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PRESIDENTIAL ADDRESS

Sustaining Food and Nutritional Security in India: An Assessment of Agri-Food Systems and Scoping for Future[*]

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I feel privileged to deliver the Presidential address in the 83rd annual conference of the Indian Society of Agricultural Economics. I thank the office bearers and members of the Association for giving me the honour. Food and nutrition security has been a very sensitive issue in India as it has the largest concentration of poor in the world. Around half of India's population is covered by one or the other scheme in which subsidized staple food is made available to the people, but the country still lags much behind on nutrition security front. For this reason, the theme chosen for my presidential address is 'Sustaining Food and Nutritional Security in India: An Assessment of Agri-food Systems and Scoping for Future'.

I

INTRODUCTION

The policy planners face the challenge of formulating suitable agricultural policy through which food security can be achieved. The present level of per-capita consumption of most food items is much below the minimum requirement of a healthy diet, and there is a need to raise per-capita consumption to reduce undernutrition and hunger in the country. Further, dietary patterns are changing towards costly energy-intensive and protein rich food items, which implies a need for enhancing the production of pulses, horticultural and livestock products to provide for healthy diet and required level of nutrition. All these factors necessitate that agri-food production must move on a high growth trajectory to meet future demand. To formulate an effective policy for food-security, one needs reliable empirical knowledge about the degree of responsiveness of input demand and crop output supply to input-output prices and technological changes. A better understanding of demand and supply elasticities helps to predict future demand and supply of food commodities under different scenarios and could help planners to take policy decisions.

Price policy is an important instrument to accelerate adoption of technology, and thereby secure higher growth in the agricultural sector. Climate change has led to

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different types of risks—adverse effects on agricultural production, rise in prices of agricultural commodities and change in the commodity demand.

Subsidies and price controls are used by governments to enhance production and meet the objective of food security in the country. Indian agricultural policies also use remunerative prices to the farmers as one of the several pathways to achieve the objective of food security and enhancing farmer's income. Farmers' net incomes have not been rising due to high cost of inputs and decelerating total factor productivity (TFP) growth. This posed a challenge for the researchers to find ways to shift the production function upward by improving the technology index.

The indiscriminate exploitation of natural resources in these intensively cultivated areas has raised concern about the long-term sustainability of the agricultural production system. The Green Revolution phase involved intensification of agriculture and rising use of inputs. Ecological problems have cropped up in various parts of the country. They include nutrient imbalance and nutrient mining in soils, overexploitation of water resources, land degradation and outbreaks of agricultural pests and diseases. These negative externalities of high-input intensive agriculture pose a serious challenge to maintain growth in productivity, sustainable use of natural resources for crop production, economic viability, farm income, and national food security. It calls for an in-depth examination of the issues related to the growth in agricultural productivity, which can be better understood by looking at the performance of crop, livestock, and fisheries sectors. The contribution of technology is crucial to face this challenge and to achieve desired growth in agri-food production. Raising public funding for agricultural research and extension (R&E) by demonstrating higher returns to investment is crucial. Investments in agricultural research along with investments in infrastructure and education will help in meeting the objective of nutritional security and poverty reduction. The obvious issues in this context are identification of research priorities in agriculture and level of research investment to meet the national food security and meet the challenge of hunger and poverty in the country.

Despite impressive growth of food production, India is still home to the maximum number of poor people in the world. India accounts for about one-fifth of the world's poor; two-thirds of them live in the rural and one-third in the urban areas. At the national level, India is self-sufficient in food, but the poor households do not have access to sufficient food, hence, remain food insecure. If India is to meet the Sustainable Development Goals (SDGs), then the highest priority must be accorded to raising the incomes and employment opportunities for the landless agricultural labourer's and marginal farm households. These households are net buyers and need hard cash to buy food from the market; their only economic resource is their 'labour' and / or undertaking diverse farm activities. Although several factors influence the extent of hunger (undernourishment), some of them have depicted overwhelming impacts under the Indian scenario.

This paper reviews dietary patterns, assesses agri-food systems, status of food security, impact of climate change and input subsidy on prices, income and food security and examines the total factor productivity and sustainability issues for crops, livestock, and fisheries sectors. Further, the hypothesis that higher allocations to R&E achieve higher TFP growth and returns is tested. Socio-economic factors associated with undernourishment of small farms are examined, and the way forward for sustaining food and nutritional security in India is put forth.

II

FOOD BASKET IN INDIA: NUTRITION AND FOOD TRENDS

It is well known that a wide range of nutrients such as proteins, fat, carbohydrates, vitamins, and minerals are needed to maintain normal activities of the human body. These nutrients are present in most foods consumed daily in various proportions. However, some foods provide only a few nutrients like sugar, edible oils, etc. Vitamins and minerals do not supply energy, but they play an important role in the metabolic activity of the body. Thus, our diet must be well balanced to provide all the nutrients in proper proportions. The dietary habits of people in different regions of the country are determined mainly by the availability of foods locally and traditional practices.

The dynamics of food consumption and nutrient intake of Indian households was investigated over the past three decades based on nationally representative sample survey data obtained from the NSSO. Disparities in nutrition intake arising out of income differentials of households is assessed and it is found that food baskets are more diversified in all income groups in both rural and urban households (Kumar *et al.* 2016). The per-capita consumption of cereals as food is declining while that of non-cereals, such as horticultural, livestock and fisheries products, is increasing (Table 1). The declining trend in pulse consumption has been observed because of high prices of pulses. Despite increasing consumption for high-value commodities, the importance of cereals and pulses continues for attaining nutritional security in the country as foodgrains account for more than three-forth share in the total calorie and protein intake.

TABLE 1: CHANGE IN FOOD CONSUMPTION PATTERN (KG/CAPITA/YEAR): INDIA.

Food groups (1)	1983 (2)	2011 (3)	Percent Change (4)
Cereals	168.0	133.4	-20.6
Pulses	11.8	10.0	-15.6
Sugar	11.4	10.0	-12.2
Edible oil	4.5	8.7	+78.5
Vegetables	47.9	56.2	+17.3
Fruits	3.3	11.9	+260
Milk	45.0	64.9	+44.3
Meat, fish and eggs	5.4	7.5	+39.7

Source: Calculated from rounds of NSS consumer expenditure survey.

Dietary shifts towards high-value food commodities have profound impact on agricultural production, food demand and nutritional security in the country. With the change in consumption pattern, there is declining intake of nutrients such as calories, proteins, and iron (Joshi *et al.*, 2016). There is substantial improvement in calcium, zinc, and beta-carotene, and on the contrary, intake levels of fats, calcium, zinc and Beta-Carotene (Vitamin A) have improved over time (Table 2).

TABLE 2: CHANGE IN INTAKE OF DIETARY NUTRIENTS: INDIA.

Nutrients (1)	1983 (2)	2011 (3)	Per cent change (4)
Calories (kcal/capita/day)	2153	2104	-2.3
Protein (g/capita/day)	60.8	56.5	-7.1
Fat (g/capita/day)	29.3	44.5	51.8
Calcium (mg/capita/day)	489	579	18.3
Iron (mg/capita/day)	40.6	35.9	-11.7
Zinc (mg/capita/day)	8.4	9.9	16.9
Beta-carotene (µg/capita/day)	1358	1676	23.5

Source: Calculated from rounds of NSS consumer expenditure survey
Note: g is grams; kcal is kilocalories; mg is milligram; µg is microgram

Much of the population still faces the issue of nutrition deficiency (Table 3). This is true for the population below the poverty line and for the population above the poverty line. Both the groups have deficiencies in different nutrients, which is an alarming situation towards nutritional security. The estimated gaps between recommended daily allowances (RDA) and real time intake of nutrients have widened. Calorie-deprived households over time have increased. Similarly, the households belonging to lower-income groups have exhibited higher levels of calorie-intake gaps. The same trend of widening nutrient gap was observed for other nutrients such as proteins, calcium, and Vitamin A, particularly among low-income rural households. Per cent of the population with under-intake of fats, iron and zinc decreased over time, thereby indicating improvements in nutritional outcomes with respect to these nutrients (Joshi *et al.,* 2016).

TABLE 3: STATUS OF UNDERNOURISHMENT IN INDIA, 2011

(unit: percent of population)

Nutrient Deficiency (1)	BPL (Poor) (2)	APL (Rich) (3)	1983 (4)	2011 (5)
Calories	87	55	65	68
Proteins	53	20	32	31
Calcium	97	48	77	68
Fats	62	10	62	27
Zinc	76	52	77	61
Iron	15	2	10	5
Beta-carotene	100	98	98	99

Source: Calculated from rounds of NSS consumer expenditure survey
Note: BPL- Population below poverty line; APL: population above the poverty line.

Pulses constitute the major source of quality protein for millions of consumers in the country and contain 2 to 3 times more protein than cereals and are the rich source of minerals and vitamins. The share of pulses in total calories intake in India accounted for 3.80 per cent in 2004 and 4.47 per cent in 2011. The contribution of pulses to total protein-intake is estimated to be 10.87 per cent and showing an increasing trend (Table 4).

TABLE 4: SHARE OF PULSE NUTRIENT IN TOTAL NUTRIENT INTAKE BY CONSUMERS IN INDIA

Nutrient	Intake/capita/day		Pulses share in total human intake	
	2004	2011	2004	2011
(1)	(2)	(3)	(4)	(5)
Calories (Kcl)	2223	2095	3.80	4.47
Protein (g)	55.83	56.29	10.04	10.87

Source: Kumar *et. al.* 2023.

With consistent changes in dietary pattern, the nutrient intake of people has also undergone significant changes over time. Due to the increase in disposable income and improvements in living standards, there has been a general trend of increasing protein intake by the people. The relevance of pulses as a major source of protein in the consumer diets has remained important despite complementarity and substitution with other food groups such as milk, meat, eggs, etc. But intake of livestock protein is independent of pulse protein intake in Indian diets.

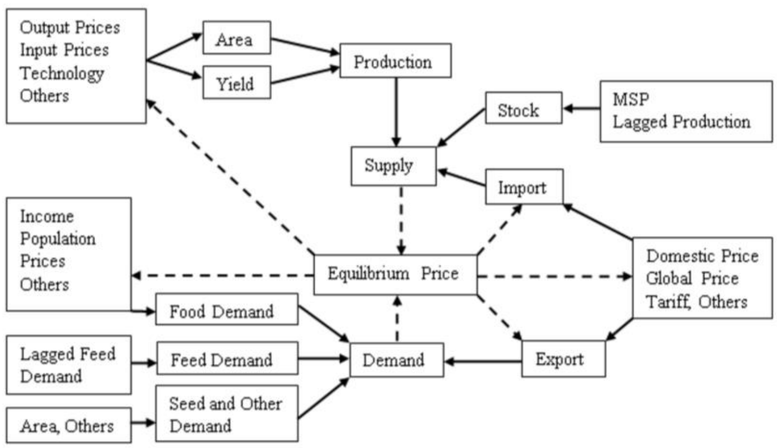
III

AGRI-FOOD SYSTEM

Commodity outlook models are designed to simulate the effects of macroeconomic policies on the quantities and prices of commodities produced and factors of production used in agri-food systems. The model used in the study is a simplified version of the unified approach described by Quizon and Binswanger (1983). This model is built to analyse the impact of development policies (subsidies, input-output price policy), demand shifters and technical changes on prices, supply, demand, and income for crops. The policies and programmes that can be considered are input subsidies, irrigation investment, agricultural research and input-output policies. The empirical model consists of several blocks of equations. The first block is the producer core system consisting of factor demand and output supply equations (yield and acreage equations). The second block consists of a consumer core system containing consumer demand equation, indirect and home away demand. The third block determines the TFP response to its sources. All the three blocks of equations are solved simultaneously to build price, supply, demand, and income models to undertake simulation exercise to answer the policy questions: What adjustments are needed in price and non-price factors to attain the specific goals of producer and consumer welfare. The model incorporates the major demand and supply side variables, output, and input prices, as well as other exogenous variables like income and population and policy variables like support price, technology etc.

A schematic representation of the linkages in the model is shown in Figure 1.

Figure 1 : Structure of Commodity outlook model



3.1 *Food Demand*

Demand for food is continuously growing and is driven by rising population, growing economy, increasing urbanisation, and changing tastes and preferences. The demand for food is also influenced by the commodity prices and thus the price policy and prices do have strong implications for both the food and nutritional security of the individuals. Several factors like magnitude of demand and supply elasticities, income distribution, regional dietary pattern, dietary diversification, changing cropping pattern and prices of own and substitute food crops play an important role in determining the future demand and supply of food items. Also, dynamic factors like changing tastes and preferences, eating out of the home, international trade, urbanisation, population growth and income growth rates also have major implications. Therefore, these factors are to be considered while projecting demand and supply.

A review of past studies has revealed wide variations in food demand projections due to their dependence on the type of data used and magnitudes of demand elasticities, income distribution, regional dietary pattern, and dietary diversification. These estimates for food demand have some limitations, which include:(i) the model specification ignores theoretical restrictions of demand relationship, (ii) aggregate analysis is done at the national level, ignoring the effect of structural changes on economy such as urbanization and regional variations, (iii) national income growth assumption is superimposed on the regions and income groups, (iv) per-capita income growth is used which ignores the population growth in the projected years and underestimates the income effect on demand because of declining population growth, and (v) ignores the surge caused in 'home-away demand' for food by the sustained rise in per-capita income, fast growing urban population and increasing employment opportunities for urban women. These deficiencies are addressed while projecting the demand to 2030 for food grains, and horticultural, livestock and fisheries products.

To estimate the income and price elasticities of demand for food commodities, several models are reported in literature. The expenditure (income) and calorie elasticities based on linear expenditure system (LEDS), Transcendental logarithmic demand system (TLDS), normalized quadratic demand system (NQDS), food characteristic demand system (FCDS), and three-stage quadratic almost ideal demand system (3-stage QUAIDS) models were compared to get a realistic view of demand elasticities (Table 5). These estimates have shown that expenditure elasticities are lower for urban than for rural consumers. The magnitude of expenditure elasticities for cereals is much higher on using LEDS, TLDS, NQDS model compared to that obtained from FCDS and three-stage QUAIDS model. It is strange to note that once the expenditure elasticities for rice and wheat are positive and significantly high in magnitude, why the actual per-capita cereal consumption does not increase with total expenditure!

