Agricultural Economics Research Review
Vol. 27 (No.1) January-June 2014 pp 1-18
DOI: 10.5958/j.0974-0279.27.1.001

Input Subsidy *vs* Farm Technology — Which is More Important for Agricultural Development?

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Abstract

The input subsidy and technology are the two significant factors for the development of agriculture in India. Concerns are often expressed about a decrease or increase in input subsidy and inadequate investment in farm technology development. Policy planners often face the questions like what would happen to output supply, factor demand, agricultural prices and farmer income under alternative input subsidy and farm technology scenarios. and what would be the impact of input subsidy and technological innovation on the welfare of producer and consumer ? To find answer to such questions, empirical unified models for two major cereals — wheat and rice — have been developed and analyzed for input subsidy and farm technology. The study has revealed that technology is the most powerful instrument for neutralizing factor price inflation and safeguarding the interest of producers as well as consumers, while input subsidy has a weak effect on output supply. The study has observed that investments in irrigation, rural literacy, capacity building, research and extension and information flow are crucial to increase supply at a higher growth rate.

Key words: Indian agriculture, input subsidy, farm technology, supply and demand, rice, wheat, TFP

JEL Classification: Q11, Q16, P42, C5

Introduction

Rising costs of farm inputs discourage their use and lead to reduction in commodity supply and profitability of farmers. The decline in supply of commodities raises their prices causing hardships to the consumers. The rise in crop prices should not only counteract the rising input costs but also to leave sufficient margin to the farmers which may be conducive to investment in agriculture. The situation can be corrected by manipulating price and non-price factors through subsidy, investment in irrigation, capital inputs, technology development, market development, etc. This study has been undertaken to develop food crop model with emphasis on rice and wheat, which account for more than 70 per cent of total foodgrains production and are the backbone of India's food security and household nutritional security. An attempt is also made to estimate the producer and consumer core systems for these commodities.

The specific objectives of the study were: (i) to develop factor demand, output supply, income, and consumer demand models for rice and wheat; (ii) to evaluate the effects of price and non-price factors on factor demand, output supply, output demand, prices and farmers' income; (iii) to simulate the model and suggest the adjustments needed in price and non-price factors to attain the specific goals, and (iv) to find out which is more important between input subsidy and technology for agricultural development.

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Methodology

The partial models were designed to simulate the effects of macroeconomic developments and policies on the quantities and prices of commodities produced and factors of production used in commodity production. The models were so designed as to be applied to either individual states or several states linked by national markets for crop output and factor demand. These markets are connected through supply-demand behaviour of producers and consumers. The producer behaviour core consists of factor demand and output supply equations in the product market. The consumer behaviour core consists of demand equations of commodities.

The study has used a simplified version of the unified approach described by Kumar *et al.* (1985). In the unified model, the system consists of factor demand and output supply, output demand and crop net income equations. This model was used to analyze the impact of input subsidies, technology, and demand shifters on prices, supply, demand and income for major food crops, viz. rice and wheat. The policies and program considered were: input subsidies, irrigation investment, agricultural research and input-output policies. The empirical model had several blocks of equations. The first block was producer core system, consisting of factor demand and output supply equations (yield and acreage equations). The second block was of consumer core system containing consumer demand equation and indirect demand equations. The third block was for the TFP response to its sources. All the three blocks of equations were solved simultaneously to build price, supply and demand, and income models to undertake simulation exercise to answer the policy questions like what adjustments are needed in price and non-price factors to attain the specific goals of producer and consumer welfare.

Producer Core System

The theory of profit function (Lau and Yotopoulos, 1972; Chand and Kumar, 1986), or cost function (Binswanger, 1974; Kumar *et al.,* 2010) provides a set of factor demand and output supply equations as:

Factor demand: $X = F(P, p, Z, T)$ …(1)

Output supply: $Q = Q(P, p, Z, T)$ …(2)

where, X is a vector of k variable inputs, P is a vector of crop output prices, p is a vector of variable input prices, Z is a vector of fixed inputs, T is a vector of technology, and Q is a vector of crop output supply. The output supply and factor demand functions are expressed in growth form as:

$$\dot{Q} = E_Q^P \dot{P} + E_Q^p \dot{p} + E_Q^Z \dot{Z} + E_Q^T \dot{T} \quad \ldots(3)$$

$$\dot{X} = E_F^P \dot{P} + E_F^p \dot{p} + E_F^Z \dot{Z} + E_F^T \dot{T} \quad \ldots(4)$$

The dot on a variable indicates the rate of change; E parameters are the elasticities of output supply and factor demand. $Q = [Q_i, Q_w]$ is the output vector for rice and wheat and X = [N, B, M, F, O] is a vector of human labour, bullock labour, machine labour, fertilizer and other inputs, respectively. P = [Pr, Pw] is a vector of rice and wheat price. p = [w, b, m, f, i] is the vector of input prices corresponding to human labour, bullock labour, machine labour, fertilizer and other inputs.

Acreage Response Model

The area response elasticity for rice and wheat was estimated using Nerlove dynamic model (1958) based on the concept of adaptive expectations. The reduced estimable equation was specified as follows:

$$A_t = f(A_{t-1}, P_{t-1}, TFP_{t-1}, \text{State dummy, Period dummy}) \quad \ldots(5)$$

where, A_t is the crop area under cultivation at time t, A_{t-1} is the one year lagged area, P_{t-1} is one year lagged crop price, and TFP_{t-1} is one year lagged TFP index.

TFP Response Model

The issue of sustainability of crop productivity is emerging fast. The productivity attained during the green revolution period has not been sustained in the post green revolution, and has posed a challenge to shift the production function by improving the technology index. It is possible through technology movers, judicious use of natural resources and harnessing of biodiversity. During green revolution era, large investments were made on agricultural research, extension and irrigation development. The total factor productivity (TFP) can be induced by such factors as research, extension, human capital (literacy), irrigation and climate. The data were analyzed with state dummy fixed effects as such specification would knock out

the climate effects. As an input to public investment decisions, it is useful to understand the relative importance of these productivity-enhancing factors in determining productivity growth. Multiple regression analysis was carried out to assess the determinants of TFP. The TFP index was regressed on the following variables:

TFP = f (Research stock, Extension stock, Literacy, Irrigation, State dummy, Period dummy)

where,

Research stock = Total research stock per hectare of crop area;

Extension stock = Total extension stock per hectare of crop area;

Literacy = Rural literacy rate in per cent;

Irrigation = Irrigated area to total crop area in per cent;

State dummy = Name of individual state; and

Period dummy = 1971-80, 1981-90, and 1991-2008.

Following Evenson *et al.* (1999), the research stock variable was constructed by summing up research investment of five-years by assigning weights as 0.2 in year t–2, 0.4 in year t–3, 0.6 in year t–4, 0.8 in year t–5 and 1.0 in year t–6. The extension stock variable was constructed by summing up three years' extension investment by assigning weights as 1.0 in year t–1, 0.8 in year t–2, and 0.4 in year t–3.

