NABARD Research Study No. 40

Prospects of India's Demand and Supply for Agricultural Commodities towards 2030

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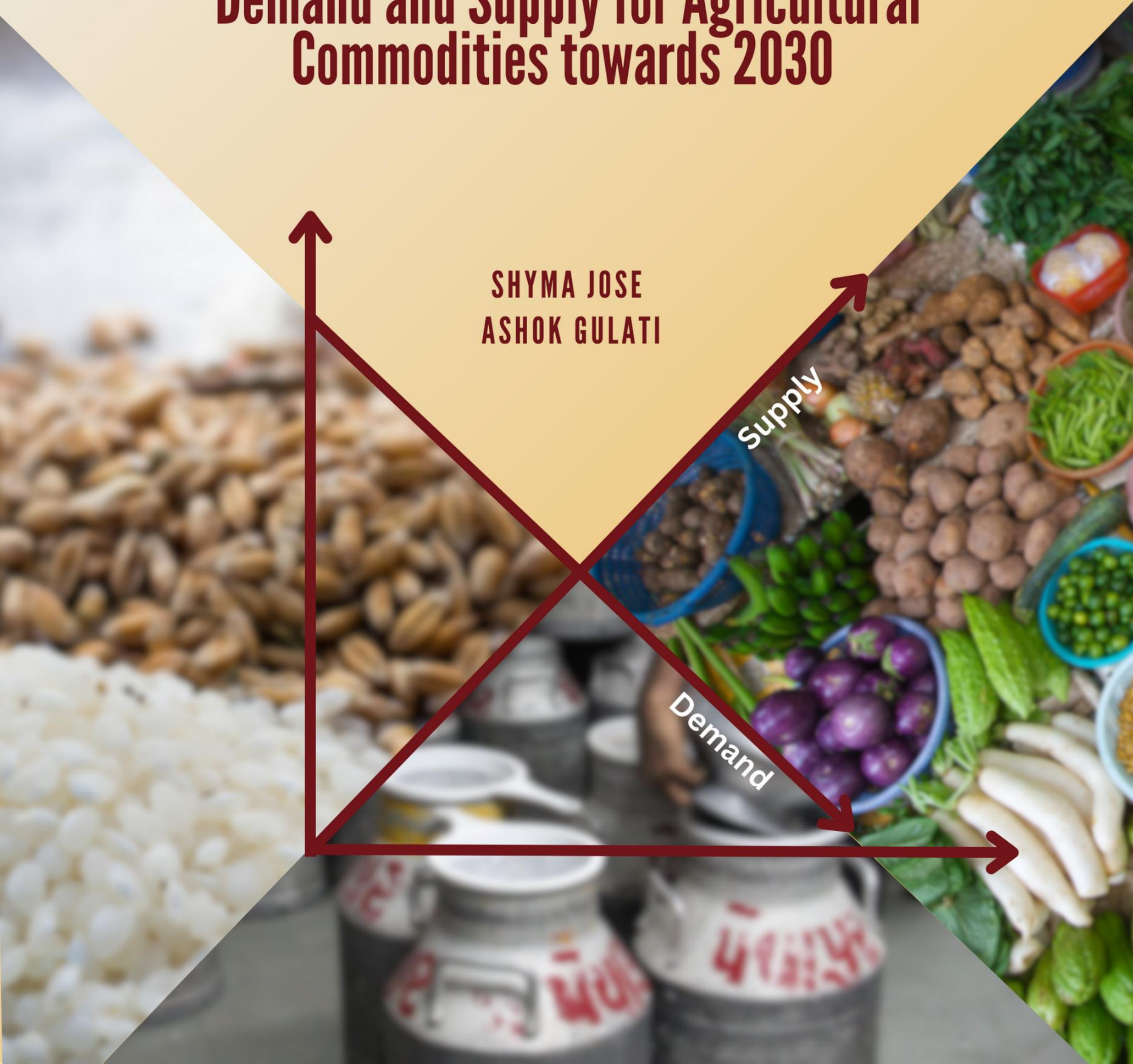

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ABBREVIATIONS USED

AIDS	Almost Ideal Demand System
FAO	Food and Agriculture Organization
FCDS	Food Characteristic Demand System
FYP	Five Year Plan
GDP	Gross Domestic Product
HYV	High Yielding Variety
IMF	International Monetary Fund
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
MMT	Million Metric Tonnes
NSSO	National Sample Survey Organization
COVID 19	Novel Coronavirus Disease
PCY	Per Capita Income
PDS	Public Distribution System
QUAIDS	Quadratic Almost Ideal Demand System
RMSE	Root Mean Square Error
SFWI	Seed Feed Wastage and Industrial Use
TE	Triennium Ending
UN	United Nations
WPP	World Population Prospect

ACKNOWLEDGEMENTS

Accurate demand and supply forecasts are necessary for policymakers to generate an outlook of essential commodities in the medium and long run. The fluctuation in production can result in a deficit in the food balance sheet, thereby, impacting food security, price stability and increasing dependence on imports. Therefore, the present report aims to provide a better understanding of the demand and supply situation of essential commodities till 2030 in India and put forth recommendations based on our findings so that India is food secure in coming years.

We gratefully acknowledge the financial support provided by the Department of Economic Analysis and Research (DEAR) - National Bank for Agriculture and Rural Development (NABARD). We would like to express our profound gratitude to Dr G.R. Chintala, Chairman, NABARD and Dr G.R. Chintala, Dr Harsh Kumar Bhanwala, former Chairman, NABARD for their support and productive interaction from the very conception of the project.

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Lastly, we extend our sincere gratitude to Ms Kriti Khurana and Ms Akshaya Aggarwal for their outstanding research support, particularly in data collation and empirical analysis. Their contributions were instrumental for finalising this study.

FOREWORD

India has come a long way from being a food insecure nation to being self-sufficient in foodgrains production. Today, the country is the largest producer of cotton, pulses, milk and jute in the world and the second-largest producer of rice, wheat, sugar and fruits and vegetables globally. However, this was not the situation during the first decade of independence. The country was on the verge of a massive famine with two consecutive droughts (1965-66 and 1966-67) and decelerating foodgrains production, making it depend heavily on food imports under the PL- 480 food aid programme of the United States.

Since then, India has made remarkable progress in food production. Through improvement in the agricultural practices, increased availability of improved variety seeds, and investment in irrigation facilities, along with price support policies, the Green Revolution technology was able to increase foodgrains production in the country during the late 1960s and early 1970s. This transformation of Indian agriculture, from relying on food imports to being self-sufficient in foodgrains production was primarily due to focussed policy interventions and innovative technology and planning for future food security, which in turn, depends upon reliable demand and supply predictions of essential food articles.

The reliable demand and supply forecasts, therefore, need to incorporate population and per capita income growth as well as changing tastes and preferences of the population to provide an accurate food balance outlook for medium to long term. For instance, during the last two decades, the demand and supply situation in Indian agriculture has undergone significant change. Owing to the rapidly increasing population coupled with sustained income growth and changing lifestyles, there has been a significant shift in the consumption pattern. Moreover, the diversification of the food basket away from traditional staples toward high-valued commodities significantly influences future prospects of the demand and supply of food items. And therein lies the challenge: how to meet the growing demand on a sustainable basis as well as moderate any fluctuation in the supply of agricultural commodities especially in the face of climate change? In this regard, the present study provides the estimates of demand, supply, and associated deficit in domestic production, if any, that has to be met through imports till 2030.

We expect this report would lead to an informed debate among various stakeholders for imparting proper planning for future policies and programmes to facilitate meeting the country's food and nutritional security in the coming decade.

Deepak Mishra
Director & Chief Executive
ICRIER

Shaji K V
Chairman
NABARD

PREFACE

The main premise of the study is to impart strategic planning for the future to sustain food security while working towards achieving nutritional security in the country till 2030. Importantly, ensuring food security in the country requires huge investments in productivity-enhancing techniques, innovative technology, and focused interventions and policies based on demand and supply projections for the medium and long term. Against this backdrop, the present study forecasts demand and supply estimates of agricultural commodities (wheat, rice, coarse cereals, cereals, pulses, foodgrains, sugar, oilseeds, fruits, vegetables, milk, and meat) for the period up to 2030. In doing so, the paper first reviews the past studies and finds out systematic biases, if any. In the light of this close examination of literature, especially their models, the present study gives its own estimates of demand and supply. Hopefully our estimates are likely to have smaller degree of error than the past studies.

The literature on demand projections of agricultural commodities in the past has used different approaches including Household Consumption, Normative, Behaviouristic and Absorption approaches. Most of these approaches to demand projections are based on the per capita consumption of agricultural commodities from the latest National Sample Survey Organisation's consumption expenditure survey round (2011-12) as the base year. Since 2011-12, the consumption basket has not only diversified but the taste and preferences have also changed remarkably. Therefore, in the present study, rather than using NSSO per capita consumption, we have used an absorption function to project the future demand of selected agricultural commodities where absorption is the summation of actual production and net import after deducting changes in government stock.

Under the scenario of the pandemic and given the medium-term forecast up to 2030-31, we have assumed alternative three GDP growth rate scenarios for projecting the demand: 5 percent (pessimistic), 6 percent (business as usual) and 7 percent (optimistic) per annum. The projected population as given by the UN's WPP (2019), under the assumption of no change, has been estimated to grow at 0.9 percent per annum between 2020 and 2030. After adjusting for the growth rate in population, per capita income (PCY) is estimated to grow at an average rate of about 4.1, 5.1 and 6.1 percent per annum, respectively, under the three GDP growth rate scenarios. We have forecasted the future demand for foodgrains (rice, wheat, coarse cereals, and pulses), sugar, oilseeds fruits, vegetables, milk, and meat up to 2030-31 using the three different scenarios of PCY growth, population projections and two sets of expenditure elasticities as estimated by Kumar et al. (2011) and the Working Group Report (2018) of the Niti Ayog. Using different scenarios and elasticities provides us with the possible range of demand for these selected for the forecasted time period.

The absorption for cereals and pulses is forecasted to increase up to 272.1 million tonnes (MT) and 33.7 MT, respectively, by the end of 2030-31 if the PCY grows by 4.1 percent per annum or increases up to 273.3 MT and 35.3 MT, respectively if the PCY grows at the rate of 6.1 percent per annum using elasticities estimated by Kumar et al. (2011). Similarly, the projected demand for fruits and vegetables will increase up to 129.5-140 MT and 228.5-241.8 MT, respectively, by the end of 2030-31 whereas the absorption of milk and meat will increase in the range of 252.3 -276.8 MT and 10.9-12.5 MT, respectively, by 2030-31 under the different assumptions of PCY growth rate. Using the elasticities given by the WG (2018) of Niti Ayog, we estimate the cereal demand by the end of 2030-31 will increase up to 260.6 MT under 4.1 percent PCY growth and 254.7 MT under 6.1 percent PCY growth. The demand for pulses will range between 37.99 to 42.21 MT in 2030-31 depending on the varying growth scenarios. Our demand estimates reiterate that the consumption basket tends to diversify towards nutritious and high-valued commodities including fruits and vegetables and dairy products, away from staples such as cereals.

Likewise, we have estimated the supply of agricultural commodities (rice, wheat, coarse cereals, cereals, pulses, foodgrains, oilseeds, milk, sugarcane, fruits, and vegetables) using the base level production and past trend of growth rate in actual production for 10 years as well as 15 years. Last 10 years trend also captures part of emerging challenges of climate change. Our estimates show that cereal production is estimated to increase up to 342.3 MT based on the trend of the last 10 years whereas the foodgrains are projected to increase up to 377.2 million tonnes inclusive of 35 MT of pulses by the end of 2030-31. In the case of fruits and vegetables, the production is expected to increase up to 145.2 and 253.5 million tonnes, respectively, by the end of 2030-31.

Based on our forecasts of agricultural commodities for the years 2020-21, 2025-26 and 2030-31, oilseed, pulses and fruits depict a supply and demand gap in the coming years, implying increasing dependence on imports for these commodities. Oilseeds, particularly, need technological breakthroughs to increase their productivity and reduce the high dependence on edible oil imports. However, self-sufficiency in traditional oilseeds such as mustard, ground nut and soya would require an additional area of 39 million hectares under oilseeds, which could cut area under cereals, endangering the food security of the country. Therefore, the country needs to ramp up its efforts in developing oil palm at home with productivity comparable to Indonesia and Malaysia with four tonnes of oil per hectare to reduce import dependency in the future. In this regard, the National Mission on Edible Oils-Oil Palm aims to promote the cultivation of oil palm and increase production up to 1.12 million tonnes by 2025-26 and 2.8 million tonnes by 2029-30, thereby, reducing dependence on edible oil imports.

Lastly, the country needs to have focussed and strategic action plans for pulses and fruits since their demand in the future shows higher growth, relative to their supply. The present study also recommends increasing production through public investment in irrigation, agricultural research especially for climate resilient varieties and infrastructural development such as road networks and agro-processing facilities. Additionally, a move towards sustainable agricultural practices needs to be prioritised that can improve grain quality and soil health, ensuring food security and sustainable growth in agriculture.

Authors

ABSTRACT

Demand and supply projections are crucial for formulating farsighted agricultural and food policies to sustain food production, ensure food security and for the efficient functioning of food systems while controlling for external factors such as changing consumption basket, taste, and preferences, changing population growth and income growth. Against this backdrop, the present study estimates demand and supply projection of major agricultural commodities such as cereals (rice, wheat, coarse cereals), pulses, milk, meat, sugar, fruits, and vegetables up to 2030-31 under alternative per capita income growth scenarios. Prior to forecasting demand and supply projections up to 2030-31, the study has validated the adopted methodology to assess the forecasting performance of the model. A review of earlier studies reveals that, for assessing the demand projection, most studies used per capita consumption of agricultural commodities from the latest National Sample Survey Organisation's consumption expenditure survey round (2011-12). However, since the food basket has registered significant change over the years, the present study has adopted an absorption approach to project demand for agricultural commodities where the absorption of a commodity is estimated after deducting changes in government stocks from the summation of production and net imports. Expenditure elasticity used for demand forecast in this study is compiled from Kumar et al. (2011) as well as Niti Ayog's Working Group (WG) Report on the Demand and Supply Projections towards 2033 (2018).

The estimated projections show that the food balance sheet will be stable in 2030-31 and the country will be self-sufficient in cereals under all the alternative scenarios. However, commodities like oilseeds, pulses and fruits are expected to experience a supply and demand gap in the coming years. A deficit in the food balance sheet would result in higher imports to meet the domestic demand, in turn, leads to a huge import bill in the long run. Therefore, the policy perspectives need to ensure a balance between domestic production and absorption of these commodities which requires investments in productivity-enhancing and technological inputs since area expansion is limited. The projections also corroborate with earlier findings that consumption patterns would indeed shift further towards high-value commodities up to 2030-31, which require major investments in market infrastructure, processing, and storage facilities such as warehouses, cold storage, cold chains, etc. Encouraging private investment and public-private partnerships (PPP) in the agricultural supply chain can reduce post-harvest losses as well improve the supply of high-valued perishable commodities. Moreover, with increasing climate change impacts over the years, the production of agricultural commodities to meet the increasing demand is a challenging task for the government and requires public-private partnerships in agricultural research and development as well as climate change mitigation research.

Notably, advisory services and timely information through agricultural extension services can incentivise farmers to shift towards sustainable agricultural practices as well as ensure the balance between demand and supply of food.

EXECUTIVE SUMMARY

The present study aims to forecast the demand and supply of major agricultural commodities up to 2030-31 which will throw light on the future's food balance sheet scenario in the country. With income growth and the changing lifestyle of people, the food consumption pattern has been diversifying towards high-valued horticulture and livestock products, away from staple foodgrains. Even though there has been a declining trend in the per capita consumption of cereals over the years, the total consumption of foodgrains has witnessed a surge due to the increasing population. The changing scenario of the consumption and production pattern of foodgrains and other major commodities coupled with the rising population and changing tastes and preferences are bound to influence the demand and supply prospects of food commodities in India.

In the past, a long tradition of empirical studies has provided demand and supply projections for agricultural commodities for the medium and long term. However, a critical assessment of these studies indicated that there are wide variations in the demand projections, particularly, for foodgrains, mainly owing to differences in models used to estimate expenditure elasticity or varying assumptions related to the gross domestic product (GDP) growth and the feed coefficient. Moreover, most of the past studies have not validated their model's forecasting strength prior to projecting ex-post demand and supply projections, making it difficult to assess the reliability and forecasting performance of the adopted models. Notably, in the present study, we have validated the ex-ante demand for agricultural commodities with actual demand to assess the robustness of the model prior to predicting future demand.