TABLE 5: A COMPARISON OF FOOD AND CALORIE INCOME ELASTICITIES ACROSS DIFFERENT DEMAND MODELS, FOR RURAL AND URBAN INDIA

Food commodities (1)	Households (2)	LEDS (3)	TLDS (4)	NQDS (5)	FCDS (6)	3-Stage QUAIDS (7)
Food-income elasticity						
Rice	Rural	0.45	0.71	0.57	0.03	0.02
	Urban	0.22	0.46	0.42	0.01	0.01
Wheat	Rural	0.44	0.63	0.55	0.07	0.03
	Urban	0.25	0.3	0.32	0.08	0.02
Coarse cereals	Rural	0.03	-0.55	-0.09	-0.12	-0.02
	Urban	-0.26	-1.62	-1.05	-0.17	0.00
Other foods	Rural	0.89	0.99	0.76	0.81	0.89
	Urban	0.84	0.98	0.88	0.67	0.77
Aggregate food-income elasticity						
All food	Rural	0.72	0.8	0.65	0.29	0.35
All food	Urban	0.73	0.8	0.73	0.28	0.32
Calorie-income elasticity						
All food	Rural	0.46	0.6	0.53	0.12	0.14
All food	Urban	0.42	0.51	0.49	0.12	0.14

Source: Kumar, 2011.

A comparison of demand elasticities calculated by different models reveals that the value for calorie-income elasticity is lowest on using from FCDS model. Bouis and Haddad (1992) have presented empirical evidence for the Indian and Philippine population, respectively, that calorie-income elasticity is not significantly different from zero across income-groups and regions. The poor households spend a high proportion of their income on food, and a large share of their total food expenditure is on a low-cost-calorie staple, to avoid going hungry. The rich households afford to substitute a part of low-cost-calorie staple with high-cost-calorie food without increasing calories. Thus, calorie-income elasticity would be highly inelastic, nearly to zero. The value for calorie-income elasticities is lowest from demand parameters of Food Characteristics Demand System (FCDS). Therefore, one can assume that the demand elasticities obtained from FCDS predict the consumer behaviour as observed in the data and may predict most reliable demand for food commodities. The studies which used FCDS-based elasticities could predict food demand in a highly credible range (Kumar, 1998).

3.2 *Income and Price Elasticity of Food Demand*

In the present study, FCDS was used for computing demand elasticities of various food commodities, viz. rice, wheat, coarse grains, and major commodity groups, such as pulses, edible oils, vegetables, fruits, milk, meat, fish and eggs and other food and non-food commodities across regions, rural/urban households, and income groups. The national level estimates of income and own price elasticities were computed as the weighted averages of the disaggregated elasticity (Table 6).

TABLE 6: INCOME AND PRICE EFFECTS ON FOOD DEMAND

Food	Income elasticity	Own price elasticity	Price effect (Sum of own & cross price elasticity)	Total effect (Sum of income & price effect)
(1)	(2)	(3)	(4)	(5)
Rice	0.024	-0.247	0.107	0.131
Wheat	0.075	-0.340	-0.010	0.065
Coarse cereals	-0.125	-0.194	0.404	0.279
Pulses	0.219	-0.453	-0.344	-0.126
Milk and milk products	0.429	-0.624	-0.780	-0.351
Edible oils	0.297	-0.504	-0.496	-0.198
Vegetables	0.259	-0.515	-0.464	-0.206
Fruits	0.361	-0.595	-0.643	-0.282
Meat, fish and eggs	0.669	-0.821	-1.222	-0.553
Sugar	0.062	-0.340	-0.020	0.042
Other food (High value)	0.748	-0.917	-2.379	-1.631

Source: Kumar *et a*l. 2011.

The income effect is positive but of small magnitude for rice and wheat, and negative for coarse cereals. The price effect (sum of own and cross price elasticities) is positive for rice and coarse cereals and mild for wheat. However, the total net effect consisting of income and price effects was positive and was 0.13 for rice, 0.065 for wheat and 0.279 for coarse cereals. With the increase in price inflation in cereals, the demand of coarse cereals for human consumption is bound to increase. It may have an adverse impact on the manufacturing of feed concentrate that in turn may influence the rearing of livestock adversely. The income has a positive and significant effect on demand for pulses (0.219), vegetables (0.259), edible oils (0.297), fruits (0.362), non-vegetarian food, viz. meat, fish, and eggs (0.669), and other high-value foods (0.748). The net price effect on food demand was found negative with high in magnitude and the estimates were -0.344 for pulses, -0.780 for milk, 0.496 for edible oils, -0.464 for vegetables, -0.643 for fruits, -1.22 for non-vegetarian food and -2.379 for high- value food. The price effect will dominate the income effect and thus pure price inflation (sum of income and price elasticities) will be negative for most of the high-value nutritive food commodities. Thus, an increase in inflation of food price will adversely affect the dietary diversification towards non-cereal food commodities and may lead to under-nourishment of consumers.

3.3. Food Supply

To understand future supply of food commodities, one needs reliable empirical knowledge about the degree of responsiveness of input demand and crop output supply to input-output prices and technological changes. The crop-related data are culled from the 'Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops' of the Directorate of Economics and Statistics (DES), Government of India. It provides time series cum cross section data on yield, use of inputs and their prices. This data set is useful to estimate the translog cost function to derive factor demand and output supply elasticities for cereals, pulses, edible oilseeds, sugarcane, onion, potato (Binswanger, 1974; Kumar, *et al.* 2010; Kumar, 2011; Kumar and Joshi, 2016).

Input Demand Elasticity

The restricted estimates of the parameters of factor share equations derived from translog cost function were estimated jointly for human labour, animal labour, machine labour, fertiliser, and other inputs, mainly irrigation, for cereals, pulses, edible oils, fiber crops, sugarcane, onion, and potato. The parameters of the share equations are used to compute elasticity of factor demand for major crops in India. The input demand elasticities with respect to own and cross prices were computed for human labour, animal labour, machine labour, and fertilisers. The matrices of input demand elasticity are presented in Appendix Tables 1-5, respectively for human labour, animal labour, machine labour, fertilisers, and other inputs (irrigation, plant protection and others). As expected, all own input price elasticities of demand have statistically significant negative signs. The elasticities of factor demand differ significantly from crop to crop and within a crop, from one input to the other, depending on the technology used.

Human Labour Demand

The human labour demand elasticity with respect to wages is significant for all the crops, except maize and sugarcane (Appendix Table 1). A positive sign for cross price elasticity with respect to the price of other variable inputs shows that the pair is substitutive, and a negative sign is the indicator of a complementary relationship. Human labour and bullock labour have a substitutive relationship for most of the crops (wheat, coarse grains, cotton, jute, and sugarcane) and are complementary for pulse. Both human labour and machine labour have shown a substitutive relationship for rice, maize, pearl millet, soybean, and cotton. Human labour has exhibited a substitutive relationship with fertilisers for wheat, coarse grains, pulse grains, oilseeds, sugarcane onion, potato and jute, and a complementary relationship with chickpea and soybean. A substitutive relationship has been observed between human labour and irrigation for all crops, except wheat. However, for the crop sector, human labour has a substitutive relation with most of the inputs and crops. With inflation in wages, human labour will be substituted by machine labour, fertiliser-use, and irrigation. It is likely to induce efficiency in crop production and may improve productivity and yield.

Animal Labour Demand:

The animal labour demand elasticity with respect to animal labour wages is negative and statistically significant for all the crops, except pulse grains (Appendix Table 2). It ranges from -0.13 for pigeon pea to -1.09 for rapeseed and mustard. A 10 per cent rise in animal labour wage would lead to a reduction in its use at an average rate of 4.9 per cent. The use of animal labour has depicted a substitutive relationship with machine labour for rice and wheat. This suggests that an increase in the animal labour wage would induce mechanization in the rice-wheat system. However, it has shown a complementary relationship with fertilisers for wheat and substitutive relationship with irrigation for wheat and oilseeds. Looking at all the crops together, a rise in the cost of animal labour would induce use of modern inputs and machine labour to enhance the productivity of farms.

Machine Labour Demand-

The machine labour demand elasticities range from -0.32 for wheat to -1.41 for sugarcane, with average elasticity of -0.95 (Appendix Table 3). The machine labour demand is more sensitive to its price than other inputs. A 10 per cent increase in the price of machine labour to farmers would lead to a decline in its use by 12.6 per cent for rice, 3.2 per cent for wheat, 7.6 per cent for pulses, 13.8 per cent for oilseeds, 14.1 per cent for sugarcane, 7.3 per cent for cotton, and 8.1 per cent for jute. A substitutive relationship exists between inputs for most of the crops.

Fertiliser Demand

The own-price elasticity of demand for fertilisers is -0.24 for rice, -0.35 for wheat, -0.81 for pulses, -1.12 for oilseeds, -0.43 for sugarcane, -0.45 for vegetables, and -1.04 for cotton (Appendix Table 4). Taking all the crops together, with a 10 per cent rise in its price, the demand for fertilisers would be reduced by 6.5 per cent on average. However, the reduction in the use of fertilisers with rise in fertilizer price will be substantial for oilseeds, cotton, and coarse grains. Fertilizer has been found to be a weak complement and substitute for all other inputs.

Irrigation Demand

The own price elasticity of irrigation demand is estimated to be -0.72. It varies substantially across crops, from -0.02 for chickpea to -1.46 for oilseeds (Appendix Table 5). With a 10 per cent increase in irrigation price, the demand for irrigation would decline by 7.1 per cent on average and would be maximum for oilseeds (14.6%) and minimum for vegetables (0.46%). Cross price elasticities of irrigation demand with respect to labour wages, animal labour wages, machine charges and fertilizer price have been found positive for most of the crops, indicating substitutive relationships.

To sum up, the wage rate has a negative effect on the use of human labour and a positive effect on the use of machine labour, fertilizer, and irrigation. This implies that with an increase in the wages, human labour becomes more costly. Once human labour becomes costly, the process of substitution of human labour by machine labour takes place. Mechanization induces fertilizer-use and irrigation and the trade-offs between these inputs improve the production efficiency and yield. Higher animal labour charges induce higher use of machine labour, as it results in the substitution of bullock-use by machine-use. Own-price elasticity of demand for machine labour and fertilizer-use has been found to be highly negative and significant. The subsidy on tractors and fertilizer would induce higher use of modern inputs and improve farming efficiency and productivity. Fertilizer price policy has a differential effect on crops. A gradual increase in fertilizer price has not declined its use in rice and wheat as compared to other crops. Rice and wheat crops are technologically advanced crops, and the relative profitability of these crops is high.

Supply Response Elasticities

The output supply elasticities for major crops are computed from the factor demand elasticities and are presented in Table 7. The output supply elasticities show the response of output prices and input prices on the supply of major crops of India. Among crops, highest supply elasticity with respect to its price was for coarse grains (0.53), followed by edible oils (0.51), cotton (0.33), jute (0.25), rice (0.24), wheat (0.22), groundnut (0.22), rapeseed & mustard (0.22), pulses (0.17), sugarcane (0.12), onion and potato (0.05). The input price response elasticities were highly inelastic, nearly zero. The crop price had a dominating response on the supply of commodities. Positive price policy will enhance domestic supply of food commodities (Kumar and Joshi, 2016).

3.4 Price Policy Model

The role of price policy for higher adoption and larger impact of modern technology is crucial. Price policy models can provide valuable insights for fixing/determining the prices for agricultural commodities. Janvry and Kumar (1981), Kumar (1984), Kumar and Mruthyunjaya (1985, 1989) developed econometric models and estimated the crop price elasticities with respect to input price changes. In developing the price policy model, one need reliable empirical knowledge about the degree of responsiveness of demand and supply of factors and product prices, irrigation, technological change, and research investments based on recent data. These elasticities to be used to compute cost of production and income elasticity with respect to factor and product prices.

TABLE 7: SUPPLY RESPONSE ELASTICITIES FOR DIFFERENT CROPS IN INDIA

Crops	Output	Input price				
	price (P)	w/P	b/P	m/P	r/P	i/P
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rice	0.2357	-0.0017	-0.0004	0.0004	0.0001	0.0017
Wheat	0.2164	0.0163	-0.0288	0.0095	-0.0095	0.0125
Coarse grains	0.5333	-0.1105	0.0952	0.0198	0.2791	0.0500
Maize	0.2533	0.0006	0.0013	-0.0025	-0.0017	0.0023
Sorghum	0.5276	-0.0073	0.0085	-0.0087	0.0057	0.0018
Pearl millet	0.5053	-0.0032	0.0071	-0.0054	0.0035	-0.0020
Pulses	0.1695	-0.0007	-0.0012	0.0020	-0.0013	0.0012
Chickpea	0.2348	-0.0011	-0.0125	0.0123	0.0015	-0.0001
Green gram	0.2992	0.0024	0.0051	-0.0028	-0.0009	-0.0038
Pigeon pea	0.1869	0.0004	0.0014	0.0023	-0.0021	-0.0020
Black gram	0.1890	0.0058	-0.0116	0.0031	-0.0042	0.0069
Edible oilseeds	0.5079	-0.0011	0.0021	0.0168	0.0062	-0.0240
Soybean	0.1516	0.0005	-0.0010	0.0012	-0.0004	-0.0003
Groundnut	0.2265	0.0003	0.0000	-0.0010	0.0007	0.0000
Rapeseed & mustard	0.2178	-0.0028	-0.0049	0.0067	0.0004	0.0006
Sugarcane	0.1216	0.0021	-0.0002	-0.0020	0.0045	-0.0044
Cotton	0.3309	0.0002	0.0000	-0.0011	0.0012	-0.0003
Jute	0.2456	0.0766	-0.0368	-0.0917	0.0319	0.0200
Onion	0.0508	0.0000	-0.0006	0.0000	0.0005	0.0001
Potato	0.0508	0.0000	-0.0006	0.0000	0.0005	0.0001

Source: Kumar 2011; Kumar and Mittal, 2022.

Notes: Here, w = Wage (Rs/hour), b = Cost on animal labour (Rs/hour), m = Cost on machine labour (Rs/hour) P = Price of crop (Rs/100 kg), r = Cost of fertilizer (NPK) (Rs/kg), i = Cost of irrigation (Rs/ha)

To stabilise the production and net income of the farmers, there is a need to adjust product price in relation to factor prices keeping in view producer and consumer welfare. An adjustment in crop price between the limits at which net income elasticity ranges between zero and one may provide enough income to the farmers to induce the adoption of improved technology. The adjustment in crop prices below the level at which income elasticity is negative will generate a negative growth in net income and will not provide incentive to the farmers for adoption of improved technology. Price adjustment above the limit where net income elasticity is positive, and elastic will give an abnormal high rate of profit to crop growers which may lead to serious repercussions on balanced cropping pattern. If the objective of the policy maker is to maintain constant returns to the production cost over years, the crop price should be adjusted upward at a rate equal to cost push inflation.

The National Commission on Agriculture suggested that crop prices are to be fixed considering the year-to-year changes on cost of production in relation to the movements in input price index. Kumar and Mittal, (2022) illustrated that for every ten points rise in input price index, the product price must be revised, upward per annum in the range of 7.9-9.4 per cent for paddy, 7.8-8.9 per cent for wheat, 7.4-10.1 per cent for coarse cereals, 7.0-7.7 per cent for gram, 5.7-9.6 per cent for sugarcane, 17.4-22.0

per cent for groundnut, 8.3 to 9.9 per cent for cotton and 7.0-7.1 per cent for jute. This price policy will have its effect through an 8-10 per cent growth in net income for most of the crops.