Supply Growth Model

Crop area (AREA), total factor productivity (TFP), supply elasticity and input-output price environment are the major sources of supply growth. The supply growth equation for commodity can be expressed as:

$$\dot{S} = E_S^P \dot{P} + E_S^{p_i} \dot{p}_i + C\dot{R}AREA + T\dot{F}P \quad \ldots(6)$$

where,

$\dot{S}$ = Supply growth for the commodity,

E_S^P = Yield response elasticity with respect to the product price,

$\dot{P}$ = Output price growth,

$E_S^{p_i}$ = Elasticity of factor demand for the ith input,

$\dot{p}_i$ = Input price growth of the ith input,

$C\dot{R}AREA$ = Acreage growth of the commodity, and

$T\dot{F}P$ = TFP growth of the commodity.

Income Model

The net income (I) from a crop is given by Equation (7):

$$I = P^*Q(P, p, Z, T) - p^*F(P, p, Z, T) \quad \ldots(7)$$

where,

P = Price of a commodity,

p = Vector of input price [w, b, m, f, i],

F = Vector of input-use [N, B, M, F, O],

w = Wages,

b = Animal labour price,

m = Machine labour price,

f = Fertilizer price,

i = Price of other inputs (irrigation, plant protection, etc.),

N = Human labour-use,

B = Animal labour-use,

M = Machine labour-use,

F = Fertilizer-use,

O = Use of other inputs (irrigation, plant protection, etc.), and

Z = Acreage.

The growth in net income in terms of elasticity can be measured as per Equation (8):

$$\dot{I} = E_I^P \dot{P} + E_I^w \dot{w} + E_I^b \dot{b} + E_I^m \dot{m} + E_I^r \dot{r} + E_I^i \dot{i} + E_I^z \dot{z} + E_I^T \dot{T} \quad \ldots(8)$$

Using the formulae developed by de Janvry and Kumar (1981), different income elasticities were computed using Equations (9) to (16) given in Box 1.

Consumer Core System

Following the consumer demand theory, the commodity demand equations in growth form can be expressed as:

Box 1

$$E_I^P = \frac{PQ}{I}\left(1 - E_Q^{w/p} - E_Q^{b/p} - E_Q^{m/p} - E_Q^{f/p} - E_Q^{i/p}\right) + \frac{WN}{I}\left(E_N^{w/p} + E_N^{b/p} + E_N^{m/p} + E_N^{f/p} + E_N^{i/p}\right)$$

$$+ \frac{bB}{I}\left(E_B^{w/p} + E_B^{b/p} + E_B^{m/p} + E_B^{f/p} + E_B^{i/p}\right) + \frac{mM}{I}\left(E_M^{w/p} + E_M^{b/p} + E_M^{m/p} + E_M^{f/p} + E_M^{i/p}\right)$$

$$+ \frac{rF}{I}\left(E_F^{w/p} + E_F^{b/p} + E_F^{m/p} + E_F^{f/p} + E_F^{i/p}\right) + \frac{iO}{I}\left(E_O^{w/p} + E_O^{b/p} + E_O^{m/p} + E_O^{f/p} + E_O^{i/p}\right) \quad \ldots(9)$$

$$E_I^w = \frac{PQ}{I}E_Q^{w/p} - \frac{wN}{I}\left(1 + E_N^{w/p}\right) - \frac{bB}{I}E_B^{w/p} - \frac{mM}{I}E_M^{w/p} - \frac{fF}{I}E_F^{w/p} - \frac{iO}{I}E_O^{w/p} \quad \ldots(10)$$

$$E_I^b = \frac{PQ}{I}E_Q^{b/p} - \frac{bB}{I}\left(1 + E_B^{b/p}\right) - \frac{wN}{I}E_N^{b/p} - \frac{mM}{I}E_M^{b/p} - \frac{fF}{I}E_F^{b/p} - \frac{iO}{I}E_O^{b/p} \quad \ldots(11)$$

$$E_I^m = \frac{PQ}{I}E_Q^{m/p} - \frac{mM}{I}\left(1 + E_M^{m/p}\right) - \frac{wN}{I}E_N^{m/p} - \frac{bB}{I}E_B^{m/p} - \frac{fF}{I}E_F^{m/p} - \frac{iO}{I}E_O^{m/p} \quad \ldots(12)$$

$$E_I^f = \frac{PQ}{I}E_Q^{f/p} - \frac{rF}{I}\left(1 + E_F^{f/p}\right) - \frac{wN}{I}E_N^{f/p} - \frac{bB}{I}E_B^{f/p} - \frac{mM}{I}E_M^{f/p} - \frac{iO}{I}E_O^{f/p} \quad \ldots(13)$$

$$E_I^i = \frac{PQ}{I}E_Q^{i/p} - \frac{iO}{I}\left(1 + E_O^{i/p}\right) - \frac{wN}{I}E_N^{i/p} - \frac{bB}{I}E_B^{i/p} - \frac{mM}{I}E_M^{i/p} - \frac{rF}{I}E_F^{i/p} \quad \ldots(14)$$

$$E_I^T = \frac{PQ}{I}E_Q^T - \frac{wN}{I}E_N^T - \frac{bB}{I}E_B^T - \frac{mM}{I}E_M^T - \frac{fF}{I}E_F^T - \frac{iO}{I}E_O^T \quad \ldots(15)$$

$$E_I^Z = \frac{PQ}{I}E_Q^Z - \frac{wN}{I}E_N^Z - \frac{bB}{I}E_B^Z - \frac{mM}{I}E_M^Z - \frac{fF}{I}E_F^Z - \frac{iO}{I}E_O^Z \quad \ldots(16)$$

Per-capita Consumer Demand

$$\dot{d} = E_d^p\dot{P} + E_d^{I_c}\dot{I}_c \quad \ldots(17)$$

$P = [P, Ps, Pc]$

$$\dot{d} = E_d^p\dot{P} + E_d^{p_s}\dot{P}_S + E_d^{p_C}\dot{P}_C + E_d^I\dot{I} \quad \ldots(18)$$

Indirect Demand

$$ID = (SEED^* CRAREA + OU)/POP \quad \ldots(19)$$

$$OU = (FEED + WAST + INDUSE)/POP \quad \ldots(20)$$

$$\dot{ID} = s_1 S\dot{E}D + s_1 CR\dot{A}REA + s_2 O\dot{U} \quad \ldots(21)$$

Total Demand

$$\dot{D} = S^* I\dot{D} + (1-S)\dot{d} + P\dot{O}P \quad \ldots(22)$$

where,

P = Price of the i^{th} output,
I_c = Per capita consumer income,
SEED = Seed rate,
CRAREA = Area under crop,
OU = Other uses,
FEED = Feed demand,

WAST = Wastages,

POP = Population,

ID = Indirect demand per capita for seed, feed, wastages and industrial uses,

S = Share of indirect demand in total demand,

s_1 = Share of seed demand in total indirect demand, and

s_2 = Share of other uses in total indirect demand.

The Unified Model

Each supply and demand relationship in every crop market has both endogenous and exogenous variables. In the market, price and quantity of a commodity are determined by its demand and supply. The exogenous shifters, viz. technology movers, population and income growth, indirect demand within domestic and international markets are not determined within the markets *per se*. The equilibrium product prices are determined by equating output supply to its demand for each crop ($S_i = D_{i;}$ I = 1, n). These equations are solved for prices and substituted into supply, demand and income equations. The endogenous variables are expressed as:

P = P (p, Lr, Lw, LIT, RES, EFT, IRR, ID, Ic, POP)

S = S (p, Lr, Lw, LIT, RES, EFT, IRR, ID, Ic, POP)

D = D (p, Lr, Lw, LIT, RES, EFT, IRR, ID, Ic, POP)

I= I (p, Lr, Lw, LIT, RES, EFT, IRR, ID, Ic, POP)

where,

p terms measure the input prices effect, Lr and Lw are the area under rice and wheat, respectively, terms LIT, RES, EFT and IRR are the supply shifters, and ID, Ic, POP are the demand shifters and measure the shifters' influence on policy variables, viz. product price (P), supply (S), demand (D) and farmers income (I). The exogenous shifters play a critical role in the policy model.