Most of the recent empirical studies on the demand prospects have used per capita consumption of agricultural commodities from the latest National Sample Survey Organisation's consumption expenditure survey round (2011-12) for assessing the demand projection. Since the consumption basket has been diversifying over the years, therefore, in the present study, we have used an absorption function to project future demand of selected agricultural commodities. Absorption is the summation of actual production and net import after deducting changes in government stock which is inclusive of both direct as well as indirect demand (seed, feed, wastage, and industrial use).

Using the absorption function, we, first, validated the forecast demand with actual absorption for the period between 2000-01 to 2019-20 with the base year as Triennium Ending (TE) 1999-00. However, for the validation exercise, we have changed the base year at five-year intervals i.e., TE 2004-05, TE 2010-11, and TE 2015-16 for foodgrains and oilseeds whereas the base year was changed at TE 2007-08, TE 2012-13, and TE 2016-17 for projecting the demand for high valued commodities. Our validation exercise illustrates that the forecast errors (measured using the root mean square error (RMSE) is less than 5 percent for agricultural commodities such as coarse cereal, pulses, meat, sugar, and oilseeds, indicating the accuracy and reliability of the model used. However, milk, rice, wheat, cereals, fruits, and vegetables and foodgrains registered more than 5 percent of RMSE, primarily due to high short-term fluctuation in productions as well net imports of these commodities. Thus, the prediction of these commodities must be interpreted with the caveat that there may be some deviation between the ex-post predictions and actual absorption.

In light of the crisis like pandemic and considering the medium-term outlook until 2030-31, we have formulated three distinct GDP growth rate scenarios: a pessimistic projection of 5 percent, a business-as-usual scenario at 6 percent, and an optimistic outlook at 7 percent annually. These projections have been based on the assumption of no change in the population, which is expected to increase by 0.9 percent annually from 2020 to 2030 according to the estimates provided by the United Nations (UN) World Population Prospects (2019). After accounting for this population growth, per capita income (PCY) is anticipated to increase at average rates of 4.1 percent, 5.1 percent, and 6.1 percent per annum, respectively, in the three growth scenarios. Using these three different scenarios of PCY growth, we have projected the future demand of foodgrains (rice, wheat, coarse cereals, and pulses), sugar, oilseeds fruits, vegetables, milk and meat up to 2030-31. In addition, we assumed the expenditure elasticities as estimated by Kumar et al. (2011) and the WG Report (2018) of the Niti Ayog to predict the demand for these agricultural commodities.

Our findings show that the total projected demand or absorption for cereals and pulses will increase up to 272.1 million tonnes (MT) and 33.7 MT, respectively, by the end of 2030-31 if the PCY grows at 4.1 percent per annum or increase up to 273.3 MT and 35.3 MT, respectively if the PCY grows at the rate of 6.1 percent per annum using elasticities estimated by Kumar et al. (2011). The projected demand for fruits and vegetables will increase up to 129.5-140 MT and 228.5-241.8 MT, respectively, by the end of 2030-31 whereas the absorption of milk and meat will increase in the range of 252.3 -276.8 MT and 10.9-12.5 MT, respectively, by 2030-31 under the different assumptions of PCY growth rate.

Similarly, the projection using the elasticities given by the WG (2018) of Niti Ayog shows that the cereal demand by the end of 2030-31 will increase up to 260.6 MT under 4.1 percent PCY growth and 254.7 MT under 6.1 percent PCY growth. The demand for pulses will range between 37.99 to 42.21 MT in 2030-31 depending upon the varying growth scenarios. Notably, in alternate PCY growth scenarios using elasticities of both the studies, our findings corroborate that the consumption basket tends to diversify towards nutritious and high valued commodities including fruits and vegetables and dairy products, away from staples such as cereals. Further, the projections of the demand for cereals and foodgrains in the future will increase but at a diminishing rate with continuous population growth.

Supply of agricultural commodities (rice, wheat, coarse cereals, cereals, pulses, foodgrains, oilseeds, milk, sugarcane, fruits, and vegetables) are estimated using the base level production and past trend of growth rate in actual production for 10 years as well as 15 years. Using the trend of the last 10 years, we found that cereal production is estimated to increase up to 342.3 MT. The foodgrains are projected to increase up to 377.2 million tonnes inclusive of 35 MT of pulses by the end of 2030-31. In the case of fruits and vegetables, the production is expected to increase up to 145.2 and 253.5 million tonnes, respectively, by the end of 2030-31.

The examination of the projected demand and supply of agricultural commodities for the year 2020-21, 2025-26 and 2030-31 illustrate that commodities like oilseed, pulses and fruits are expected to experience a deficit in the food balance sheet in the coming years. Therefore, there is a need to increase the level of production and productivity of oilseeds, pulses, and fruits since their demand in the future shows higher growth, relative to their supply. Oilseeds, particularly, need technological breakthroughs to increase its productivity, thereby improving the oilseed's balance sheet in the long run and reducing the high dependence on edible oil imports. The National Mission on Edible Oils-Oil Palm, a centrally sponsored scheme, with an investment of Rs.11,040 crores aim to promote the cultivation of oil palm and increase production up to 1.12 million tonnes by 2025-26 and 2.8 million tonnes by 2029-30, reducing dependence on edible oils imports. The scheme may increase oil palm production in the coming decades but self-sufficiency in oil palm production may not be sustainable as the crop is a water-guzzling crop with a long gestation period.

Notably, for increasing the supply of high-value commodities in accordance with increasing demand as well as to manage surpluses of the other commodities, there is a need for huge investments in market infrastructure, processing, and storage facilities such as warehouses, cold storage, cold chains etc to build an efficient and reliable value chain, linking farm to the market efficiently and effectively. Incentivising private players as well as public-private partnerships (PPP) to build an agricultural supply chain, similar to the AMUL model for dairy products, can eliminate post-harvest wastage as well as facilitate the balance between domestic production and demand.

Ensuring long-term food security and achieving higher yield, investments in productivity-enhancing agricultural inputs such as fertilizer, high-yielding seeds etc. along with irrigation coverage are critical. However, efficient allocation of productivity-enhancing inputs requires limiting the subsidies provided for water, electricity and fertilizer which can further be invested for micro, medium and long-term irrigation facilities, road networks and agro-processing facilities. Essentially, sustainable agricultural practices need to be prioritised that improve grain quality and soil health, ensuring sustainable growth in agriculture. Particularly since excessive use of chemical fertilizers by farmers, especially in rice and wheat, can have detrimental effects on the environment including ground and surface water.

Not just that, with changing climatic scenarios over the years, the production of agricultural commodities to meet the increasing demand is a challenging task for the government and requires public-private partnerships in agricultural research and development as well as climate-smart practices. For instance, Bayer, a private sector global company, has introduced 'Better Life Farming,' an agri-entrepreneurship model in India, in partnership with other private players to provide knowledge of good agricultural practices and access to the latest technologies, thereby, providing opportunities for increasing agricultural productivity.

Lastly, to maximise the spill-over of productivity-enhancing and technological inputs, agricultural intensification needs to be accompanied by agricultural extension services. Strengthening farmer producer organisation (FPO) can play a significant role in increasing access to agricultural extension services to disseminate efficient information as well as train smallholders to adopt sustainable agricultural practices and location-specific farm technologies.

Introduction

India has become self-sufficient in food production with the foodgrains production reaching an all-time high of 305.44 million tonnes (according to the 3rd advance estimates 2020-21). However, this was not the situation during the first decade of independence: India was on the verge of a massive famine with two consecutive droughts (1965-66 and 1966-67) and decelerating foodgrains production (Kumar, et al. 2007). Food scarcity made the country depend heavily on food imports under the PL-480 food aid programme of the United States.

The turning point came with the implementation of the Green Revolution, which brought about remarkable improvements in agriculture. This transformation was made possible through targeted policy interventions, technological innovations, and investments in irrigation facilities, as well as price support policies. These efforts led to increased foodgrain production during the late 1960s and early 1970s, enabling India to become self-sufficient in food production (Hazell, 2009). In addition, India witnessed a steady increase in per capita availability of foodgrains from 144 to 171 kg per annum between 1951 and 1971 (DAC&FW).

Today, India is the largest producer of cotton, pulses, milk and jute in the world and the second-largest producer of rice, sugar fruits and vegetables globally. The transition of Indian agriculture, from being dependent on food imports to being self-sufficient in foodgrains with a sufficiently diversified agricultural sector was due to focussed policy interventions and planning for future food security, which in turn, depends upon demand and supply projections of important food articles. These projections encompass various factors including current availability or absorption, population and income growth as well changing tastes and preferences of the population.

During the last two decades, the demand and supply situation in Indian agriculture has undergone significant change. Owing to continuous population growth coupled with sustained income growth and changing lifestyles, there has been a significant shift in the consumption pattern (Kumar et al., 2009). The per capita consumption of foodgrains particularly cereals has declined considerably while the demand for high valued commodities like fruits and vegetables, livestock products as well as processed food have increased over time (Kumar et al., 2006; 2007, Jose, 2016).

The diversification of the food basket away from traditional staples towards high-valued commodities has a direct impact on future prospects of the demand and supply of food items. Therefore, it is important to accurately estimate demand and supply projections of major agricultural commodities and accordingly formulate a long-term policy perspective to sustain food security in the coming decade while encompassing the changes in consumption patterns of Indian households, income, population, and other factors.

Furthermore, the emergence of the COVID-19 pandemic in 2020 and new variants of coronavirus has had an unprecedented impact on food availability, accessibility, and livelihood of people around the world. Last year, the looming threat of COVID-19 was expected to affect agricultural activities and agricultural growth, albeit, the unprecedented foodgrains production and unabated agricultural exports had a positive impact on farmers and the economy. Nevertheless, the re-emergence of the pandemic can cause fluctuation in the food balance sheet of the country given the economic disruptions due to recurring lockdowns. Therefore, forecasting accurately the demand and supply of agricultural commodities in the immediate future can facilitate the government in fixing tentative targets and formulating necessary policies to help achieve those targets.

In view of this, the present paper will estimate demand and supply projections of agricultural commodities (wheat, rice, coarse cereals, cereals, pulses, foodgrains, sugar, oilseeds, fruits, vegetables, milk, and meat) for the period 2020-2030. Specifically, the paper will attempt to answer the following questions:

a) What are the various methodologies used in the estimation of demand and supply projections for food commodities till 2020 by various studies?
b) What is the error between actual demand for select agricultural commodities (wheat, rice, coarse cereals, cereals, pulses, foodgrains, sugar, oilseeds, fruits, vegetables, milk, and meat) compared to the ex-ante forecast of demand till 2019-20 by various researchers in the past? What is the difference between actual demand and predicted demand with respect to the model adopted by this study?
c) Lastly, we will generate our own estimates of demand and supply for the select food commodities till 2030 after validating the demand and supply of these commodities in the past.

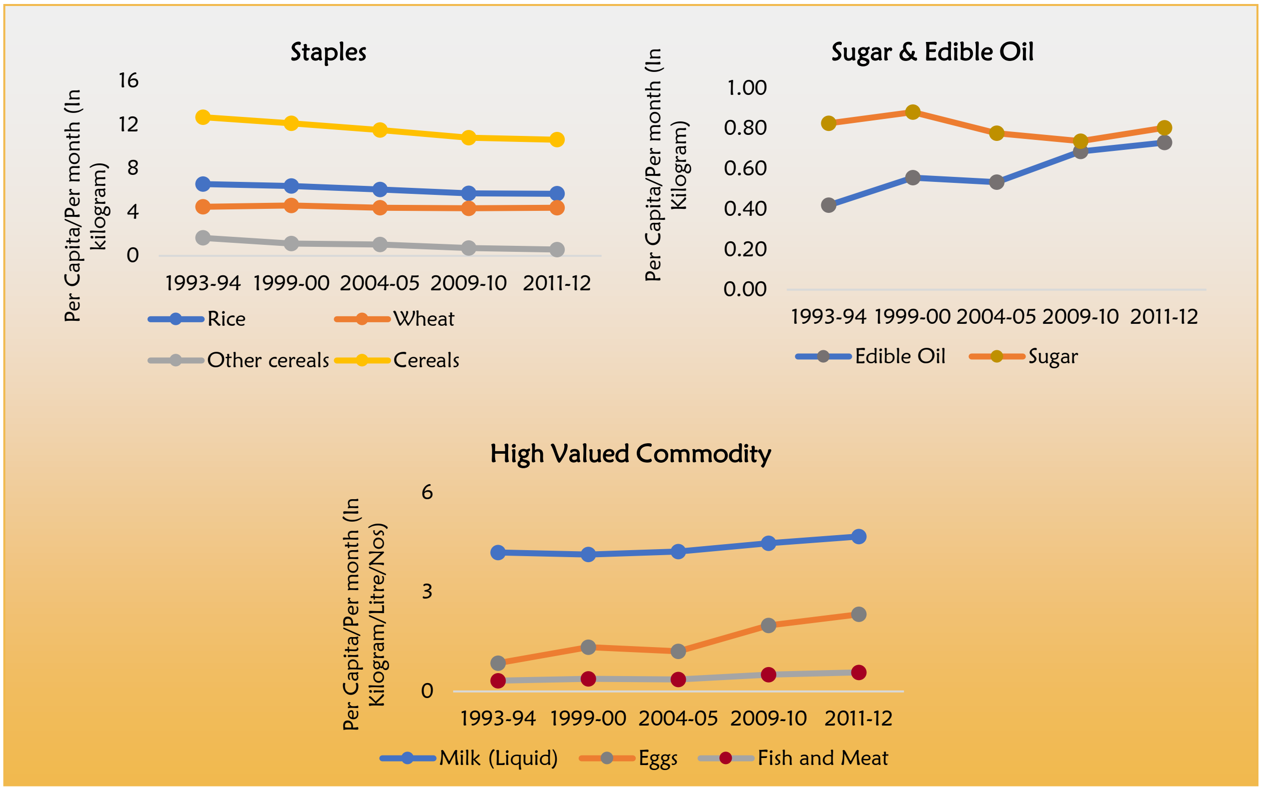
This paper is organized into 6 broad sections. After introducing the objective of this study to estimate demand and supply projections as well as discussing the past trends in food consumption in section 1, we have reviewed the past literature on demand-supply projections of agricultural commodities in section 2. The section also examined the methodologies adopted by the different studies to comprehend the model to be used for the present study. In Section 3, we will validate the demand projections for 2020 made in the past by various studies with the actual absorption of cereals and non-cereal commodities for the period between 2000-01 to 2019-20. In section 4, we will estimate the demand projections for agricultural commodities (wheat, rice, coarse cereals, cereals, pulses, foodgrains, sugar, oilseeds, fruits, vegetables, milk, and meat) up to 2030-31. Section 5 will first validate the ex-ante supply of major agricultural commodities between the period 2000-01 to 2019-20 and thereafter, estimate supply projections up to 2030 under alternative scenarios. Lastly, we have concluded and put forward the policy recommendations in section 6.

Changing consumption pattern in India

To accurately forecast the demand for food for the entire population, it is essential to analyse the consumption basket and how they react to changes in income, prices as well as taste and preferences.

Assessing the NSSO's consumption expenditure highlights the changing consumption pattern of Indian households. **Figure 1** illustrates that there has been a decline in the per capita consumption of cereals from 12.68 kg per capita/per month in 1993-94 to 10.62 kg per capita/per month in 2011-12. This may be attributable to various factors including diversification of food basket, changing lifestyles or rise in income (Mittal 2008). On the contrary, the per capita consumption of high valued commodities has significantly increased over the same period. For instance, the consumption of eggs has increased from 0.86 to 2.32 eggs per capita/per month whereas milk consumption has increased from 4.18 to 4.67 litres of milk per capita/per month between 1993-94 and 2011-12. Higher economic growth coupled with a sizable increase in the population is causing a shift in the food basket of the people away from staple food to high-valued horticulture and livestock commodities (Kumar et al. 2007).

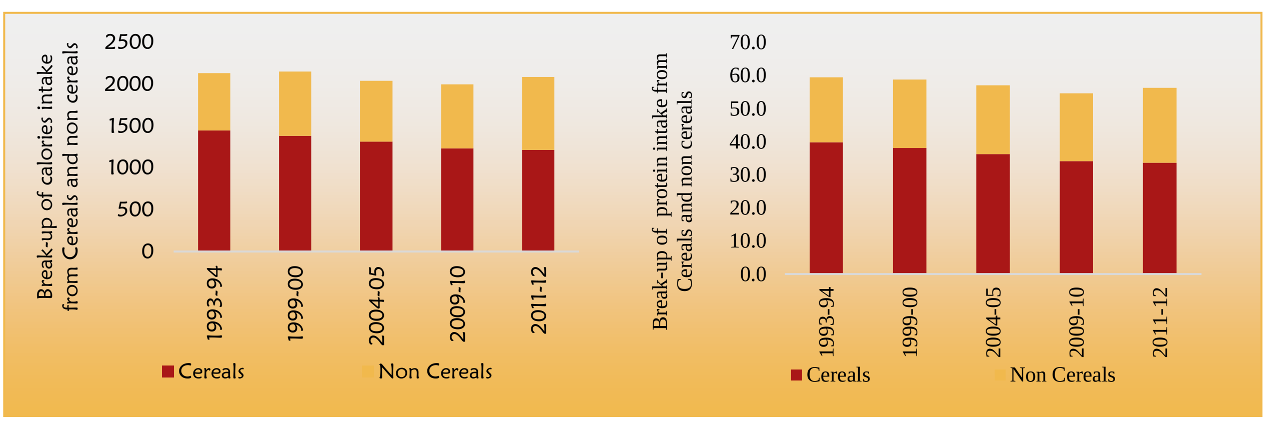
Figure 1: Trend in the per capita consumption of food commodities (cereal & non-cereal) in India



Source: Computed using data from NSSO Household Consumption of Various Goods and Services in India Surveys, various rounds.