3.5. Future Projections of Food Demand and Supply

Will India be able to produce enough to meet its growing food demand? Will the country open for imports of food commodities over the next decades (2020-2030)? What will be the likely trends in future demand of various food commodities? Will the supply of key food commodities continue to keep pace with their demand? These are the questions that require answers to evolve appropriate agricultural price policy. To provide a glimpse, food supply and demand gaps for foodgrains, edible oils and sugar are presented in Table 8 and for high-value commodities such as vegetables, fruits, milk, meat, eggs, and fish are given in Table 9. In case of high-value commodities, supply (production), demand and availability (net domestic supply) have been computed from production after adjusting for post-harvest losses. The gap has been computed as the difference between the availability and the demand.

TABLE 8: DEMAND-SUPPLY PROJECTIONS AND GAPS FOR MAJOR FOOD GRAINS, EDIBLE OILS AND SUGAR, INDIA (UNIT: MILLION TONS)

Commodities (1)	Year (2)	Supply Projection (3)	Demand Projection (4)	Supply-Demand Gap (5)
Rice	2010	95.7	98.7	-3
	2030	122.1	122.4	-0.3
Wheat	2010	84.2	83	1.2
	2030	128.8	114.6	14.2
Coarse cereals	2010	39.6	36.4	3.2
	2030	64.2	47.2	17
Total cereals	2010	219.5	218.1	1.4
	2030	315.1	284.2	30.9
Pulses	2010	16.2	18	-1.8
	2030	26.4	26.6	-0.2
Food grains	2010	234	236.2	-2.2
	2030	338.8	310.8	28
Edible oils	2010	8.2	13.6	-5.4
	2030	19.1	21.3	-2.2
Sugar	2010	27.7	27.6	0.1
	2030	40.3	39.2	1.1

Source: Kumar and Joshi, 2016.
Note: Base year= 2010.

The total demand for an individual commodity comprises direct as well as indirect demand. The direct demand consists of food consumption at home and outside the home. The indirect demand includes its use as seed and feed, industrial use, and wastage. An attempt has been made to provide credible estimates of future demand for foodgrains and other food commodities by estimating their demand at the disaggregated level in terms of income levels, rural and urban households, and states/union territories (UTs) of India, and these are added-up to derive the estimates of food demand at the all-India level.

The direct demand for food is driven by population growth, income growth and changes in income distribution. The total demand for foodgrains, except for export, was arrived by adding their direct demand (human food consumption at home and outside home) and indirect demand (seed, feed, industrial uses, and wastages).

TABLE 9: DEMAND-SUPPLY PROJECTIONS AND GAPS FOR HIGH-VALUE FOOD COMMODITIES IN INDIA

Commodities	Supply, demand & gap	Projections (Million tons)		Post-harvest losses (%)
		2010	2030	
Vegetables	Supply (S)	140.6	210.5	23.99
	Demand (D)	124.7	192	
	Availability (A)	106.9	160	
	Gap (A- D)	-17.8	-32	
Fruits	Supply (S)	73.5	116.4	20.00
	Demand (D)	64.8	103	
	Availability (A)	58.8	93.1	
	Gap (A- D)	-6	-9.9	
Milk	Supply (S)	116.5	188.7	5.03
	Demand (D)	111.9	170.4	
	Availability (A)	110.6	179.2	
	Gap (A- D)	-1.3	8.8	
Poultry & bovine meat	Supply (S)	4.4	8.4	4.98
	Demand (D)	5.2	9.2	
	Availability (A)	4.2	8	
	Gap (A- D)	-0.9	-1.2	
Eggs	Supply (S)	3.1	6.2	5.02
	Demand (D)	3.4	5.8	
	Availability (A)	2.9	5.9	
	Gap (A- D)	-0.5	0.1	
Fish	Supply (S)	7.4	13.9	15.05
	Demand (D)	6.4	11.1	
	Availability (A)	6.3	11.9	
	Gap (A- D)	-0.1	0.8	

Note: Base year: 2010.
Source: Kumar and Joshi, 2016.

In the year 2030, the total foodgrains demand will grow to the level of 311 Mt comprising 122 Mt of rice, 115 Mt of wheat, 47 Mt of coarse grains and 27 Mt of pulses. Demand projections for high-value commodities include the demand for edible oils, sugar and horticultural, livestock, poultry, and fishery products. The demand for edible oils will grow faster than the growth in population and food grains. The total domestic demand for edible oils is projected to be 21.3 Mt in 2030. The requirement of edible oils will continue to remain higher than the domestic production in the country and shall depend on their import in large quantities. The sugar demand at the national level is estimated to grow to 39 Mt by the year 2030.

The factor demand and output supply elasticities for cereals, pulses, edible oilseeds, sugarcane, onion, and potato have been used to project domestic supply of these commodities. For fish, livestock (milk, meat), poultry (chicken meat, eggs), horticultural commodities (vegetables and fruits), input-output data were not available, therefore, supply projections for these commodities are made based on past growth trend in their production.

By 2030, the demand for vegetables is projected to increase to 192 Mt, fruits to 103 Mt and milk to 170 Mt. Fish demand including indirect demand is assessed to be in the range of 11 Mt by 2030. The national demand for eggs is projected to be 5.8 Mt by 2030. The demand for eggs will grow faster than the population growth and will increase pressure on the supply of coarse grains and oilcakes as feed.

The supply of rice is projected to be 122.1 Mt by the year 2030. A look at the past trend reveals that India has been marginally surplus in rice production and has been even exporting rice in small volumes. As per these projections, India is not likely to remain rice surplus and may even become deficit in rice production in the coming years. The domestic production of wheat is projected to be 128.8 Mt by 2030. A perusal at the supply-demand scenario reveals that wheat demand will continue to be met from domestic production and there may even be surplus of about 14.2 Mt by 2030. It has been observed that a shift in consumption from rice to wheat is taking place even in the traditional rice-eating states in the country. Therefore, the surplus wheat production is likely to substitute rice leading to lower availability of surplus wheat.

The domestic production of coarse cereals is estimated to grow to 64 Mt by 2030. The surplus of coarse grains is projected to be of 17 Mt in 2030. This projection of demand-supply balance of coarse grains has provided some valuable insights about the possible level of self-sufficiency in India in coarse grains production, particularly their availability for meeting the feed requirements of the fast-growing livestock sector products in the years to come. The domestic supply of total cereals, that is, the sum of rice, wheat, and coarse grains production, is projected to be 315 Mt by 2030. A look at the supply-demand balance for cereals reveals that their demand in future will be met with the national production and there could even be a surplus of 31 Mt by 2030. The domestic production of pulses is projected to be 26 Mt in 2030. The supply of pulses will fall short of their demand and the country will have to continue rely on imports to meet the domestic requirements.

The domestic supply of total foodgrains, that is, the sum of rice, wheat, coarse cereals, and pulses, is projected to be about 339 Mt by 2030. A look at the supply and demand balance of foodgrains reveals that their future domestic demand will be met with national production, and there is likely to be surplus of about 28 Mt in 2030.

Like pulses the deficit in edible oils supply is projected to be about 2.2 Mt by 2030 and thus the country will continue to depend on imports of edible oils even in the coming decades. The domestic production of edible oils is projected to be about 19 Mt by 2030. The supply of sugar is projected to be 40 Mt by 2030 and will be enough to meet the domestic demand, besides generating a marginal surplus.

The projections of domestic supply of high-value commodities show that the supply-demand gap in the total vegetables and fruits will be substantial unless post-harvest losses are minimized. Supply-demand gap in milk reveals that the country will be able to meet its domestic demand with surplus of 8.8 Mt by 2030. The total meat production from cattle, buffalo, sheep, goat, pig, and poultry at all-India level increased from 1.85 Mt in 2000 to 4.2 Mt in 2010. Looking at the past growth, the supply of total meat by 2030 is projected to be 8.0 Mt by 2030, but the total meat production will be short of their demand in future. The country will be able to meet the domestic demand for eggs with a marginal surplus. India is the second largest producer of fish in the world with contribution of 5.54% to the global production. The total fish production during 2010 is estimated at 8.03 Mt with a contribution of 5.07 Mt from inland sector and 2.96 Mt from marine sector. The projected domestic fish supply of 11.9 Mt in 2030. The supply-demand gap of fish is projected to be 0.4Mt to 0.7 Mt, and thus the country will continue to remain self-reliant in fish supply and be able to export even at the present level production. It may be noted that India has already surpassed the projections of rice, pulses, milk, and fish reported for the year 2030. The supply projections for these commodities are underestimated. It is suggested that the projections must be revised by using elasticities based on a new set of data.

IV

CLIMATE CHANGE AND FOOD SECURITY

Agriculture in India, especially during the monsoon season, is highly vulnerable to the extreme variability in climatic factors and this affect production, demand, and prices of agricultural commodities (Kumar, Joshi, and Aggarwal 2014). A partial generalized equilibrium model was developed and used to simulate the effects of deficit rainfall on acreage, yield, production, demand, and prices of different agricultural commodities (rice, sorghum, pearl millet, maize, pigeon pea, groundnut, and cotton). The estimated elasticities of acreage, production, price, income, and food demand are presented in Table 10 and are used to examine the effect of drought on crop economy and trade potential for these commodities (Table 11).

TABLE 10: ELASTICITY OF ACREAGE, PRODUCTION, PRICE, INCOME, AND FOOD DEMAND WITH RESPECT TO DROUGHT, INDIA.

(1)	Rice (2)	Sorghum (3)	Pearl millet (4)	Maize (5)	Pigeon pea (6)	Groundnut (7)	Cotton (8)
Crop area	-0.437	-0.086	-0.275	-0.113	0.000	-0.055	-0.431
Yield	-0.634	-0.678	-0.765	-0.277	-0.453	-0.363	-0.405
Production	-1.071	-0.764	-1.040	-0.390	-0.453	-0.418	-0.836
Price	2.332	1.384	1.345	1.561	0.980	0.531	0.558
Gross revenue	1.261	0.621	0.305	1.171	0.527	0.113	-0.278
Demand	-0.547	-0.181	-0.176	-0.205	-0.360	-0.222	-0.690

Note: Base year is 2010.
Source: Kumar, Joshi, and Aggarwal, 2014

Drought has negative effect on acreage, yield, and production, leading to a rise in crop prices and reduction in consumer demand. It is estimated that with 10 per cent deficit rainfall, production of rice and pearl millet will fall by more than 10 per cent. The corresponding fall in production will be 8.4 per cent for cotton and 7.6 per cent for sorghum. The production of maize, groundnut and pigeon pea will fall by about 4 per cent each. The food prices will have an inflationary trend. Rice being a staple commodity will witness an increase in its prices as high as 23 per cent followed by maize (16 per cent), sorghum and pearl millet (13 per cent each), pigeon pea (10 per cent) and groundnut and cotton (about 5 per cent each).

TABLE 11: EFFECT OF DROUGHT ON CROP ECONOMY, INDIA.

(*per cent*)

Drought intensity (1)	Rice (2)	Sorghum (3)	Pearl millet (4)	Maize (5)	Pigeon pea (6)	Groundnut (7)	Cotton (8)
Supply of commodities							
10.00	-10.71	-7.64	-10.40	-3.90	-4.53	-4.18	-8.36
20.00	-21.43	-15.27	-20.81	-7.80	-9.07	-8.36	-16.72
30.00	-32.14	-22.91	-31.21	-11.71	-13.60	-12.54	-25.08
Price of commodities							
10.00	23.32	13.84	13.45	15.61	9.80	5.31	5.58
20.00	46.65	27.69	26.90	31.22	19.60	10.62	11.15
30.00	69.97	41.53	40.35	46.83	29.39	15.93	16.73
Value of output							
10.00	12.61	6.21	3.05	11.71	5.27	1.13	-2.78
20.00	25.22	12.41	6.09	23.42	10.53	2.26	-5.57
30.00	37.83	18.62	9.14	35.13	15.80	3.39	-8.35
Demand for commodities							
10.00	-5.47	-1.81	-1.76	-2.05	-3.60	-2.22	-6.90
20.00	-10.94	-3.63	-3.53	-4.09	-7.21	-4.43	-13.80
30.00	-16.41	-5.44	-5.29	-6.14	-10.81	-6.65	-20.69

Source: Kumar et al., 2014.

The supply-demand projections reveal that there will be a deficit of about 14 million tons in rice in 2030 in case of 20 per cent drought if government intends to maintain the prices stable under deficit rainfall (Table 12). The gap will be of about 28 million tones under a 30 per cent deficit rainfall scenario. For sorghum and cotton also, there will be deficit in supply-demand in case of a drought of 20 or 30 per cent intensity. In the case of rice, the projected huge deficit in supply will have two serious implications: (i) global rice prices will significantly shoot up as India would import rice to meet its domestic demand; and (ii) the market price of rice would rise in India and there would be an adverse effect on food security of the poor which would drag them into poverty trap.

TABLE 12: PROJECTED SUPPLY-DEMAND GAP FOR SELECTED CROPS UNDER DIFFERENT DROUGHT SITUATION (MILLION TONS)

Crop	2010	2030		
	Normal rainfall	Normal rainfall	20 per cent deficit	30 per cent deficit
(1)	(2)	(3)	(4)	(5)
Rice	0.27	15.6	-13.91	-28.66
Sorghum	0.48	0.09	-0.94	-1.45
Pearl millet	0.72	6.60	2.84	0.96
Maize	1.65	15.34	11.54	9.63
Cotton	0.00	0.00	-2.03	-3.04

Source: Kumar et al., 2014.

Government intervention would be necessary to ensure food and nutritional security of resource-poor consumers and smallholders. This will require a strong social safety net program for the targeted population to ensure adequate supply of food to the vulnerable groups, especially economically weak consumers. In the long-run, technological interventions would be necessary to mitigate the effect of drought and therefore more research efforts and investment on alternative coping-mechanisms would be necessary to protect poor from the effects of drought.

V

CROP PRODUCTIVITY AND SUSTAINABILITY

TFP is an important measure to evaluate the performance of any production system and sustainability of a growth process. Development economists and agricultural economists have examined productivity growth over time and differences among countries, regions, crops, livestock, and fisheries. At the farmers' level, sustainability concerns are being expressed that the input levels must continuously increase to maintain the yield at the old level. The indiscriminate exploitation of natural resources in these intensively cultivated areas has raised concern about the long-term sustainability of the agricultural production system and natural environment. Non-positive trend in TFP has been widely accepted and used as an indicator of the unsustainability of the production system. The farming system is sustainable if it can maintain TFP growth over time. The TFP index of individual crops and agri-food systems was worked out using the Divisia-Tornqvist index and further analysis on return to research investment (Rosegrant and Evenson (1992), Kumar *et al.* (2004) and Chand *et al.* (2011).