These models can be cast in growth rates of the endogenous variables, exogenous variables (shifters) and elasticity of the demand and supply curves in all markets. The model **m**easures the impact on the growth rate of endogenous variables with a small change in the growth rate of shifter variables. The model allows asking questions like what would happen to output supply, factor demand, agricultural prices and incomes under alternative technology change scenario, or what would be the effect of input subsidy and labour-saving technological change on producer and consumer welfare? Empirical unified models for rice and wheat have been developed and analyzed for policy concern in the study.

Results and Discussion

Estimates of Producer Core System

The econometric application of new production theory based on the duality relationship between production function and variable profit / cost function was a major development in generating supply response estimates. Following Binswanger (1974), translog cost function has been used to derive a system of factor demand equations and to estimate factor demand and output supply elasticities (for details *see* Kumar *et al.,* 2010). Information on yield and input-use and their prices were obtained from the records of the "Comprehensive Scheme for the Study on Cost of Cultivation of Principal Crops" of the Directorate of Economics and Statistics, Government of India, for the period 1972-2009.

Input Demand Elasticity

The restricted estimates of the parameters of translog cost function model were obtained by jointly estimating the four factor share equations, viz. human labour, animal labour, machine labour and fertilizer for rice and wheat crops. Most of the restricted estimates were highly significant for all the factor share equations for both the crops. The parameters of share equations, though have little economic meaning, are used to compute the elasticity for factor demand. The input demand elasticities were estimated with respect to own and cross prices for human labour, animal labour, machine labour, fertilizers and other inputs (irrigation, plant protection and others). The factor demand elasticities for rice and wheat crops are given in Table 1. As expected, all own input price elasticities of demand had statistically significant negative signs. The magnitude of factor demand elasticity differed significantly across crops and inputs, depending on the level of agricultural development and technology used.

For rice, the own price elasticity of input demand was estimated to be -0.61 for machine labour, followed by irrigation and plant protection (-0.54), animal labour

Table 1. Estimates of partial elasticities of factor demand for rice and wheat crops, India

Crop inputs	Input prices				
	w/P	b /P	m/P	f/P	i/P
			Rice		
Human labour	-0.2484	0.1847	0.0472	-0.0582	0.0747
t-Value	-11.6	17.7	4.0	-6.0	6.0)
Animal labour	0.6402	-0.4072	-0.0617	-0.0785	-0.0928
t-Value	17.7	-10.9	-2.6	-3.3	-3.6
Machine labour	0.2648	-0.1000	-0.6142	0.1713	0.2781
t-Value	4.0	-2.6	-8.7	3.7	5.5
Fertilizer	-0.2420	-0.0941	0.1268	-0.2137	0.4230
t-Value	-6.0	-3.3	3.7	-5.4	13.1
Other inputs	0.2007	-0.0719	0.1331	0.2734	-0.5353
			Wheat		
Human labour	-0.3055	0.1528	0.0087	0.1625	-0.0186
t-Value	-8.59	8.69	0.28	6.50	-0.57
Animal labour	0.3715	-0.6200	0.1920	-0.2125	0.2691
t-Value	8.69	-13.09	4.06	-4.60	5.43
Machine labour	0.0164	0.1492	-0.3370	0.2216	-0.0502
t-Value	0.28	4.06	-3.46	4.19	-0.48
Fertilizer	0.3093	-0.1664	0.2232	-0.3368	-0.0294
t-Value	6.50	-4.60	4.19	-5.19	-0.44
Other inputs	-0.0233	0.1387	-0.0333	-0.0193	-0.0628

Note: The figures within the parentheses are the corresponding student *t*-statistics
Here, *w* = Wage (₹/hour), *b* = Cost on animal labour (₹/hour), *m* = Cost on machine labour (₹/hour), *P* = Price of commodity (₹/100 kg), f = Cost on fertilizer (NPK) (₹/kg), *i* = Cost on irrigation and other inputs (₹/ha)

(-0.41), human labour (-0.25), and fertilizer (-0.21). The estimates indicate that demand for machine labour is sensitive to its price. On the policy front, a reduction in machinery prices through subsidy is expected to expand mechanization in rice farming and enhance rice productivity. The demand for animal labour, machine labour and Fertilizers is influenced significantly by the change in wages. With a raise in wages, the demand for animal labour and machine labour is likely to increase and for fertilizer-use is likely to decline.

For wheat crop, the animal labour demand is sensitive to animal labour wages. The demand elasticity was estimated to be as high as -0.62 for animal labour, followed by -0.34 each for machine labour and Fertilizers, -0.31 for human labour and was highly inelastic for irrigation (-0.06). Cross price elasticities across machine labour and human labour were positive and significant and indicated the substitutive relationship between human labour and machine labour for rice. A substitutive relationship was observed for animal labour and machine labour for wheat. It was because the mechanized operations are easier for wheat than for rice and are more farmer-friendly.

High animal labour charges will induce a higher use of machine labour as it results in substitution of animal labour with machine labour. In wheat production, the technology being used was such that animal labour could be easily substituted by machine labour. Wheat is an irrigated crop and therefore, irrigation demand is not sensitive to rise in irrigation price. The subsidy on farm machinery and fertilizers would induce higher use of modern inputs and improve farming efficiency and productivity.

Yield Response Elasticities

The yield response elasticities for rice and wheat crops were derived from the factor demand elasticity

Table 2. Yield response elasticity for rice and wheat, India

Prices	Rice	Wheat
Commodity price (P)	0.2249	0.2667
Input price		
Human labour (w/P)	-0.0786	-0.0615
Animal labour (b/P)	-0.0369	-0.1271
Machine labour (m/P)	-0.0335	-0.0336
Fertilizer (f/P)	-0.0155	-0.0347
Other inputs (i/P)	-0.0603	-0.0099

Note: The figures within the parentheses are the corresponding student t-statistics

Here, w = Wage (₹/hour), b = Cost on animal labour (₹/hour), m = Cost on machine labour (₹/hour) P = Price of crop (₹/100 kg), f = Cost on fertilizer (NPK) (₹/kg), i = Cost on irrigation and other inputs (₹/ha)

matrix and the results are presented in Table 2. The yield response elasticities have shown the response of commodity price and input price on supply of rice and wheat. The yield response elasticity with respect to crop output price was estimated as 0.22 for rice and 0.27 for wheat. The input responses were highly inelastic, nearly zero. The crop price had the dominating influence on the supply of commodities and therefore, a positive price policy will enhance food supply.

Acreage Response Elasticities

Following Nerlove's adjustment model, the acreage elasticity with respect to lagged acreage was estimated to be 0.85 for rice and 0.86 for wheat (Table 3). The price of rice has a significant positive impact on its acreage. However, wheat price has not shown a significant effect on its acreage. Technology (TFP) has depicted a positive and significant effect on area under the crop. With the development of technology, the cropping pattern will shift in favour of the major food crops.