Note: Estimates at the All-India level is computed taking the weighted average of per capita consumption of food commodities in rural and urban areas where the rural and urban population has been taken as weights.

Figure 2: Break-up per capita per day intake of calories and proteins by food group in India



Source: NSSO report No 560 (68th round), Nutritional Intake in India

Note: All-India figures of calories and proteins derived from cereals and non-cereals is calculated by taking the weighted average of the calories and proteins intake in the rural and urban areas where the rural and urban population has been taken as weights.

Similarly, the assessment of nutritional intake using NSSO's data also reveals a clear shift from cereal to non-cereal food items (**Figure 2**). However, the percentage increase in the intake of calories and proteins derived from non-cereal commodities could not compensate for the percentage decline in the calories and proteins obtained from cereal commodities leading to an overall decline in the per capita per day intake of calories and protein.

Despite a considerable decline in per capita consumption of cereals with a concomitant increase in that of non-cereal products, however, in absolute terms, cereal absorption has increased over the years. This is primarily due to the continuous increase in population as well as increased demand for feed. Another factor attributable to augmenting demand for cereals is because foodgrains particularly, rice and wheat, are a cheap source of energy and proteins for low-income people, and hence, are considered to be the main pillars of household food and nutritional security. In addition, various nutritional and food security programmes including the Public Distribution System (PDS) (the largest food safety net programme covering 813 million individuals) provide subsidized foodgrains to the people, further increasing the absorption of cereals.

Review of Literature

There is a vast literature that analyses the consumption pattern of major food items in India and estimates demand and supply forecasts for the same. However, the forecast given by various studies varies widely due to the difference in their assumptions related to population growth rates, expenditure elasticities, gross domestic product (GDP) growth rates and feed demand. Moreover, different researchers have used different methodologies to project the demand and supply of food articles. A critical evaluation of these studies would develop a better understanding of the methodologies used by researchers in the past.[1] Based on the literature review of the empirical studies, we will be able to choose the appropriate models to project the demand and supply of food articles for the period between 2020-2030.

Rosegrant et al. (1995) estimated the demand and supply forecasts for agriculture commodities up to 2020 for a set of 35 countries using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model developed by the International Food Policy Research Institute (IFPRI). In the study, the demand for agricultural commodities was assumed to a dependent on population growth, price, and income. The elasticities and feed demand ratios were derived from the Food and Agriculture Organization's (FAO) World Food Model and past literature. With income growth (GDP) of 5.5 percent and population growth of 1.7 percent, the study forecasted that the per capita food availability in India would increase from 2332 to 2692 kilocalories per day between 1990 to 2020. Moreover, the diet diversification from cereals to meat and other processed products was predicted to be slow while the demand for feed was forecasted to increase considerably. The study stated that India would be a marginal exporter of wheat and high-quality basmati rice by 2020.

Bhalla et al. (1999) used a log inverse expenditure function across different expenditure classes to project the demand and supply of various commodities (cereals, milk and milk products, meat, and eggs) up to 2020. The demand projections for cereals were estimated based on the assumptions about growth in population and per capita income, urbanization, changes in consumption behaviour, distribution of income, and livestock production systems. The baseline projections for each of the commodities were computed using the per capita income and consumption expenditure from the 50^{th} round (1993-94) of the National Sample Survey Organisation (NSS). For estimating the expenditure elasticities till 2020, the study used their best conjectures with the assumption that cereal expenditure was inelastic whereas expenditure on livestock products was elastic. Further,

[1] Annexure 1 provides brief gist of the past studies along with their adopted methodology and assumptions to estimate demand and supply projections.

the authors highlighted, that with increasing per capita income, the demand for livestock products will drive the future demand for cereals mainly for livestock feed. The demand for cereals in 2020 was estimated under the alternative scenarios of growth in per capita income: 2 percent, 3.7 percent, and 6 percent. For the supply projections, the authors extrapolated the production with past growth rate trend (which was 2.7 percent per annum) after deducting seed, feed, and wastage (SFW) (almost 7.5 percent of the production). The supply projections for cereals up to 2020 were under alternative assumptions of extending input use for irrigation and fertilizers, including other genetic and technical changes which were the main factors inflating output projections in the past.

Mittal (2008) was one of the few studies that projected the demand and supply of edible oil and sugar/sugarcane apart from foodgrains for the years 2011, 2021 and 2026 using the consumption expenditure survey of NSSO. The total demand is estimated as the summation of the direct demand and the indirect demand where the direct demand is as a function of base year demand, population, expenditure elasticity and economic growth. The expenditure elasticity of demand was computed using the two-stage Quadratic Almost Ideal Demand System (QUAIDS) and was adapted from Mittal (2006). With 1999-2000 as the base year, the direct demand was estimated under two alternative GDP growth rate scenarios – 8 percent and 9 percent. The study found that the demand projection for cereals would increase due to continuous population growth and a surge in demand for seed, feed, wastage, and industrial use (SFWI). The supply projections were forecasted for the same years using the average annual yield growths between the years 1993-and 2003. The gap between supply and demand was found to be increasing over the years for cereals, pulses, edible oil and sugar. The study recommended that for sustaining self-sufficiency in the country, the policymakers need to address productivity enhancement through public investment in irrigation, research and efficient use of water, plant nutrition and other inputs.

Chand (2007) provides the demand projection for foodgrains (rice, wheat, coarse cereals and pulses) for the years 2011-12 and 2020-21 using the per capita demand projection as a function of per capita consumption in the base year (2004-05), income elasticity, the growth rate in per capita income during the period 1993-94 to 2004-05 and rate of change in demand due to changes in tastes and preferences. Total demand was calculated as the sum of direct demand and indirect demand. Indirect demand for foodgrains is based on the trend analysis of the gap between per capita food supply and direct demand. However, since the NSSO estimate does not include food consumed outside the home and food used in various bakery products, hence, it has not been included in the demand projection. The study used income elasticity of demand given in Kumar (1998) which was based on the Food Characteristic Demand System (FCDS). Chand concludes that in order to meet the growing demand, foodgrain production needs to grow by at least 1.86 percent annually, otherwise, the country would have to depend on food imports.

Kumar et al. (2009) estimated the demand for foodgrains for the years 2011-12, 2016-17 and 2021-22. The expenditure elasticities were estimated from the household level data of NSSO survey's 61st round (2004-05). In the study, household's direct demand was taken as a function of the per capita consumption (with the base year 2004-05), projected population, per capita income growth and expenditure elasticity. Unlike the demand projections given by Chand (2007) and Mittal (2008), which suffer from considerable bias in their projections as the studies do not consider the regional and income distributional effects, the projection by Kumar et al. (2009) included varying consumption patterns across income groups (very poor, moderately poor, non-poor lower income, non-poor higher income), lifestyle (rural/urban) and region (eastern, western, northern, and southern). Accounting for the distributional effects of income and population was deemed critical to avoid any bias in the demand projections. Demand elasticities, calculated using the Food Characteristic Demand System (FCDS), were negative for wheat and coarse cereals across all expenditure strata (rural and urban) indicating a declining trend in their per capita consumption among poor households. The paper aggregated the elasticities at the sub-group level to obtain the national-level estimates. Total demand was calculated by adding direct household demand to indirect demand where indirect demand for foodgrains includes seed, feed, wastage, and industrial use. The findings of the paper corroborated Mittal's (2008) recommendation that in order to meet the future demand, the yield of crops should be raised.

The Report of the Working Group on Foodgrains (2011) forecasted the demand and supply projections of the agricultural commodities for the 12th Five Year Plan (FYP) as well as validated the ex-ante demand and supply projection of foodgrains for the 9th (1997-98 to 2001-02), 10th (2002-03 to 2006-07) and 11th (2007-08 to 2011-12) FYPs. In order to verify the demand projections for food commodities for the 9th, 10th and 11th FYP, two approaches- Normative and Behaviouristic- were used. For the 12th FYP, the demand for foodgrains, edible oil and sugar was predicted using four different approaches – Household Consumption, Normative, Behaviouristic and Absorption approach. Several alternative scenarios of GDP growth rate of 9 percent and 8 percent with a population growth of 1.3 percent were assumed to forecast the demand. The base year consumption for different commodities was estimated based on two scenarios; per capita availability for TE 2010-11 and the consumption reported in the 66th round of household consumption expenditure survey (2009-10) of NSSO. While making the supply projections, the report adopted five different methods including the simple regression method (based on time trend of the last ten years production), exponential growth rate method, multiple regression method, average annual growth rates method and compound growth rate method.

Kumar, et al. (2012), predicted the household demand for wheat and rice for the period from 2015-2025 using the QUAIDS model. The expenditure elasticities for several goods were estimated using the 61st Round of the National Sample Survey (NSS) for the years 2004–05. As the past studies on the demand and supply forecast for the year 2000 had largely overestimated their projections and the studies conducted after 2010 have wide variations in their future prediction, therefore, the authors found it rather difficult to rely on their findings. The study has addressed some of these shortcomings by using two different approaches, i) a Cobb-Douglas production function relating the crop output to various factors such as total area, fertilizer consumption and annual average rainfall, and ii) a Cobb-Douglas yield function determining the crop's output as a product of crop's total acreage and its yield, which were modelled individually. Further, a residual value approach was applied to estimate the indirect demand, which included i) estimates of SFW from previous literature ii) commodity balance approach and iii) the Input-Output (I-O) tables of the Indian economy. The production, acreage and yield functions were estimated using the data for the period 1981-82 to 2007-08. The supply forecasts were estimated by developing supply models for rice and wheat whereas the crop's output was determined using a production function approach as well as using separate modelling of crop acreage and yield approach. The supply projections were forecasted in alternative scenarios such as business as usual, optimistic, and pessimistic scenarios.

Parappurathu et al. (2014) used the Cereal Outlook Model to forecast the demand and supply of major staples such as wheat, rice, and maize for 2016-17, 2020-21 and 2025-26 (with 2010-11 as the base year). The paper used food and feed equations for estimating the total demand for each crop which were adjusted for trade, government stocks and population to arrive at the national estimate. Further, the model also linked each of these three staples with other auxiliary crops such as chickpea, pigeon pea, rapeseed, mustard, etc., through their competitive and substitutive relationships to project future demand and supply, respectively. On the supply side, area, yield, and production were modelled at the six regional levels, namely East, West, North, South, Hills and North-East. The area and yield equations were fitted separately for each region under each crop. The estimates of production were obtained from the estimates of area and yield for each of these regions and the national production estimates were computed by aggregating these regional estimates.

Kumar et al. (2016) attempt to assess the future demand-supply gap for major food commodities including rice, wheat, coarse cereals, pulses, edible oils, vegetables, fruits, milk, poultry, eggs, fish and sugar by 2020 and 2030 under alternate assumptions of income growth rate and income distribution. Similar to Kumar et al. (2009), this study considers that household direct demand is driven by population growth, income growth and changes in income distribution. The household consumption survey data from NSSO's 38th (1983-84) and 61st rounds (2004-05), were used to analyse the shifts in dietary patterns and food expenditure. The per capita expenditure was taken as a proxy for per capita income. The total demand was obtained by adding direct household consumption (at home and outside the home) and indirect demand (seed, feed, industrial uses, and wastages). Demand elasticities, calculated using the FCDS, were found to be negative (inelastic) for coarse cereals and positive (elastic) for livestock and horticultural products. The supply for different commodities was estimated using TE 2010 as the base year production. Crop prices were found to be highly responsive to the supply of commodities and hence, it was concluded that a positive price policy would augment the domestic supply of food commodities. Among the food commodities, rice, pulses, and edible oils depicted a substantial supply and demand gap in 2020 and 2030, implying high dependence on import of these commodities. The study recommended increasing production through public investment in irrigation, agricultural research, and infrastructural development.

To address the issue of food security and management of grain supply in the future, Niti Aayog constituted a Working Group (2018) to estimate the demand and supply of food commodities including cereals, pulses, and high-value commodities for the years 2019-20, 2023-24 and 2032-33. The WG used three approaches to forecast food demand, namely Household Consumption Approach, Normative Approach and Behaviouristic Approach. The behavioural approach takes into account growth in population and changes in consumption behaviour due to changes in per capita income measured in terms of expenditure elasticities. The study used per capita consumption from the NSSO's 68th round (2011-12) (which was considered as the base year). Overall, the demand and supply gap for foodgrains illustrated a trend of 3.3 percent per annum which was simulated using the TE 2014-15 data of major foodgrains to compute the future gap. Under the Behaviouristic Approach, the estimates for demand were projected based on two GDP growth scenarios – 6 percent and 8 percent per annum and expenditure elasticities were calculated using the Almost Ideal Demand System (AIDS). The demand for SFWI is estimated to cross 120 MT by the end of 2032-33 primarily because the demand for grain as animal feed is expected to increase considerably. The findings of the WG showed that the country will be in a quite comfortable position with respect to foodgrains as the balance sheet for cereals will be in surplus except pulses and oilseeds in which the country may face an acute deficit. For supply projections, the report used a simultaneous equation model, using historical data for the period between 1980-81 and 2015-16, to estimate four variables namely, area, yield, real domestic price and exports. Productions of agricultural commodities were estimated using crop area and yield equations. The projections have been calculated based on exponential growth rates using historical data for area and yield and three three-stage least square method.

The next section will discuss the different assumptions adopted by various studies to estimate future demand based on which we will develop our framework to project the demand-supply for agricultural commodities till 2030.

Methodology for forecasting and validating demand and supply of agricultural commodities

The review of literature has examined clearly the various methodologies adopted in the different studies and highlighted what are the key factors for the divergence in the forecasted estimates between these studies.

Before projecting the future demand and supply, we will, first, validate the ex-ante forecast for the period between 2000-01 and 2019-20 to gauge how close these projections are to ex-post reality. Although there are numerous studies in the past that have tried to forecast demand and supply of agriculture commodities in India, however, only a few, for instance, Kumar et al. (2012) and the Report of Working Group on Foodgrains (2011), have validated the past forecasts. The validation exercise will ascertain the appropriateness of the methodology used in generating the demand forecast, thereby, giving us an opportunity to assess the strength of the model. Based on the assessment, corrective actions can be taken, if needed, so that the demand forecast for food commodities in the future (2020-21 to 2030-31) could be more robust and closer to actual figures. Hence, after validating the reliability and accuracy of the model from the past, we will estimate demand and supply forecasts of the food commodities up to 2030-31.

The literature review underscores that the previous studies used the best available techniques of their time, under different assumptions about expenditure elasticities, GDP growth rates and feed coefficient to estimate the demand function. Table 1 gives a brief glimpse of the demand functions, methodology, assumptions, feed coefficients and elasticities used in past studies. Most of these studies have forecasted demand using the similar demand function which included the base year per capita consumption simulated by population projection, per capita income growth and expenditure elasticities. For example, the demand function used by Kumar et al. (2016) takes into account variation in consumption across lifestyle (rural/urban) and income groups (very poor, moderately poor, non-poor lower income, non-poor higher income), while, the demand functions used by Chand (2007) and Niti Aayog (2018) take into account variation in consumption across lifestyle only. According to Kumar et al. (2016), the variation across lifestyle and income groups was deemed important to avoid any bias due to the distributional effects of income and population in the forecasted demand for agricultural commodities.

Within the demand function, the source of divergence in the food projection estimates predominantly stemmed from differences in GDP growth rates, expenditure elasticity and feed demand (Chand, 2003). Since elasticities[2] play a major role in the estimation of future demand for food, understanding the method of computing the elasticities could facilitate policymakers in decision-making. Earlier studies have used different models to compute expenditure elasticities such as the Food Characteristic Demand System (FCDS), Almost Ideal Demand System (AIDS) and Quadratic Almost Ideal Demand System (QUAIDS), therefore, there are large variations in elasticities. For instance, the magnitude of cereal's expenditure elasticity was positive as in the case of Bhalla and Mittal whereas it was negative in Kumar (1998), and Kumar et al. (2012) (**Table 1**). A negative elasticity for cereals implies that cereals are assumed to be an inferior good i.e., any increase in the income would lead to a decrease in the consumption of the commodity, therefore indicating diversification of food basket towards high-value commodities like livestock products, fruits, and vegetables. Moreover, this would mean that any increase in the direct demand for cereals arises on account of a surge in population and not due to income growth (Chand, 2003).