5.1 Indo-Gangetic Plain

The irrigated agro-eco-system is the mainstay of India's agricultural economy. It is the backbone of the public distribution system and is a strong base for the food security of the country. Most of the irrigated agriculture in India is concentrated in the Indo-Gangetic Plain (IGP), which is one of the most fertile agricultural regions in the world. IGP accounted for nearly 44 million hectares of cultivated land in the year 2002 and is spread mainly over the states of Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, and West Bengal, and parts of Jammu and Kashmir, Himachal Pradesh, and Rajasthan. The region is endowed with highly productive alluvial soils, rich groundwater resources, and favourable climatic conditions that permit growing of two or more crops in a year. IGP region is dominated by the rice-wheat cropping system, which has been the cradle of the "Green Revolution".

Kumar *et al.*, 2004 analysed crop sector TFP in IGP covering 94 districts. In IGP during 1981-1996, the crop sector output grew at the rate of 3.5 per cent per annum, input index at 2.3 per cent per annum and TFP, at 1.2 per cent. West Bengal depicted the highest growth in TFP index at the rate of 3.1 per cent, whereas it was 2.2 per cent in Haryana, 1.4 per cent in Bihar, 1.2 per cent in Punjab, and 0.6 per cent in Uttar Pradesh. There was relatively higher growth in TFP indices during the 1980s as compared to the 1990s. The finding of a decline in TFP growth in crop sector in the 1990s is consistent with the results presented by Kumar et. al. (1998) for rice-wheat cropping systems in IGP states. TFP growth is decelerating in large areas under crops in a number of districts of IGP, clearly showing signs of un-sustainability. The performance of district wise TFPG revealed that 42.4 per cent of the gross cropped area (GCA), which recorded a high TFP growth during 1980s, declined to 13.9 per cent during 1990s (Table 13). The area under moderate TFP growth had also declined, while the area under low TFP growth increased. The area under stagnant TFP has increased from 28.4 per cent during 1980s to 39.3 per cent during 1990s. The TFP indices did not improve in more than 39.3 per cent of GCA during 1990s and on the contrary, they had declined in 22.5 per cent of the GCA. In fact, quite a significant proportion of the cropped area in the IGP is turning out to be unsustainable.

TABLE 13. DISTRIBUTION OF SHARE OF GCA BY TFP GROWTH IN INDO-GANGETIC PLAIN OF INDIA

TFP Growth (1)	1981-90 (2)	1990-96 (3)	1981-96 (4)
Negative: negative and statically significant TFPG	4.4	22.5	8.8
Stagnant: statically non-significant TFPG	28.4	39.3	26.3
Low: less than 1 per cent TFPG	3.9	7.5	12.1
Moderate: 1-2 per cent TFPG	21.0	16.8	22.9
HIGH: >2 per cent TFPG	42.4	13.9	29.9
GCA (000ha)	47865	47865	47865

Source: Kumar *et al.* (2004).

In the 1980s, 35 districts recorded a high growth in TFP; this number was reduced to 14 districts during the 1990s. The number of districts registering even moderate TFP growth had also declined. However, the number of districts recording a low and stagnant growth in TFP had increased. Forty districts of the IGP did not register any growth in TFP during 1990s; and the corresponding figure was 33 during 1980s. Furthermore, in as many as 23 districts, the TFP had declined, while this number was only 4 during 1980s. The districts falling in categories of negative and stagnant growth of TFP are the priority districts where the problem of sustainability is serious and needed long-term investment for the development of physical and institutional infrastructure and natural resource management (Kumar *et al.* 2004).

5.2 Priority States by Crop

To identify the priority states for investment to raise crop productivity and address the issues of technological progress and sustainability, various states were classified into five groups according to magnitude of growth in TFP, as under: Negative growth: TFP, growth less than “0”; Stagnant growth: TFP growth positive but less than 0.5 per cent ; Low growth: TFP growth 0.5-1 per cent; Moderate growth: TFP growth 1.0-2.0 per cent ; High growth: TFP growth more than 2 per cent.

Table 14 summarises some new evidence generated on crop- and state wise TFP growth based on cost of cultivation data. Technological gains have not occurred in several crops and states. In the case of rice, bajra, cotton and jute all selected states witnessed moderate to high improvement in TFP. Similarly, TFP growth in wheat was found positive in all states except Himachal Pradesh. In the case of jowar, half of the states show low to moderate growth in TFP and the remaining show decline in TFP.

TABLE 14. TRENDS IN TOTAL FACTOR PRODUCTIVITY BY VARIOUS CROPS IN SELECTED STATES OF INDIA: 1975-2005.

Crops	Total factor productivity growth class				
	Positive				Negative
	<0.5 per cent (Insignificant)	0.5-1 per cent (Low)	1-2 per cent (Moderate)	>2 per cent (High)	
(1)	(2)	(3)	(4)	(5)	(6)
Cereals					
Rice	KN, MP, HY BH, OR, WB	AS, KR, UP	AP, TN	PB	
Wheat	BH, WB	MP, RJ	HY, PB, GJ, UP		HP
Maize	MP	UP	BH	AP	HP, RJ
Jowar		TN	MH, AP		MP, RJ, KN
Bajra		UP	HY	RJ, TN, GJ, MH	
Pulses					
Gram	MH, MP, UP		HY	BH	RJ
Moong			AP	RJ	MP, MH, OR
Arhar		GJ, KN	MH, MP	AP	TN, UP, OR
Urad	MH	UP	AP	RJ	MP, OR, TN
Oilseeds					
R&M	UP	AS	RJ	MP	WB, PB, HY
Groundnut			MH, GJ, AP	OR	TN, KN
Soybean		MP, RJ	UP		MH
Cash crops					
Sugarcane					BH, KN, HY, AP, MH, TN, UP
Fibre crops					
Cotton	PB	HY	GJ, MH	AP	
Jute	AS		WB, OR, BH		

Source: Chand et. al. (2011).

Notes: AP: Andhra Pradesh, AS: Assam, BH: Bihar, GJ: Gujarat, HP: Himachal Pradesh, HY: Haryana, KN: Karnataka, KR: Kerala, MP: Madhya Pradesh, MH: Maharashtra, OR: Orissa, PB: Punjab, RJ: Rajasthan, TN: Tamil Nadu, UP: Uttar Pradesh, WB: West Bengal.

About one-third of the selected states experienced fall in TFP in pulse crops. However, Bihar, Rajasthan and Andhra Pradesh witnessed high growth in TFP. Out of sixteen states for which information was available in respect of oilseeds, TFP was found negative in six states, namely West Bengal, Punjab, Haryana, Tamil Nadu, Karnataka and Maharashtra. In the case of sugarcane, all the seven states selected for the study experienced deterioration in TFP. The results relating to TFP growth indicate that technological gains have not been experienced in several crops in many states. Many states show negative, stagnant, or poor growth in total factor productivity for some crop under the study. Only a few states have shown outstanding performance of productivity growth and technological change which has moved the average productivity gain at the country level to a comfortable position, leading to the impression that technological gain have taken place in almost all the crops at the country level. However, the disaggregate analysis shows that a few states and crops did not witness any technological progress. The priority must be focussed for those states which fall under the negative TFP growth or have shown poor performance with less than 0.5% TFP growth. If the sustainability issue of crop system as implied by TFP trend is not addressed properly, it will adversely affect the long-term growth as well as the national food and household nutritional security.

5.3 Distribution of Crop Area based on TFP Growth

An attempt was made to construct TFP growth index for the total crop sector based on distribution of area and TFP growth of selected crops. This was done by assigning scores 0 to 4 to various TFP growth categories and using crop-share in area as the weight. The states were further ranked based on weighted growth rate of TFP score with the highest TFP growth score equated to 100.The estimates for the 16 major states of India are presented in Table 15.

TABLE 15. DISTRIBUTION OF GROSS CROP AREA ACCORDING TO TFP GROWTH AND ITS INDEX BY STATE, INDIA.

State	TFP growth class					Index of TFP growth score	
	Negative	>0.5	0.5-1	1.0-2.0	>2	Value	Rank
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Punjab	0.6	9.5	0.0	53.9	35.9	100.0	1
Gujarat	2.3	0.0	3.7	70.0	24.0	99.5	2
Andhra Pradesh	2.3	0.0	0.0	85.4	12.3	96.9	3
Rajasthan	23.4	0.0	16.9	20.1	39.6	80.2	4
Tamil Nadu	24.0	0.0	0.0	74.3	1.7	72.9	5
Haryana	10.1	18.6	11.3	60.0	0.0	70.2	6
Uttar Pradesh	11.9	6.2	34.4	47.5	0.0	69.1	7
Maharashtra	13.0	2.9	50.4	29.2	4.5	66.4	8
Assam	0.0	3.0	97.0	0.0	0.0	62.5	9
Madhya Pradesh	15.1	55.5	25.0	2.1	2.4	38.5	10
West Bengal	4.8	87.0	0.0	8.2	0.0	35.4	11
Bihar	5.0	90.3	0.0	2.0	2.7	34.0	12.
Orissa	6.2	89.9	0.0	0.0	3.9	33.5	13
Kerala	28.6	71.4	0.0	0.0	0.0	22.7	14
Karnataka	67.5	17.2	6.9	0.0	8.5	20.6	15
Himachal Pradesh	46.1	53.9	0.0	0.0	0.0	17.1	16
All states	7.7	1.3	53.3	37.7	0.0	70.1	-

Source: Chand et. al. (2011)

Punjab, Gujarat, and Andhra Pradesh have been found to fall under high total factor productivity status with almost 90 per cent or more cropped area experiencing moderate to high growth in TFP (more than 1 per cent). About 60 per cent area in Rajasthan witnessed more than 1 per cent growth in TFP. Rajasthan, Tamil Nadu, Haryana, Uttar Pradesh, and Maharashtra states have experienced low to high TFP growth, the cropped area being distributed across all TFP growth classes. The other states, viz., Madhya Pradesh, West Bengal, Bihar, Orissa, Kerala, Karnataka, and Himachal Pradesh have shown relatively low performance in productivity growth and a large share of their cropped area fell under negative, stagnant, or poor productivity category.

The state of Punjab topped the TFP growth score (100). The indices varied from 17.1 for Himachal Pradesh to 99.5 for Gujarat. This shows that technology-driven growth was highest in Punjab and lowest in Himachal Pradesh.

TFP growth score of crop sector in Gujarat, Andhra Pradesh, Rajasthan, and Tamil Nadu was higher than the all-India index, whereas for the states of Uttar Pradesh, Maharashtra, Assam, Madhya Pradesh, West Bengal, Bihar, Orissa, Kerala, Karnataka, and Himachal Pradesh, remained below the average of the country. The index for the state of Haryana was almost same as the all-India average index. Based on this it can be concluded that the states of Madhya Pradesh, West Bengal, Bihar, Orissa, Kerala, Karnataka, and Himachal Pradesh must receive higher priority in the research resource allocations, infrastructural development and technology generation and dissemination to improve sustainability of the growth process.

VI

INPUT SUBSIDY VERSUS FARM TECHNOLOGY

Input subsidy and technology are the two significant factors for the development of agriculture. Concerns are often expressed about a decrease or increase in input subsidies and inadequate investment in agricultural technology development. Policy planners often face the questions like what would happen to food supply, input use, food prices and farmer’s 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 producers and consumers? The partial unified model was designed (Kumar *et al*. 2014) and simulated to suggest the adjustments needed in price and non-price factors to answer such questions. The withdrawal of fertilizer subsidy will have a negative impact on the supply of commodities and their prices will increase. Technological changes induce commodity supply. The positive and negative impacts can be neutralized exclusively by adjusting the TFP sources.

If we withdraw the fertilizer subsidy and depend exclusively on technology to ensure complete product price stability, then the required adjustment in technology was computed and is given in Table 16. Presenting a scenario of 10 per cent withdrawal on fertilizer subsidies, the study has revealed that for its compensation, investment on agricultural research and extension would have to be increased at the annual growth rate of 6 per cent, literacy 0.4-0.7 per cent and irrigation 0.3-0.4 percent. These investments will increase TFP growth by 0.18-0.20 per cent from the base level. The sources of TFP growth are the most powerful instruments that need to be manipulated not only to neutralise factor price inflation but also to safeguard the interest of producers and consumers, while the input price subsidy is likely to have a weak effect on commodity supply. Public policies like investments in irrigation, rural literacy, research, and extension are crucial to increase commodity supply at a higher rate of growth.

TABLE 16. TECHNOLOGY *VERSUS* FERTILIZER SUBSIDY- REQUIRED GROWTH IN SOURCES OF TFP.

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 (per cent) to counter withdrawal of 10 per cent subsidy on fertilisers	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Rice	Wheat	Rice	Wheat	Rice	Wheat
Fertiliser 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	NSs	2.595	Ns
Research & extension	-0.1009	-0.0538	0.6646	0.6000	6.640	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

Note: Ns- Not significant. Source: Kumar and Joshi, 2014.

The input subsidy has a positive effect on input use, crop production 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 MSP 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 MSP program is essential to protect the welfare of farmers.

VII

LIVESTOCK SECTOR

Livestock plays an important role in Indian economy. About 20.5 million people depend upon livestock for their livelihood. Livestock contributed 16% to the income of small farm households as against an average of 14 per cent for all rural households. Livestock provides livelihood to two-thirds of rural community. It also provides employment to about 8.8 per cent of the population in India. The livestock sector contributes 4.11 per cent gross domestic product (GDP) and 25.6 per cent of total Agriculture GDP and provides milk, meat and eggs for human consumption. India is number one milk producer in the world. It produces about 176.34 million tons of milk in a year (2017-18). Similarly, it produces about 95.22 billion eggs, 7.70 million tonnes of meat in a year. At constant prices, the value of output from livestock was about 31.1 per cent of the value of the output from total agriculture and allied sectors.

7.1 Total Factor Productivity of Livestock Sector

Livestock is a source of subsidiary and regular income to many poor families and offer social security. The livestock sector has shown no progress in productivity before 1970-71. The real swing started during the 1980s when the sector's output touched nearly 4 per cent and TFP growth jumped to nearly 1.8 per cent, contributed 45 per cent to the total output growth (Birthal *et al*. 1999). Avila and Evenson (2004) have also reported the accelerating growth in the livestock TFP, growing at the rate of 2.7 per cent per year during 1981-2001 period, contributing 69 per cent to the total livestock output growth. Kumar *et al.* (1977) reported 1.8 per cent TFP growth and 29 per cent rate of return on investment in the research and extension activities of the Indo-Swiss cattle breeding project, Kerala.