Table 3. Acreage response elasticities for rice and wheat, India

Variable	Rice	Wheat
Lagged crop area	0.8530**	0.8610**
Commodity price	0.0494**	-0.0167
TFP	0.0618**	0.0798**

Note: ** Significant at 1 per cent level

Table 4. Elasticity of TFP with respect to sources for rice and wheat, India

Sources of TFP	Rice	Wheat
Rural literacy	0.1221	0.7959
Research stock	0.0443	0.0464
Extension stock	0.0873	-0.0915^{ns}
Irrigated area (%)	0.5842	0.7354

Note: ns=Non-significant coefficient

TFP Elasticities

Multiple regression analysis was carried out to study the factors influencing TFP for rice and wheat crops. The TFP index was regressed on rural literacy, research stock, extension stock and irrigation. The state dummy was also included in the estimation to control fixed effects. A term for interaction between research and extension was also included in the estimation. The elasticity of TFP with respect to various sources at mean level was computed and is given in Table 4.

The results revealed that irrigation, agricultural research, and extension services delivery are the important sources of TFP. These TFP elasticities were used to build the supply model described in the subsequent section. Additional investment on irrigation and rural literacy have been found to be highly productive and rewarding and would go a long way in stepping up TFP in India and will shift the food supply functions upwards.

Supply Elasticities

Using the yield, acreage, and TFP elasticities with respect to their exogenous variables, supply elasticities were derived and are given in Table 5. The supply elasticities with respect to input prices are very low and less than one, the lowest for fertilizer prices and the highest for wages. The commodity supply is not sensitive to fertilizer price. Supply is highly responsive to commodity price. This has obvious implications on the determination of the level of government price support for agricultural output. A 10-per cent raise in the commodity price will induce additional supply of 2.7 per cent for both rice and wheat.

Among non-price factors, the acreage, irrigation, literacy and research are the powerful instruments which need to be simulated to attain supply growth at

Table 5. Supply response elasticities for rice and wheat, India

Sources	Yield response		Acreage response		TFP response		Supply response	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Commodity price	0.2249	0.2667	.0494				0.2742	0.2667
Input price								
Human labour	-0.0786	-0.0615					-0.0786	-0.0615
Animal labour	-0.0369	-0.1271					-0.0369	-0.1271
Machinery labour	-0.0335	-0.0336					-0.0335	-0.0336
Fertilizer	-0.0155	-0.0347					-0.0155	-0.0347
Other inputs	-0.0603	-0.0099					-0.0603	-0.0099
TFP sources								
Rural literacy					0.1221	0.7959	0.1296	0.8594
Research stock					0.0443	0.0464	0.0470	0.0501
Extension stock					0.0873		0.0927	
Irrigated area					0.5842	0.7354	0.6203	0.7941
Supply shifters								
Acreage			0.8530	0.8610			0.8530	0.8610
TFP	1.00	1.00	0.0618	0.0798				

the desired levels. Irrigation, literacy and research are the major sources of TFP growth. A 10-per cent growth in irrigation will increase output supply by 6.2 per cent for rice, and 7.9 per cent for wheat. Rural education also enhances farming efficiency. A 10-per cent raise in education level would induce substitution of traditional labour with machine labour and would result in 1.3 per cent increase in rice production and 8.6 per cent rise in wheat production.

Using commodity supply elasticities with respect to its sources and growth rate of each source, the contribution of each source to supply growth was computed for both rice and wheat crops and the results are presented in Table 6. The output price revealed the supply growth of 45 per cent for rice and of 31 per cent for wheat. The input prices depicted a negative supply growth. The net price effect on supply growth was estimated to be 0.2 per cent for rice and -9.6 per

Table 6. Sources of supply for rice and wheat in India

Sources	Annual growth, %		Supply elasticities		Sources of supply, %	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Commodity price	6.98	7.09	0.2742	0.2667	45.3	31.4
Input price						
Human labour	10.20	10.08	-0.0786	-0.0615	-19.0	-10.3
Animal labour	10.02	10.65	-0.0369	-0.1271	-8.8	-22.4
Machinery labour	8.01	8.01	-0.0335	-0.0336	-6.3	-4.5
Fertilizer	4.40	4.54	-0.0155	-0.0347	-1.6	-2.6
Other inputs	6.58	6.99	-0.0603	-0.0099	-9.4	-1.2
TFP sources						
Rural literacy	2.53	2.88	0.1296	0.8594	7.8	41.0
Research stock	5.24	3.51	0.0470	0.0501	5.8	2.9
Extension stock	2.48	2.62	0.0927		5.4	0.0
Irrigated area (%)	2.53	2.88	0.6203	0.7941	37.2	37.9
Supply shifters						
Acreage	2.16	1.94	0.8530	0.8610	43.6	27.7

Table 7. Income elasticities with respect to input and output price for rice and wheat, India

Price	Income elasticity	
	Rice	Wheat
Output price		
Commodity price	3.4826	3.4172
Input price		
Human labour	-1.0310	-0.6692
Animal labour	-0.6165	-0.5583
Machine labour	-0.2515	-0.3692
Fertilizers	-0.3487	-0.4069
Other inputs (irrigation, etc.)	-0.3539	-0.4136

cent for wheat. The acreage could contribute 43.6 per cent to rice supply growth and 27.7 per cent to wheat supply growth. The TFP sources accounted for about half of the rice supply growth and two-thirds of wheat supply growth. Among the TFP sources in rice supply, irrigation contributed 37 per cent, followed by research and extension (11.2%) and literacy (7.8%). Irrigation and literacy were found to be most important sources for wheat supply growth. Higher investments on irrigation, education and research will induce substantial growth in supply of both these food crops.

Crop Income Elasticities

The elasticities of factor demand and output supply were used to compute crop net income elasticities with respect to input and output prices. These elasticities for rice and wheat crops are presented in Table 7. The income elasticity with respect to output price was found quite high (highly elastic) for both the crops and was estimated to be 3.4 for wheat and 3.5 for rice. The income elasticities with respect to input price like human labour, animal labour, machine labour, fertilizer and irrigation were negative for both the crops. The negative income elasticities were the highest with respect to wages, followed by input price for animal labour, irrigation, fertilizer and machinery. Since paddy is a labour-intensive crop, a raise in human labour wages and animal labour price will have a bigger negative impact on income from paddy than from wheat crop. With a rise in modern input prices, the decline in income will be slightly more in wheat than in rice crop.

From these elasticities, the impact of pure price inflation on crop income can be measured assuming dp/p = dw/w = db/b = dm/m = dr/r = di/i. Since all the relative prices remain constant, the elasticities of output and derived factor demand with respect to relative prices are equal to zero. The elasticity of income with respect to pure price inflation was estimated to be 0.88 for rice and 1.0 for wheat. With a 10-per cent pure price inflation, the income of producer will increase by 8.8 per cent from rice and 10.0 per cent from wheat. Thus, even though pure price inflation is neutral on output level and factor use, it has a strong positive effect on crop income. If there is a 10-per cent inflation in factor price, then to sustain the producer income from crop, there would be a need to increase commodity price by 7.5 per cent for rice and 7.1 per cent for wheat.