[2] Expenditure elasticity reveals the percentage change in consumption (demand) of a given commodity with respect to change in income.

Table 1: Methodology & assumptions for food demand projections in 2020 by different studies

Study	Demand Function	Methodology used to estimate elasticities	Expenditure elasticities	Feed coefficients
Rosegrant, Agcaoili-Sombilla, and Perez (1995)	IMPACT Model	-	Taken from FAO 1987, various country studies	Feed ratio taken from FAO 1986
Kumar (1998)#	-	FCDS	Cereals R- (-) 0.007 U – (-) 0.037	-
Bhalla, Hazell and Kerr (1999)	-	Log inverse expenditure function	Cereals R-0.29 U-0.18	1.2 kg of cereals per kg of Meat & Eggs and 0.12 kg of cereals per kg of milk
Chand (2007)	$Dt_n = Dt_0$ [(1 + η* $Y_g)^{**(n)}$ + ΔP_r	FCDS	Cereals R- (-) 0.007 U – (-) 0.037	Trend analysis of gap between per capita food supply and direct demand
Mittal (2008)	$D_t = d_0 * N_t * (1 + y * e)^t$	QUAIDS	Rice-0.01 Wheat- (-) 0.070 Cereals- 0.165	Taken from Kumar (1998)
Kumar et al. (2012)	$C_t = POP_t$ *{ PC_0 * (1 + $g_{0-t})^t$}*365/ 30 + indirect demand	QUAIDS	Rice- (-) 0.21 Wheat- (-) 0.13	Rice: 11.4percent Wheat: 26.7percent
Kumar, Joshi, Mittal (2016)	-	FCDS	-	-
Niti Aayog (2018)	$Q_{ijt} = q_{ij0} * P_{jt} * (1 + g_{jt} * e_{jt})^t$	AIDS	Cereals R- (-)0.13 U- 0.04	Estimated using residual approach. Under this approach net consumption is deducted from net production.

Source: Author's Compilation from the studies cited

Note: # Estimates for elasticities have been taken Chand (2003)

Another significant variable that could be responsible for the variation in the estimation of the projected demand for foodgrains is the feed coefficient. Most studies reviewed have used a different approach to calculate the feed demand. While some have used the commodity-balance approach (Kumar et al., 2012), others have used the coefficients synthesized from other sources, primarily from past studies (Rosegrant et al., 1995 and Mittal, 2008). Conventionally, indirect demand was assumed to be 12.5 percent[3] of the total foodgrains production. The indirect demand for foodgrains has experienced a significant surge over the years which has been inadequately addressed in the past studies, thereby, widening the gap between direct demand for foodgrains and domestic supply (Kumar et al, 2012 & Chand, 2007). Studies like the WG report of Niti Aayog (2018) and Mittal (2008) have addressed this issue by taking into account changing tastes and preferences and diversification of consumption towards livestock and milk products, resulting in higher demand for feed.

Further, the past studies have used different approaches to estimate the total demand and the total supply of food commodities. From the literature review, it is clear that the demand projections can be estimated using the Household Consumption Approach, Normative Approach[4], the Behavioural Approach or the Absorption Approach. Studies have pointed out that the projections based on the behavioural approach solve the shortcoming of short-term static behaviour in consumption as in the case of the household consumption approach and normative approach. The behavioural approach mainly takes into account the behaviour of consumption concomitant with changing per capita income, and elasticity of consumption/expenditure with a growing population.

Additionally, the recent empirical studies on demand and supply prospects have used the per capita consumption of agricultural commodities from the latest CES 68th round (2011-12) as the baseline data for assessing the demand projection. However, as discussed earlier, the consumption pattern has changed quite considerably over the years. Therefore, in the present paper, we will make use of the 'Absorption approach' to compute the demand projections for the period 2020-2030. The absorption or 'actual disappearance' of the quantity of a commodity in a particular year is the summation of actual production and net import after deducting the changes in government stock (Planning Commission, 2011). Also, given by the following formula:

Actual Absorption (Including SFWI) = Production + Imports – Exports – Change in stocks

[3] According to the DES norms, the SFW is assumed to be 7.6 percent for Rice, 12.1 percent for Wheat, and 22.1 percent for Pulses

[4] Annexure 2 gives a brief description of these four approaches.

where the actual absorption not only includes direct demand (human consumption) but also indirect demand (absorbed in seed, feed, wastage, and industrial use (SFWI)). Any deduction from government stocks over the years increases the supply for consumption (absorption in the system) and vice-versa (Planning Commission, 2011). Moreover, as the data on the stocks held with private traders and consumers are not available, we have considered only changes in government stocks. For projecting the future demand as well as for ex-ante validation of the agricultural commodities demand, we make use of the Absorption Function given as:

$$A_t = A_0 * N_t (1 + y * \eta_t)^t$$

A_t = Projected Absorption in period t
A_0 = Per capita absorption of commodity in base year
N_t = Population in period t
y = Growth in Per Capita Income (PCY)
η_t = Elasticity of the commodity
t = Time period
Per capita Absorption = $\frac{(\text{Production} - \text{Exports} + \text{Imports} (+/-) \text{Change in stock})}{\text{Population}})$

For computing per capita absorption of different agricultural commodities, we have used data from the latest Agricultural Statistics at a Glance (2020) and Pocket Book of Agricultural Statistics (2020) from the Directorate of Economics and Statistics (DES), Government of India (GOI). The data for the change in government stock has been taken from the Department of Food & Public Distribution, net imports of agricultural commodities from the Ministry of Commerce (GoI), projected population from the United Nation's World Population Prospect (WPP) (2019) while the per capita income growth has been computed after deducting population growth from GDP growth. The GDP growth has been calculated using the MOSPI, GoI.

For projecting the demand and supply of food commodities, we have used elasticities (η_t) estimated by Kumar et al. (2011) as well as the Working Group (WG) Report on Demand & Supply Projections Towards 2033 (2018) published by the Niti Aayog. Using two sets of elasticises will help us estimate and measure the extent of variation in the demand and supply predictions. **Table 2** shows the elasticities that we have used in the study.

Table 2: Assumption of elasticities by different authors

Commodities	Niti Aayog's WG Report (2018) *(weighted average)*	Kumar et al. (2011)
Cereals	(-) 0.102	Rice (0.0245) Wheat (0.0746) and Coarse Cereals (-0.1249)
Pulses	0.491	0.2187
Fruits and Vegetables	0.716	Vegetables (0.259) & Fruits (0.362)
Milk	0.689	0.429
Meat	0.689	0.669
Oilseeds	-	0.2972
Sugar	-	0.0619

Source: Author's Compilation from Niti Aayog's WG Report (2018) and Kumar et al. (2011) from 'Estimation of Demand Elasticity for Food Commodities in India'

Note: Niti Aayog's WG Report (2018) provided elasticities at the rural and urban level. To compute elasticity at all-India level, we have been taken weighted averages of these elasticities using the share of rural and urban population from the Census Population Projections (2019) as weights.

For the supply projections, first, we will compute the actual production/supply in the base year, which is the average production in triennium ending (TE) 2019-20 in our study. Then, using the base year's production and average annual growth rate of production during the past decade as well as the last 15 years, we have forecasted the supply of major food commodities for the period between 2020 and 2030.

Validation of demand forecasts by past studies

Analysing the difference between the forecasts made by earlier studies and the actual absorption gives us an opportunity to comprehend the reasons behind the prediction error. Based on the errors, we can try to rectify the methodology and various assumptions, if need be, so as to estimate more reliable and robust demand and supply projections. In the present section, we will estimate the actual absorption of rice, wheat, coarse cereals, and cereals for 2019-20 in order to validate the results of the projected demand up to 2020 by various studies in the past. **Table 3** shows the actual absorption of select agricultural commodities in 2019-20. These commodities include rice, wheat, coarse cereals, cereals, oilseeds, sugar, meat, milk, fruits, and vegetables. In 2019-20, the total absorption of vegetables and fruits (288 MT) surpassed the total absorption of cereals (254 MT).

Table 3: Actual absorption of select agricultural commodities in 2019-20

Agricultural Commodities	Actual Absorption (million tonnes [MT])
Rice	107.60
Wheat	98.52
Coarse Cereals	47.85
Cereals	253.97
Oilseeds*	32.63
Pulses	28.35
Sugar	27.52
Fruits	102.19
Vegetables	187.13
Milk	198.43
Meat	7.44

Source: Directorate of Economics and Statistics, DAHD; DGCIS, FCI, Department of Food & Public Distribution; various years

*Note: *Oilseeds includes nine major oilseeds produced in the country as given by DES, GoI: groundnut castor seed, sesamum, niger seed soyabean, sunflower, rapeseed & mustard, linseed, and safflower. The net imports for oilseeds also include data on export and import for these nine oilseeds only.*

Table 4 compares the estimated ex-ante demand projections for rice, wheat, and cereals for 2020 and 2021 as given by various studies and the actual absorption in 2019-20. This has been done to show how close these ex-ante projections are to the actual demand, thereby, establishing credibility about the methodology used for demand forecast.

The difference between the actual absorption and the projected demand illustrates that many past studies have overestimated the demand for agricultural commodities. For instance, Rosegrant et al. (1995) and Bhalla et al. (1999) have overestimated the demand projections for cereals by 50.3 MT (at 5.5 percent GDP growth rate) and 120.8 MT (at 6 percent GDP growth rate) with an error of about 19.8 percent and 47.6 percent, respectively. Although the study by Kumar et al. (1998) also overestimated the actual cereals demand in 2020, however, the error ranged between 4.6 (at 7 percent GDP growth rate) and 5.1 percent (at a 4 percent GDP growth rate). One plausible factor for a small percent error could be due to the fact that the elasticities assumed by Kumar et al. (1998) for cereals were inelastic and negative as opposed to Bhalla et al. (1998), who assumed elastic and positive elasticities for cereals. Moreover, Bhalla et al. (1998) assumed that, given a significant increase in the production of meat, dairy and poultry, any increase in livestock production after 1993 would require 1.2 kg of cereal per kilogram of meat. This led the feed projection to 50.1 and 107.5 million tonnes and total cereal demand projections to 296.2 and 374.7 million tonnes in 2020 under the alternative scenarios of the GDP growth rate of 3.7 and 6 percent, respectively. Notably, the study forecasted a demand and supply deficit of about 53.6 million tonnes in 2020 at 6 percent GDP growth. Not just that, the study by Rosegrant et al. (1995) assumed that the production of rice and wheat will grow faster than 2.0 percent per year whereas meat imports will increase but would remain relatively small compared to the size of the Indian economy. On the other hand, the predictions made by other studies including Mittal (2008) and the WG report by the Niti Aayog (2018) have underestimated the future demand for cereals for 2020-21, with a small percent error in their estimation.

The prediction for rice has been overestimated by almost all the studies for 2020 and 2021. For example, the percent error (overestimation) for rice forecasts ranges from 2.0 percent in Mittal (2008) (at 9 percent GDP growth rate) to 34.6 percent in Rosegrant et al., 1995 (at 5.5 percent GDP growth rate). On the contrary, the demand projection for wheat in 2020 has been consistently underestimated in the past except for the estimation given by Kumar (1998). The percent error (underestimation) ranges from -0.2 percent as estimated in the study by Kumar et al. (2016) to -37.0 percent as estimated by Mittal (2008) at 9 percent GDP growth rate.

Only a few studies in the past have forecasted the demand for oilseeds, sugar, and high-valued agricultural commodities. Table 5 provides the difference as well as the error between the estimated ex-ante demand projections of fruits, oilseeds, sugar, milk, and meat with actual absorption for the years 2020 and 2021. The examination of projected demand for oilseeds, sugar and high valued agricultural commodities suggests that the WG (2018) of the Niti Aayog has consistently overestimated the demand forecasts. For instance, for the year 2020-21, the error for the oilseed's demand forecast estimated by the Niti Ayog was about 99 percent (at 8 percent GDP growth rate) while the error was almost 125 percent for the sugar forecast estimated by Mittal (2008) (at 9 percent GDP growth). On the other hand, Kumar et al. (2016) underestimated the demand for fruits, vegetables, and milk in 2020. While interpreting the percent error in Tables 4-5, we need to be cautious about the fact that the computed errors for each of these demand forecasts by different studies have been estimated for a year only. As a result, a low percent error for a year is not enough to check the robustness of the assumptions made by the authors in the past.

The reason for validating the ex-ante forecast of these past studies with the actual absorption was to comprehend the modus operandi used by researchers and account for the shortcomings in their empirical framework. Further, this exercise can be useful in developing a credible and strong model to project the demand for agricultural commodities by 2030. In the next section, we will validate the methodological framework adopted in the present study, prior to forecasting the demand for agricultural commodities up to 2030.

Table 4: Difference between actual absorption and predicted estimates of cereals by different studies (in million tonnes)

Study	Assumed GDP/PCY	Validating year for the demand forecasts by diff studies	Study Estimates for various years	Difference (Study estimates Actual absorption)	Error (Difference /Actual Absorption) *100	Study Estimates for various years	Difference (Study estimates Actual absorption)	Error (Difference /Actual Absorption) *100	Study Estimates for various years	Difference (Study estimates Actual absorption)	Error (Difference/Actual Absorption) *100
			Rice			Wheat			Cereals		
Rosegrant, Agcaoili-Sombilla, and Perez (1995)	GDP – 5.5 percent	2020	144.8	37.2	34.6	95.6	-2.9	-3.0	304.3	50.3	19.8
Kumar (1998)	GDP – 4 percent	2020	122.4	14.8	12.1	104.8	6.3	6.4	267.0	13.0	5.1
	GDP – 5 percent		122.1	14.5	11.8	102.8	4.3	4.3	265.8	11.8	4.7
	GDP – 7 percent		121.9	14.3	11.7	100.3	1.8	1.8	265.7	11.7	4.6
Bhalla, Hazell and Kerr (1999)	GDP- 2 percent	2020	-	-	-	-	-	-	257.3	3.3	1.3
	GDP-3.7 percent		-	-	-	-	-	-	296.2	42.2	16.6
	GDP-6 percent		-	-	-	-	-	-	374.7	120.8	47.6
Chand (2007) *	NNPFC- 9 percent	2011-12	84.7*	-	-	62.7*	-	-	218.9	5.12	2.4
		2020-21	89.1*	-	-	67.5*	-	-	261.5	16.7	6.8
	PCY-7.57 percent										
Mittal (2008)	GDP-8 percent	2011	94.5	0.23	0.24	60.1	-21.38	-26.5	187.8	-26	-12.20

	PCY-6.67 percent										
	GDP-9 percent		94.4	0.13	0.14	59.0	-22.48	-27.6	188.5	-25.3	-11.8
	PCY-7.67 percent										
Mittal (2008)	GDP-8 percent	2021	96.9	2.0	2.1	66.8	-35.3	-34.6	242.8	-2.0	-0.8
	PCY-6.67 percent		96.8	1.9	2.0	64.3	-37.8	-37.0	245.1	0.3	0.1
Kumar, Joshi, Birthal (2009)	GDP – 9 percent	2021-22	113.3	18.4	19.4	89.5	-12.6	-12.3	233.6	-11.2	-4.6
	PCY – 7.91 percent										
Kumar et al. (2012)	PCY – 5 percent	2020-21	101.0	6.1	6.4	90.6	-11.5	-11.2	-	-	-
	PCY – 6 percent		100.2	5.3	5.6	90.2	-11.9	-11.6	-	-	-
Kumar, Joshi, Mittal (2016)	-	2020	111.8	4.2	3.9	98.3	-0.2	-0.2	252.6	-1.4	-0.5
Niti Aayog (2018)	GDP – 6 percent	2016-17	103.02	5.87	6.04	89.51	-12.39	-12.2	231.50	-11.0	-4.54
	GDP – 8 percent		102.54	5.39	5.6	89.09	-12.81	-12.6	231.67	-10.83	-4.47
	GDP – 6 percent	2020-21	107.0	12.1	12.8	94.4	-7.7	-7.5	244.9	0.1	0.0
	GDP – 8 percent		106.2	11.3	11.9	93.7	-8.4	-8.2	245.6	0.8	0.3

Source: Author's Estimation and compilation from various studies

*Note: For validating the different study estimates, the actual absorption for 2019-20 and 2020-21 have been compared with the predicted demand of select agricultural commodities for the years 2020 and 2020-2021/2021-2022 respectively. Actual absorption for the year 2020-21 for rice (94.89 million tonnes), wheat (102.07million tonnes) and cereals (244.79 million tonnes) has been calculated using the fourth advance estimates from DES. GoI. *Demand projections for rice and wheat includes only the direct demand. Negative sign indicates underestimation (Predicted < Actual) and positive sign indicates overestimation (Predicted>Actual*

