,024,573**

Indirect Energy Use

Indirect energy refers to the energy content of farm inputs, such as fertilizers, herbicides, farm buildings, and machinery. In this study, the term "indirect energy" has been used narrowly to include only fertilizers and farm chemicals. There are two reasons for this: first, estimating the energy content of farm machinery and buildings is too complicated, and second, the energy content of these inputs, like sunk costs, does not vary with the production decisions.

Fertilizers and herbicides are the most widely used as indirect energy inputs. The energy content of these inputs varies by the type of fertilizers and herbicides. The energy invested in producing, storing, and transporting fertilizers is assumed to be 60,700 KJ per kilogram of nitrogen, 12,560 KJ per kilogram of phosphate, and 6,700 KJ per kilogram of potash. The breakdown of energy in nitrogen fertilizer is 90 percent natural gas, 5.2 percent liquid fuels, and 4.8 percent electricity. The energy embodied in phosphate is 47.4 percent electricity, 26.7 percent liquid fuel, and 25.9 percent natural gas. Potash contains 42.1 percent electricity, 31.3 percent liquid fuel, and 26.7 percent natural gas (Pimentel, 1980., Lockeretz, 1980).

Table 3 summarizes the fertilizer use, converted to energy content for the four states. Most of the indirect energy use was associated with nitrogen sharing almost 85 percent followed by phosphate fertilizers using about 13 percent of total indirect energy use in Agriculture. The use of potash fertilizer is limited. The calculations of energy content from fertilizer use assume that 50 percent of all nitrogen fertilizers consumed was urea, and the other 50 percent was ammonium nitrate.

Table 3: Energy Content of Fertilizers Use in the Major Wheat Growing Regions in India, in TeraJoules

Nitrogen (A)	**1981-82**	**1989-90**	**1994-95**	**1999-2000**
Haryana	14,154	19,588	23,705	28,585
Madhya Pradesh	5,771	7,553	9,017	10,825
Punjab	38,393	51,857	61,376	72,672
Uttar Pradesh	37,178	51,711	80,103	71,869
Sub-total (A)	95,496	130,709	174,201	183,951
% of Total	**86.61**	**86.48**	**85.24**	**85.29**
Phosphate (B)				
Haryana	2,286	3,178	4,021	5,125
Madhya Pradesh	557	765	980	1,256
Punjab	5,750	7,964	10,040	12,653
Uttar Pradesh	5,048	6,909	12,920	10,279
Sub-total (B)	13,641	18,816	27,961	29,313
% of Total	**12.37**	**12.45**	**13.68**	**13.59**
Potash (C)				
Haryana	345	476	573	690
Madhya Pradesh	56	79	92	107
Punjab	151	230	293	375
Uttar Pradesh	568	841	1,245	1,237
Sub-total (C)	1,120	1,626	2,203	2,409
% of Total	**1.02**	**1.08**	**1.08**	**1.12**
Total Fertilizer				
Haryana	16,785	23,242	28,299	34,400
Madhya Pradesh	6,384	8,397	10,089	12,188
Punjab	44,294	60,051	71,709	85,700
Uttar Pradesh	42,794	59,461	94,268	83,385
Total	**110,257**	**151,151**	**204,365**	**215,673**

Source: Calculations based on data obtained from, "Energy Demand for Agriculture in India in the Year 2000", by T.K. Moulik, B.H. Dholakia, and P.R. Shukla, IIM, Ahmedabad, 1988.

Carbon Emissions from Indirect Energy Use in Agriculture

The use of fertilizer input, like electrical energy, does not release carbon directly but the inputs embodied in the manufacturing process contribute to CO_2 emissions. CO_2 emissions from fertilizer use are calculated based on the types of embodied energy. Nitrogen is the dominant source of CO_2 emissions among the three fertilizers with almost 85 percent of the total fertilizer energy derived by the nitrogen (Table 3), and almost 87 percent of the total CO_2 emissions from fertilizer use associated with nitrogenous fertilizers (table 4). Like high carbon emissions from direct energy use, the Punjab and Uttar Pradesh also release about 75 percent of total carbon emissions from indirect energy use.