Consumer Demand Elasticities

A multi-stage (three-stage) budgeting framework has been used to estimate demand elasticities for cereals (See for methodology Dey, 2000; Dey *et al.*, 2008; Kumar *et al.*, 2011) and the results are presented in Table 8. The income elasticities were less than one for all the cereals (highly inelastic) with magnitude of -0.03, -0.05, -0.06 and -0.04 for rice, wheat, maize and other coarse cereals, respectively. The own-price elasticities were found negative for all the cereals, as expected. For rice and wheat the own price elasticities were more than one — -1.30 and -1.81, respectively. For maize and other coarse cereals, these elasticities were less than unity — -0.45 for maize and -0.77 for other cereals. The own-price elasticities were much higher than expenditure elasticities. The own-price elasticities for demand were negative and cross price elasticities were positive, indicating substitution across cereals types. The implication is that food prices need to be kept low for achieving food security.

Table 8. Consumer demand elasticities for cereals in India

Elasticity	Rice	Wheat	Maize	Other coarse cereals
Income	-0.03	-0.05	-0.06	-0.04
Price				
Rice	-1.30	0.45	0.04	0.00
Wheat	0.57	-1.81	-0.09	-0.03
Maize	2.22	-3.85	-0.45	0.26
Other coarse cereals	-0.09	-0.20	0.07	-0.77

Table 9. Source-wise demand elasticities for rice and wheat, India

Demand sources	Consumer demand		Total demand	
	Rice	Wheat	Rice	Wheat
Price				
Rice	-1.3003	0.5687	-1.2343	0.5062
Wheat	0.4505	-1.8059	0.4276	-1.6073
Maize	0.0356	-0.0943	0.0338	-0.0839
Other coarse cereals	0.0012	-0.0330	0.0012	-0.0293
Income	-0.0305	-0.0512	-0.0289	-0.0455
Indirect sources				
Seed			0.0130	0.0214
Acreage			0.0130	0.0214
Other uses*			0.0378	0.0885
Population	1.00	1.00	0.9492	0.8901

*Other uses = Feed + wastage + industrial uses

Aggregate Demand for Rice and Wheat

The aggregate demand for commodities is influenced by not only price and income factors included in the per capita consumer demand equations, but also by non-price factors (shifters) like population, seed rate, acreage, feed, other industrial uses and trading of commodities. By using the respective shares of consumer demand, seed and other uses (given in Appendix Table 2), the aggregate demand elasticities for commodities were computed and are presented in Table 9.

The own-price elasticity of aggregate demand has been estimated to be -1.23 for rice and -1.61 for wheat. The cross price elasticity of the substitute commodities was positive and less than one. The rice demand elasticity with respect to wheat price has been estimated to be 0.43 and the wheat demand elasticity with respect to rice price has been estimated to be 0.51. With one per cent increase in own price, the decline in demand would be 1.23 per cent for rice and 1.61 per cent for wheat. After adjusting the substitution effect, the net negative impact on demand would be 0.81 per cent for rice and 1.1 per cent for wheat. Income has revealed inelastic negative effect on the aggregate demand for rice and wheat. It explains the observed phenomenon that the per capita cereals consumption is declining over time. Rice and wheat are the strong substitutes for each other in the consumer food basket, whereas maize and other coarse cereals are the weak substitutes for rice and wheat.

Population and indirect demand (seed, feed, wastages and industrial uses) are the strong demand shifters. The aggregate demand elasticity with respect to population was estimated to be 0.95 for rice and 0.89 for wheat, which are both less than one. Thus, their demand will grow at a rate lower than of the population growth, indicating a declining trend in the cereals consumption, as has been observed in the consumer expenditure data collected by NSSO. This decline is basically attributable to the structural shift in the dietary pattern and increasing availability of a wide variety of other food commodities.

Simulated Results of Unified Model

The exogenous variables in the unified model have been classified as price and non-price factors. The price factors included factor price and acreage. The non-price factors included growth in productivity through technology, population, consumer income, trade, and other uses. The technology is influenced by the investment in research, extension, literacy, irrigation, infrastructure, etc. The estimated supply and demand models provide the elasticity of price and non-price factors, indicating the direct partial effects of each one of them on factor demand, output supply and demand and crop net income. At equilibrium, the rice demand growth is equal to rice supply growth ($\dot{D}r = \dot{S}r$) and wheat demand growth is equal to wheat supply growth ($\dot{D}w = \dot{S}w$). By solving these equations simultaneously, the equilibrium price determination equations were derived as per Equations (23) and (24):

$$\dot{P}r = 0.0086\dot{P}m - 0.0040\dot{P}oc + 0.0622\dot{w} + 0.0453\dot{b} + 0.0277\dot{m} + 0.0160\dot{r} + 0.0416\dot{o} - 0.5569\dot{L}R - 0.1375\dot{L}w - 0.2267L\dot{I}T - 0.0394R\dot{E}S - 0.0615E\dot{X}T - 0.5413\dot{R}R + 0.0395ID - 0.2266\dot{I}c + 0.7751P\dot{O}P \quad \ldots(23)$$

$$\dot{P}w = -0.0382\dot{P}m - 0.0154\dot{P}oc + 0.0480\dot{w} + 0.0750\dot{b} + 0.0244\dot{m} + 0.0215\dot{r} + 0.0170\dot{o} - 0.1629\dot{L}r - 0.4479\dot{L}w - 0.4837L\dot{I}T - 0.0358R\dot{E}S - 0.0180E\dot{X}T - 0.5440I\dot{R}R + 0.0545\dot{I}D - 0.0299\dot{I}c + 0.6590P\dot{O}P \quad \ldots(24)$$

where, Pr, Pw, Pm, and Poc are the commodity prices of rice, wheat, maize and other cereals, respectively.

By substituting the equilibrium price of rice and wheat in farm input demand equation (Table 1), commodity demand (Table 9), commodity supply (Table 5) and net crop income (Table 7), the net effects of price and non-price sources on input demand (Table 10) and on supply, demand and net income (Table 11) for rice and wheat were computed. These equilibrium models are useful for commodity market planning as they provide instant results to understand the role of price factors (input prices, subsidy, etc.) and non-price factors, i.e. supply shifters (investment on research, extension, literacy, irrigation, etc.) and demand shifters (population, indirect demand, consumer income, etc.) on food security and welfare of producers (farmers) and consumers. Using the elasticities given in Table 10 and Table 11 and the growth observed in exogenous variables, the sources of growth for factor demand,