Table 5: Difference between actual absorption and predicted estimates for non-cereals by different studies (in million tonnes)

Study	Assumed GDP/PCY	Validating year of the prediction by diff studies	Study Estimates for various years	Difference	Error	Study Estimates for various years	Difference	Error	Study Estimates for various years	Difference	Error	Study Estimates for various years	Difference	Error	Study Estimates for various years	Difference	Error	Study Estimates for various years	Difference	Error
			Sugar*			Oilseeds			Fruits			Vegetables			Meat			Milk		
Mittal (2008)	GDP-8%, PCY-6.67%	2011	26.7	3.8	16.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	GDP-8%, PCY-6.67%		29.3	6.4	27.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	GDP-8%, PCY-6.67%	2021	55.0	25.8	93.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	GDP-9%, PCY-7.67%		65.7	36.5	124.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kumar, Joshi, Mittal (2016)	-	2020	33.1	5.6	20.3	-	-	-	80.9	-21.3	-20.8	154.8	-32.3	-20.9	6.8	-1.2	-14.6	138.3	-60.1	-30.3
Niti Aayog (2018)	GDP- 6%	2016-17	-	-	-	52.67	22.5	74.5	102.24	9.1	9.7	185.39	10.6	6.1	-	-	-	149.47	-15.9	-9.6
	GDP- 8%		-	-	-	55.95	25.77	85.4	104.41	11.3	12.1	194.43	19.63	11.2	-	-	-	155.15	-10.23	-6.2
	GDP- 6%	2020-21	-	-	-	63.5	27.9	78.4	122.73	19.2	18.6	220.4	29.1	15.2	-	-	-	177.8	-20.6	-10.4
	GDP- 8%		-	-	-	70.8	35.2	98.9	127.53	24.0	23.2	240.4	49.1	25.6	-	-	-	190.3	-8.1	-4.1

Source: Author's Estimation and compilation from various studies

Note: For validating the different study estimates, the actual absorption for 2019-20 and 2020-21 has been compared with the predicted demand of select agricultural commodities for the years 2020 and 2020-2021, respectively, for oilseeds, sugar, fruits, and vegetables. However, for milk and meat, the actual absorption of 2019-20 has been compared with 2020 and 2020-21. Actual absorption for the year 2020-21 for sugar (29.2 million tonnes), oilseeds (35.99 million tonnes), fruits (103.5 million tonnes) and vegetable (191.35million tonnes) is calculated from DES, GoI (Fourth Advance Estimate for sugarcane and oilseeds), ISMA, DGCIS and Department of Agriculture, Cooperation and Farmers Welfare (First advance Estimate for Fruits and Vegetables)

**Sugar data for 2020-21 as on July 14, 2021*

-Negative sign indicates underestimation (Predicted < Actual) and positive sign indicates overestimation (Predicted>Actual)

Demand Projections of Agricultural Commodities up to 2030–31

Forecasting accurately the demand for agricultural commodities is a challenging task. Seldom has any earlier study ventured to provide validation for the models that they have adopted for demand projections. Validating the past demand is an important exercise to show the degree of error between the forecasted and actual food demanded. Without validation, it becomes difficult to assess the reliability of the forecasting performance of the models. In this section, we will undertake the exercise to project ex-ante demand for rice, wheat, coarse cereals, cereals, pulses, foodgrains, sugar, oilseeds, fruits, vegetables, milk, and meat till 2019-20 to ascertain the accuracy of the methodology used in generating the forecast in the future.

For validating our model, we have predicted the ex-ante absorption from 2000-01 to 2019-20 using the base year absorption simulated by population growth and per capita income growth. The base year is the average actual per capita absorption of each commodity during Triennium Ending (TE) 1999-00 where the base year per capita absorption was revised after every five years (i.e., TE 2004-05, TE 2010-11, and TE 2015-16) to take into account the fluctuations in production, change in stocks and trade scenario of the commodities. However, while calculating the predicted demand for high valued commodities, the base year absorption was assumed to be TE 1999-00, TE 2007-08, TE 2012-13 and TE 2016-17. The base year for ex-ante prediction of fruits and vegetables was revised as there has been a substantial increase in production of horticulture commodities after 2005-06, particularly after the implementation of the National Horticulture Mission (NHM) 2005-06. Similarly, the base year for meat and milk was revised due to a significant increase in the value of livestock output during the 11th FYP which was largely driven by the demand for protein food. In addition, the Government of India launched the National Livestock Mission during the 12th FYP to encourage the growth of the livestock sector (Department of Animal Husbandry, Dairying and Fisheries, Annual Report 2019-20).

Further, the GDP grew at 7.2 percent per annum from 2000-01 to 2010-11 and 6.6 percent per annum from 2011-12 to 2019-20. The growth rate of the population was 1.6 percent and 1.1 percent per annum during these two periods, respectively. After adjusting the population growth rate from GDP growth, the growth of per capita income was estimated at 5.6 and 5.5 percent during the same time periods. As already discussed in the methodology section, we have used elasticities estimated by Kumar et al. (2011) and the WG report (2018) of the Niti Aayog to predict the demand for agricultural commodities up to 2030-31. Taking the above-mentioned factors into consideration, the absorption of rice, wheat, coarse cereals, cereals, pulses, foodgrains, sugar, oilseeds, fruits, vegetables, milk, and meat from 2000-01 to 2019-20 has been projected (see **Figure 3** and **Figure 4**).

Figure 3: Actual and predicted absorption of cereals and non-cereal commodities (2000-01 to 2019-20) (using Kumar et al. (2011) Elasticities)

Source: Author's Estimation

Figure 4: Actual and predicted absorption of cereals and non-cereal commodities (2000-01 to 2019-20) (using elasticities estimated by WG report (2018) of the Niti Aayog)

Source: Author's Estimation

For measuring the accuracy and goodness of fit between the ex-ante predicted absorption and actual absorption, we have estimated the R-square as well as root mean square error for each commodity from 2000-01 to 2019-20 using elasticities given by Kumar et al. (2011) and Niti Aayog's WG Report (2018). Higher the R-square, better tis the goodness of fit of the model fits the data[5]. For instance, in the case of pulses, which has R-square of 0.86, indicate that approximately 86 percent of observed variation in the predicted demand can be explained by the model. At the same time, Root Mean Square (RMSE) is the measure

[5] R^2, which is also called the coefficient of determination, is a statistical measure which represents the variation in the dependent variable explained by the independent variables in a model. The range of R^2 varies between zero and one.

of accuracy of the model. The more accurate the model would be, the lesser would-be error. **Table 6** shows the values of R-square and RMSE for rice, wheat, coarse cereals, cereals, pulses, foodgrains, sugar, oilseeds, fruits, vegetables, milk, and meat.

Table 6: R2 and Root Mean Square Error (RMSE) (2000-01 to 2019-20)

Commodities	R^2		RMSE	
	Niti Aayog's WG Report (2018)	Kumar et al. (2011)	Niti Aayog's WG Report (2018)	Kumar et al. (2011)
Rice	-	0.34	-	6.6
Wheat	-	0.70	-	6.8
Coarse Cereals	-	0.67	-	3.9
Cereals	0.86	0.83.7	10.71	11.34
Pulses	0.84	0.86	2.50	2.73
Foodgrains	-	0.87	-	13.6
Fruits*	0.95	0.93	14.4	5.8
Vegetables*	0.95	0.94	14.4	10.1
Meat	0.65	0.59	1.36	1.5
Milk	0.98	0.99	7.93	9.5
Sugar	-	0.82	-	2.5
Oilseeds	-	0.25	-	1.15

Source: Author's Estimation

*Note: * indicates that the R^2 and RMSE/degree of deviation has been calculated together for fruits and vegetables using Niti Aayog's elasticities*

The table illustrate that the value of RMSE/degree of deviation is less than 5 for agricultural commodities such as coarse cereal, pulses, meat, sugar, and oilseeds, however, milk, rice, wheat, cereals, fruits, and vegetables and foodgrains have RMSE more than 5 percent. Thus, our model for projecting the future demand for coarse cereal, pulses, meat, sugar, oilseeds will provide forecasts with least error. The agricultural commodities including rice, wheat, milk, fruits, and vegetables relatively have a volatile absorption and significantly influenced by the market dynamism and price movements, resulting in relatively higher deviation between actual and predicted values. This could be due to external factors such as trade policies, domestic policies which significantly affects production, net imports as well as the government stock (in case of rice and wheat). The deviation between projected absorption and the ex-post reality could be relatively higher for these commodities.

Similarly, the value of R-square is more than 65 percent for all the commodities except oilseeds (25 percent), rice (33 percent) and meat (59 percent) corroborating that the methodological framework and assumptions adopted in this paper to validate the actual absorption with projected demand can be used to forecast future demand.

The future forecast for demand is based on the growth rate of population and the base year absorption after controlling for the changes in per capita income and the elasticity of consumption/expenditure of agricultural commodities. The base year per capita absorption has been calculated by taking the average of actual per capita absorption of each commodity for TE 2019-20 after adjusting for changes in stocks, exports, and imports. Given the current scenario of the pandemic and given the medium-term forecast up to 2030-31, we have assumed alternative three GDP growth rate scenarios for projecting the demand: 5 percent (pessimistic), 6 percent (business as usual) and 7 percent (optimistic) per annum. The projected population, under the assumption of no change, has been estimated to grow at 0.9 percent per annum between 2020 and 2030. After adjusting for the growth rate in population, per capita income is estimated to grow at an average rate of 4.1, 5.1 and 6.1 percent per annum, respectively, under the three growth rate scenarios. The population projection numbers have been taken as given by the UN's WPP (2019).

Further, as discussed earlier, the demand projections have been estimated using the elasticities estimated by Kumar et al. (2011) and WG (2018) of the Niti Aayog. Various studies on the demand and supply prospects have made several assumptions about the seed, feed, wastage as well as any usage of foodgrains for industrial purposes (SFWI). Since we are projecting the total demand based on the absorption function, SFWI is already included in the base year absorption. The demand projections based on the above assumptions have been estimated for the period from 2020-21 to 2030-31 and have been presented in **Table 7, Table 8,** and **Table 9**.

Our findings show that the total cereal demand projected for 2030-31 is 272 MT if the PCY grows at 4.1 percent per annum and 273.3 MT if the PCY grows at the rate of 6.1 percent per annum using elasticities estimated by Kumar et al. (2012). During the same period and using the same elasticities, demand for rice, wheat and coarse cereals is expected to range between 113.5-114.1 MT, 110.9-112.8 MT and 47.7-46.4 MT, respectively. The projections for pulses during 2030-31 range between 33.7-35.3 MT under the alternative PCY growth scenarios. In the case of high valued commodities, during 2030-31, the projected demand for fruits and vegetables is estimated to be in the range of 129.5-140.0 MT and 228.5-241.8 MT, respectively, when the per capita income growth ranges between 4.1 to 6.1 percent. For livestock products, we have estimated that absorption of meat will increase from 7.25 MT in the base year (TE 2019-20) to 10.9 MT in the low growth scenario and 12.5 MT under the high growth scenario in 2030-31 whereas the demand for milk is estimated to range between 252.3-276.8 million tonnes in 2030-31.

Table 7: Predicted demand for rice, wheat, coarse cereals, cereals, pulses and foodgrains from 2020-21 to 2030-31 (using Kumar et al. (2011) elasticities) (In million tonnes)

PCY growth – 4.1 percent						
Years	Rice	Wheat	Coarse Cereals	Cereals	Pulses	Foodgrains
2020-21	103.1	98.8	46.1	248.0	28.3	276.2
2021-22	104.2	100.0	46.3	250.5	28.8	279.3
2022-23	105.3	101.3	46.5	253.1	29.3	282.4
2023-24	106.4	102.5	46.7	255.6	29.9	285.5
2024-25	107.4	103.8	46.9	258.1	30.4	288.5
2025-26	108.5	105.0	47.1	260.5	30.9	291.5
2026-27	109.5	106.2	47.2	263.0	31.5	294.4
2027-28	110.5	107.4	47.4	265.3	32.0	297.3
2028-29	111.5	108.6	47.5	267.6	32.6	300.2
2029-30	112.5	109.8	47.6	269.9	33.1	303.0
2030-31	113.5	110.9	47.7	272.1	33.7	305.8
PCY growth – 5.1 percent						
Years	Rice	Wheat	Coarse Cereals	Cereals	Pulses	Foodgrains
2020-21	103.1	98.8	46.1	248.0	28.3	276.3
2021-22	104.3	100.2	46.2	250.6	28.9	279.5
2022-23	105.4	101.5	46.3	253.2	29.5	282.7
2023-24	106.5	102.8	46.5	255.8	30.1	285.9
2024-25	107.6	104.2	46.6	258.3	30.7	289.1
2025-26	108.7	105.5	46.7	260.8	31.3	292.2
2026-27	109.7	106.8	46.8	263.3	32.0	295.2
2027-28	110.8	108.1	46.9	265.7	32.6	298.3
2028-29	111.8	109.3	47.0	268.1	33.2	301.3
2029-30	112.8	110.6	47.0	270.4	33.8	304.3
2030-31	113.8	111.8	47.1	272.7	34.5	307.2
PCY growth – 6.1 percent						
Years	Rice	Wheat	Coarse Cereals	Cereals	Pulses	Foodgrains
2020-21	103.1	98.9	46.0	248.0	28.4	276.4
2021-22	104.3	100.3	46.1	250.7	29.0	279.7
2022-23	105.5	101.7	46.2	253.3	29.7	283.1
2023-24	106.6	103.1	46.2	256.0	30.4	286.3
2024-25	107.7	104.5	46.3	258.5	31.1	289.6
2025-26	108.8	105.9	46.4	261.1	31.8	292.9
2026-27	109.9	107.3	46.4	263.6	32.5	296.1
2027-28	111.0	108.7	46.4	266.1	33.2	299.3
2028-29	112.0	110.1	46.4	268.5	33.9	302.4
2029-30	113.1	111.4	46.4	270.9	34.6	305.5
2030-31	114.1	112.8	46.4	273.3	35.3	308.6

Source: Author's Estimation

Table 8: Predicted demand for oilseeds, sugar, fruits, vegetables, and meat from 2020-21 to 2030-31 (using Kumar et al. (2011) elasticities) (In million tonnes)

PCY growth – 4.1 percent						
Years	Oilseeds	Sugar	Fruits	Vegetables	Meat	Milk
2020-21	32.3	27.5	102.5	188.7	7.6	194.5
2021-22	33.0	27.8	105.1	192.6	7.9	199.9
2022-23	33.7	28.1	107.7	196.5	8.2	205.3
2023-24	34.4	28.5	110.3	200.4	8.5	210.9
2024-25	35.2	28.8	112.9	204.3	8.8	216.5
2025-26	35.9	29.1	115.6	208.3	9.1	222.3
2026-27	36.7	29.4	118.3	212.3	9.4	228.1
2027-28	37.4	29.8	121.0	216.4	9.8	234.0
2028-29	38.2	30.1	123.8	220.4	10.1	240.0
2029-30	38.9	30.4	126.6	224.5	10.5	246.1
2030-31	39.7	30.7	129.5	228.5	10.9	252.3
PCY growth – 5.1 percent						
Years	Oilseeds	Sugar	Fruits	Vegetables	Meat	Milk
2020-21	32.4	27.5	102.9	189.2	7.6	195.4
2021-22	33.2	27.8	105.8	193.6	8.0	201.6
2022-23	34.0	28.2	108.8	198.0	8.3	207.9
2023-24	34.8	28.5	111.8	202.5	8.7	214.4
2024-25	35.7	28.9	114.9	207.0	9.1	221.1
2025-26	36.6	29.2	118.1	211.6	9.5	227.9
2026-27	37.4	29.6	121.3	216.2	9.9	234.9
2027-28	38.3	29.9	124.5	220.8	10.3	242.0
2028-29	39.2	30.2	127.9	225.5	10.7	249.3
2029-30	40.1	30.6	131.2	230.3	11.2	256.7
2030-31	41.0	30.9	134.6	235.1	11.7	264.3
PCY growth – 6.1 percent						
Years	Oilseeds	Sugar	Fruits	Vegetables	Meat	Milk
2020-21	32.5	27.5	103.3	189.7	7.7	196.2
2021-22	33.4	27.9	106.6	194.6	8.1	203.3
2022-23	34.3	28.2	110.0	199.5	8.5	210.6
2023-24	35.3	28.6	113.4	204.5	8.9	218.1
2024-25	36.2	29.0	117.0	209.6	9.4	225.8
2025-26	37.2	29.3	120.6	214.8	9.8	233.7
2026-27	38.2	29.7	124.3	220.1	10.3	241.9
2027-28	39.2	30.1	128.1	225.4	10.8	250.3
2028-29	40.2	30.4	132.0	230.8	11.4	258.9
2029-30	41.3	30.8	136.0	236.2	11.9	267.7
2030-31	42.3	31.1	140.0	241.8	12.5	276.8