7.2 Demand Elasticities of Non-Veg Livestock-Based Food

A multi-stage (three-stage) budgeting framework was used for modelling the behavior of non-vegetarian food consuming households. In the first stage, the household makes decisions on how much of their total income (expenditure) is to be allocated for food consumption, conditional on consumption of the non-food goods and the household and demographic characteristics. In the second stage, the household allocates a portion of food expenditure on non-vegetarian food consumption. In the third stage, the household allocates total non-vegetarian food expenditure among different non-vegetarian items. The demand elasticities of goat meat, poultry, eggs, fish, and other meat are estimated using unit data on household consumer expenditure collected under various NSS rounds. The uncompensated and compensated own-price elasticities of various types of non-vegetarian food, evaluated at the expenditure quartile-specific mean, are given in Table 17. Uncompensated elasticities of demand represent changes in quantity demand because of changes in prices, which capture both price effect and income effect. Compensated elasticities of demand refer to the portion of change in quantity demanded which capture only price effect. The own-price elasticities vary significantly across meat types indicating the importance of estimating demand elasticities by non-vegetarian food groups. The lowest price elasticities were observed for fish (-0.72 to –0.78), which has the highest share (about 50 per cent) in total non-vegetarian food expenditure. Low value meat has the highest (in absolute terms) own-price elasticity for all the expenditure quartile groups, implying that a small increase in price of pork and bovine meat would reduce their consumption in relative higher proportion. The own-price elasticities for goat meat, poultry, eggs were elastic and ranged between -1.1 for goat and -1.4 for eggs. The variation between uncompensated and compensated price elasticities were marginal for goat meat, poultry, eggs, and low value meat reflecting that income effect from price changes were small. Fish had the lowest compensated own-price elasticities. It was almost half in absolute terms as compared to un-compensated elasticities, reflecting its large share in total non-vegetarian food expenditure. Low expenditure (income) groups were more sensitive to price changes than higher expenditure (income) groups except in the case of low value meat. There were variations in terms of own-price elasticity (both compensated and uncompensated) across non-vegetarian food groups, although these variations were marginal except in the case of fish.

TABLE 17: OWN-PRICE ELASTICITY OF VARIOUS NON-VEGETARIAN FOODS IN INDIA.

Income Group (1)	Goat meat (2)	Poultry (3)	Eggs (4)	Fish (5)	Low value meat (6)
Uncompensated					
Very Poor	-1.09	-1.25	-1.39	-0.77	-2.45
Poor	-1.08	-1.25	-1.37	-0.78	-2.99
Non-poor	-1.07	-1.25	-1.37	-0.78	-3.23
Rich	-1.06	-1.22	-1.37	-0.74	-3.94
All	-1.07	-1.23	-1.37	-0.76	-3.62
Compensated					
Very Poor	-0.91	-1.08	-1.22	-0.36	-2.38
Poor	-0.87	-1.07	-1.19	-0.36	-2.98
Non-poor	-0.86	-1.05	-1.19	-0.36	-3.25
Rich	-0.81	-0.98	-1.17	-0.37	-4.01
All	-0.82	-1.00	-1.17	-0.37	-3.67

Income elasticities of different non-vegetarian food groups across income groups are given in Table 18. The income elasticities vary substantially across food types and income groups. Poultry has a higher income elasticity (0.56-0.60) followed by fish (0.36), goat meat (0.27) and other low value meat (-0.16). Income elasticities for all the food groups consistently fall with an increase in per-capita expenditure (income) level of the household. Except pig and bovine meat, none of the groups under study became an inferior good at the highest income quartile. This suggests that even a very rapid increase in aggregate per-capita income in the medium term is not likely to turn non-vegetarian food to an inferior good in India. The results revealed that when total income increases, people tend to spend more on poultry and fish, and relatively less on low value meat (inferior meat).

TABLE 18: INCOME ELASTICITY OF MEAT, EGGS AND FISH IN INDIA.

Income Group (1)	Goat meat (2)	Poultry (3)	Eggs (4)	Fish (5)	Low value meat (6)
Very Poor	0.39	0.85	0.86	0.55	0.18
Poor	0.35	0.76	0.76	0.48	0.03
Non-poor	0.31	0.67	0.68	0.42	-0.06
Rich	0.22	0.46	0.50	0.30	-0.21
All	0.27	0.56	0.60	0.36	-0.16

VIII

FISHERIES SECTOR

The fisheries, a sunrise sector in India has recorded faster growth as compared to the crop and livestock sectors. Fisheries sector has demonstrated an outstanding 8%

average annual growth rate from FY 2013 – 14 to 2021-22 with record fish production of 16.25 Mt in FY 2021-22. The sector provides livelihood to more than 28 Million people along the value chain. The fisheries and aquaculture production contributes around 1 per cent to India's GDP and over 5 per cent to the agricultural GDP. The sector is undergoing a transformation and contributes to the livelihood of a large section of the economically underprivileged population of the country. Policy support, production strategies, public investment in infrastructure, research and extension for fisheries had significantly contributed to increased fish production. India ranks second in fish-production in the world. Production increased from a mere 0.75 Mt in 1950-51 to 5.66 Mt in 2000-01 and reached a record level of 16.25 Mt in 2021-22. According to the Economic Survey of India 2021-22, the fisheries sector has grown at an annual rate of 10.87 per cent since 2014-15. Traditionally, marine fisheries were the main source of growth (share 70 per cent in 1950s) but with the increased focus on aquaculture during the past 3-4 decades, the scenario has changed tremendously. At present, 75 per cent of the total fish production (16.25 Mt) is being contributed by inland capture and aquaculture (12.12 Mt) and 25 per cent by marine fisheries (4.13 Mt). The contribution of inland fisheries to total fish production has increased significantly from less than one third of total production in 1950-51 to about three forth at present.

8.1 Total Factor Productivity of Fisheries Sector

Aquaculture Sector: The fish input, output and TFP indices for aquaculture farming revealed that the input index moved 20 points during 1992-98 with a growth rate of 2.1 per cent per annum. The output index of fish has jumped 45 points with an annual growth rate of 6.1 per cent. The TFP index has moved with an annual growth rate of 4.0 per cent. The TFP growth rates in the aquaculture sector are found to be much higher than the crop and livestock sector (Kumar *et al.* 2004).

Marine Sector: Input index for the marine sector has moved 25 points during 1987-1998 with an annual growth rate of 2.1 per cent. The fish output index increased from 62 points in the year 1991 and 83 points in the year 1998 with an annual growth of 4.1 per cent. The TFP growth has moved 47 points with 2.0 per cent annual growth. The growth in the marine sector was observed to be higher than the TFP growth in the crop sector (Kumar *et al.* 2004).

8.2 Fish Supply Response and Factor Demand

The supply and demand studies on the fisheries sector have not been adequately addressed at the disaggregated level by production environment and by species groups which would be more imperative and useful for assessing supply and demand at the national level. Fish production and consumption is characterized by many species coming from marine and inland sources. The fish species were aggregated into 8 groups based on commercial value, price, taste, and preferences of fish species by consumers and experts' opinion. Many inland and marine fish species are produced and consumed in India. They are classified into 8 groups (Table 19).

Inland fish (Aquaculture): Indian major carps (IMC), other freshwater fish (OFW), and freshwater shrimp (FS).
Marine fish: pelagic high-value (PHV), pelagic low-value (PLV), demersal high-value (DHV), demersal low-value (DLV), shrimp, and molluscs.

TABLE 19: SPECIES GROUPS AND SPECIES COMPOSITION IN INDIA

Species Group (1)	Short name (2)	Major species (3)
Freshwater fish (aquaculture)		
(1) Indian major carps	IMC	Rohu, Catla, Mirgal, calbasu
(2) Other freshwater fish	OFW	Silver carp, grass carp, common carp, murrels, hilsa (inland), and other unspecified inland fish
(3) Prawn/Shrimp	FS	Penaeid shrimp
Marine Fish (capture)		
(4) Pelagic High-Value	PHW	Seer fish, oceanic tunas (yellowfin tuna, skipjack tuna), large carangids (Caranx sp.), pomfrets, pelagic sharks, mullets
(5) Pelagic Low-Value	PLW	Sardines, mackerel, anchovies, bombay duck, coastal tunas, scads, horse mackerel, barracudas
(6) Demersal High-Value	DHV	Rock cods, snappers, lethrinids, big-jawed jumper (Lactarius), threadfins (polynemids)
(7) Demersal Low-Value	DLV	Rays, silverbellies, lizard fish, catfish, goat fish, nemipterids, soles
(8) Crustaceans	MS	Shrimps, lobsters
(9) Molluscs and others	Molluscs	Cephalopods (squids, cuttlefishes and octopus), mussels, oysters, non-penaeid prawns, etc.

Aquaculture Fish Supply and Input Demand Elasticities

The own-price elasticity estimates had the expected sign; they were greater than unity for IMC and OFW and less than unity for prawn/shrimp (FS). Prawn cultivation was capital intensive as compared to other species (Table 20). The short run price effect on supply was sharp and quick for IMC and OFW as compared to FS. The price of IMC would affect the FS supply negatively. The cross-price elasticity of IMC and FS was negative and highly elastic (-4.03). The input price had a mild effect on IMC supply whereas the supply of prawn and OFW would affect sharply. Since the acreage effect on fish supply is quite high (0. 7) for all the aquaculture species groups, it can be used as an instrument for increasing fish supply to meet the domestic demand and export till new technological breakthrough in fish comes about. The inland fish supply was not sensitive to input prices as the cross-input price and fish supply elasticities were highly inelastic except feed price in case of prawn and OFW. The higher fish price would not attract higher use of inputs. The input demand elasticity with respect to own-prices were estimated -0.75 for labour, -0.87 for feed and -1.54 for fertiliser demand. One-way complementarities between labour and material inputs were observed. In India, fish culture is largely practiced in village ponds, tanks and cages with low level of input use, lack of good quality fish seed, lack of access of poor farmers to fish nurseries and unorganised system of fish marketing. Therefore, fish productivity was observed quite low. Most fish producers belong to socio-economically backward community. Any improvement in fish production practices through institutional efforts would increase the demand for quality inputs and supply of fish. This would reduce the cost per unit of production and increase the income level and quality of life of these poor households.

TABLE 20: AQUACULTURE FISH SUPPLY AND INPUT DEMAND ELASTICITIES.

	Fish supply			Input demand		
	IMC	OFW	Prawn	Labour	Feed	Fertilizer
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fish price						
Indian major carps	1.560	0.294	-4.032	0.174	0.032	-0.013
Other freshwater fish	0.157	1.716	-0.224	0.254	0.818	0.637
Fresh water Shrimp/Prawn	-0.645	-0.221	0.727	0.127	0.043	0.171
Input price						
Wage	-0.046	-0.185	-0.210	-0.746	0.047	0.270
Feed price	-0.048	-0.415	-0.417	0.272	-0.872	-0.138
Fertilizer price	0.001	-0.088	-0.113	0.107	-0.009	-1.544
Area in hectare	0.731	0.737	0.73	0.717	0.794	0.626

Source: Kumar *et al.* (2006).

Marine Fish Supply and Input Demand

As seen in Table 21, the own-price elasticity of fish supply was highest for Shrimp (0.49), followed by DHV (0.45), PLV (0.32), molluscs (0.28), PHV (0.28) and minimum for DLV (0.20). The effect of diesel price on shrimp supply was more negatively pronounced than that on the supply of other species groups. The effect of wage on fish supply was highly inelastic. It was because, the labour input was almost

TABLE 21: MARINE FISH SUPPLY AND FACTOR DEMAND ELASTICITIES, INDIA

Variable	PHV	PLV	DHV	DLV	FS	Molluscs	Fuel	Labour
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PHV price (Rs/kg)	0.276							0.001
PLV price		0.326						0.001
DHV price			0.454					0.001
DLV price				0.203				0.001
MS price					0.494			0.003
Mollusc price						0.278		0.001
Average fish price							0.095	
Fuel price (Rs/lit)	-0.059	-0.242	-0.142	-0.368	-0.964	-0.274	-1.099	-0.001
Wage (Rs/day)	-0.004	-0.004	-0.010	0.002	0.005	0.000	-0.002	-0.016
Coast length (km)	0.445	0.309	0.375	0.527	0.367	0.714	1.080	
Year	0.318	0.602	0.033	0.576	1.101	0.284	1.639	

Source: Kumar *et al.* 2006

fixed for marine fishing for a given technology. The diesel price elasticity of fuel demand was highly elastic (-4.6). The operating costs accounted for a maximum proportion of (92 per cent) of the total cost in traditional fishing units followed by ring seine (89 per cent), gill net (84 per cent), trawler (78 per cent) and purse seine unit (74 per cent).

Supply response to fish price is stronger under aquaculture than marine environment in India. Price and technology are the important instruments to induce supply. The change in relative prices of fish species will change the species mixed in total supply.

8.3 Demand Elasticity for Fish by Species

Among species, Indian major carps (IMC) would play dominating role in meeting the fish demand for Indian consumers. The Indian major carps contributed almost half of the total consumption followed by pelagic low value (17.6 per cent), the freshwater carps (13.2 per cent), shrimps including freshwater and marine (6.6 per cent), pelagic high value (6.1 per cent), demersal (4.4 per cent) and molluscs (2.7 per cent).

Available demand studies for the fish sector are limited by their high degree of aggregation, and the lack of empirical basis for estimating the underlying elasticity of demand. The three-stage budgeting framework with quadratic almost ideal demand system (QAIDS) model was used for fish demand analysis by species using consumer expenditure survey data of India (Dey, 2000; Kumar *et al.* 2005) Income and price elasticities of fish demand was evaluated at mean level for different economic groups.

Income Elasticity: Income elasticities of different fish food groups across income groups are given in Table 22. The income elasticities of fish demand were positive and high but vary substantially across fish species by income group. But at

TABLE 22: INCOME ELASTICITY OF DEMAND FOR DIFFERENT GROUPS OF FISH IN INDIA.

Fish group	Expenditure Quartile				
	I	II	III	IV	All
(1)	(2)	(3)	(4)	(5)	(6)
Indian major carps	1.63	1.79	1.54	1.36	1.62
Other freshwater fish	1.64	1.80	1.54	1.36	1.62
Prawn/Shrimp	1.14	1.72	1.54	1.39	1.61
Pelagic high value	0.72	1.76	1.54	1.37	1.62
Pelagic low value	1.66	1.81	1.54	1.34	1.62
Demersal high value	1.56	1.79	1.54	1.36	1.62
Demersal low value	1.64	1.80	1.54	1.36	1.62
Molluscs	3.75	2.01	1.55	1.12	1.66

Source: Kumar *et al.* 2005

Notes: I : Quartile 1- Per-capita weekly expenditure < Rs.85; II : Quartile 2- Per-capita weekly expenditure Rs.85 – 122; III : Quartile 3- Per-capita weekly expenditure Rs.122 – 170; IV : Quartile 4- Per-capita weekly expenditure > Rs. 170.

national level, the magnitude of income elasticities is varied in the narrow range among the fish types (1.61 for shrimp to 1.66 for molluscs). Looking at the variability in elasticities across fish types and income quartile, one can infer that all the species are not homogenous for the consumers. Fish demand would rise with income growth and preference of species mix would also change. The income elasticities were elastic and had been falling for the households living above the poverty line (Quartile II to Quartile IV). Fish would not be an inferior good even for the high-income group of consumers. High fish demand is expected with higher economic growth and shifts in dietary pattern.