Table 10. Factor demand elasticities for rice and wheat in India

Sources	Human labour		Animal labour		Machine labour		Fertilizer		Other inputs	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Price of substitute of rice and wheat										
Maize	0.0021	0.0026	0.0035	0.0054	0.0053	0.0029	0.0018	0.0029	0.0046	0.0005
Other coarse cereals	-0.0010	-0.0012	-0.0016	-0.0025	-0.0025	-0.0014	-0.0009	-0.0014	-0.0022	-0.0003
Input price										
Wages	-0.2329	-0.2865	0.6655	0.4101	0.3030	0.0373	-0.2287	0.3303	0.2340	-0.0193
Animal labour	0.1959	0.1667	-0.3888	-0.5919	-0.0722	0.1645	-0.0844	-0.1512	-0.0476	0.1415
Machine labour	0.0540	0.0171	-0.0504	0.2091	-0.5972	-0.3276	0.1327	0.2325	0.1479	-0.0316
Fertilizer	-0.0543	0.1674	-0.0720	-0.2027	0.1811	0.2269	-0.2103	-0.3314	0.2819	-0.0183
Other inputs	0.0851	-0.0059	-0.0758	0.2949	0.3037	-0.0362	0.4319	-0.0153	-0.5130	-0.0602
Acreage										
Rice	0.8617	-0.1701	0.7732	-0.3453	0.6580	-0.1876	0.8810	-0.1875	0.7019	-0.0350
Wheat	-0.0342	0.9580	-0.0560	0.9147	-0.0845	0.9537	-0.0294	0.9537	-0.0736	0.9914
Supply shifters (TFP sources)										
Literacy	-0.0563	-0.0693	-0.0923	-0.1406	-0.1392	-0.0764	-0.0484	-0.0763	-0.1214	-0.0142
Research stock	-0.0098	-0.0120	-0.0160	-0.0244	-0.0242	-0.0133	-0.0084	-0.0133	-0.0211	-0.0025
Extension stock	-0.0153	-0.0188	-0.0250	-0.0381	-0.0378	-0.0207	-0.0131	-0.0207	-0.0329	-0.0039
Irrigated area	-0.1344	-0.1653	-0.2204	-0.3356	-0.3324	-0.1824	-0.1157	-0.1823	-0.2897	-0.0340
Demand shifters										
Indirect demand	0.0098	0.0121	0.0161	0.0245	0.0243	0.0133	0.0084	0.0133	0.0212	0.0025
Consumer income	-0.0066	-0.0081	-0.0109	-0.0165	-0.0164	-0.0090	-0.0057	-0.0090	-0.0143	-0.0017
Population	0.1925	0.2368	0.3156	0.4805	0.4761	0.2612	0.1656	0.2610	0.4149	0.0487
All sources										
Inputs price	-0.2329	-0.2865	-0.3888	-0.5919	-0.5972	-0.3276	-0.2103	-0.3314	-0.5130	-0.0602
Acreage	0.8275	0.7879	0.7172	0.5695	0.5735	0.7660	0.8516	0.7662	0.6283	0.9564
Supply shifters	-0.2158	-0.2654	-0.3538	-0.5387	-0.5336	-0.2928	-0.1856	-0.2926	-0.4651	-0.0546
Demand shifters	0.1957	0.2407	0.3209	0.4885	0.4840	0.2655	0.1684	0.2653	0.4218	0.0495

Table 11. Price, supply, demand and income elasticities with respect to sources for rice and wheat in India

Sources	Price		Supply		Demand		Income	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Price of substitute of rice and wheat								
Maize	0.0086	-0.0382	0.0024	-0.0102	0.0068	-0.0181	0.0301	-0.1306
Other coarse cereals	-0.0040	-0.0154	-0.0011	-0.0041	-0.0005	-0.0066	-0.0140	-0.0527
Price of inputs								
Wages	0.0622	0.0480	-0.0616	-0.0748	-0.0562	-0.0457	-0.8144	-0.5050
Animal labour	0.0453	0.0750	-0.0245	-0.1071	-0.0238	-0.0976	-0.4587	-0.3021
Machine labour	0.0277	0.0244	-0.0259	-0.0271	-0.0238	-0.0252	-0.1550	-0.2858
Fertilizer	0.0160	0.0215	-0.0111	-0.0289	-0.0105	-0.0265	-0.2931	-0.3334
Other inputs	0.0416	0.0170	-0.0489	-0.0054	-0.0441	-0.0062	-0.2090	-0.3556
Acreage								
Rice	-0.5569	-0.1629	0.7003	-0.0434	0.6306	-0.0201	-0.9393	-0.5566
Wheat	-0.1375	-0.4479	-0.0377	0.7414	-0.0218	0.6718	-0.4789	-0.5307
Supply shifters (TFP sources)								
Literacy	-0.2267	-0.4837	0.0675	0.7304	0.0730	0.6627	-0.7895	-1.6529
Research stock	-0.0394	-0.0358	0.0362	0.0405	0.0333	0.0377	-0.1371	-0.1224
Extension stock	-0.0615	-0.0180	0.0759	-0.0048	0.0682	-0.0022	-0.2141	-0.0614
Irrigated area	-0.5413	-0.5440	0.4718	0.6490	0.4354	0.6004	-1.8850	-1.8590
Demand shifters								
Indirect demand	0.0395	0.0545	0.0108	0.0145	0.0123	0.0208	0.1377	0.1864
Consumer income	-0.0266	-0.0299	-0.0073	-0.0080	-0.0088	-0.0109	-0.0928	-0.1022
Population	0.7751	0.6590	0.2126	0.1758	0.2744	0.2232	2.6992	2.2519
All sources								
Input price	0.1928	0.1859	-0.1720	-0.2171	-0.1584	-0.2013	-1.9303	-1.7818
Acreage	-0.6944	-0.6108	0.6626	0.6980	0.6088	0.6518	-1.4182	-1.0873
TFP	-0.8688	-1.0815	0.6514	1.4151	0.6099	1.2986	-3.0258	-3.6958
Demand shifters	0.7880	0.6836	0.2161	0.1823	0.2779	0.2330	2.7441	2.3360

output price, supply demand, and income were computed for both rice and wheat crops and are shown in Table 12 and Table 13, respectively.

Sources of Input Demand

The own input price has a negative and the acreage a positive effect on factor demand (Table 10). The technology movers improve the input-use efficiency and cut the input-use in producing the same output. Thus, the factor demand elasticities with respect to technology are negative for all the inputs. The elasticities of factor demand with respect to demand shifters are positive and are dominating for population. Among shifters, the acreage and population induce higher use of inputs.

All the sources of input demand at observed growth rates, given in Table 12, revealed that the demand for human labour will increase at the rate of 1.85 per cent for rice and 0.82 per cent for wheat per annum. The animal labour demand will increase at the growth rate of 2.77 per cent for rice and 0.85 per cent for wheat. The demand for machine labour will be higher for wheat than for rice. The fertilizer demand will grow at a high rate of 2.97 per cent for wheat and 1.4 per cent for rice. The demand for irrigation and plant protection chemicals would be higher for wheat than for rice. The