Source: Author's Estimation

Table 9: Predicted demand for cereal and non-cereal commodities from 2020-21 to 2030-31 (using elasticities of the WG (2018) of the Niti Aayog) (In million tonnes)

PCY growth – 4.1 percent					
Years	**Cereals**	**Pulses**	**Milk**	**Meat**	**Fruits and Vegetables**
2020-21	249.4	28.57	196.6	7.6	296.2
2021-22	250.7	29.43	204.1	7.9	307.9
2022-23	252.0	30.30	211.8	8.2	319.9
2023-24	253.3	31.20	219.9	8.5	332.4
2024-25	254.5	32.12	228.1	8.8	345.2
2025-26	255.7	33.05	236.6	9.2	358.5
2026-27	256.8	34.00	245.4	9.5	372.1
2027-28	257.8	34.97	254.4	9.8	386.2
2028-29	258.8	35.96	263.7	10.2	400.7
2029-30	259.7	36.97	273.2	10.6	415.7
2030-31	260.6	37.99	283.0	11.0	431.1
PCY growth – 5.1 percent					
Years	**Cereals**	**Pulses**	**Milk**	**Meat**	**Fruits and Vegetables**
2020-21	249.1	28.71	197.9	7.7	298.3
2021-22	250.2	29.71	206.8	8.0	312.2
2022-23	251.3	30.74	216.1	8.4	326.7
2023-24	252.3	31.81	225.8	8.7	341.7
2024-25	253.2	32.90	235.8	9.1	357.4
2025-26	254.1	34.01	246.3	9.5	373.7
2026-27	255.0	35.16	257.1	9.9	390.6
2027-28	255.7	36.34	268.3	10.4	408.2
2028-29	256.4	37.55	280.0	10.8	426.5
2029-30	257.1	38.79	292.1	11.3	445.5
2030-31	257.6	40.05	304.6	11.8	465.2
PCY growth – 6.1 percent					
Years	**Cereals**	**Pulses**	**Milk**	**Meat**	**Fruits and Vegetables**
2020-21	248.8	28.84	199.2	7.7	300.4
2021-22	249.7	30.00	209.6	8.1	316.5
2022-23	250.5	31.19	220.5	8.5	333.5
2023-24	251.3	32.42	231.9	9.0	351.3
2024-25	251.9	33.69	243.8	9.4	369.9
2025-26	252.6	35.00	256.3	9.9	389.5
2026-27	253.1	36.36	269.3	10.4	409.9
2027-28	253.6	37.76	283.0	10.9	431.4
2028-29	254.1	39.20	297.2	11.5	453.8
2029-30	254.4	40.68	312.1	12.1	477.3
2030-31	254.7	42.21	327.6	12.7	501.8

Source: Author's Estimation

Similarly, we have projected the absorption of selected agricultural commodities using the elasticities given by the WG (2018) of the Niti Ayog. We found that the cereal demand by the end of 2030-31 will increase from 253.97 MT in the base year (TE 2019-20) to 260.6 MT under 4.1 percent PCY growth and 254.7 MT under 6.1 percent PCY growth. The demand for pulses will range between 37.99 to 42.21 MT depending upon various growth scenarios in 2030-31. The foodgrains absorption is estimated to increase up to 298.5 MT under 4.1 percent per annum PCY growth and 297 MT if the PCY grows at 6.1 percent per annum. Since the expenditure elasticity of cereals is estimated to be negative, the growth in the demand for cereals and foodgrains is expected to increase at a diminishing rate in the future. In other words, with income growth, the consumption basket of the people tends to diversify towards nutritious and high valued commodities including fruits and vegetables and dairy products, away from staples such as rice and cereals. We found that the demand for fruits and vegetables will increase from 289.32 MT in the base year (TE 2019-20) to 431.1 million tonnes under the assumption of 4.1 percent PCY growth and 501.8 under 6.1 percent PCY growth by the end of 2030-31. The livestock product, using the WG (2018) elasticities, is estimated to be in the range of 283-327.6 MT for milk and 11-12.9 MT for meat in 2030-31. Evidently, the growth in the demand for non-cereals and high-valued commodities is expected to exceed the population growth rate and increase at a faster rate than cereal commodities under all the alternative scenarios. Further, the comparison of the demand projections using the Kumar et al (2011) and WG (2018) elasticities from 2020-21 to 2030-31, illustrates that the demand forecasts for pulses, meat, milk, fruits, and vegetables estimated by the WG (2018) of the Niti Aayog are much higher than Kumar et al (2012). This is primarily because the magnitude of the elasticities given by the Niti Aayog (2018) report are higher than that of Kumar et al. (2011) for the commodities except cereals which have an inelastic demand according to WG's (2018) report.

Supply projections of Agricultural Commodities up to 2030–31

Like demand forecasts, various studies have forecasted the supply of agricultural commodities to compute if the country's food balance sheet will be in deficit/surplus in the near future, medium-term and long term. The estimated ex-ante supply forecasts as given by various studies are compared with the actual supply for rice, wheat, cereals and foodgrains in **Table 10**. The table compares only those studies whose forecast estimates can be validated with the actual supply up to 2020-21. We have discussed in detail the supply estimates by various studies in **ANNEXURE 3**.

The difference between the actual and projected supply illustrates that most studies have underestimated the supply of foodgrains. However, the comparisons of the commodities such as rice, wheat and pulses show that their ex-ante supply forecasts have been underestimated (where error is negative) by most studies while some have overestimated (where error is positive) their supply. For instance, the studies including Rosegrant et al. (1995) and Kumar et al. (2012), have overestimated the supply of rice with an error ranging between 22.8 percent to 6.0 percent whereas studies such as Mittal (2008), the Working Group Report of the Planning Commission (2011), WG Report (2018) of Niti Ayog, Kumar Joshi and Mittal (2016) have underestimated the supply of rice for 2011, 2016 and 2021, respectively.

Similarly, for wheat and pulses, most studies have underestimated their ex-ante supply predictions where the error between actual supply and predicted supply ranges between -15.5 percent (Mittal, 2008) to -2.2 percent (WG Report of the Niti Ayog, 2018) for wheat and -10.1 percent (Kumar, Joshi, and Mittal (2016) to -5.8 percent (Mittal, 2008) for pulses. The gap between the actual and ex-ante predicted supply of foodgrains is as high as 33.5 million tonnes according to estimates given by Mittal (2008) for 2011 whereas the difference is lower for the Working Group Report of Planning Commission (2011) at 3.1 million tonnes for the year 2016.

Table 11 provides the difference as well as the error between the estimated ex-ante supply projections of fruits, oilseeds, sugar, sugarcane, and milk with the actual supply for the various studies. Given the different methods of estimating the supply projections with varying assumptions related to past trends of production across studies, the supply forecasts vary considerably. For instance, the examination of the ex-ante supply forecast for oilseeds with actual supply shows that the error ranged from -19.6 percent (Mittal, 2008) to 1.2 percent (Working Group of Planning Commission, 2011). Similarly, in fruits and vegetables, we found the error between actual and predicted estimated ranged between -4.2 percent (Kumar et al. 2016) to 11.6 percent (WG Report of the Niti Ayog, 2018) and between -1.2 percent (Kumar et al. 2016) and 9.1 percent (WG Report of Niti Ayog, 2018), respectively. Surprisingly, we found that the supply forecast for oilseeds, sugar, fruits, and vegetables given by the WG (2018) of the Niti Aayog for the year 2020-21 has been consistently overestimated. On the contrary, the supply forecast for milk has been underestimated by Kumar et al. (2016) and the Niti Ayog Report (2018) with a deviation of 41.8 and 4.5 million tonnes, respectively.

Table 10: Difference between actual supply and predicted estimates by different studies for cereals and foodgrains (in million tonnes)

Study	Validation of the predicted supply for the year	Study Estimates	Difference (Study estimates - Actual absorption)	Error	Study estimates	Difference (Study estimates - Actual absorption)	Error	Study estimates	Difference (Study estimates - Actual absorption)	Error	Study estimates	Difference (Study estimates - Actual absorption)	Error	Study estimates	Difference (Study estimates - Actual absorption)	Error
Study	Year	Rice			Wheat			Total Cereals			Pulses			Foodgrains		
Rosegrant, Sombilla et al (1995)	2020	145.8	27.1	22.8	96.4	-11.6	-10.8	306.6	32.1	11.7	-	-	-	-	-	-
Bhalla, Hazell and Kerr (1999)*	2020	-	-	-	-	-	-	321.1	46.6	17.0	-	-	-	-	-	-
Mittal (2008)#	2011	95.7	-9.6	-9.1	80.2	-14.7	-15.5	209.7	-32.5	-13.4	16.1	-1.0	-5.8	225.8	-33.5	-12.9
	2021	105.8	-16.5	-13.5	91.6	-17.9	-16.4	242.2	-40.7	-14.4	17.6	-8.1	-31.6	259.8	-48.9	-15.8
Working Group Report (2011)&	2016	97.9	-11.8	-10.7	103.7	5.2	5.3	250.6	-1.4	-0.6	21.5	-1.7	-7.3	272.0	-3.1	-1.1
Kumar, et al (2012)^	2020-21	135.85 (SP1)	13.6	11.1	96.28 (SP1)	-13.2	-12.1	-	-	-	-	-	-	-	-	-
		130.85 (SP2)	8.6	7.0	100.15 (SP2)	-9.4	-8.6	-	-	-	-	-	-	-	-	-
		133.41 (SP3)	11.1	9.1	93.57 (SP3)	-16.0	-14.6	-	-	-	-	-	-	-	-	-
		129.55 (SP4)	7.3	6.0	99.46 (SP4)	-10.1	-9.2	-	-	-	-	-	-	-	-	-
Kumar, Joshi, Mittal (2016)@	2020	108.1	-10.6	-8.9	104.2	-3.8	-3.5	262.6	-11.9	-4.3	20.7	-2.3	-10.1	281.2	-16.3	-5.5
WG report of the Niti Aayog (2018)$	2017-18	112.5	-0.3	-0.2	100.2	0.3	0.3	256.8	-2.8	-1.1	22.1	-3.3	-13.1	278.9	-6.1	-2.2
	2020-21	119.8	-2.5	-2.1	107.1	-2.4	-2.2	273.9	-9.0	-3.2	23.7	-2.0	-7.9	297.6	-11.1	-3.6

Source: Author's Estimation and compilation from various studies

Note: For validating supply estimates, the actual supply for 2019-20 and 2020-21 have been compared with the predicted supply of select agricultural commodities by various studies for 2020 and 2020-2021, respectively. Negative sign indicates underestimation (Predicted < Actual) and positive sign indicates overestimation (Predicted>Actual)

** Study used 7 different scenarios to predict the supply of cereals in 2020. The projection of supply of cereals in the table above shows the future production of cereals is extrapolated using past growth trend. # indicates that the supply projections were forecasted using yield growths of 1993-2003 and the base year for area and production was 2003-04.*

& Supply projections are made on the average annual growth rate in production. ^ shows that there are 4 sets of supply projections (SP) in the table are as per the business-as-usual scenario and the projections are based on the average annual growth rate in output from 1992-93 through 2007-08. The Business As Usual (BAU) Scenario shows current trends in Public Investment in Agriculture (IGV) (4.33%), Private Investment in Agriculture (IPV)(8.76%), and fertilizer-consumption growth continue in the future. @ indicates that supply of different commodities has been projected using the Trans log cost function to derive the output supply elasticities and the base year production was taken to be TE2010 $ indicates that the supply has been estimated using a simultaneous equation model using four variables (area, yield, farm harvest prices and quantity of exports). For horticulture crops and commercial crops only area and yield were taken.

Table 11: Difference between actual supply and predicted estimates by different studies for oilseeds, sugar, sugarcane, fruits, vegetables, and milk (in million tonnes)

Study	Validation of the prediction for the year	Study Estimates	Difference (Study estimates - Actual absorption)	Error	Study estimates	Difference (Study estimates - Actual absorption)	Error	Study estimates	Difference (Study estimates - Actual absorption)	Error	Study estimates	Difference (Study estimates - Actual absorption)	Error	Study estimates	Difference (Study estimates - Actual absorption)	Error
Study		Edible oils/oilseeds			Sugar/Sugarcane			Vegetables			Fruits			Milk		
Mittal (2008)#	2011	29.9	0.2	0.7	245.0	-116.0	-47.3	-	-	-	-	-	-	-	-	-
	2021	36.9	0.8	2.2	255.2	-144.0	-36.1	-	-	-	-	-	-	-	-	-
Working Group Report (2011)&	2016	32.5	1.2	4.0	411.4	105.3	34.4	-	-	-	-	-	-	-	-	-
Kumar, Joshi, Mittal (2016)@	2020	-	-	-	33.1 (sugar)	5.7	20.8	186.6	-2.3	-1.2	97.7	-4.3	-4.2	156.6	-41.8	-21.1
WG report of the Niti Aayog (2018)$	2017-18	34.0	2.5	8.0	333.8	-46.1	-12.1	184.6	0.2	0.1	100.2	2.8	2.8	169.9	-6.4	-3.6
	2020-21	37.8	1.7	4.7	353.6	-45.6	-11.4	211.3	17.7	9.1	115.2	12.0	11.6	193.97	-4.5	-2.3

Source: Author's Estimation and compilation from various studies

Note: For validating supply estimates, the actual supply for 2019-20 and 2020-21 have been compared with the predicted supply of select agricultural commodities by various studies for 2020 and 2020-2021, respectively. The ex-ante supply of milk for 2020 and 2021 has been compared with the actual supply of 2019-20. Actual supply for fruits and vegetables (First Advance estimates) for 2020-21 are given by Department of Agriculture, Cooperation and Farmers Welfare whereas for oilseeds and sugarcane, we have used DES, GoI (Fourth Advance estimate).

 # indicates that the supply projections were forecasted using yield growths of 1993-2003 and the base year for area and production was 2003-04.

& shows that the supply projections are made on the average annual growth rate in production.

^ shows that there are 4 sets of supply projections (SP) in the table are as per the business-as-usual scenario and the projections are based on the average annual growth rate in output from 1992-93 through 2007-08. The Business As Usual (BAU) Scenario shows current trends in Public Investment in Agriculture (IGV) (4.33%), Private Investment in Agriculture (IPV)(8.76%), and fertilizer-consumption growth continue in the future.

@ indicates that supply of different commodities has been projected using the Trans log cost function to derive the output supply elasticities and the base year production was taken to be TE2010

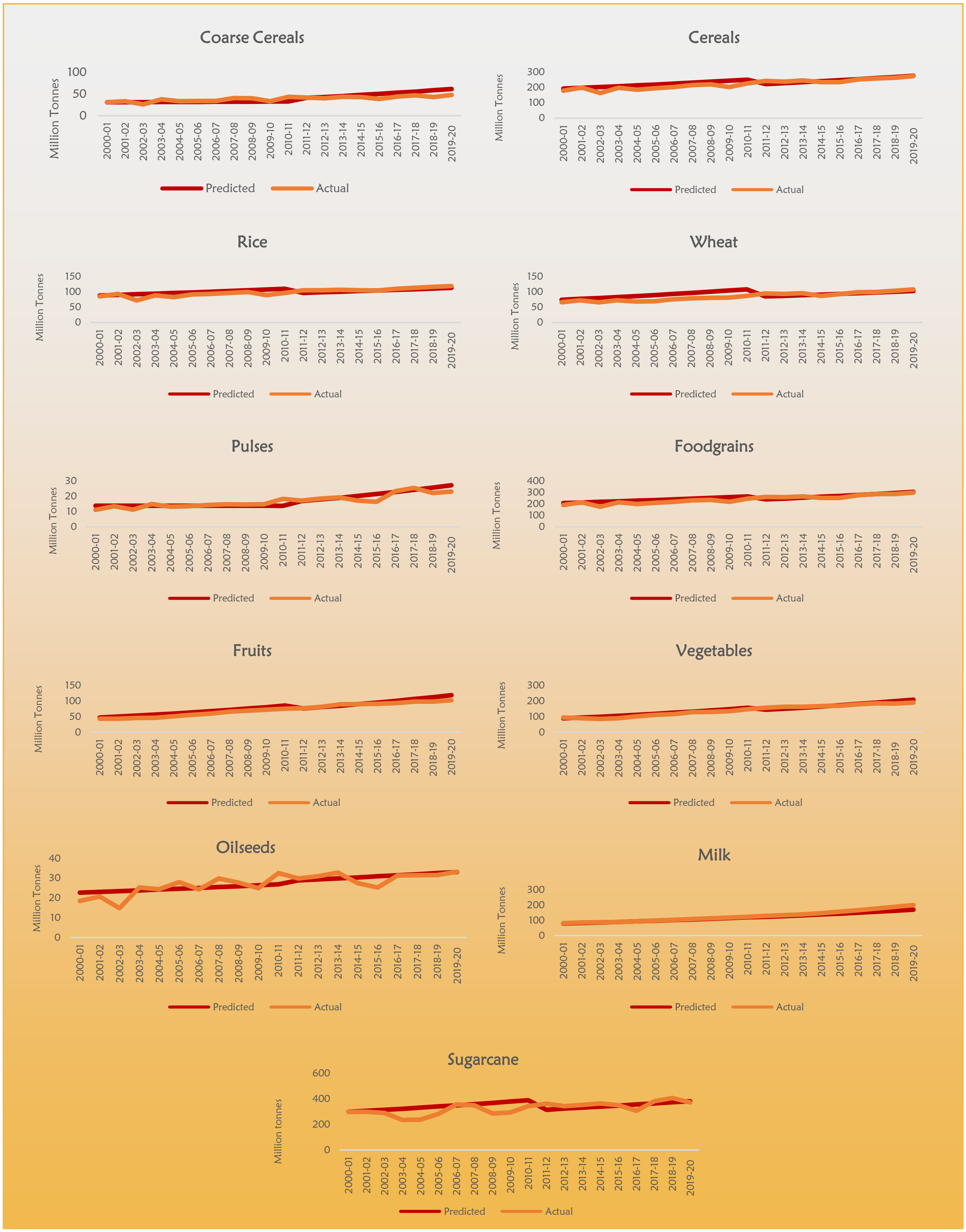
$ indicates that the supply has been estimated using a simultaneous equation model using four variables (area, yield, farm harvest prices and quantity of exports). For horticulture crops and commercial crops only area and yield were taken.