Price elasticity: The uncompensated and compensated elasticities of various fish types were evaluated at income quartile-specific means. Uncompensated elasticities of demand represent the change in quantity demanded as a result of change in prices by capturing both price effect and income effect. Compensated elasticities of demand refer to the portion of change in quantity demanded which capture only price effect. Looking at results in Table 23, the own-price elasticities were negative whereas, the cross-price elasticities were positive and highly inelastic. Fish demand was sensitive to price changes.

TABLE 23: OWN-PRICE ELASTICITY OF DEMAND FOR DIFFERENT GROUPS OF FISH IN INDIA.

	Expenditure Quartile				
Fish group	I	II	III	IV	All
(1)	(2)	(3)	(4)	(5)	(6)
Uncompensated own-price elasticity					
Indian major carps	-0.99	-0.99	-0.99	-0.99	-0.99
Other freshwater fish	-0.99	-0.99	-0.99	-0.99	-0.99
Prawn/Shrimp	-0.96	-0.99	-0.99	-1.00	-0.99
Pelagic high value	-0.78	-0.98	-0.99	-0.99	-0.99
Pelagic low value	-1.04	-1.06	-1.04	-1.05	-1.05
Demersal high value	-0.46	-0.92	-0.96	-0.95	-0.95
Demersal low value	-0.88	-0.93	-0.85	-0.82	-0.88
Molluscs	-1.01	-1.00	-1.00	-0.99	-1.00
Compensated own-price elasticity					
Indian major carps	-0.36	-0.45	-0.50	-0.60	-0.52
Other freshwater fish	-0.83	-0.84	-0.89	-0.89	-0.87
Prawn/Shrimp	-0.95	-0.93	-0.90	-0.83	-0.88
Pelagic high value	-0.78	-0.91	-0.87	-0.81	-0.86
Pelagic low value	-0.90	-0.97	-0.93	-0.96	-0.95
Demersal high value	-0.46	-0.90	-0.93	-0.92	-0.92
Demersal low value	-0.86	-0.90	-0.84	-0.81	-0.86
Molluscs	-0.99	-0.96	-0.96	-0.97	-0.97

Source: Kumar *et al.* 2005.

Notes.I: Quartile 1- Per-capita weekly expenditure < Rs.85; II: Quartile 2- Per-capita weekly expenditure Rs.85 – 122; III: Quartile 3-Per-capita weekly expenditure Rs.122–170; IV : Quartile 4-Per-capita weekly expenditure > Rs. 170.

Uncompensated own-price elasticities were in the range between -0.88 for DLV to -1.05 PLV. The compensated elasticities were much lower than that of uncompensated elasticities for aquaculture particularly the IMC species. The compensated own-price elasticity was -0.97 for molluscs, followed by PLV (-0.95), DHV (-0.92), shrimp (-0.88), OFWF (-0.97), PHV (-0.86), DLV (-0.86) and minimum for IMC (-0.52). IMC species are highly preferred fish among consumers in India and its demand seems to be less responsive to price changes keeping income constant. Week substitution among species and low-price response to fish type demand were expected among consumers keeping income constant.

Different fish species were not found to be homogenous for consumers. All eight fish types included in the study were to have positive income elasticity greater than one for all income levels. Hence, with higher income, fish demand would increase substantially with change in species mix. The own-price elasticities by species were negative and near to unity. Technology-driver would increase fish supply and lower down the fish prices. This would increase fish consumption, improve nutritional security and social welfare. Policymakers and researchers must think about the investment needed to develop technologies for augmenting fish productivity.

TFP growth for fish sector was high (2-4 per cent) even to crop and livestock sectors (<2 per cent see Rosegrant and Evenson, 1992; Kumar *et al*., 1998; Birthal *et al*. 1999; Kumar *et al.*, 2005). The contribution of technology in fish supply is estimated to be 48 per cent and 29 per cent respectively for inland and marine sectors. Social welfare is anticipated for both producers and consumers. The technological development in fisheries would make the fish available at cheaper price and would improve household nutritional security.

Aquaculture should be given a priority in the national strategies adopted in the primary sector. Fish production is technology-driven and development in the sector is largely dependent on prioritization of fish farming technologies to benefit poor households. Constraints to its growth range from input supply, post-harvest services, processing, and marketing, in addition to dissemination of technology. On the input side, the major constraints are the unavailability of quality fish seed, and lack of access to credit. Both need to be addressed through development of hatchery and broodstock centres as well as focus on credit delivery systems. On the post-harvest and processing side, there is a need to invest in landing and post-harvest facilities, training of fishers and processors towards better quality and global food safety standards and market access. Strengthening community-based institutions for managing common areas, as well as investments in appropriate stock enhancement and enrichment systems, are promising means for increasing supply under marine environment and thereby benefit the poor fishermen.

IX

PUBLIC INVESTMENTS IN AGRICULTURAL RESEARCH AND EXTENSION

The technological innovation evolved because of enhanced resource allocations to agricultural research and extension (R&E) together with favourable policy support have improved agricultural performance and thereby contributed to poverty alleviation in India (Evenson and Jha, 1973; Rosegrant and Evenson, 1992; Kumar and Rosegrant, 1994, Pal and Singh, 1997). The studies have highlighted the role of agricultural R&E investment in improving the technical change with impressive 33 per cent rates of returns (Chand *et al.* 2011). have reported that The expenditure on agricultural R&E in India is much more effective in reducing poverty and accelerating growth than most other competing alternatives (Fan *et al.*, 1999). Investment in agricultural R&E mainly took place in the public sector, though the share of the private sector has also started picking up in recent years.

As of TE 2010, the share of expenditure in agricultural research and education in total agricultural GDP was 0.66 per cent and that of agricultural extension and training was only 0.18 per cent. The academic community has been advocating raising research investment to 1 percent of agricultural GDP to achieve 4 per cent agricultural growth to attain household food security and alleviation of poverty and hunger. Even this level of investment would not be sufficient to achieve growth target in the sector amidst a variety of emerging challenges like shrinking natural resource base, climate change, slowdown in TFP growth, etc. (Mruthyunjaya and Kumar, 2009).

In this context, Joshi *et al.* 2015 attempted to address several questions such as: whether the contribution of state governments to agricultural R&E investments has been on the decline as noted by past studies? How agricultural R&E funding differs temporally and spatially across the country? What is the present rate of returns to investments of R&E spending in agriculture, and whether the longstanding argument for increasing the share of R&E expenditure in total allocations to the sector justified? It is therefore important to analyse the different dimensions of investment in agricultural R&E and its relationship with agricultural productivity. More specifically, to track past patterns of public spending on R&E to see if they have been sufficient; To explore variation in public spending on R&E across states; to estimate the returns to R&E spending; and to check if states that spend more achieve higher TFP growth. R&E investments in Indian agriculture have grown consistently over the past five decades, in both absolute terms and as a share of GDP agriculture (Table 24).

TABLE 24: AVERAGE ANNUAL INVESTMENT ON AGRICULTURAL RESEARCH AND EXTENSION IN INDIA: 1961-2010

	Investment (in million rupees at 2004-05 prices)		Share of total R&E investment (per cent)		Annual growth (per cent)	
Period (1)	Research (2)	Extension (3)	Research (4)	Extension (5)	Research (6)	Extension (7)
1961-70	4410.6	2303.7	64.95	35.05	3.2	7.2
1971-80	6721.5	2266.0	77.51	22.49	8.1	-2.2
1981-90	13536.0	4401.6	75.23	24.77	6.5	9.3
1991-00	20645.4	6046.1	77.71	22.29	6.1	2.7
2001-10	33903.9	7730.5	81.43	18.57	3.8	9.1

In terms of resource allocations to the agricultural sector, the research component has received higher attention as compared to extension component and the gap between the two appears to have widened over the years. Similarly, there has been a higher focus on crop sub-sector vis-à-vis livestock sub-sector (Table 25). The relative neglect of the livestock sector indeed is a matter of concern and should be pondered over while making future allocations. However, the fisheries sub-sector has been receiving higher allocations in consecutive plan periods, whereas the share of soil and water conservation has remained volatile. Significant variations in investment intensity exist across states with per hectare R&E investments differing by as high as 1:20 between the lowest intensity and highest intensity states (Table 26).

TABLE 25: STRUCTURAL CHANGES IN RESEARCH AND EXTENSION INVESTMENT BY AGRICULTURAL SUB-SECTORS, INDIA.

Government (1)	Period (2)	Agriculture (crop) (3)	Livestock (4)	Fisheries (5)	Soil and water Conservation (6)
	Per cent share of total research investment				
India (states + centre)	1961-70	72.21	21.86	2.67	3.25
	1971-80	73.95	21.21	2.49	2.35
	1981-90	73.96	21.95	2.44	1.66
	1991-00	79.20	16.00	3.52	1.28
	2001-10	78.66	11.38	4.15	5.81
	Per cent share of total extension investment				
India (states + center)	1961-70	88.35	5.06	3.70	2.89
	1971-80	88.35	5.06	3.70	2.89
	1981-90	88.35	5.06	3.70	2.89
	1991-00	89.54	3.38	3.76	3.32
	2001-10	89.74	5.83	3.02	1.42
	Per cent share in agricultural GDP				
India	2007-08	68.2	25.1	5.1	-

TABLE 26: RESEARCH AND EXTENSION INVESTMENT INTENSITY BY STATE IN INDIA, 2001-10

	Per ha. of net cropped area		Per thousand population	
State (1)	Rupees (2)	Growth, (per cent) (3)	Rupees (4)	Growth, (per cent) (5)
Andhra Pradesh	520.8	14.3	64.4	12.9
Assam	821.9	13.4	72.7	11.8
Bihar	438.6	12.8	24.6	7.9
Gujarat	436.4	11.6	69.9	9.8
Haryana	1007.3	15.8	140.9	13.6
Himachal Pradesh	2879.9	14.1	228.7	12.4
Karnataka	373.5	12.8	62.4	10.8
Kerala	1543.5	11.9	99.8	10.9
Madhya Pradesh	97.2	12.5	20.5	7.9
Maharashtra	414.4	10.2	64.7	8.3
Jammu & Kashmir	2461.7	17.7	145.4	15.2
Odisha	173.6	12.0	23.8	9.8
Punjab	590.8	9.9	89.8	8.5
Rajasthan	98.6	8.6	23.2	6.3
Tamil Nadu	1008.6	10.8	71.0	8.1
Uttar Pradesh	183.6	5.1	15.4	2.8
West Bengal	389.5	11.4	22.9	9.8
India	382.5	11.3	44.3	9.3

9.1 Returns to Investment on R&E

While the level of R&E investments and its intensity is a crucial factor that determines the agricultural productivity of states and for India, the actual returns to investment depend considerably on the total factor productivity (TFP) and its growth. TFP growth is determined by factors such as research and extension stock created over the years, infrastructure, quality of natural resources, etc. For estimating marginal value product (MVP) and internal rates of return (IRR) to R&E investments, the total factor productivity growth of crop sector for different states were computed for the period 1980-2008 and the results are presented in Table 27. The respective shares of TFP growth in the total output growth in the states were also obtained to understand the relative contribution of TFP growth to output growth. Wide variations existed in the TFP growth across states. The states associated with high levels of TFP growth were Tamil Nadu (2.88 per cent), Gujarat (2.39 per cent), Odisha (1.87 per cent), Madhya Pradesh and Chhattisgarh (1.17 per cent). On the other hand, the states like Bihar & Jharkhand (0.19 per cent), Maharashtra (0.21 per cent), Himachal Pradesh (0.21 per cent), West Bengal (0.21 per cent), Assam (0.26 per cent), and Karnataka (0.37 per cent) exhibited low performance. The overall TFP growth for India was worked out to be 1.09 per cent. The share of TFP in output growth also varied considerably across states, with high estimates for Tamil Nadu (80.2 per cent), Odisha (79.9 per cent), Gujarat (45.2 per cent), and Haryana (38.3 per cent). At all-India level, the contribution of TFP to total agricultural output growth was estimated to be 29.1 per cent.

TABLE 27: TOTAL FACTOR PRODUCTIVITY GROWTH IN CROP SECTOR BY STATE, 1980-2008

(per cent)

State (1)	Input growth (2)	Output growth (3)	TFP growth (4)	TFP share in output growth (5)
Andhra Pradesh	1.49	2.17	0.69	31.10
Assam	1.18	1.44	0.26	18.07
Bihar & Jharkhand	0.80	0.99	0.19	18.57
Gujarat	2.76	5.15	2.39	45.19
Haryana	2.50	4.11	1.61	38.27
Himachal Pradesh	2.17	2.38	0.21	8.50
Karnataka	1.48	1.84	0.37	19.51
Madhya Pradesh and Chhattisgarh	3.21	4.37	1.17	26.69
Maharashtra	4.16	4.36	0.21	4.53
Odisha	0.47	2.35	1.87	79.86
Punjab	1.85	2.75	0.90	32.04
Rajasthan	3.50	4.24	0.74	17.41
Tamil Nadu	0.71	3.59	2.88	80.22
Uttar Pradesh and Uttarakhand	1.48	2.23	0.75	32.98
West Bengal	2.03	2.25	0.21	9.23
All-India	2.66	3.75	1.09	29.01

The MVP and IRR to R&E investments in different states of India were estimated based on the respective average decadal R&E investments, value of product

(VOP) of crops, share of TFP growth in output growth and TFP elasticity with respect to R&E investments (Table 28). As expected, the states with the higher share of TFP in output growth performed better in terms of MVP and IRR also. The MVP values ranged from less than one to nearly 40, whereas the range of IRR was 18 per cent to 80 per cent. The states with high MVP and high IRR included Madhya Pradesh, Odisha, Uttar Pradesh and Uttarakhand, Tamil Nadu, Punjab, Gujarat, Andhra Pradesh. On the other hand, the poor returns to investment were exhibited by the states like Himachal Pradesh, Maharashtra, and Assam.