Table 12. Growth by different sources in input use for rice and wheat in India

Sources	Human labour		Animal labour		Machine labour		Fertilizer		Other inputs	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Price of substitutes of rice and wheat										
Maize	0.015	0.018	0.024	0.038	0.037	0.020	0.013	0.020	0.032	0.003
Other coarse cereals	-0.007	-0.008	-0.011	-0.017	-0.017	-0.010	-0.006	-0.010	-0.015	-0.002
Input price										
Wages	-2.376	-2.889	6.790	4.136	3.092	0.376	-2.333	3.331	2.388	-0.195
Animal labour	1.963	1.775	-3.896	-6.301	-0.723	1.751	-0.846	-1.610	-0.477	1.506
Machine labour	0.432	0.137	-0.404	1.674	-4.782	-2.623	1.063	1.862	1.184	-0.253
Fertilizer	-0.239	0.760	-0.317	-0.920	0.797	1.030	-0.926	-1.504	1.241	-0.083
Other inputs	0.560	-0.041	-0.499	2.061	1.998	-0.253	2.841	-0.107	-3.375	-0.421
Acreage										
Rice	1.860	-0.367	1.669	-0.745	1.421	-0.405	1.902	-0.405	1.515	-0.076
Wheat	-0.066	1.860	-0.109	1.776	-0.164	1.851	-0.057	1.851	-0.143	1.925
Supply shifters (TFP sources)										
Literacy	-0.143	-0.200	-0.234	-0.405	-0.353	-0.220	-0.123	-0.220	-0.308	-0.041
Research stock	-0.051	-0.042	-0.084	-0.086	-0.127	-0.047	-0.044	-0.047	-0.111	-0.009
Extension stock	-0.038	-0.049	-0.062	-0.100	-0.094	-0.054	-0.032	-0.054	-0.081	-0.010
Irrigated area	-0.341	-0.476	-0.559	-0.966	-0.843	-0.525	-0.293	-0.525	-0.734	-0.098
Demand shifters										
Indirect demand	0.014	0.017	0.023	0.034	0.034	0.019	0.012	0.019	0.030	0.004
Consumer income	0.000	0.000	-0.001	-0.001	-0.001	0.000	0.000	0.000	-0.001	0.000
Population	0.270	0.332	0.442	0.673	0.667	0.366	0.232	0.365	0.581	0.068
All sources										
Price of rice and wheat substitutes	0.008	0.010	0.013	0.020	0.020	0.010	0.006	0.010	0.017	0.001
Input price	0.340	-0.259	1.675	0.650	0.381	0.281	-0.201	1.972	0.961	0.555
Acreage	1.794	1.493	1.561	1.030	1.257	1.446	1.845	1.447	1.372	1.849
Supply shifters	-0.573	-0.767	-0.938	-1.556	-1.416	-0.846	-0.492	-0.845	-1.234	-0.158
Demand shifters	0.283	0.348	0.464	0.706	0.700	0.384	0.243	0.384	0.610	0.072
All sources	1.852	0.824	2.774	0.850	0.941	1.276	1.401	2.967	1.726	2.319

demand for human labour and animal labour will grow faster for rice as compared to wheat.

Sources of Commodity Price

Input prices have inflationary effect on market price of both rice and wheat (Table 13). With increase in price of input, its use decreases, and consequently, commodity supply decreases and commodity price increases. Across farm inputs, input price effect on commodity prices is highest of wages, followed by animal labour and machine labour and is the least of fertilizer prices. The inflationary pressure on input prices will increase the prices of both rice and wheat at the rate of 1.7 per cent per year. Rice and wheat being the major staple cereals and accounting for more than half of the food expenditure of poor consumers, the rise in price of these cereals has a negative impact on welfare of the poor. Increase in area under crop or its substitutes will have a negative effect on crop output price. One per cent expansion in acreage will lead to a decrease in commodity price by 1.47 per cent for rice and by 1.22 per cent for wheat. Supply shifters or technology movers (literacy, research, extension, and irrigation) have a negative effect on the market price of a crop. At the observed past growth of technological development, the commodity prices are expected to decline at the rate of 2.3 per cent for rice and 3.1 per cent for wheat.

Table 13. Growth by different sources in commodity price, supply, demand and income for rice and wheat in India

Sources growth, %	Price		Supply		Demand		Income	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
Price of cereals								
Maize	0.060	-0.267	0.017	-0.071	0.047	-0.126	0.210	-0.911
Other coarse cereals	-0.028	-0.107	-0.008	-0.029	-0.003	-0.046	-0.098	-0.368
Price of inputs								
Wages	0.635	0.484	-0.629	-0.754	-0.573	-0.461	-8.309	-5.093
Animal labour	0.454	0.798	-0.246	-1.140	-0.238	-1.039	-4.596	-3.216
Machinery	0.222	0.195	-0.207	-0.217	-0.191	-0.202	-1.241	-2.288
Fertilizer	0.070	0.098	-0.049	-0.131	-0.046	-0.120	-1.290	-1.513
Other inputs	0.274	0.119	-0.322	-0.038	-0.290	-0.043	-1.375	-2.485
Area under crop								
Rice	-1.202	-0.352	1.512	-0.094	1.361	-0.043	-2.028	-1.202
Wheat	-0.267	-0.869	-0.073	1.439	-0.042	1.304	-0.930	-1.030
Supply shifters (TFP sources)								
Literacy	-0.575	-1.393	0.171	2.103	0.185	1.908	-2.001	-4.759
Research stock	-0.206	-0.126	0.190	0.142	0.175	0.132	-0.718	-0.429
Extension stock	-0.152	-0.047	0.188	-0.013	0.169	-0.006	-0.530	-0.161
Irrigated area	-1.372	-1.566	1.196	1.869	1.104	1.729	-4.778	-5.352
Demand shifters								
Indirect demand	0.055	0.076	0.015	0.020	0.017	0.029	0.193	0.261
Consumer income	-0.001	-0.001	0.000	0.000	0.000	-0.001	-0.005	-0.005
Population	1.085	0.923	0.298	0.246	0.384	0.312	3.779	3.153
Sources of growth								
Coarse cereals	0.032	-0.374	0.009	-0.100	0.044	-0.172	0.112	-1.279
Input price	1.654	1.694	-1.452	-2.280	-1.339	-1.865	-16.812	-14.595
Cropping pattern	-1.469	-1.221	1.439	1.346	1.319	1.261	-2.958	-2.232
Technology mover (TFP)	-2.306	-3.132	1.745	4.101	1.632	3.763	-8.028	-10.702
Demand shifter	1.139	0.997	0.312	0.266	0.401	0.341	3.967	3.409
All sources	-0.949	-2.035	2.053	3.333	2.057	3.327	-23.718	-25.399

Among different inputs, irrigation has emerged as the most important source contributing to food security, due to inducing a considerable decline in commodity prices (1.37 per cent for rice and 1.57 per cent for wheat annually). Irrigation, literacy and research investment contribute to a higher input efficiency and supply and lower unit cost and market price for cereals, benefiting both producers and consumers. Among the demand shifters, population plays a dominating role in generating demand and raising prices by 1.09 per cent for rice and 0.92 per cent for wheat annually. Consumer income has the minimum effect on cereal prices. It seems that the positive effects of input prices and demand shifters on market prices of rice and wheat have nullified the negative effect of acreage and TFP sources. The growth in product price by all sources will decline at the rate of 0.95 per cent for rice and 2.03 per cent for wheat. The income elasticity with respect to commodity price is highly elastic (Table 7); therefore, in the absence of minimum support price (MSP), the producer income will decline substantially for both rice and wheat.

Sources of Supply, Demand and Farm Income

As seen in Table 11, the net effects of price factors on supply, demand and farm income were negative, as expected. The capital inputs (machinery) have mild and negative effects on output supply and farm income.

The fertilizer subsidy of 10 per cent will increase fertilizer-use by 2.1 per cent for rice and 3.3 per cent for wheat (Table 10) and a mild increase in the commodity supply (0.11-0.29%), demand (0.11-0.26%), and farmers' income by 2.93-3.33 per cent. Input subsidy providing 10-per cent reduction in input prices, will help in a decline in commodity prices by 1.9 per cent, and would raise commodity supply by 1.7 per cent for rice and 2.2 per cent for wheat and will raise profitability by 19.3 per cent from rice and 17.8 per cent from wheat cultivation. Input subsidy will not be feasible in the long-run. A viable solution can be found by appropriate adjustments in technology movers, mainly irrigation led by literacy, research and extension investment.