The validation of supply forecasts of past studies with the actual supply can highlight the varying factors for deviation and help us compute a strong methodology to accurately predict the supply of agricultural commodities by 2030. For estimating the supply projection of agricultural commodities such as rice, wheat, coarse cereals, cereals, pulses, foodgrains, oilseeds, fruits, and vegetables for the period between 2020-21 and 2030-31, we use the base-level production and the past trend of average annual growth rates in actual production.

Like demand forecasts, we have tried to validate the ex-ante supply projections with the actual production for the period during 2000-01 to 2019-20 before estimating supply up to 2030. This exercise gives us a better understanding to accurately estimate the future supply of agricultural commodities and highlights the deviation between these ex-post projections and the actual supply, thereby, establishing credibility about the methodology used for supply forecast.

The base-level production is estimated by taking the average production in TE 1999-00 for projecting ex-ante projections till 2010-11 and for projecting supply between 2011-12 to 2019-20, the base year was changed again at TE 2010-11. The ex-ante supply projections from 2000-01 to 2010-11 and 2011-12 to 2019-20 are based on the past ten years' average annual growth rate of production from 1991-92 to 2000-01 and 2010-11 to 2019-20, respectively. The ex-ante supply projections for the period from 2000-01 to 2019-20 for the selected agricultural commodities- rice, wheat, coarse cereals, cereals, pulses, foodgrains, oilseeds, milk, sugarcane, fruits, and vegetables have been presented in **Figure 5**.

Figure 5: Actual & predicted supply of cereals and non-cereal commodities (2000-01 to 2019-20)



Source: Author's Estimation, Production data from 1990-91 have been taken from the Agriculture Statistics at a glance (2019) and Vegetable Statistics 2013 (ICAR)

For projecting the supply for the agricultural commodities from 2020-21 to 2030-31, we have adopted a similar approach. The supply projection is estimated under the assumption that the future forecasts of each of the selected commodities will increase at the rate of past trends. First, we estimated the base year production by taking average production in TE 2019-20 and simulated it with average annual growth rate of production for each of the selected commodities for the last 10 years (2010-11 and 2019-20) as well as last 15 years (2006-07 and 2019-20). The supply prospects for 2020-21 to 2030-31 for foodgrains have been presented in **Table 12**.

Table 12: Supply projections for foodgrains from 2020-21 to 2030-31 (In million tonnes)

Commodities	Rice	Wheat	Coarse Cereals	Cereals	Pulses	Foodgrains
Annual average growth rate for 10 years						
Base Year (TE 2019-20)	116.0	103.8	45.9	265.7	23.5	289.2
2020-21	118.9	106.4	46.6	271.9	24.4	296.3
2021-22	121.8	109.2	47.2	278.2	25.3	303.5
2022-23	124.8	112.0	47.9	284.7	26.2	310.9
2023-24	127.9	114.9	48.6	291.3	27.1	318.4
2024-25	131.0	117.8	49.2	298.1	28.1	326.2
2025-26	134.2	120.9	49.9	305.0	29.2	334.2
2026-27	137.5	124.0	50.6	312.1	30.2	342.3
2027-28	140.9	127.2	51.3	319.4	31.3	350.7
2028-29	144.3	130.5	52.1	326.9	32.5	359.3
2029-30	147.9	133.8	52.8	334.5	33.7	368.2
2030-31	151.5	137.3	53.5	342.3	34.9	377.2
Annual average growth rate for 15 years						
2020-21	118.3	107.2	47.4	272.9	24.6	297.5
2021-22	120.6	110.8	48.8	280.3	25.8	306.1
2022-23	123.0	114.5	50.4	287.8	27.0	314.9
2023-24	125.4	118.3	51.9	295.6	28.3	323.9
2024-25	127.9	122.2	53.6	303.6	29.7	333.3
2025-26	130.4	126.2	55.2	311.9	31.1	343.0
2026-27	133.0	130.4	57.0	320.4	32.6	352.9
2027-28	135.6	134.8	58.7	329.1	34.1	363.2
2028-29	138.2	139.2	60.6	338.0	35.7	373.8
2029-30	141.0	143.9	62.5	347.3	37.4	384.7
2030-31	143.7	148.6	64.4	356.8	39.2	396.0

Source: Author's Estimation

If we consider the trend of last 10 years, the cereal production is estimated to increase up to 342.3 MT whereas the foodgrains is estimated to increase up to 377.2 MT by the end of 2030-31. Alternatively, if the supply growth follows the pattern of the last 15 years, the cereals and foodgrains supply are estimated to increase to 356.8 MT and 396.0 MT by 2030-31. The production of pulses is estimated to increase from 24.4 MT in 2020-21 to 29.2 MT in 2025-26, further increasing to 35 MT up to 2030-31, if we consider the last decade's growth period. On the other hand, if we consider the supply growth will follow the last 15 years trend, the pulses production will grow up to 39.2 million tonnes by 2030-31.

Further, we find that the production of high value commodities will experience significant increase (**Table 13**). In case of fruits and vegetables, the production of fruits is expected to increase from 102.6 to 145.2 MT between 2020-21 and 2030-31 if we assume the prospects will follow the past 10 years growth rate whereas the vegetables will increase from 185.5 to 253.5 MT during the same period. On the contrary, if we consider that the horticulture commodities will follow the last 15 years, the fruits production will increase up to 150.9 MT and vegetable will increase up to 282.5 MT by 2030-31.

Under alternative growth scenarios, the milk production between 2020-21 to 2030-31 is expected to increase from 197.9 MT in 2020-21 to 340.5 MT in 2030-31 and from 197.3 to 328.8 MT during the same period. Similarly, sugarcane production will range between 430.8-518.1 MT in these two growth scenarios whereas the oilseeds production will rise meagrely up to 35-40.5 MT by the end 2030-31.

Table 13: Supply projections for non-cereal commodities from 2020-21 to 2030-31 (in million tonnes)

Commodities	Oilseeds	Sugarcane	Fruits	Vegetables	Milk
Annual average growth rate for 10 years					
Base Year (TE 2019-20)	32.1	385.3	99.1	185.5	187.5
2020-21	32.3	389.2	102.6	190.8	197.9
2021-22	32.6	393.2	106.3	196.3	209.0
2022-23	32.8	397.2	110.0	202.0	220.6
2023-24	33.1	401.2	113.9	207.8	232.9
2024-25	33.4	405.3	117.9	213.8	245.9
2025-26	33.6	409.4	122.1	219.9	259.6
2026-27	33.9	413.6	126.4	226.3	274.1
2027-28	34.2	417.8	130.8	232.8	289.4
2028-29	34.4	422.1	135.5	239.5	305.5
2029-30	34.7	426.4	140.2	246.4	322.5
2030-31	35.0	430.8	145.2	253.5	340.5
Annual average growth rate for 15 years					
2020-21	32.8	395.8	103.6	192.7	197.3
2021-22	33.5	406.6	108.3	200.2	207.6
2022-23	34.2	417.7	113.1	208.0	218.5
2023-24	34.9	429.1	118.2	216.1	230.0
2024-25	35.7	440.8	123.5	224.6	242.0
2025-26	36.4	452.8	129.1	233.3	254.7
2026-27	37.2	465.2	134.9	242.4	268.1
2027-28	38.0	477.9	141.0	251.9	282.1
2028-29	38.8	490.9	147.3	261.7	296.9
2029-30	39.6	504.3	154.0	271.9	312.5
2030-31	40.5	518.1	160.9	282.5	328.8

Source: Author's Estimation

Summary and Policy Recommendations

Accurate demand and supply prediction provides a reasonably good means for policymakers to generate an outlook of essential commodities in the medium and long run. The fluctuation in production can result in a deficit in the food balances sheet, thereby, impacting food security and increasing the dependence on imports.

In the present study, we have estimated the demand and supply forecasts of selected agricultural commodities such as rice, wheat, coarse cereals, cereals, pulses, oilseeds, sugar, fruits, milk, vegetables, and meat for the period between 2020-21 to 2030-31. Besides, the recent trend in the per capita consumption among Indian households reveals a shift in the consumption basket away from staples to high-valued commodities. For instance, the per capita consumption of cereals at the all-India level has declined from 12.68 kg/month in 1993-94 to 10.62 kg/ month in 2011-12 whereas the per capita consumption of high-valued horticulture and livestock commodities like eggs (0.86 per capita/per month to 2.32 per capita/per month), milk (4.18 to 4.67 litres per capita/per month) and fish and meat (0.33 to 0.57 kg per capita/month) have increased in the last two decades. This shift in consumption pattern indicates diet diversification towards nutritious and high valued commodities and change in tastes and preferences of people with increasing income. While forecasting future demand and supply trends, it is essential to control these variables for accurate projections. The study, before forecasting demand and supply up to 2030-31, has attempted to validate the actual absorption and supply of agricultural commodities with the ex-ante prediction from 2000-01 to 2019-20 using the absorption function and supply function. This exercise is necessary to assess the reliability of the absorption function employed before predicting demand estimates till 2030-31.

Various papers in the past have forecasted the demand using per capita consumption reported by the NSSO's household consumption-expenditure survey as the baseline consumption. However, in this study, we have used the average of per capita actual absorption of selected agricultural commodities as the base year absorption rather than using the consumption expenditure survey of 2011-12. The base year has been taken as TE 1999-00 absorption for each of the commodities, however, we changed the base year every five years for validation of foodgrains i.e., TE 2004-05, 2010-11 and 2015-16. For high valued commodities, we have changed the base year to TE 2007-08, TE 2012-13, and TE 2016-17 for the validation exercise. The expenditure elasticities for the selected agricultural commodities have been assumed as given in Kumar et al. (2011) and the WG (2018) of the Niti Aayog. The validation exercise with actual absorption values revealed that the forecast error (measured by root mean square error) was less than 5 percent for coarse cereal, pulses, meat, sugar, and oilseeds. Notably, the strong forecasting performance of the model reinforces our confidence in the forecasting ability of the absorption function for future years. However, ex-ante forecasts of agricultural commodities such as milk, rice, wheat, cereals, foodgrains, fruits and vegetables recorded RMSE of more than 5 percent. This is primarily because the demand for foodgrains, milk and fruits and vegetables in the short run are subject to larger fluctuation which results in higher error in ex-ante validation. Using Kumar et al. (2011) elasticities, the projected absorption for cereals and foodgrains were estimated to be in the range of 272.1-273.32 MT and 305.8-308.5 MT, respectively, by the end of 2030-31 under different PCY growth scenarios. Similarly, using elasticities given by the WG report (2018) of the Niti Ayog, we estimated that the cereal and foodgrains absorption will increase up to 260.6 and 298.5 MT, respectively, if the PCY grows at 4.1 percent. On the other hand, the cereal and foodgrains absorption will increase up to 254.7 and 297 MT, respectively, under the assumption of high PCY growth (6.1 percent). The projected food demand for cereals and foodgrains using the elasticities of the WG (2018) is estimated to be lower than the projection made using the elasticities of Kumar et al. (2011) as the Niti Ayog has assumed the cereals to be inferior or Giffen's good. The increase in predicted demand for cereals and foodgrains in the future will be mainly due to population growth, however, the growth in their demand is expected to increase at a diminishing rate.

In addition to the demand predictions, the paper has also attempted to project the supply of rice, wheat, coarse cereals, cereals, pulses, foodgrains, sugarcane, milk, oilseeds, fruits, and vegetables based on base-level production in TE 2019-20 and trend in the production growth in the last 10 years and 15 years. The projected supply of foodgrains up to 2030-31 is estimated to increase up to 377.2 MT if we consider the past 10 years' growth rate. On the other hand, the supply projections can increase to 396.0 MT considering the past trend of 15 years. The supply of fruits and vegetables will increase up to 145.2 and 253.5 MT, respectively, considering the past 10 year's growth rate, whereas, under the assumption that growth will follow the last 15 year's trend, the supply will increase up to 160.9 and 282.5 MT, respectively.

Based on the study's findings we suggest the following recommendations to meet the future demand for agricultural commodities.

The gap between projected demand and supply of agricultural commodities or in other words, a deficit in the food balance sheet would result in higher imports to meet the domestic demand, in turn, leads to a huge import bill in the long run. Moreover, imports are a short-run solution to improve the country's supply. **Table 14** manifests the gap between the projected demand and supply of agricultural commodities in 2020-21, 2025-26 and 2030-31. Commodities like oilseed, pulses and fruits are expected to experience a supply and demand gap in the coming years. Therefore, there is a need to increase the level of production and productivity of oilseeds, pulses, and fruits since their demand in the future shows an increasing trend. This could be achieved through greater emphasis on research and development aimed at the introduction of cost-reducing technology focusing on productivity enhancement. This would facilitate meeting the country's food requirements by maintaining the balance between domestic production and demand.

Notably, the deficit of oilseeds in the food balance sheet in 2030 is worrisome for the country given the large edible oil imports as high as 13.4 million tonnes (including palm oil imports) during 2020-21. A technological breakthrough in oilseeds to increase productivity or area expansion are two possible solutions to improve oilseeds' balance sheet in the long run. Moreover, the break-up of edible oil imports shows that the share of palm oil is about 56 percent, followed by soybean oil at 27 percent and sunflower at 16 percent. Additionally, oil palm has a better yield rate compared to oilseed field crops (Niti Ayog, 2018). To increase the area under the oil palm and improve its production, the central government has been making efforts through various schemes and programmes. In 2014-15, the National Mission on Oilseeds and Oil Palm (NMOOP), implemented under the 12th Five Year Plan, proposed to increase the production of vegetable oils from the oilseeds and oil palm. At present, this scheme is being implemented through the National Food Security Mission (Oilseeds) and National Food Security Mission (Oil Palm) respectively. Moreover, recently, the central government has announced a new scheme, National Mission on Edible Oils-Oil Palm, with an investment of Rs.11,040 crores to promote the cultivation of oil palm and increase production to reach 1 million tonnes by 2025-26, thereby, reducing dependence on edible oils imports. However, farmers need to realise remunerative prices to shift towards producing oil palm. The revision of the pricing formula by CACP which has linked the market-based formula for fixing the price could help farmers realise good returns. Further, the fresh fruit bunches of oil palm are perishable and require processing within 24 hours. Initiatives that incentivise private investments or public-private partnership for agro-processing facilities needs to be prioritised for oil palm (Hussain and Mohapatra, 2021). Additionally, the CACP (2012) report on the 'Oil Palm: Pricing for Growth, Efficiency & Equity' has recommended raising the import duty whenever the import price of crude palm oil falls below US $800 per tonne to protect the Indian producers. Lastly, given that the oil palm is a water-guzzling crop with a long gestation period, complete self-sufficiency or *atmanirbharta* in palm oil production may not be a sustainable goal.