Many states that fared low on investment intensity were also found to be backward in terms of agricultural productivity and poverty. The study determined the returns to R&E investment to various states as well as at all India level with two common indicators, viz. VMP and IRR. With a high disparity in TFP in agriculture and its share in output growth, wide variations in VMP and IRR have been noticed across states. While the states like Madhya Pradesh, Odisha, Uttar Pradesh, and Tamil Nadu have fared better in terms of returns to investments, the low-performing states included Himachal Pradesh, Maharashtra, and Assam. It has also been observed that high investment intensity did not necessarily result in high returns to investment. The states with a higher share of TFP growth in output growth performed better in terms of returns to investment. Hence, it is suggested that a conscientious shift of focus from investment heads of low significance to the important head of agricultural R&E is necessary to meet the future growth challenges in the agriculture sector. The policy decisions therefore must be fine-tuned towards this end so that growth in this sector is not compromised in the times to come.

TABLE 28: ESTIMATED MVP AND IRR TO R&D INVESTMENT IN AGRICULTURAL (CROP) SECTOR, INDIA.

State (1)	MVP of R&E investment (2)	IRR (%) to investment in R&E
Andhra Pradesh	9.56	51.83
Assam	2.64	32.54
Bihar & Jharkhand	5.84	43.74
Gujarat	9.77	52.22
Haryana	5.63	43.16
Himachal Pradesh	0.79	19.17
Karnataka	6.70	45.90
Madhya Pradesh & Chhattisgarh	37.86	80.27
Maharashtra	0.69	18.00
Odisha	38.34	80.58
Punjab	11.65	55.37
Rajasthan	8.62	50.06
Tamil Nadu	11.35	54.90
Uttar Pradesh & Uttarakhand	24.12	69.94
West Bengal	5.54	42.91
All-India	8.17	49.14

Note: TFP elasticity with respect to R&E was assumed to be 0.296 (estimated by Fan *et al.*, 1999).

9.2 Food Security, Research Priorities and Resource Allocation

The green revolution during 1960s and 1970s consisting of use of high-yielding crop verities, fertilisers, irrigation, and plant protection measures increased production of major agricultural commodities such as foodgrains, vegetables, fruits, milk, eggs, and fish several fold. The increase in domestic agricultural production has also made a visible impact on the national food and nutritional security. Total factor productivity in agriculture, which brings sustainable growth, is either rising very slowly or has ceased to increase. While the supply side picture is marred with several challenges, demand for food is rising rapidly due to unchecked growth in population and rise in income levels. The increase in food production to meet the requirement must be achieved from the limited, diminishing, and degrading resources. The public resources in agricultural research are becoming inadequate in meeting the expanding research objectives and complex agenda for agricultural research. India has benefited significantly from investment in agricultural research in the past. There is a need to optimally allocate the available scarce resources. Several research prioritization studies were made in India, mostly using modified congruence approach providing normative-relative research priorities in terms of regions (states in India) and individual commodities/ commodity groups (Jha *et al*., 1995). To address priority areas with additional resources, research resources must increase 3 to 4 times in research allocations, raising the level to at least 1 per cent of the agricultural GDP (Kumar *et al.* 2010).

X

POVERTY ALLEVIATION AND NUTRITIONAL SECURITY

Despite impressive growth of food production, India is still home to the maximum number of poor people in the world. India accounts for about one-fifth of the world's poor; two-thirds of them live in the rural and one-third in the urban areas. At the national level, India is self-sufficient in food, but the poor households do not have access to sufficient food, hence, remain food insecure.

Generally, there is a higher concentration of poor and hungry people in rainfed areas as compared with those in irrigated zones. Even with 20 per cent irrigation intensity, there is a sharp fall in the proportion of hunger and poverty, and it remains there irrespective of further intensification of irrigation. It is, therefore, argued that extensive irrigation rather than intensive irrigation will prove much more effective in alleviating poverty. Such a strategy will not only reduce poverty and hunger but will also promote equity and environmental protection and natural resource conservation.

The cropping systems involving food grain crops, there is higher concentration of poverty and hunger under cropping system based on coarse grains, followed by those under rice-based and wheat-based cropping systems. Rice-wheat system is most effective for reducing hunger.

Livestock have the highest effect on reducing poverty and hunger in our country. In rural India, 43 per cent of the people who do not own even a single livestock are largely malnourished. Addition of one cattle or one buffalo to the household assets reduces the hunger prevalence by 16 percentage points in cattle and 25 percentage points in buffalo. In India, the land: man, ratio is small, and the distribution of land is skewed, the diversification of crop-based rural economy into animal husbandry mixed farming system must be encouraged for rapid economic development and generation of equitable income and employment in the country. The crossbreeding program made a significant contribution in increasing the productivity of milch cattle. The returns to investment on cross breeding program are estimated to be 40 per cent (Kumar, *et al*. 1977). Research and extension investments on the crop and fishery sectors have improved over time at the expense of the livestock sector (Joshi *et al.* 2015). The relative neglect of the livestock sector is a matter of concern and should be considered while making future resource allocations.

Literacy has a very high impact on poverty alleviation as well as on hunger reduction. The illiterate people are largely poor and malnourished. Education, even up to primary level, is extremely effective in reducing both poverty and hunger. Graduation and technical education are, of course, the important instruments for reducing both poverty and hunger. Therefore, the educational policy of the country must be geared to remove illiteracy as soon as possible. Free education coupled with midday meals in the schools will go a long way in reducing both poverty and hunger (Kumar and Dey, 2006). The skill development of people in both agriculture and non-agriculture sectors is essential for achieving economic and social goals (Mittal and Kumar, 2000).

At the national level, Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) has facilitated the largest employment-providing program ever started by a country in the world. Its benefits have reached 22.5 per cent of the rural households (30% BPL households, 37% agricultural labourers, 27% sub-marginal farmers (holding < 0.5 ha land) and 21% landless households) and it has been successful in reducing the poverty level in the country by 4 per cent and making substantial increase in calorie intake as well as protein intake, leading to a decrease in the numbers of undernourished and nutrition-deficit households by 8-9 per cent (Table 29). The economically weaker states of the country have benefited more and have implemented the schemes under MGNREGA more vigorously (Kumar and Joshi, 2013).

TABLE 29: IMPACT OF MGNREGA IN INDIA.

Per cent of household (1)	Beneficiaries (2)	Non-beneficiaries (3)	Per cent of households lifted (4)
Below poverty line	40.6	44.6	-4.0
Calories deficit	36.3	44.2	-7.9
Protein deficit	17.7	26.9	-9.2

Source: Kumar and Joshi, 2013.

XI

CONCLUSIONS AND POLICY SUGGESTIONS

During the past two decades, the per-capita consumption of cereals as food has declined while that of horticultural, livestock and fisheries products has increased. There is no doubt that household income and food prices strongly influence the food dietary pattern of the households. In India, the food basket has become more diversified in both rural and urban areas with a significantly higher share of milk, fruits, vegetables, meat and fish. Dietary shift towards high-value food commodities will have a profound impact on agricultural production, marketing, processing, and retailing sector. Despite increasing demand for high-value commodities, the importance of cereals and pulses will continue for attaining nutritional security in the country because food grains account for more than three-fourth share in the total calorie and protein intake. Cereals continue to be the most important food for nutritional requirements and is also the cheapest source of energy and protein. The price of cereals plays an important role in providing food and nutritional security in India.

An assessment of crop demand-supply balance under different scenarios provides valuable insights on the possible levels of self-sufficiency and trade potential for each of the selected crops in the coming years. It may be noted that India has already surpassed the projections of rice, pulses, milk, and fish reported for the year 2030. The supply projections for these commodities are underestimated. It is suggested that the projections must be revised by using elasticities based on a new set of data. Overall, the demand for rice and wheat will be met with their domestic production in the coming years. Pulses, and edible oils would be short in supply in relation to demand in the coming years and India will remain open for imports of these commodities. The policies that can help in maintaining the TFP growth in the long run will be able to keep a balance between domestic production and demand for cereals, pulses, edible oils, and sugar. High attention should be accorded to post-harvest management, agro-processing, and value-addition technologies to reduce the heavy post-harvest losses.

The sustainability issue of crop productivity is fast emerging. All the efforts need to be concentrated on accelerating growth in TFP, whilst conserving natural resources and promoting ecological integrity of agricultural system. The public policies such as investments in irrigation, rural literacy, and agricultural research and extension are crucial to increase TFP and food supply at a higher growth rate. Extension services need to be strengthened by scaling-up investment levels and improving the quality of extension. Reforms in marketing and macroeconomic policies are needed to encourage long-term investment and technological changes in the agricultural sector.

Climate change has led to an increase in different types of risks which adversely affected agricultural production, led to an increase in the prices of agricultural commodities, and affected the commodity demand. The benefits of higher prices are not getting passed to most farmers, especially small holders, but seized by middlemen/traders. Access to even the limited irrigation water may overcome the drought conditions during the critical crop growth stages, which would substantially reduce the number of undernourished farm-households (Singh *et al.*, 2002).

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's income. 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 MSP is essential to protect the welfare of farmers.

The demand and supply studies for the fish sector are limited by their high degree of aggregation, and the lack of empirical basis for estimating the underlying elasticities of demand and supply. Three-stage budgeting framework with quadratic almost ideal demand system (QAIDS) model has been used for fish demand analysis by species, using consumer expenditure survey data of India. For supply analysis of fish by production environments and species group, we used normalized quadratic form of the profit function. Supply and demand studies in the fisheries sector have been addressed at the disaggregated level by species grown in different production environments. Aquaculture would hold the key to meet the future supply challenges. Among species, IMC would play a dominating role in meeting the fish demand. Price and income elasticities of demand vary across species and income classes. Supply response to fish price change has been stronger for aquaculture than marine fisheries. Price and technology have been reported as important instruments to induce higher supply. The change in the relative prices of fish species would change the species-mix in the total supply.

The R&E investments in the crop and fishery sectors have improved over time at the expense of the livestock sector. The relative neglect of the livestock sector is a matter of concern and should be taken into consideration while making future allocations. However, the fisheries sub-sector has been receiving higher allocations in consecutive plan periods, whereas the share of soil and water conservation has remained volatile. The states with a higher R&E investment and higher share of TFP growth as a part of output growth performed better in terms of returns to investment on R&E. The R&E investment in the crop sub-sector in India has been especially rewarding, generating returns that are close to 50 per cent. R&E resource allocation must focus and shift from low significance to the important head of agricultural.

Small farmers below 1 ha of land constitute more than half of the number of hungry and poor people. Livestock and fisheries sector should receive high priority with multiple objectives of diversifying agriculture, raising income, employment, and meeting the nutritional security of the poor farm households. Education level, livestock status, irrigation facilities, and agricultural diversification have tremendous impact on rural employment opportunities and alleviation of hunger and poverty. Literacy has emerged as an important driver of adoption of technology, use of modern inputs like machine, fertilisers, and yield. Literacy will play a far more important role in the globalised world than it did in the past. In future agriculture will increasingly be science-led and will require modern economic management, high return to investment on education is expected (Mittal and Kumar, 2000). Rural infrastructures (roads), education and irrigation - amount to a 'win-win' strategy for reducing rural poverty by also increasing the non-farm economy and raising rural wages. There is a need to create necessary policy environment to reduce risk for small farmers, through enterprise diversification, generation of new livelihoods, and off-farm income.

Poverty is mainly a rural phenomenon and urban poverty is also an indirect effect of rural poverty. As an impact of COVID-19 there is large scale loss of livelihood and food, and nutrition security of the population is largely affected. Larger numbers of people in both rural and urban regions shave moved below the poverty line. All pillars of Food security – production, availability, accessibility, and utilization got impacted. Given these additional constraints on agriculture and food-nutrition security, it is even more important to have the right price policy. Science and policies must have a human face as the poor do not want charity; they want opportunity to build their future by enrichment with knowledge, freedom and equity and must be provided a congenial environment.

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APPENDIX TABLE 1: ESTIMATES OF HUMAN LABOUR DEMAND ELASTICITIES FOR CROPS, INDIA

Crop	w/P	b/P	m/P	r/P	i/P
Rice	-0.1680	-0.0177	0.0640	-0.0086	0.1303
	(-4.95)	(-0.89)	(4.02)	(-0.47)	(6.74)
Wheat	-0.3060	0.1540	0.0035	0.1693	-0.0210
	(-8.65)	(8.81)	(0.11)	(6.81)	(-0.65)
Coarse grains	-0.3923	0.1992	-0.0029	0.1549	0.0410
	(-11.56)	(11.27)	(-0.18)	(7.13)	(2.54)
Maize	-0.0178	0.0137	0.0426	-0.0476	0.0090
	(-0.45)	(0.69)	(2.63)	(-1.60)	(0.40)
Sorghum	-0.4017	0.1738	-0.0025	0.1696	0.0609
	(-16.28)	(9.74)	(-0.16)	(10.34)	(4.39)
Pearl millet	-0.3446	0.1436	0.0812	0.1055	0.0143
	(-10.74)	(6.55)	(4.97)	(7.07)	(1.03)
Pulses	-0.2332	-0.0822	0.1246	0.0656	0.1253
	(-4.21)	(-2.69)	(4.25)	(2.88)	(3.33)
Chickpea	-0.2876	0.0935	0.2659	0.0352	-0.1070
	(-5.64)	(2.92)	(8.54)	(1.47)	(-3.03)
Pigeon pea	-0.2730	-0.0755	0.1551	0.0576	0.1358
	(-4.67)	(-2.69)	(5.59)	(1.81)	(3.23)
Green gram	-0.4750	0.1261	0.0957	0.0187	0.2346
	(-7.08)	(5.59)	(2.41)	(1.37)	(4.11)
Black gram	-0.2133	0.1920	-0.0202	0.0280	0.0134
	(-5.88)	(10.62)	(-0.73)	(1.88)	(0.49)
Edible oilseeds	-0.5021	-0.0071	0.0222	0.2071	0.2799
	(-14.70)	(-0.35)	(0.76)	(10.01)	(7.37)
Rapeseed & mustard	-0.1595	0.0263	0.0342	0.0377	0.0612
	(-5.35)	(1.29)	(1.16)	(1.61)	(2.43)
Groundnut	-0.2837	0.0733	0.0152	0.1363	0.0588
	(-6.55)	(3.72)	(1.12)	(6.37)	(2.09)
Soybean	-0.1917	0.0899	0.1642	0.0838	-0.1462
	(-3.07)	(2.40)	(4.67)	(1.95)	(-3.17)
Sugarcane	-0.0768	0.0871	0.0221	-0.1073	0.0749
	(-1.84)	(4.31)	(0.92)	(-3.92)	(3.10)
Onion	-0.1077	0.0060	-0.0562	0.0691	0.0889
	(-1.96)	(0.26)	(-2.65)	(2.22)	(2.22)
Potato	-0.1077	0.0060	-0.0562	0.0691	0.0889
	(-1.96)	(0.26)	(-2.65)	(2.22)	(2.22)
Cotton	-0.3534	0.1688	0.0369	0.1117	0.0360
	(-9.68)	(8.73)	(2.45)	(5.72)	(1.26)
Jute	-0.0846	0.0884	0.0252	-0.0576	0.0287
	(-2.31)	(4.70)	(1.98)	(-2.91)	(2.35)
All crops	-0.3017	0.0354	0.0372	0.0867	0.1424