Table 4: CO_2 Emissions from Fertilizer Use in the Major Wheat Growing Regions of India (tonnes of C)

Nitrogen (A)	**1981-82**	**1989-90**	**1994-95**	**1999-2000**
Haryana	207,629	287,350	347,740	419,334
Madhya Pradesh	83,225	108,941	130,053	156,120
Punjab	521,102	703,854	833,043	986,369
Uttar Pradesh	504,623	701,875	1,087,231	975,472
Sub-total (A)	1,316,579	1,802,020	2,398,067	2,537,295
% of Total	**88.17**	**88.04**	**87.23**	**86.92**
Phosphate (B)				
Haryana	46,795	65,031	82,292	104,876
Madhya Pradesh	10,041	13,791	17,659	22,638
Punjab	55,410	76,749	96,758	121,945
Uttar Pradesh	48,648	66,581	124,518	99,060
Sub-total (A)	160,894	222,152	321,227	348,519
% of Total	**10.77**	**10.85**	**11.68**	**11.94**
Potash (C)				
Haryana	7,024	9,704	11,673	14,062
Madhya Pradesh	1,025	1,430	1,668	1,956
Punjab	1,629	2,471	3,156	4,031
Uttar Pradesh	6,110	9,045	13,397	13,308
Sub-total (A)	15,788	22,650	29,895	33,357
% of Total	**1.06**	**1.11**	**1.09**	**1.14**
Total (A+B+C)				
Haryana	261,448	362,085	441,705	538,271
Madhya Pradesh	94,291	124,162	149,381	180,714
Punjab	578,141	783,074	932,957	1,112,345
Uttar Pradesh	559,381	777,501	1,225,146	1,087,840
Total	**1,493,261**	**2,046,822**	**2,749,189**	**2,919,171**

Impacts of Changes in the Cost of Direct and Indirect Energy Inputs

In this section the short-run impacts of two scenarios were analyzed: (i) the increase in cost of direct energy inputs by 10, 20, and 30 percent and (ii) the increase in fertilizer price by 10, 20, and 30 percent. The impacts of these policies on CO_2 emissions were then calculated.

Increase in Direct Energy Price

Table 5 shows the results of a 10, 20, and 30 percent increase in direct energy input price. The response to this change in price results in the demand for all factors of production to change. The changes in CO_2 emissions, however assumed as a result of changes in the use of direct and indirect energy inputs only. Thus the cross price effects of direct and indirect energy inputs were used in the overall changes in CO_2 emissions. The increase in the prices of direct energy inputs by 10 to 30 percent has failed to reduce the carbon emissions even by one percent.

Table5: Impact of an increase in Cost of Direct Energy Input on CO_2 Emissions (tonnes of C)

Direct Energy	1999-2000	10%	20%	30%
Refined Petroleum	1,399	1,382	1,364	1,347
Electricity	626	618	611	603
Total	**2,025**	**2,000**	**1,975**	**1,950**
% change		-1.23	-2.47	-3.70
Indirect Energy				
Fertilizer	2,919	2,935	2,951	2,967
% change		0.55	1.10	1.65
GRAND TOTAL	**4,944**	**4,935**	**4,926**	**4,917**
% change		-0.18	-0.36	-0.53

Note: The calculations used own price elasticity for direct energy input as -0.122 and the cross price elasticity for direct and indirect energy input as 0.055. These elasticity estimates are from the study by Paul and Mehta, 1991.

Increase in Indirect Energy Price

Table 6 shows the results of a 10, 20, and 30 percent increase in indirect energy prices. The results are similar to the ones obtained for the direct energy input price increase. The percentage reductions are however twice those that are obtained in the direct energy input price increase. The results indicate that substantial reductions in CO_2 emissions cannot be achieved with price manipulations.

Table 6: Impact of an increase in Cost of Indirect Energy Input on CO_2 Emissions (tonnes of C)

Direct Energy	1999-2000	10%	20%	30%
Refined Petroleum	1,399	1,427	1,465	1,498
Electricity	626	639	656	670
Total	2,025	2,066	2,121	2,168
% change		2.01	4.73	7.10
Indirect Energy				
Fertilizer	2,919	2,853	2,788	2,722
% change		-2.26	-4.48	-6.75
GRAND TOTAL	4,944	4,919	4,909	4,890
% change		-0.51	-0.71	-1.09

Note: The calculations use own price elasticity for indirect energy input as -0.225 and the cross price elasticity for indirect and direct energy input as 0.201. These elasticity estimates are from the study by Paul and Mehta, 1991.

Non Price Options

The carbon emissions can be reduced up to certain extent by adopting Resource Conservation Technologies (RCT) in Agriculture. Akhtar (2006) reported that resource conservation technologies improve the input use efficiency by 20 to 30 percent which will certainly reduce the carbon emissions also. The use of carbon emitting inputs in agriculture can be curtailed by limiting their supply or restrictions in their use as was done by Punjab Government. The farmers in Punjab have been restricted to grow Paddy before June 10 (Punjab Preservation of Subsoil Water Ordinance 2008) to reduce the energy used for irrigation in summer.

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