Table 14: Demand - supply gap of agricultural commodities (in million tonnes)

(Assumption: demand estimated at 5.1 percent PCY growth using elasticities given by Kumar et al. (2011) and supply projected based on past 10 years growth rate)

Food Items	Gap = Supply - Demand		
	2020-21	2025-26	2030-31
Rice	15.8	25.5	37.7
Wheat	7.6	15.4	25.5
Coarse Cereals	0.5	3.2	6.4
Cereals	23.9	44.2	69.6
Pulses	-3.9	-2.1	0.4
Foodgrains	20.0	42.0	70.0
Oilseeds	-0.1	-3.0	-6.0
Milk	2.5	31.7	76.2
Fruits	-0.3	4.0	10.6
Vegetables	1.6	8.3	18.4

Source: Author's Estimation

Moreover, the past literature as well as this study have shown how the consumption basket has been diversifying towards high valued nutritious commodities away from cereals. Consequently, the demand for high-value commodities such as horticulture, dairy, and livestock has been growing and is set to increase in the coming years. The policy perspective needs to ensure a balance between domestic production and the absorption of these commodities. Notably, diversification towards high-value commodities requires major investments in market infrastructure, processing, and storage facilities such as warehouses, cold storage, cold chains, etc. to build an efficient and reliable value chain. Further, these measures can significantly reduce the food wastages which is estimated by CIPHET (2015) study to range between 4.58-15.88 percent in fruits and vegetables, 2.71 percent in meat, 10.52 percent in fisheries and 6.74 percent in poultry. Encouraging private investment as well as public-private partnerships (PPP) in the agricultural supply chain to link farmers to the market efficiently and effectively can reduce post-harvest losses as well improve the supply of these high valued perishable commodities. Additional investments are needed in technological innovations, particularly low-cost storage solutions such as hermetic bags and reusable plastic crates for transportation and storage.

Our projections show that the food balance sheet will be stable and the country will be self-sufficient in cereals in 2030-31 under the business-as-usual scenario. However, to sustain long-term food security in foodgrains and achieve higher growth in its yield, it is important to invest in productivity-enhancing agricultural inputs such as fertilizer, high-yielding seeds etc. along with irrigation coverage rather than depend upon area expansion. However, excessive use of chemical fertilizers by farmers, especially in rice and wheat, can have detrimental effects on the environment including ground and surface water., Therefore, sustainable agricultural practices need to be promoted. These practices can improve grain quality, and soil health and ensure sustainable growth in agriculture. Further, there is a need for the government to educate the farmers and encourage them to use organic manure and reduce the use of urea as a fertilizer by reducing the fertilizer subsidies. Emphasis needs to be laid to ensure an efficient allocation of inputs by limiting subsidies provided for water, electricity, and fertilizer so that those available resources can be re-invested in irrigation, rural roads, and marketing infrastructure (Niti Ayog, 2018; Gulati and Banerjee, 2019).

To facilitate and maximise the spill-over of productivity-enhancing and technological inputs, agricultural intensification needs to be accompanied by agricultural extension services. Notably, the input usage without the transfer of technical know-how will not be able to improve agricultural productivity or food production in the future. Advisory services and timely information on improved farm practices, yield-enhancing inputs etc. through agricultural extension services can incentivise farmers to shift towards sustainable agricultural practices without impacting agricultural productivity or climate change. Importantly, in this regard, the farmer-producer organisation (FPO) can play a significant role in increasing access to agricultural extension services.

Climate change is affecting the four pillars of food security: availability, access, utilisation, and stability, thereby, threatening the livelihood of the farmers. A recent crop yield study by Gupta et al. (2017) has estimated that warming[6] has led to a decline in wheat yield by 5.2 percent during the period between 1981 and 2009. With climate change increasing over the years, the production of agricultural commodities to meet the increasing demand is a challenging task for the government and requires public-private partnerships in agricultural research and development as well as climate change mitigation research. This needs to be accompanied by changes in policies and regional cooperation towards sustainable agricultural practices. For instance, the Government of India has initiated a programme for climate-resilient villages as a pilot learning platform to develop, implement, evaluate, and disseminate climate-smart agricultural innovations with community participation (Srinivasa Rao et al. 2016).

Further, climate-smart practices need to be promoted to build resilience and adaptive capacity in food systems based on soil and water management and pest control to improve food security and agricultural production for the future generation. Increasing investments

[6] According to the Inter-Governmental Panel on Climate Change (UNEP, 2018), human-induced warming has reached approximately 1°C above pre-industrial levels in 2017 and is likely to reach 1.5°C, in the coming years if drastic actions are not taken. This would result in mercurial weather conditions, increased temperature and changing precipitation patterns and greater frequency of droughts, cyclones, melting of glaciers etc.

in ICT tools and precision agricultural techniques including GPS, weather monitoring by satellite and large-scale sensors and remote sensing techniques can increase awareness among the farmers to identify and adapt to the best possible solutions and techniques through training and agricultural extension services, thereby, improving profitability and sustainability in Indian agriculture. Further, private players need to be provided incentives to set up digital farming solutions and encourage wider adoption of new and existing technologies among smallholders. For instance, Bayer, a private sector global company, has introduced 'Better Life Farming,' an agri-entrepreneurship model in India, in partnership with other private players including International Finance Corporation, Netafim, DeHaat, Agri Bazaar, Big Basket, and Yaar to provide knowledge of good agricultural practices and access to the latest technologies, thereby, providing opportunities for increasing agricultural productivity (Gulati et al. 2021).

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ANNEXURE 1

Table A1: Overview of projected demand

Study	Predicted up to Year	Assumed rate of growth in GDP/PCY	Rice	Wheat	Total Cereals	Pulses	Foodgrains	Edible oils/Oilseeds	Sugar	Vegetables	Fruits	Milk	Meat	Poultry	Eggs	Demand Function	Methodology used	Expenditure elasticities	Feed coefficients
Rosegrant, Agcaoili-Sombilla, and Perez (1995)	2020	GDP – 5.5%, PCY – 3.8 %	144.8	95.6	304.31	-	-	-	-	-	-	-	5.4	-	-	-	IMPACT Model	Taken from FAO 1987, various country studies	Feed ratio taken from FAO 1986
Kumar (1998)#	2020	GDP – 4%	122.4	104.8	267	-	-	-	-	-	-	-	-	-	-	-	FCDS	Cereals R= (-) 0.007, U= (-) 0.037	-
		GDP – 7%	121.9	100.3	265.7	-	-	-	-	-	--	-	-	-	-				
Bhalla, Hazell, and Kerr (1999)	2020	PCY- 2 percent	-	-	257.3	-	-	-	-	-	-	-	19.9<	-	-	-	-	Rural and Urban Cereals: 0.1 Milk and eggs:1.25 and 0.74 Milk and milk products: 1.53 and 1.05	1.2 kg of cereals per kg of Meat & Eggs and 0.12 kg of cereals per kg of milk
Chand (2007)	2011	-	84.7	62.7	159.1	11.8	169.9	-	-	-	-	-		-	-	$Dt_n = Dt_0 [(1 + \eta^* Y_g)^{**(n)} + \Delta P_r$	-	Food Characteristic Demand System (FCDS) Same as estimated by Kumar (1998)	Trend analysis of gap between per capita food supply and direct demand
	2020-21	-	89.1	67.5	166.6	12.5	179.1	-	-	-	-	-		-	-				
Mittal (2008)	2011	GDP- 8percent PCY- 6.61percent	94.5	60.1	187.8	23.0	129.4	15.7 (edible oil)	26.7 (sugar)	-	-	-		-	-	$D_t = d_0 * N_t * (1 + y * e)^t$	QAIDS model	QUAIDS Rice:0.01 Wheat: -0.07 Total cereals: 0.165 Pulses: 0.59 Edible oil: 0.548 Sugar: 0.818	Same as Kumar (1998)
	2021	GDP- 8percent PCY- 6.67percent	96.9	66.8	242.8	38.7	210.8	26.7	55	-	-	-		-	-				
	2026	GDP- 8percent PCY- 7.01percent	102.2	69.1	273.5	51	324.5	35.3	81.1	-	-	-		-	-				
	2011	GDP- 9percent PCY- 7.61percent	94.4	59	188.5	24.1	212.6	16.8	29.3	-	-	-		-	-				

	2021	GDP-9percent PCY-7.67percent	96.8	64.3	245.1	42.5	287.6	30.2	65.7	-	-	-		-	-				
	2026	GDP-9percent PCY-8.01percent	102.1	65.9	277.2	57.7	334.9	40.9	100.7	-	-	-		-	-				
Kumar, Joshi, Birthal (2009)	2011	GDP – 9percent PCY – 7.75percent (2011-16)	101.1	81.1	211.6	15.5	227.1	-	-	-	-	-		-	-	D_{ijkt} = d_{ijk0} * N_{ijkt} * (1 + y * $e_{ijk})^t$	-	FCDS Rice: 0.016 Wheat: -0.08 Coarse cereals: -0.16 Pulses: 0.214	Feed coefficients assumed to be 9.5 percent of the total production of rice, 13.5 percent of wheat, 41 percent of coarse cereals, and 10.8 percent of pulses.
	2016	GDP – 9percent PCY – 7.75percent (2011-16)	106.8	86.9	223.6	17.5	241.2	-	-	-	-	-		-	-				
	2021-22	GDP – 9percent PCY – 7.91percent (2016-21)	113.3	89.5	233.6	19.5	253.2	-	-	-	-	-		-	-				
Working Group Report (2011), Planning Commission	2016	GDP – 9percent	106.3	87.8	208.5	15.5	2214.01	57.9 (oilseeds)	156.1 (sugar cane)										
Kumar et al. (2012)	2020-21	4percent	101.9	91.2	-	18.2	-	-	-	-	-	-	-	-	-		QAIDS model	Rice- (-) 0.21 Wheat- (-)0.13 Pulses- (-) 0.24	2020-21 Rice- 0.114 Wheat-0.267 Pulses-0.408
		5percent	101	90.6	-	17.9	-	-	-	-	-	-	-	-	-				
		6percent	100.2	90.2	-	17.8	-	-	-	-	-	-	-	-	-				
	2025-26	4percent	108.6	101.7	-	20.5	-	-	-	-	-	-	-	-	-				2025-26 Rice- 0.139 Wheat-0.317 Pulses-0.458
		5percent	107.2	100.9	-	20.2	-	-	-	-	-	-		-	-				
		6percent	106.4	100.5	-	20.1	-	-	-	-	-	-	-	-	-				
Kumar, Joshi, Mittal (2016)	2020	-	111.8	98.3	252.6	21.9	274.4	17.0	33.1	154.8	80.9	138.3		6.8	4.4	-	-	FCDS	-
	2030	-	122.4	114.6	284.2	26.6	310.8	21.3	39.2	192	103.0	170.4		9.2	5.8				

WG report (2018) by Niti Ayog	2020-21	-	110	97-98	235-237	23	258-260	14	39.6	183	113	154.62		-	14.75	Total demand = Base year per capita consumption (2011-12)*projected population	Household Consumption Approach	-	Trend analysis of gap between per capita food supply and direct demand
	2032-33	-	125	117-118	306-318	28-31	334-349	19-20	46.37	254.45	175.91	220.5		-	25.01				
	2020-21 Moderate	-	-	-	278-281	50-51	328-332	15(includes fat and oils)	20	150	50	125		-	-	Total domestic demand = Annual per capita recommended consumption *projected population	Normative Approach	-	
	2032-33 Moderate	-	-	-	343-356	59-61	402-418	17(includes fat and oils)	23	173	58	145		-	-				
	2020-21	GDP-6percent	107	94.4	244.9	26.6	271.5	17.8	-	220.4	122.7	177.8		-	18.1	$Q_{ijt} = q_{ij0} * P_{jt} * (1 + g_{jt} * e_{jt})^t$	Behaviouristic Approach	AIDS	-
	2032-33		117.9	110	288.9	37.1	326	31.8	-	374.1	206.8	300.9		-	36.8				
	2020-21	GDP-8percent	106.2	93.7	245.6	30.1	279.3	21.1	-	240.4	127.5	190.3		-	20				
	2032-33		115.8	108.6	294.2	45	339.2	40.1	-	462.7	227.1	355.1		-	44.7				

Source: Compiled by the authors from various sources

Table A2: Overview of projected supply

Study	Predicted up to the Year	Rice	Wheat	Total Cereals	Pulses	Foodgrains	Edible oils/oilseeds	Sugar/ Sugarcane	Vegetables	Fruits	Milk	Poultry	Eggs	Fish
Rosegrant, Sombilla et al (1995)	2020	145.77	96.38	306.56	-	-	-	-	-	-	-	-	-	-
Bhalla, Hazell et al (1999)*	2020	-	-	321.1	-	-	-	-	-	-	-	-	-	-
Mittal (2008)#	2011	95.7	80.2	209.7	16.1	225.8	10.1	25	-	-	-	-	-	-
	2021	105.8	91.6	242.2	17.6	259.8	12.5	26	-	-	-	-	-	-
	2026	111.2	97.9	260.2	18.4	278.6	13.9	26.6	-	-	-	-	-	-
Working Group Report (2011)&	2016	97.93	103.74	250.55	21.45	272	32.52	411.40	-	-	-	-	-	-
Kumar, Mehta, Pullabhotla et al (2012)^	2020	135.85 (SP1) 130.85 (SP2) 133.41 (SP3) 129.55 (SP4)	96.28 (SP1) 100.15 (SP2) 93.57 (SP3) 99.46 (SP4)											
	2025	153.14 (SP1) 144.48 (SP2) 149.35 (SP3) 142.70 (SP4)	101.99 (SP1) 110.17 (SP2) 98.61 (SP3) 104.34 (SP4)											
Kumar, Joshi, Mittal (2016)@	2020	108.1	104.2	262.6	20.7	281.2	12.5	33.4	186.6	97.7	156.6	6.6	4.7	10.2
	2030	122.1	128.8	315.1	26.4	338.8	19.1	40.3	210.5	116.4	188.7	8.4	6.2	13.9
WG Report of the Niti Aayog (2018)$	2020-21	119.76	107.1	273.9	23.7	297.6	37.8	36.1	211.3	115.2	193.9	-	109.8	13.6
	2032-2033	151.7	138.8	352.3	33.9	386.2	59.9	44.4	362.8	202.6	329.7	-	215.9	23.5

Source: Compiled by the authors from various sources

*Note: * indicates that 7 scenarios have been used to predict the supply of cereals in 2020. The projection of supply of cereals in the table above shows the future production of cereals is extrapolated using past growth trend.*

 # indicates that the supply projections were forecasted using yield growths of 1993-2003 and the base year for area and production was 2003-04.

& shows that the supply projections are made on the average annual growth rate in production.

^ shows that there are 4 sets of supply projections (SP) in the table are as per the business-as-usual scenario and the projections are based on the average annual growth rate in output from 1992-93 through 2007-08. The Business As Usual (BAU) Scenario shows current trends in Public Investment in Agriculture (IGV) (4.33%), Private Investment in Agriculture (IPV)(8.76%), and fertilizer-consumption growth continue in the future.

@ indicates that supply of different commodities has been projected using the Trans log cost function to derive the output supply elasticities and the base year production was taken to be TE 2010

$ indicates that the supply has been estimated using a simultaneous equation model using four variables (area, yield, farm harvest prices and quantity of exports). For horticulture crops and commercial crops only area and yield were taken.

ANNEXURE 2

Household Consumption Approach

Under the Household Consumption approach, annual per capita consumption of various commodities as reported in the National Sample Survey Office (NSSO) is multiplied by the projected population of each year to arrive at the projected demand for that particular year.

Total Domestic Demand = (Annual per capita consumption X Projected population) + SFW

Where SFW stands for seed, feed, wastage, and industrial use.

Normative Approach

Under the Normative approach the annual per capita dietary allowance for Indians for sedentary and moderate lifestyle prescribed by the National Institute of Nutrition, Hyderabad is multiplied by the projected population to arrive at the total requirement for human consumption.

Total Domestic Demand = (Annual per capita recommended consumption X projected population) + SFW

The drawback of both the approach is that they assume short term static behaviour in consumption i.e., change in income has no effect on the pattern of consumption.

ANNEXURE 3

Table A3: Comparison of projected food supply by various studies with our estimates

Commodities	Our Estimates (growth trend of past 10 years)		Rosegrant et al. (1995)	Bhalla et al (1999)	Mittal (2008)		Kumar, Joshi, Mittal (2016)		WG report of the Niti Aayog (2018)	
	2020	2030	2020	2020	2021	2026	2020	2030	2020	2032
Rice	118.9	151.5	145.77	-	105.8	111.2	108.1	122.1	119.7	151.7
Wheat	106.4	137.3	96.38	-	91.6	97.9	104.2	128.8	107.1	138.8
Cereals	271.9	342.3	306.56	347.1	242.2	260.2	262.2	315.1	273.9	352.3
Pulses	24.4	34.9	-	-	17.6	18.4	20.7	26.4	23.7	33.9
Foodgrains	296.3	377.2	-	-	259.8	278.6	281.2	338.8	297.6	386.2
Fruits	102.6	145.2	-	-	-	-	97.7	116.4	115.2	193.9
Vegetables	190.8	253.5	-	-	-	-	186.6	210.5	211.3	362.8

Source: Author's Compilation from various sources

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