Note: The figures within the parentheses are the corresponding student t-statistics
Here, w = Wage (Rs/hour), b = Cost on animal labour (Rs/hour), m = Cost on machine labour (Rs/hour), P = Price of crop (Rs/100 kg), r = Cost of fertilizer (NPK) (Rs/kg), i = Cost of irrigation (Rs/ha)
Source: Kumar 2011; Kumar and Mittal 2023

APPENDIX TABLE 2: ESTIMATES OF ANIMAL LABOUR DEMAND ELASTICITIES FOR CROPS, INDIA

Crop	w/P	b/P	m/P	r/P	i/P
Rice	-0.0582	-0.2802	0.2439	0.0196	0.0749
	(-0.89)	(-3.97)	(6.29)	(0.39)	(1.63)
Wheat	0.3727	-0.6213	0.1856	-0.2018	0.2648
	(8.81)	(-13.26)	(3.96)	(-4.41)	(5.40)
Coarse grains	0.4698	-0.7473	0.1712	-0.0500	0.1564
	(11.27)	(-17.60)	(8.67)	(-2.13)	(8.06)
Maize	0.0377	-0.5235	0.1755	0.0039	0.3064
	(0.69)	(-8.49)	(6.06)	(0.08)	(7.44)
Sorghum	0.3269	-0.4706	0.0806	0.0050	0.0581
	(9.74)	(-11.56)	(3.64)	(0.21)	(2.73)
Pearl millet	0.3912	-0.8273	0.3102	-0.0541	0.1801
	(6.55)	(-13.50)	(9.19)	(-2.04)	(6.67)
Pulses	-0.1897	-0.1543	0.2704	-0.0118	0.0854
	(-2.69)	(-1.88)	(4.84)	(-0.33)	(1.26)
Chickpea	0.1860	-0.8796	0.5722	0.0457	0.0757
	(2.92)	(-10.96)	(9.74)	(1.28)	(1.31)
Pigeon pea	-0.1823	-0.1264	0.0246	0.1218	0.1624
	(-2.69)	(-2.03)	(0.63)	(3.15)	(3.14)
Green gram	0.2860	-0.4454	0.1353	0.0942	-0.0701
	(5.59)	(-6.88)	(3.54)	(4.38)	(-1.59)
Black gram	0.5032	-0.7677	0.1733	-0.1543	0.2456
	(10.62)	(-10.15)	(4.11)	(-6.40)	(4.47)
Edible oilseeds	-0.0176	-0.4878	-0.0043	-0.0291	0.5388
	(-0.35)	(-8.51)	(-0.07)	(-0.76)	(7.25)
Rapeseed & mustard	0.0827	-1.0879	0.6046	0.0566	0.3440
	(1.29)	(-12.93)	(6.97)	(0.93)	(4.93)
Groundnut	0.1837	-0.4647	0.1276	0.0069	0.1466
	(3.72)	(-12.16)	(6.63)	(0.22)	(4.20)
Soybean	0.1773	-0.5131	0.2671	-0.0094	0.0780
	(2.40)	(-4.75)	(5.21)	(-0.20)	(1.22)
Sugarcane	0.7560	-0.7777	-0.2332	0.2571	-0.0022
	(4.31)	(-5.50)	(-1.98)	(1.75)	(-0.02)
Onion	0.0245	-0.2293	0.0673	0.1342	0.0033
	(0.26)	(-1.91)	(1.82)	(1.91)	(0.03)
Potato	0.0245	-0.2293	0.0673	0.1342	0.0033
	(0.26)	(-1.91)	(1.82)	(1.91)	(0.03)
Cotton	0.5865	-0.9390	0.1443	-0.0924	0.3006
	(8.73)	(-12.76)	(5.06)	(-2.98)	(4.83)
Jute	0.3569	-0.5034	-0.0352	0.1454	0.0363
	(4.70)	(-8.45)	(-1.18)	(3.36)	(1.20)
All crops	0.2111	-0.4895	0.1309	0.0188	0.1287

Source: Kumar 2011; Kumar and Mittal 2023

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

Here, w = Wage (Rs/hour), b = Cost on animal labour (Rs/hour), m = Cost on machine labour (Rs/hour), P = Price of crop (Rs/100 kg), r = Cost of fertilizer (NPK) (Rs/kg), i = Cost of irrigation (Rs/ha)

APPENDIX TABLE 3: ESTIMATES OF MACHINE LABOUR DEMAND ELASTICITIES FOR CROP IN INDIA

Crop	w/P	b/P	m/P	r/P	i/P
Rice	0.3920	0.4536	-1.2564	0.0635	0.3473
	(4.02)	(6.29)	(-15.31)	(0.95)	(5.01)
Wheat	0.0070	0.1515	-0.3236	0.2307	-0.0656
	(0.11)	(3.96)	(-3.20)	(4.20)	(-0.61)
Coarse grains	-0.0132	0.3326	-0.9256	0.3456	0.2606
	(-0.18)	(8.67)	(-11.17)	(5.07)	(4.65)
Maize	0.2445	0.3661	-0.8120	-0.1563	0.3578
	(2.63)	(6.06)	(-6.64)	(-1.30)	(4.38)
Sorghum	-0.0113	0.1933	-0.6661	0.2327	0.2514
	(-0.16)	(3.64)	(-7.89)	(3.29)	(4.71)
Pearl millet	0.2849	0.3996	-0.7073	0.2058	-0.1830
	(4.97)	(9.19)	(-7.22)	(3.29)	(-3.58)
Pulses	0.4123	0.3879	-0.7598	0.0426	-0.0830
	(4.25)	(4.84)	(-6.20)	(0.76)	(-0.80)
Chickpea	0.5737	0.6210	-1.0825	-0.1851	0.0728
	(8.54)	(9.74)	(-11.58)	(-4.09)	(0.99)
Pigeon pea	0.7056	0.0463	-0.8209	0.0967	-0.0277
	(5.59)	(0.63)	(-6.19)	(0.88)	(-0.21)
Green gram	0.4379	0.2729	-0.1447	-0.1378	-0.4283
	(2.41)	(3.54)	(-0.76)	(-2.73)	(-2.61)
Black gram	-0.0834	0.2735	0.0884	-0.0026	-0.2759
	(-0.73)	(4.11)	(0.62)	(-0.04)	(-2.76)
Edible oilseeds	0.0841	-0.0065	-1.3750	-0.1327	1.4301
	(0.76)	(-0.07)	(-7.56)	(-1.34)	(7.40)
Rapeseed & mustard	0.0826	0.4650	-1.0986	0.0207	0.5303
	(1.16)	(6.97)	(-7.40)	(0.28)	(4.02)
Groundnut	0.1049	0.3512	-0.6558	0.3970	-0.1972
	(1.12)	(6.63)	(-6.63)	(5.12)	(-1.80)
Soybean	0.3830	0.3158	-0.3852	-0.4624	0.1488
	(4.67)	(5.21)	(-4.39)	(-5.82)	(1.92)
Sugarcane	0.2275	-0.2770	-1.4102	1.4267	0.0330
	(0.92)	(-1.98)	(-5.14)	(6.92)	(0.23)
Onion	-0.7099	0.2071	0.5892	0.3460	-0.4323
	(-2.65)	(1.82)	(1.93)	(1.43)	(-2.29)
Potato	-0.7099	0.2071	0.5892	0.3460	-0.4323
	(-2.65)	(1.82)	(1.93)	(1.43)	(-2.29)
Cotton	0.2143	0.2409	-0.7372	0.2360	0.0460
	(2.45)	(5.06)	(-6.35)	(2.37)	(0.53)
Jute	0.5671	-0.1965	-0.8183	0.1898	0.2580
	(1.98)	(-1.18)	(-3.48)	(1.00)	(1.76)
All crops	0.1728	0.1851	-0.9506	0.3061	0.2865

Note: The figures within the parentheses are the corresponding student t-statistics
Here, w = Wage (Rs/hour), b = Cost on animal labour (Rs/hour), m = Cost on machine labour (Rs/hour), P = Price of crop (Rs/100 kg), r = Cost of fertilizer (NPK) (Rs/kg), i = Cost of irrigation (Rs/ha)
Source: Kumar 2011; Kumar and Mittal 2023

APPENDIX TABLE 4: ESTIMATES OF FERTILIZER DEMAND ELASTICITIES FOR CROP IN INDIA

Crop (1)	w/P (2)	b/P (3)	m/P (4)	r/P (5)	o/P (6)
Rice	-0.0345	0.0238	0.0415	-0.2452	0.2144
	(-0.47)	(0.39)	(0.95)	(-3.57)	(4.30)
Wheat	0.3111	-0.1532	0.2147	-0.3504	-0.0222
	(6.81)	(-4.41)	(4.20)	(-5.63)	(-0.34)
Coarse grains	0.8352	-0.1143	0.4065	-1.2358	0.1085
	(7.13)	(-2.13)	(5.07)	(-10.57)	(1.47)
Maize	-0.2205	0.0065	-0.1263	0.0051	0.3352
	(-1.60)	(0.08)	(-1.30)	(0.03)	(3.54)
Sorghum	1.0489	0.0165	0.3189	-1.6839	0.2995
	(10.34)	(0.21)	(3.29)	(-12.32)	(3.69)
Pearl millet	0.9046	-0.1704	0.5029	-1.5790	0.3419
	(7.07)	(-2.04)	(3.29)	(-9.92)	(3.46)
Pulses	0.6424	-0.0500	0.1259	-0.8094	0.0911
	(2.88)	(-0.33)	(0.76)	(-5.12)	(0.51)
Chickpea	0.3440	0.2244	-0.8381	-0.2532	0.5229
	(1.47)	(1.28)	(-4.09)	(-1.32)	(2.55)
Pigeon pea	0.5161	0.4519	0.1905	-0.6957	-0.4628
	(1.81)	(3.15)	(0.88)	(-2.64)	(-1.93)
Green gram	0.2537	0.5646	-0.4091	-0.6204	0.2113
	(1.37)	(4.38)	(-2.73)	(-5.72)	(1.14)
Black gram	0.3840	-0.8063	-0.0087	-0.5932	1.0242
	(1.88)	(-6.40)	(-0.04)	(-3.66)	(5.22)
Edible oilseeds	0.9695	-0.0550	-0.1639	-1.1183	0.3677
	(10.01)	(-0.76)	(-1.34)	(-9.21)	(2.66)
Rapeseed & mustard	0.1355	0.0648	0.0308	0.2152	-0.4463
	(1.61)	(0.93)	(0.28)	(1.81)	(-3.78)
Groundnut	0.6800	0.0136	0.2873	-1.1260	0.1451
	(6.37)	(0.22)	(5.12)	(-10.49)	(1.61)
Soybean	0.3343	-0.0190	-0.7902	-0.1662	0.6412
	(1.95)	(-0.20)	(-5.82)	(-0.84)	(4.59)
Sugarcane	-0.3256	0.0899	0.4201	-0.4278	0.2434
	(-3.92)	(1.75)	(6.92)	(-4.32)	(3.84)
Onion	0.2681	0.1269	0.1063	-0.4579	-0.0434
	(2.22)	(1.91)	(1.43)	(-3.89)	(-0.42)
Potato	0.2681	0.1269	0.1063	-0.4579	-0.0434
	(2.22)	(1.91)	(1.43)	(-3.89)	(-0.42)
Cotton	0.3882	-0.0924	0.1413	-1.0416	0.6044
	(5.72)	(-2.98)	(2.37)	(-12.79)	(11.04)
Jute	-0.7601	0.4750	0.1110	0.2949	-0.1208
	(-2.91)	(3.36)	(1.00)	(1.43)	(-1.20)
All crops	0.4051	-0.0456	0.0882	-0.6458	0.1982

Source: Kumar 2011; Kumar and Mittal 2023

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

Here, w = Wage (Rs/hour), b = Cost on animal labour (Rs/hour), m = Cost on machine labour (Rs/hour) P = Price of crop (Rs/100 kg), r = Cost of fertilizer (NPK) (Rs/kg), i = Cost of irrigation (Rs/ha)

APPENDIX TABLE 5: ESTIMATES OF IRRIGATION AND OTHER INPUTS DEMAND ELASTICITIES FOR CROP IN INDIA

Crop (1)	w/P (2)	b/P (3)	m/P (4)	r/P (5)	o/P (6)
Rice	0.3375	0.0589	0.1469	0.1389	-0.6823
Wheat	-0.0269	0.1403	-0.0426	-0.0155	-0.0553
Coarse grains	0.1458	0.2357	0.2021	0.0715	-0.6551
Maize	0.0307	0.3794	0.2124	0.2463	-0.8688
Sorghum	0.2641	0.1339	0.2416	0.2100	-0.8496
Pearl millet	0.0657	0.3044	-0.2402	0.1836	-0.3135
Pulses	0.2324	0.0687	-0.0465	0.0173	-0.2718
Chickpea	-0.1293	0.0460	0.0408	0.0646	-0.0221
Pigeon pea	0.4164	0.2061	-0.0187	-0.1582	-0.4456
Green gram	0.5628	-0.0742	-0.2245	0.0373	-0.3014
Black gram	0.0356	0.2488	-0.1771	0.1986	-0.3059
Edible oilseeds	0.4288	0.3330	0.5780	0.1203	-1.4601
Rapeseed & mustard	0.1617	0.2893	0.5799	-0.3281	-0.7028
Groundnut	0.0552	0.0549	-0.0269	0.0273	-0.1105
Soybean	-0.1780	0.0482	0.0777	0.1958	-0.1436
Sugarcane	0.1169	-0.0004	0.0050	0.1252	-0.2467
Onion	0.0920	0.0008	-0.0354	-0.0116	-0.0458
Potato	0.0920	0.0008	-0.0354	-0.0116	-0.0458
Cotton	0.0547	0.1314	0.0120	0.2642	-0.4622
Jute	0.2034	0.0638	0.0812	-0.0650	-0.2834
All crops	0.2489	0.1636	0.2153	0.0895	-0.7172

Source: Kumar 2011; Kumar and Mittal 2023.

Notes: The estimates were derived using homogeneity condition in the model. Therefore, student t- statistics are not computed.

Here, w = Wage (Rs/hour), b = Cost on animal labour (Rs/hour), m = Cost on machine labour (Rs/hour) P = Price of crop (Rs/100 kg), r = Cost of fertilizer (NPK) (Rs/kg), i = Cost of irrigation (Rs/ha)