Unlike price factors, technology movers which influence the TFP, can have a stronger effect on factor demand and output supply, but have a negative impact on commodity price. Thus, crop income to farmers would decline substantially because it is highly elastic with respect to output price. With 1-per cent increase in technology, the supply will increase by 0.65 per cent for rice and by 1.41 per cent for wheat and the price will decline by 0.87 per cent for rice and by 1.08 per cent for wheat. Due to the decline in price, the consumer demand will increase by 0.61 per cent for rice and 1.30 per cent for wheat and net income will decline by as high as 3.0 per cent from rice and 3.7 per cent from wheat. The area under crop will increase the supply, reduce the price, increase the demand, and reduce the income. However, the demand shifters, viz. indirect demand (seed, industrial use, and trade) and population have positive effects on prices, supply, demand and income from crops.

Under the assumption that the factor price inflation will continue at the same rate as was observed in past, no change in acreage, technology movers, and demand shifters, the price of rice will increase by 1.65 per cent and its supply, demand, and income will decline by 1.45 per cent, 1.34 per cent and 16.8 per cent, respectively (Table 13). Similarly, for wheat crop, the output price will increase by 1.69 per cent and wheat supply, demand and income will decline by 2.01 per cent, 1.86 per cent and 14.6 per cent, respectively. The acreage has a negative impact on output price with annual growth rate of 1.47 per cent for rice and 1.22 per cent for wheat. The supply will increase at the annual growth rate of 1.44 per cent for rice and 1.35 per cent for wheat. Demand will grow at the annual rate of 1.32 per cent for rice and 1.26 per cent for wheat. However, income will decline at an annual rate of 2.96 per cent for rice and 2.23 per cent for wheat.

The technology movers will shift the supply function upward and supply will increase at an annual growth rate of 1.74 per cent for rice and 4.1 per cent for wheat. The price of the commodity will decline by 2.3 per cent for rice and by 3.13 per cent for wheat. The decline in price will have a positive impact on demand with the growth rate of 1.63 per cent for rice and 3.76 per cent for wheat. The profitability will decline at the annual rate of 8.03 per cent in rice and 10.7 per cent in wheat. The demand shifters, as a result of indirect demand and population growth, will increase the price at the rate of 1.14 per cent for rice and 1.0 per cent for wheat. The higher output price has a positive response on supply which will grow at the annual rate by 0.31 per cent for rice and 0.27 per cent for wheat and profitability will increase at the rate of 3.97 per cent from rice and 3.40 per cent from wheat. Taking all price and non-price factors together, the supply will increase at the rate of 2.05 per cent for rice and 3.33 per cent for wheat annually. The price will decline at the rate of 0.95 per cent in rice and 2.03 per cent in wheat. This will have adverse influence on profitability. The crop net income is likely to decline by 23.7 per cent in rice and 25.4 per cent in wheat. To safeguard farmers' interests, the government intervention becomes essential for price, production and income stabilization.

Fertilizer Subsidy and Crop Price Stabilization

The price growth model provides the output price elasticies with respect to input price, acreage, technology movers, and demand shifters. If we withdraw the fertilizer subsidy and depend exclusively on technology to ensure complete product price stability (dp/p =0), then the required adjustment in technology has been computed and is given in Table 14. Withdrawal of fertilizer subsidy will have a negative impact on the supply of rice and wheat and their prices will increase. The technological changes induce output supply. The positive and negative impacts can be neutralized exclusively by adjusting the technology sources at the desired levels to compensate withdrawal of 10-per cent fertilizer subsidy. The results are presented in the last column of Table 14. For this, the

Table 14. Technology vs fertilizer subsidy withdrawal: Required growth in TFP sources for rice and wheat, India

Particulars	Output price elasticity with respect to fertilizer price and TFP sources		Elasticity of TFP sources with respect to fertilizer price		Required change in TFP sources to counter withdrawal of 10% subsidy on fertilizer,	
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Fertilizer price	0.0160	0.0215				
TFP sources						
Literacy rate	-0.2267	-0.4837	0.0704	0.0444	0.704	0.444
Research stock	-0.0394	-0.0358	0.4051	0.6000	4.051	6.000
Extension stock	-0.0615	-0.0180	0.2595	Ns	2.595	Ns
Research & extension	-0.1009	-0.0538	0.6646	0.6000	6.646	6.000
Irrigated area	-0.5413	-0.5440	0.0295	0.0395	0.295	0.395
All sources	-0.8688	-1.0815	0.0184	0.0199	0.184	0.199

Ns: non-significant

literacy rate will have to be increased by 0.44-0.70 per cent, investment on research and extension needs to be increased at the growth rate of 6.0-6.6 per cent annually, and irrigation must increase at the growth rate of 0.30-0.40 per cent annually. The required growth in technology (TFP) is estimated to be 0.18-0.20 per cent annually to compensate 10-per cent fertilizer subsidy burden and ensure food price stability. The model can also be used to estimate the required adjustment in TFP and its sources to attain price stabilization under population pressure.

Conclusions

Technology, acreage and population are the most powerful instruments that need to be manipulated not only to neutralize factor price inflation but also to safeguard the interest of producers and consumers, the input-price subsidy is likely to have a weak effect on supply. It is the technology that has a substantial impact on food supply. Public policies like investments in irrigation, rural literacy, research and extension are crucial to increase supply at higher growth rate. The input subsidy has a positive effect on input use, crop supply and farm income, but technology shifters have a positive and strong influence on commodity supply and a substantial negative effect on farmer income because of the decline in market price in the absence of minimum support price policy. Also, the input subsidy to farmers and price subsidy to consumers will not be feasible in the long-run as they involve a substantial share of public resources. A viable solution can only be found with appropriate adjustments in the non-price factors. An effective minimum support price program is essential to protect the welfare of farmers. To compensate the impact of 10-per cent reduction in fertilizer subsidy, the TFP growth will have to be increased from the present level by 0.18 per cent for rice and 0.20 per cent for wheat by adopting appropriate measures.

Acknowledgement

The authors are thankful to the anonymous referee for the constructive suggestions which helped in improving the presentation of the paper.

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Received: October, 2013; Accepted: January, 2014

Appendix Table 1. Cost and return structure of paddy and wheat in India

Item	Paddy	Wheat
Yield (q/ha)	36.9	33.6
Price (₹/q)	765	993
Human labour (₹/ha)	33658	48456
Animal labour (₹/ha)	10571	8557
Machine labour (₹/ha)	3014	4245
Fertilizer (₹/ha)	3407	5729
Other inputs (₹/ha)	1819	5128
Net income (₹/ha)	11837	17962

Appendix Table 2. Demand sources for rice and wheat in India, 2009

Demand sources	Demand in thousand tonnes		Share in total demand	
	Rice	Wheat	Rice	Wheat
		Human demand		
Household	90673	63138	0.9194	0.7606
Home away	2947	10750	0.0299	0.1295
		Indirect demand		
Seed	1280	1780	0.0130	0.0214
Feed	791	3895	0.0080	0.0469
Wastages	539	1227	0.0055	0.0148
Industrial uses	2396	2225	0.0243	0.0268
Total	98626	83015	1.0000	1.0000

Source: Joshi and Kumar (2011)